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WORLD BUILDING CONGRESS

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SESSION 3B
Indoor Environment and User Comfort
L'environnement intérieur et le confort de l'usager

BRUITS INTERNES LIES AU DEVELOPPEMENT DU BATIMENT INTELLIGENT

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Cette publication correspond à une volonté de sensibilisation. Elle donnera donc quelques exemples sans volonté de recensement systématique. Elle correspond à une situation européenne et plus précisément française. Elle représente les différentes pistes de recherche qu'entend entreprendre le **laboratoire** de **PHYSIQUE ENVIRONNEMENT** dans le cadre de **HD 2000**, espace d'information, de formation et de recherche construit sur le Campus de Beaulieu à Rennes à l'initiative de **Gaz de FRANCE** (1400 m^2 dont deux appartement expérimentaux de 5 et 2 pièces principales. Entièrement meublés, ces appartements peuvent recevoir des occupants pendant une période de recherche in situ.

I - LE BATIMENT INTELLIGENT GENERE-T-IL DES BRUITS

L'émergence du bâtiment intelligent correspond à la double volonté de faire entrer le progrès technologique à l'intérieur du bâti et de développer les industries électroniques grand public. Celles-ci se trouvent en effet confrontées à une saturation prévisible du marché. La multiplicité des produits blancs (machine à laver, frigidaire ...) et des produits bruns (radio, télévision, magnétoscope...) ne peut se développer à l'infini... Il convenait de mettre en place un nouveau marché.

Le bâtiment intelligent peut remplir ce rôle.

Il convient cependant de ne pas oublier qu'une enveloppe bâtie est destinée à être occupée par l'homme, pour sa satisfaction et son bien être. Une dimension ergonomique voire sociologique apparaît alors. Pour cela une maitrise de l'ambiance devient nécessaire mais elle doit être contenue dans des limites acceptables ou plutôt souhaitées par l'occupant.

I.1) Parmi les paramètres physiques de l'environnement influant sur le confort global, le bruit est un élément se pliant mal à une réglementation. La loi française par exemple défini des limites normatives basées sur la notion d'émergence par rapport à un bruit de fond environnant corrigé par de nombreux facteurs (durée, heure d'apparition du bruit...). Cette législation présente de nombreuses difficultés d'application;la gêne individuelle ressentie, en partie à base psychosomatique étant dans une large mesure indépendante des normes,de caractère général par nature.
Il est donc d'autant plus nécessaire d'être sensible aux bruits que nous appelons négatifs (1) lors de la construction d'un bâtiment.

Nous nous posons la question de savoir si le bâtiment intelligent va générer de nouveaux bruits négatifs et parallèlement s'il permettra d'introduire plus facilement des bruits positifs c'est-à-dire apportant une satisfaction, tout en évitant que ce bruit positif ne devienne négatif pour les voisins.

L'investissement **"bâtiment intelligent"** appelé en France **"Domotique"** Immotique, Indusbatique,, Scolatique ..., selon sa destination, correspond pour le moment à un surcoût relativement important. Nous pensons donc qu'il va au départ être concomitant à d'autres investissements généraux de confort intérieur. La maison domotique comportera donc des équipements généraux non domotiques absents des logements actuels. Ces équipements seront générateurs de bruits négatifs. Citons par exemple les baignoires à bulles (jacuzi) les aspirateurs centralisés...

I.2) Le bâtiment intelligent de par ses potentialités va entraîner des bruits **"neufs"**. Cela a déjà été le cas historiquement : les anciennes chaudières à charbon une fois chargées produisaient peu de bruit, un brûleur à mazout, une chaudière à gaz qui démarre peuvent entraîner bruit et vibrations..

La notion même de régulation thermique (chauffage ou climatisation) entraine une succession d'arrêt et de démarrages consécutifs. La gêne créée par un bruit intermittent est différente de celle engendrée par un bruit continu mais ni l'un ni l'autre ne peuvent être négligés même si les niveaux mesurés sont relativement faibles.

I.3) L'habitat devenant plus **"confortable"** et le temps de travail hebdomadaire tendant à terme à diminuer dans les pays développés, le taux d'occupation des logements va augmenter. L'influence des bruits sur l'individu va donc croître.

I.4) La domotique et les pannes consécutives qui en résulteront seront, elles aussi, génératrices de bruits négatifs. Les alarmes intempestives sont de ce type. La domotique doit permettre d'assurer en tout lieu et à tout instant une sécurité globale de l'individu et de ses biens. En contrepartie toute anomalie doit être signalée immédiatement afin de pouvoir soit passer en contrôle manuel, soit réparé.
Ainsi on risque d'avoir un environnement agressé régulièrement par tout un système d'alarme. On peut facilement imaginer le paysage sonore ainsi

créé en contemplant les alarmes montées sur les automobiles. Dans l'habitat pour le moment ces alarmes se limitent aux systèmes anti-intrusion. Qu'en sera-t-il lorsque seront développés les alarmes incendies, de présence de gaz, d'auto-contrôle des systèmes ?

I.5) La multiplication des flux d'intercommunication du bâtiment avec l'extérieur va entraîner des problèmes acoustiques :

- entre zones occupées par différents individus. Si plusieurs canaux TV sont écoutés dans des pièces voisines le risque de gêne augmente rapidement.
- dans une zone à utilisation spécifique. A terme la **domotique** débouche en partie sur le travail à domicile (pour certaines professions) et l'éducation à distance. Activités qui réclament une ambiance silencieuse. Comment travailler utilement dans un environnement acoustique perturbé ?

I.6) La notion de programmation inhérente à la **Domotique** peut, elle aussi, entrainer des nuisances.

Pour des raisons de tarification, l'énergie électrique est d'un coût moins élevé de nuit. La **domotique** peut permettre la mise en route d'une machine à laver la vaisselle ou le linge à une heure avancée de la nuit. Actuellement ce type d'usage se fait manuellement et la gêne ressentie par les voisins est certaine. Qu'en sera-t-il lorsque ces systèmes seront généralisês. Inversement l'on peut imaginer que la **Domotique** puisse empêcher tout branchement de ce type après 10 H du soir. Il y a alors programmation de la gêne.

I.7) La facilité de gestion des dispositifs de confort thermique et de renouvellement d'air amène le développement de solutions telles que le chauffage aéraulique et des systèmes de climatisation jouant sur la température de l'air. Cet air est obligatoirement pulsé ce qui entraîne des bruits de ventilateurs et de déplacement d'air. Bien évidemment ces bruits ont toujours existés, le bâtiment intelligent va les généraliser.

Nous voyons sur ces quelques exemples que le bâtiment intelligent peut donc être générateur de bruits négatifs.

II.8) Par contre la **domotique** permettra de gérer les bruits positifs.

Répartition d'une musique d'ambiance, création d'un paysage sonore relié aux activités de l'individu ou pouvant avoir un retentissement sur son comportement (bruits de source, chants d'oiseaux...)

Nous avons évoqué il y a quelques temps la possibilité d'accompagner l'utilisation des micro ordinateurs d'une musique faible semblable dans son principe à la musique de films de cinéma (2).

De même il est possible de diffuser une musique à la limite de l'audible suffisante pour "meubler le silence" (2).

II.9) D'autres bruits sont à la fois positifs et négatifs. C'est ainsi que certaines sociétés proposent sur le marché des simulateurs de présence jouant à la fois sur la lumière et le bruit (mise en route automatique de récepteur radio, émission de message). Encore que d'une efficacité relative ces bruits peuvent devenir rapidement fortement négatifs... pour les voisins.

II - DES SOLUTIONS ?

Elles sont de plusieurs types.

II.1) Mettre au point des systèmes peu bruyant de haute qualité et grande fiabilité.

Nous devons ajouter "et d'un coût peu élevé".
En effet le marché de la domotique n'est pas dans le très haut de gamme : à quoi peu servir un système gérant les économies d'énergie pour un milliardaire ? Le marché doit être grand public. De plus les produits devenant très rapidement obsolètes, il faut que l'investissement soit faible afin d'envisager un amortissement rapide.

Le bruit apparaît généralement avec le vieillissement des matériels, plus rapide sur les dispositifs bas de gamme.

Le problème du bruit doit être pris en compte dès la conception de ce matériels par le bureau d'études en y intégrant la notion de durée des qualités acoustiques.

II.2) Envisager des systèmes de principes différents

Les systèmes de climatisation classiques sont particulièrement bruyants. Nombre de touristes peu habitués à ce type de bruit préfèrent "couper la clim" de nuit pour pouvoir dormir lorsqu'ils visitent des régions ou ces matériels sont développés.

D'autres solutions peuvent être envisagées.

a) Abandonner l'idée d'une climatisation basse température comme l'on peut la trouver en Amérique du Nord et ne retenir qu'une climatisation "haute" permettant un confort relatif mais cependant suffisant pour maintenir un degré d'activité efficace.

Diverses solutions vont être proposées :

a) Utilisation du rayonnement de paroi froide faisant circuler une eau basse température dans les parois des logements. Cela pose divers problèmes notamment de condensation. Ce système préconisé par le laboratoire de **PHYSIQUE ENVIRONNEMENT** dès 1978 (3) a été développé par diverses sociétés et testé dans HD 2000.

b) Gaz de France ayant recours au procédé développé par le constructeur suédois MUNTERS a testé avec succès le rafraichissement d'été par humidification de l'air extrait, le froid est produit naturellement par un humidificateur à ruissellement (4). Dans ce cas tout l'air est refroidi.

Les gains en température sont de l'ordre de 5° à 6°C. Ce qui peut être nettement insuffisant en régions tropicales mais convenable dans une grande zone climatique semi-tempérée, chaude.

Nous n'avons cité ces deux exemples que pour montrer la nécessité de réfléchir à des solutions novatrices simples plutôt que d'essayer de perfectionner des solutions connues. Sans oublier cependant que le milieu du bâtiment n'évolue que lentement.

II.3) Une action sur le bâti

L'élévation des coûts, notamment du foncier qui retentit sur le prix global du logement couplé à une certaine spéculation, a amené une standardisation des logements, de surface de plus en plus réduite.

Nous avons vu que la maison **domotique** doit prévoir, notamment pour le travail et l'éducation à domicile (5), des espaces,certes restreints,mais adaptés à ces nouvelles fonctions du bâti. Il y a là une sorte de quadrature du cercle difficilement cernable. L'architecte doit concevoir une espace ayant de nouvelles fonctionalités dans une surface de plus en plus réduite. Il découle obligatoirement de cette opposition une nouvelle démarche de conception.

La domotique peut inversement l'aider dans cette démarche. Si une mère aime "entendre" son bébé situé dans une autre pièce, l'isolation phonique devient un facteur négatif. Le contrôle à distance (microphone, télévision intérieure...) permet de concilier les deux objectifs.

II.4) Pour avoir une efficacité, l'architecte ne doit pas seulement rester un concepteur d'espace. Il doit intégrer une dimension technologique. Trop souvent les architectes soutraitent les lots techniques en les ignorant totalement. Si ce n'est pas à l'architecte bien évidemment de "faire les calculs" d'ailleurs généralement effectués par programme informatique, il convient qu'il possède suffisamment de technicité pour intégrer intellectuellement les problèmes du bruit dans sa démarche créative.

II.5) Il convient bien évidemment de ne pas oublier la qualité du travail fourni par les entreprises lié directement à la prise de conscience des personnels. Une tâche d'éducation apparaît donc nécessaire.

III - CONCLUSION

Tous ces éléments permettront d'intégrer le confort acoustique dans le confort global. Encore faut-il relier la notion de confort global à la population occupante. Nous avons surtout évoqué ici l'habitat. Les mêmes problèmes se retrouvent pour les immeubles à vocations spécifiques, bureaux, maison pour 3ème âge, hôpitaux, hôtels, écoles...

Le Laboratoire de **PHYSIQUE ENVIRONNEMENT** a choisi d'axer ses recherches sur deux thèmes porteurs : les bâtiments scolaires et les locaux de santé (hôpitaux, handicapés, maisons de retraite...) en intégrant tous les paramètres de l'environnement physique et non seulement l'acoustique.

Ces études permettront peut être de répondre à l'interrogation.:

"LA DOMOTIQUE peut-elle apporter une solution aux problèmes acoustiques générés par la DOMOTIQUE" ?

B I B L I O G R A H I E :

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(5) - La scolatique, une nouvelle pensée du batiment scolaire
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DOMOSCIENCE 90 Edité en 91 RENNES

Energy and Comfort Characteristics of User-Controlled Localized Environmental Systems (UCLES)

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1. Introduction

During the last few years, an increasing interest in user-controlled, localized environmental systems has emerged. In the specialized technical literature such systems are referred to as local thermal distribution systems, task ventilation systems, personal environment units or occupant-controlled systems. In the present paper the term User-Controlled, Localized Environmental Systems (UCLES) is used.

According to this environmental control philosophy, building users are allowed to adjust their microclimates in response to individual preferences and perceived comfort conditions. UCLES are designed to effect local/zonal control near the occupant rather than environmental tempering of the total space normally provided by conventional environmental centralized systems. Moreover, they seek to provide individual control for each occupant and respond to variations in the perceived ambient conditions (air temperature, humidity, airflow speed, sound, and light) caused by changing occupancy patterns and internal heat gains during the working period. For objective reasons (which will be discussed later on), the current focus is on the application of UCLES in office buildings.

The development of UCLES has preceded the evolution of the modern electronic office which demands different environmental control to that provided by conventional systems. There are a number of factors which are important for choosing effective environmental systems for modern offices:

(i) conventional systems are not designed to take account of the high sensible heat gains at spot zones due to a variety of electronic hardware;
(ii) open-plan offices bring together into the same space and environment, different occupants performing a range of diverse tasks. Each employee, however, would probably prefer discrete conditions matching his/her subjective sensation of comfort and health throughout the work period;
(iii) the rapid technological and organizational changes in companies, as well as frequent relocations due to fast development and growth, require flexible environmental systems which can be altered to match the needs of changing occupants;
(iv) growing awareness of employees and employers about comfort and health conditions at the workplace, and the adverse implications for the productivity of workers if proper conditions are not provided; and
(v) the huge amount of power and communication cables which

often require raised floors to be installed; the resulting floor void lends itself as an accommodation for services cabling and conditioned air distribution facilities.

UCLES provide effective remedies to some of the above adverse effects of the modern office characteristics, and benefit from high-tech opportunities now available.

2. <u>Description and Application</u>

A few UCLES are already found at various stages of development. Different systems are distinguished from each other by certain operational and control features such as the environmental elements which the system can control, the method of supply of conditioned air, and the technology used for control.

In this paper, two systems are presented for the sake of acquaintance with UCLES. Both are still at an early stage of development. The first is the Personal Environment Unit (PEM) of Johnson Controls (Johnson Controls, 1988). The system comprises two air vents mounted on either side of the desk in a typical modern workstation. A control panel at desk level lets the user adjust the temperature as well as the quantity and direction of the air. A radiant heating panel under the desk, also controlled by the employee, supplies additional warmth to the lower part of the body. Task lighting can be modulated from the control panel and adjusted for the kind of work being done at the moment. A white noise generator providing a sound like a rush of air masks other background noise, thus allowing extra privacy. An occupancy sensor is used to shut off al unnecessary equipment, thus maximizing energy conservation. Basically, the PEM acts as a variable air volume (VAV) system for each person with a primary air supply of 13 C and discharge temperatures in the range 16-26 C. Raised floors and/or vertical chases in partitions can be used for distribution of conditioned air between different spaces in the building.

The second UCLES presented here is the Environment 2000 system manufactured by Atlas Compac Ltd. (Atlas Compac, 1989). A raised modular floor of about 220 mm height is provided above the floor slab to create a plenum through which primary air may be delivered from any conventional airconditioning system. It is the secondary conditioned air supply terminals which form the heart of the system. The bulk of the secondary air supply is provided by the Air Treatment Terminals (ATTs). Supplementary supply of cooled air for the personal comfort of occupants is provided by Individual Environment Controllers (IECs). The primary air is returned to the primary air handling unit through a ceiling void which need be no more than 200 mm in height. Users of Environment 2000 are able to control the temperature and direction of the discharge air. The number of ATT units needed in a space is determined by the total load. Usually, these are located adjacent to workstations.

3. Aims of Research

3.1 Verification of UCLES Advantages

From the limited operational experience with UCLES, the following advantages seem to be likely but need to be verified by an objective field study, namely:

(i) UCLES introduce conditioned air directly to locations where the heat load from electronic peripherals is generated;
(ii) they have the potential for creating good air circulation in the conditioned space, by spreading the supply over the floor area or the space rather than in fixed spots;
(iii) they enable the introduction of supply air directly to the occupancy zone, thus preventing inconvenient thermal stratification;
(iv) they provide individual control for occupants so that they can control their conditions, not only in response to thermal sensation, but to psychological and other subjective needs as well;
(v) they offer the flexibility required from environmental systems when reshaping the workplace in response to new technologies and changing needs of the occupants.

Despite these apparent advantages, further development and application of UCLES is dependent on various characteristics which have not been explored yet.

3.2 Principal Research and Development Needs

Research is needed to explore the energy and comfort characteristics (Arens et al., 1990; Fisk et al., 1990), and the effectiveness of UCLES, namely:

(i) to explore the energy saving potential of UCLES under a variety of performance conditions;
(ii) to study the implications of UCLES on indoor air quality;
(iii) to study the relationship between local fresh air supply rate and odour concentration;
(iv) to develop an understanding of total comfort (i.e. thermal, light, and sound) of occupants under "real" dynamic working conditions;
(v) to develop a monitoring and self-assessment electronic facility (i.e., sense diary) attached to UCLES; and
(vi) to develop a tangible quantitative correlation between productivity of workers and the perceived environmental conditions at the workplace.

An extensive research programme has been launched in our department to study the above issues. Our goal is to gain better understanding of the field performance of UCLES. The findings of the research will enable us to devise the salient features of improved UCLES prototypes.

4. Conclusions

User-controlled, localized environmental systems have a very good potential for environmental control in office buildings. They are most suitable for use in workstations equipped with high heat-generating electronic peripherals.

However, there are still various aspects of UCLES to be explored before this new environmental control strategy can be implemented on a big scale.

Acknowledgments

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Evaluation of Thermal Comfort and Indoor Air Quality

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1. INTRODUCTION

A comfortable indoor environment is a necessity for occupants' good health and high productivity. Thermal comfort and indoor air quality depend on several environmental parameters including fresh air flow rate, air movement, air temperature, mean radiant temperature, humidity and contaminant sources in the air supply system or in the space. Their optimum values depend on the occupant conditions such as metabolic rate, clothing and personal hygiene. Improved thermal comfort is achieved at home or in workplaces through proper thermal mass and insulation together with appropriate heating, ventilation or airconditioning systems. The design and maintenance of ventilation systems has a decisive effect on the quality of indoor air. Poor indoor air quality is a principal cause of "sick building syndrome". An effective ventilation system enables indoor air quality to be controlled with minimum energy consumption and occupant dissatisfaction. In designing such a system a knowledge of airflow pattern, temperature and contaminant distributions in spaces is needed.

This paper presents some results of an investigation into the air movement, thermal comfort and indoor air quality in a naturally ventilated classroom. The investigation has been carried out both experimentally and numerically.

2. EXPERIMENTAL METHOD

Zainal and Croome (1990a, 1990b) investigated the indoor environment of a naturally ventilated classroom at Reading University for various arrangements of window and door openings. Air velocities and temperatures were measured at a horizontal level 0.9 m above the floor with omnidirectional hot wire anemometers. Air flow rates were determined using the concentration decay method with iso-butane as the tracer gas.

Thermal comfort was measured using a comfort meter; indoor air quality was assessed on the basis of the carbon dioxide levels during the occupancy periods. A subjective evaluation of thermal comfort and indoor air quality was also undertaken using a questionnaire comprising seven point scales on warmth and freshness. It was found that in summer when all the windows and doors were closed indoor air was unacceptable for comfort both in terms of thermal environment and odour intensity or freshness due to insufficient supply of fresh air. However when some windows were opened the indoor environment was improved (Zainal and Croome, 1990b); door openings have added a significant effect. Another test in which the thermal environment was monitored in the occupancy period for one week showed that on average the thermal comfort was acceptable when all the windows were closed whilst the door was occasionally opened (Zainal and Croome, 1990a).

3. NUMERICAL METHOD

The principle for the numerical evaluation of thermal comfort and indoor air quality is the incorporation of airflow model with the comfort model. The airflow model is based on the continuity equation, Navier-Stokes equation, thermal energy equation and the diffusion equation for transport of gases or particles as well as the equations representing the effects of turbulence. The solution of these equations is coded in a computer program called ARIA-R and the verifications of the CFD program have been presented by the present authors (Gan, et al. 1991a, 1991b & 1991c).

Thermal comfort is evaluated in terms of the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) proposed by Fanger (1982), which are related to air temperature, velocity, mean radiant temperature and vapour pressure of air for given values of metabolic rate, work and thermal resistance of clothing. Indoor air quality evaluation is based on the concentration of CO_2. In the present evaluation the air velocity, temperature and contaminant distribution are given by the flow equations. The mean radiant temperature for any point in the space is taken as a function of the temperature and thermal properties of room surfaces and the shape factors between the surfaces. Other parameters are taken as fixed values for the whole space. A number of numerical predictions have been made for the thermal comfort and distribution of CO_2 in the classroom, one of which is discussed below.

4. DISCUSSION

In the prediction presented here, six windows were half open. Air flowed into the room through four windows on one wall and flowed out from two windows on the opposite wall (cross-ventilation, see Figure 1). The measured air change rate is 3.62 per hour, and the calculated air velocity at the windows for air supply is 0.356 m/s at 19.9°C. The room was occupied by twenty-two people. The occupants were simulated as obstacles. It is assumed that each occupant produces 100 W heat and 4.7×10^{-3} l/s CO_2. The supply air is assumed to have a CO_2 concentration of 350 ppm. Heat gains due to solar penetration through windows and artificial lighting were also included.

The predicted air flow pattern in the room space, distributions of temperature, predicted percentage of dissatisfied and CO_2 concentration on the level 0.9 m above the floor are shown in Figure 1. The predicted airflow pattern was complicated due to the presence of obstacles and the effect of thermal buoyancy (Fig. 1 (a)). The air temperature is high close to the occupants due to the body heat (Fig. 1 (b)). The predicted velocity and temperature distributions have been compared with experimental results (Gan, et al. 1991a & 1991b).

Figure 1 (c) shows that a comfortable thermal environment is attained for this case. The average PPD in the occupied zone (floor to 1.8 m high) is about 8%, (between neutral and slightly warm). The test for this prediction was, however, conducted under a mild outdoor environment (about 20°C). According to this result, if the outdoor air temperature is much higher the indoor environment will be beyond the acceptable level for thermal comfort unless it is compensated for by a higher air flow rate. Therefore, in a hot climate some measure may have to be taken to provide sufficient and preferably cool fresh air without causing excessive draught if discomfort in the space is to be avoided. In a cold season, heat needs to be provided to maintain indoor thermal comfort which conforms with normal practice.

The predicted concentration of CO_2 is relatively high in zones away from the air supply openings compared to that in the areas close to the windows used for the air supply (Fig. 1 (d)). However, the average concentration of CO_2 in the room is low (670 ppm) due mainly to the high air flow rate; based on 3.62 air changes per hour this is about 15 l/s per person.

Previous investigations (see Gan, et al. 1991b & 1991c) indicate that thermal comfort and contaminant distribution are affected by the density and distribution of occupants and by locations of the supply and extract openings. The optimum arrangement of window and door openings for comfort will therefore vary for different combinations of these factors. Effects of turbulence, standard deviation around the mean air velocity are being investigated at head and foot levels.

5. CONCLUSIONS

This investigation has shown that a reasonably comfortable indoor environment in naturally ventilated rooms can be achieved by appropriate arrangement of window/door openings in a mild climate. However, this may be difficult to maintain during a hot summer. It has also been shown that the 3-D CFD program ARIA-R can be used to evaluate the thermal comfort and indoor air quality in ventilated rooms.

Further experimental and numerical investigations of these indoor environment criteria in offices are currently under way for a variety of systems in different buildings. Measurements will be undertaken at head and foot levels.

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HABITAT
RELATION CONFORT-SANTE

FOCALISATION SUR LE CHAUFFAGE ET LA VENTILATION

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1. L'ETUDE CONFORT / SANTE : EDF - GDF - FNB

Les sources d'insatisfactions des occupants dans l'habitat se focalisent souvent sur le chauffage et la ventilation des pièces aussi bien dans les logements neufs que dans ceux plus anciens. Ceci est principalement dû pour le chauffage à un manque de réelles possibilités pour l'occupant de personnaliser son ambiance thermique.

Pour la ventilation, cela est sans doute plus dû à un manque de perception de "l'utilité" de la ventilation, qui n'a pas encore aujourd'hui un véritable statut alors que les usagers se plaignent de la difficulté de maîtriser par exemple les migrations d'odeurs entre pièces.

Une approche nouvelle pour élaborer des réponses techniques

Face à la complexité de la problématique, une réflexion prospective pluridisciplinaire a été engagée. Elle a déterminé une union de compétences et de moyens techniques, nécessaire pour élaborer un tel projet. L'équipe suivante a ainsi été constituée :

- Electricité de France (E.D.F.)
- Gaz de France (G.D.F.)
- La Fédération Nationale du Bâtiment (F.N.B.)
- Le Centre Expérimental de Recherches et d'Etudes du Bâtiment et des Travaux Publics (C.E.B.T.P.).

Ce groupe de travail réunit des professions très différentes (ingénieurs, chercheurs sociologues, médecins épidémiologies, statisticiens, spécialistes marketing...).

L'objectif de cette collaboration est de rédiger, des cahiers des charges fonctionnels et exigentiels de procédés de maîtrise des ambiances thermiques et olfactives (qualité de l'air).

Ce programme de recherche–développement comporte plusieurs sous–objectifs :

- Une enquête socio–culturelle à caractère épidémiologique nationale, décrite dans la présente communication.
- Une enquête approfondie avec des mesures sur un échantillon restreint. cette quantification technique des niveaux de pollution permettra de posséder des données d'entrées pour la modélisation. la détermination des composantes de cet échantillon sera effectuée à partir de situations dégradées et de typologies–types identifiées lors de l'enquête socio–culturelle.
- L'utilisation d'un code de calcul aéro–hygro–thermique multizones comportant un module de pollution gazeuse, validée en laboratoire. Un tel outil est fort utile pour simuler des études d'efficacité de systèmes de ventilation.

Les cahiers des charges de produits, d'équipements et même de services répondant aux concepts définis dans le cahier des charges fonctionnels feront l'objet d'une diffusion auprès du grand public comme auprès des professionnels.

<u>Mise au point de l'enquête socio–culturelle</u>

Le questionnaire mis au point comporte trois composantes ce qui lui donne une dynamique originale. Ces trois familles de questions sont :

- Une composante TECHNIQUE qui décrit de manière aussi complète que possible les caractéristiques du logement (implantation, orientation, nature du bâti...), des systèmes de chauffage et de ventilation, des équipements et des matériaux présents à l'intérieur.

- Une composante SOCIOLOGIQUE destinée à étudier la façon dons les occupants d'un logement se comportent par rapport à leurs conditions d'environnement intérieur et à l'utilisation des équipements. Elle contient des données sur le mode de vie (appropriation des espaces, type et horaires des activités menées...) comme des données qualitatives sur les satisfactions et sur les attentes précises des usagers en regard de leur environnement intérieur (adaptation, maîtrise, autonomie, personnalisation...) et, en particulier, par rapport à l'interaction entre équipements et qualité des ambiances.

- Une composante MEDICALE avec deux finalités :

    * Révéler les perturbations éventuelles apportées à la santé des occupants par les concentrations en polluants et les conditions climatiques régnant à l'intérieur du logement,
    * Déceler les interactions entre la perception du confort et la morbidité déclarée par les occupants.

  Cette partie a été rédigée en collaboration avec des médecins épidémiologistes à partir d'un inventaire des relations potentielles équipements–santé. La santé est identifiée d'après la prévalence hebdomadaire d'affections déclarée. Cette période de huit jours a été sélectionnée en fonction de la capacité d'un usager moyen de se remémorer avec fiabilité les informations recherchées

L'environnement arrêté pour l'enquête a été le suivant :

- Un interview à domicile dans 560 logements en période de chauffage (période de plus fort confinement).
- 100 questions par logement pour une durée d'entretien estimée à 1 heure et 15 minutes. Ce questionnaire est très dense mais la préenquête nous montre que sa durée est compatible avec le temps limite d'attention des interviewés.
- Uniquement chez des locataires. Un propriétaire de son logement est en effet moins enclin à s'en plaindre.
- Interview d'une seule personne par foyer. Cette personne répond sur la santé de chacun des occupants. Lorsque plusieurs adultes sont présents lors de l'enquête, les observations de la maîtresse du foyer (personne la plus à même de parler de l'état de santé des enfants) sont de préférence recueillies.
- Compte–tenu des objectifs spécifiques de l'étude, les logements présentant certaines caractéristiques sont volontairement sur–représentés par rapport à la moyenne française, de manière à permettre une analyse plus aisée des relations Habitat – Confort – Santé. Aussi, l'échantillonnage s'effectue en respectant certains quotas impératifs et en essayant d'approcher d'autres quotas conseillés.

2. PREMIERS ENSEIGNEMENTS :

L'échantillon a comporté 564 logements et 1765 occupants identifiés dont les activités et la santé ont fait l'objet d'une analyse individuelle.

Les résultats présentés par la suite résultent d'une analyse statistique classique (tris à plat et recherche d'associations à l'aide de tris croisés). Le caractère multifactoriel des problèmes apparaissant dans cette étude impose de prendre quelques précautions avant de déduire des liens de causalités potentielles à partir de relations descriptives. A ce propos, nous soulignons qu'ultérieurement un traitement analyse factorielle des correspondances de type multivarié sera effectué.

Les logements visités (COMPOSANTE TECHNIQUE)

Signes de dégradation :

- Des moisissures ont été notées dans 34 % des logements, ce qui est considérable. Dans 75 % des cas de logements où des moisissures apparaissent, au moins une chambre est touchée et dans 42 % des cas, la salle de bains est concernée. Par contre, les moisissures n'apparaissent en cuisine que dans 20 % des logements.
- Des condensations (définies comme de la buée persistante sur les fenêtres) ont été relevées dans 57 % des logements. Ce phénomène se situe principalement dans les pièces techniques (cuisine, salle de bains et les chambres).
- Des odeurs persistantes sont présentes dans 23 % des logements (essentiellement en cuisine ou en chambre)

Le vécu de l'habitat et de ses équipements (COMPOSANTE SOCIOLOGIQUE)

Pratiques domestiques :

- 85 % des usagers ouvrent certaines fenêtres durant la saison de chauffe. Ces ouvertures très fréquentes se situent essentiellement en chambres et en cuisine. Elles sont de plus, d'assez longue durée. Seulement 40 % des chambres et 31 % des cuisines aérées, sont ouvertes quotidiennement moins de 20 minutes. L'ouverture des fenêtres en hiver s'effectue tout d'abord pour renouveler l'air (raisons principales d'ouverture dans 50 à 90 % des cas suivant les pièces).
- 93 % des usagers ouvrent certaines fenêtres hors saison de chauffage et ceci pendant plus d'une heure par jour dans environ 80 % des cas. Le premier motif d'ouverture est le désir de renouveler l'air.
- 14 % des usagers obturent certaines bouches de ventilation. Les principales raisons évoquées pour expliquer cette action sont la crainte du froid dans 62 % des cas, les gênes occasionnées par les courants d'air dans 45 % des cas et les salissures. Par ailleurs, 1/3 des occupants ne nettoient jamais les bouches de ventilation.
- Seulement le tiers des usagers a la possibilité de moduler le débit de ventilation de son logement. Parmi ces usagers, la moitié n'utilise jamais cette possibilité.
- 1/4 des usagers possédant une ventilation mécanique contrôlée (VMC) la stoppe de manière intermittente (surtout la nuit) ou en permanence. Ces arrêts sont motivés par une gêne sonore (36 % des cas), par une incompréhension du rôle de la VMC dans 29 % des cas et par un désir d'économie d'énergie dans 18 % des cas.
- 15 % des usagers emploient des évaporateurs–humidificateurs.

Les tiers facteurs étudiés sont très nombreux : ainsi les transports, les habitudes tabagiques, l'ambiance professionnelle, etc... ne sont pas décrits volontairement ici. Seuls quelques éléments sont repris à titre d'exemple :

3. L'APPRECIATION DU CONFORT

Attentes et insatisfactions des occupants

Globalement, les usagers se déclarent contents du confort de leur logement. Seulement 13 % des personnes interrogées s'en estiment peu satisfaites et 4 % pas satisfaites du tout. Classées par importance décroissante, les principales sources d'insatisfactions potentiellement associées aux équipements sont :

– Mauvaise étanchéité des fenêtres	30 %
– Ventilation (83 % des plaignants la considèrent même inefficace ou absente)	30 %
– Bruit	23 %
– Confort d'été	22 %
– Confort d'hiver	20 %
– Système de chauffage	19 %
– Odeurs persistantes (mais seuls 55 % des plaignants pensent que ce problème peut être traité par une meilleure ventilation)	11 %

Préétude des relations santé, confort, habitat (COMPOSANTE MEDICALE)

Environ 1/5 des occupants des logements visités a souffert de troubles pendant la semaine précédant l'enquête. Ce taux élevé s'explique d'abord par la bénignité de certains troubles relevés et par la composition de l'échantillon (familles à enfants), ensuite par la période de recueil (printemps) favorable au développement d'affections oto-rhino-laryngologiques et respiratoires. Ces 21,3 % de troubles divers se décomposent en 41 % de fatigue physique, 29 % de fatigue nerveuse et 29 % de maladies.

Taux de morbidité en fonction de paramètres sur l'habitat :

De très nombreux facteurs liés à l'habitat, à son équipement et son environnement semblent significativement associés à la fréquence d'affection (date de construction, lieu d'implantation, densité de population dans le logement, présence de condensation et de moisissures, chauffage par appareils indépendants, type de ventilation, durée quotidienne d'aération du logement, intervention sur le système de ventilation...) mais sans être à ce stade corrélé et a fortiori sans que les causalités soient encore définies.

Il en est de même de tiers facteurs (âge, catégorie sociale, tabagisme, présence d'animaux...) très inter-dépendants avec les premiers facteurs. Il convient donc de bien identifier les imbrications entre les différents éléments. Par exemple, le plus grand taux d'affections trouvé chez les personnes disposant d'un humidificateur ou évaporateur sur un radiateur ne découle-t-il pas d'une implantation des humidificateurs essentiellement dans les populations plus sensibles ?

De même, la plus grande morbidité dans les logements avec peu de fenêtres par occupant n'est-elle pas liée au milieu social de ces occupants ?

Certains facteurs tels que le type d'habitat (individuel et collectif) ou le type de régulation ne semblent pas influer sur le taux d'affections.
Certaines associations sont plus marquées lorsqu'elles sont étudiées au niveau d'une affection spécifique. En voici, quelques exemples qui seront l'objet d'investigation complémentaires pour éliminer les éventuels facteurs de confusion :

- Plus de troubles respiratoires chroniques dans les logements anciens réhabilités.
- Plus de troubles respiratoires chroniques dans les logements construits après 1974.
- Plus de troubles respiratoires chroniques en présence d'animaux domestiques.
- Plus de troubles respiratoires chroniques en présence de fumeurs.
- Plus de troubles ORL et pulmonaires dans les logements avec peu d'ouverture.
- Plus de troubles ORL si absence de système de ventilation ou ventilation "fruste".

Du fait de l'intervention évidente de nombreux facteurs agissant simultanément, l'interprétation de ces associations est aussi très délicate. Ainsi la plus grand prévalence de troubles respiratoires chroniques en présence de certains types de ventilation peut apparaître quelquefois mais peut être en effet de l'âge des occupants de ces logements ou d'une mauvaise utilisation de la ventilation et a contrario la majorité des troubles chroniques a priori corrélé peuvent avoir une origine antérieure au dernier déménagement.

Ainsi, la fréquence de pathologies aiguës et de troubles respiratoires chroniques est toujours significativement plus élevée en présence de signes de dégradation du bâti.

A noter également :

- La proportion de troubles respiratoires postérieurs au dernier déménagement (34 %).
- La proportion de personnes estimant qu'un lien santé–logement est possible (17 %).

Correspondance morbidité / Jugement sur le confort :

L'appréciation subjective de confort est souvent liée à la bonne santé déclarée et inversement.

Afin d'identifier le rôle de chacun des facteurs agissant simultanément, une analyse de type multivarié avec recherche des correspondances est en cours.

CONCLUSIONS

Nous avons tenu à témoigner de la difficulté à mettre en oeuvre de tels programmes dont le budget global avoisine 3,5 MF Français pour une durée d'études de 3 ans, les résultats ne sont pas encore tous publiables, mais on peut observer à travers une étude de ce type que de plus en plus, seules des équipes pluridisciplinaires réunissant : sociologues, médecins–épidémiologistes, médecins, ingénieurs, statisticiens, architectes, responsables marketing, pourront demain répondre aux besoins de la recherche issus d'une remise en question d'un objet banal puisqu'il s'agit de l'habitat et de ses modes de chauffage et de ventilation, éléments pourtant familiers à chacun d'entre nous.

Nota : Cette étude a été réalisée avec les participations principales suivantes :

- M. PERRAY de la Direction des Etudes et des Techniques Nouvelles de Gaz De France,
- MM. FAUCONNIER et LOEWENSTEIN de la Direction des Etudes et des Recherches d'Electricité De France,
- MM. CLUZEL, COHAS et GRELAT du Centre Expérimental de Recherches et d'Etudes du Bâtiment et des Travaux Publics,
- Melle LEMAIRE de l'Agence de l'Environnement et de la Maîtrise de l'Energie,
- M. LALBA de l'Agence Nationale pour l'Amélioration de l'Habitat,
- Melle VEUILLEZ et M. DUCHENE de la Fédération Nationale du Bâtiment,
- Docteur FERLEY et M. LEFREVE–NAVE de l'Institut Français de Démoscopie,
- Docteur ZMIROU de l'Institut Universitaire d'Hygiène et de Santé Publique de Grenoble,
- M. BOUILLE et Mme SMADJA du Groupement Recherche Energie Technologie Société d'E.D.F.,
- M. ORMIERES de la Direction des Etudes Commerciales de G.D.F.

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INDOOR AIR QUALITY EVALUATION USING A DATA PROCESSING MODEL

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Before starting my lecture there are a couple of points that I want to say:

- All our research on Indoor Air Quality is connected and even if they operate at different levels, they have the same goal: to provide useful instruments of evaluation to designers and operators.

- I am one of the members of an interdisciplinary team that is working on this project. The software "Control of the Residential Indoor Air Quality: has been, in fact, prepared for the National Research Council (CNR) by A. Baglioni, N. Boschi, M. Beretta, S. Piardi, M. Bonecchi, S. De Angelis, S. Piccinni and M. Salvi

Like everybody knows, after the energy crunch of the 70's, the designers, in order to reduce energy costs in building construction, ended up with significantly "tighter" buildings.

In that way, we started to keep under control one problem, but at the same time, we realized that another problem, called Indoor Air Quality, was coming up.

As previously shown in this conference, and in otherwise, specifically on this topic, the indoor environment has the characteristic to be complex.

Designers can simplify the problem of dealing with indoor environmental quality by thinking about it at every step of their work. They can eliminate most of the Indoor Air Quality problems by considering Indoor Air Quality during site evaluation and design, planning design development and the preparation of construction documents.

But at the same time, we know that building design involves much detailed information in a wide variety of subjects, many of which are not yet familiar to most building designers.

In this way, a processing model can be very useful to evaluate the pollution load of the building, during the design phase. It concerns the choice of materials as well as design parameters (location, layout of the rooms, HVAC system, light acoustic, space, colors, image, atmosphere, etc.).

Right now we can represent the situation saying that:

1) traditional design cannot control indoor air quality factors;

2) few objective scientific data are available; and

3) scientific data are not enough to evaluate the whole indoor pollution score.

Consequently, we need to somehow:

1) collect data (more than this, we need to rationalize the existence, and at the same time, to increase them);

2) screen meaningful traditional design parameters;

3) empirically quantify qualitative data;

4) compare values for different data collection: scientific data collection from different research fields (site design, chemical-physical analysis); laboratory test results (emission rate, pollution load of technical laying);

5) with new software, test the data and their own interactions.

We ended up with a software because we thought it was the only way to deal with design criteria that require a vast amount of data about the positioning of various elements inside the buildings, the behaviour of materials, the characteristics of the products used for laying and maintenance, indoor ventilation, and the outside location of the building itself.

The software that we made has quite a few very good issues for the operators:

1) high and complex analysis in a very short time;

2) able to test existing buildings;

3) management of a large number of factors and their own interaction;

4) semantic differential scales are used to return the results;

5) evaluation of the single choice itself and in relation to the whole pollutant score.

Operator advantages:

1) flexible system;

2) updating system;

3) interface compatibility (i.e., energetics, performance to the fire, safety);

4) new implementation performance (i.e., CAD, standard);

5) evaluation scales and the choice of the parameters can be easily changed or integrated.

The structure looks like a flow chart with interactions between different branches.

This program can evaluate the pollutant load of different elements (materials, products, furniture, layout, ventilation, etc.). The working approach seems to us to be similar to the events that occur in the biological field since we face a sequence of pre-existing causes which are impossible to resolve separately.

It is necessary to simplify the job with a methodical approach concerning the identification of significant data collected, while maintaining the complexity of the environment. From the operative point of view, to simplify things, we proceed step by step starting with the study of individual rooms, then the apartment, and finally the whole building. The room is the smallest element of the building system, yet is the most significant and complex one. In fact, by starting with the room, it was possible to consider the apartment as a sum of rooms and similarly the building as a sum of apartments. Naturally, at every step, it was necessary to add correction factors.

The initial information was widened and enriched with a collection of data from pertinent literature and experts' opinions. The final result was a series of specific checklists concerning any planning factor considered important. These checklists include evaluations and observations and were the basis for the software we produced.

The first problem was to find weightable values. Scientific data are not enough to evaluate the whole indoor pollution score; qualitative data must also be used; therefore, two problems must be faced; qualitative data must be empirically quantified and different data must be compared using the same scale.

Another problem is that important factors taken into consideration by our program are presumed risks during the laying, but so far it has been impossible to quantify their effect since no laboratory tests are available.

Another example is that we know room layout and orientation of the living spaces can have a positive influence in neutralizing some of the polluting sources. Again these effects are not quantifiable by scientifically proved values.

We have lab-tested data, emission rates, empirical data and other data coming from different scientific fields (chemical-physical analysis, site design) which somehow had to be unified in a unique comparable scale.

As I have said before, one of the gravest problems is weighting because it seems impossible to find a scientific method. For example, monitoring materials is a time consuming and difficult work because it is indispensable to create real conditions. In order to attribute values to the different factors, we have produced a synthesis of judgements, expressed by various experts and information from existing documentation. Since we do not have absolute values, we elaborated a coloured scale, which is easy to understand for software users.

Using the software, the architect has the possibility to check his choice at any moment by controlling the colour scale of the single element as well as of the whole building.

Integrated Checkout of Performances: Applications of our method (NOMO)*

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1. Foreword

In the framework of a research aiming at reviewing the methodologies that make up the various stages of the building process, a device has been developed for an integrated checkout of environmental performances, that is based on nomographic representations.
This instrument makes it possible to control the thermal, acoustic and illumination design performance of the building object already at the stage of project definition (preliminary project).
This is possible, owing to the small amount of data required, which in turn stems from a very accurate preliminary analysis that has led to the identification of the variables and parameters which significantly define the building object.
The numerous disciplines relating the design of a building often operate disjointedly, in an incoordinate manner.
The instrument in question is thought to become an intersciplinary tool, so as to achieve broader planning awareness.
Howerer, providing a useful instrument for the decision-making process is the more difficult, the lower the definition stage of the virtual building object.
Moreover, each attempt to elaborate methods aiming at solving problems, at this stage, in a deterministic manner are doomed to failure, for creativity is a basic factor which can hardly be rationalized. In this respect, our device is thought to be a simple procedural tool to help investigate possible project alternatives concerning environmental comfort.
As far as this problem is concerned, a great contribution has come from the United States [1], were the American Institute of Architecture (AIA) has drafted a handbook that systematically deals with those aspects related to performance integration, though under a qualitative point of view.
Indeed, some of the environmental aspects have already been dealt with, in a quantitative perspective, in various studies but in some of them integration was completely neglected [4, 7, 8], or the planning issue was arbitrarily influenced in advance by a system of "weights" among the various environmental performances.

2. Device description

The new device allows the simultaneous assessment, in a given environment, of the following aspects:
1) illumination design characteristic: "mean daylight factor" (fattore medio di luce diurna (FMLD) = (Ei/Ee) * 100%
were Ei stands for internal lighting.
Ee external lighting obtained on a plane placed horizontally from the vault of heaven with homogeneous luminance.
2) acoustic characteristic: "gross deadening" evaluated at various freequencies as D = L1 - L2 in dB;
3) thermal characteristics: "thermal load" "winter ΔT" "summer ΔT"; "ΔT" indicates temperature differences between the outer and the inner environment, reckoned on the basis of the minimum and maximum values of internal temperature (in wintertime and summertime respectively). The thermal load is calculated both in stationary condition (in the latter case as the sum of average values per hour).
The building environment taken into consideration is theoretically limited only in its form (rectangular) and the interfloor height (3,00 m); at this stage no account is taken of overhangs and undercut of the elevation. The other typical parameters of the environment can be assigned any other value. For the sake of simplicity, the device has been elaborated as a graphical representation -nomograms- and the measures related to the context were divided into two groups:
- those with continuous variability
- those with discrete variability

The first group includes geometrical parameters: front width, room surface, glazed surface; the second group includes the other typical features of the environment; position in the elevation, orientation, technology, climatic zone of the building.
A preliminary analysis of the technological survey has led to the assessment, for the moment, of the most interesting building solutions.
Furthermore, the variability range of parameters

* This study was sponsored by the National Research Council (CNR) at the National Union of Italian Cooperatives (UNCI), in the framework of the "Progetto Finalizzato Edilizia" (Building Aimed Project).

has also been chosen according to a building perspective so as to avoid distortions and for the sake of the graph's handiness.

3. The application of nomograms in the technological choices on the border-line of a building

One of the first and direct applications consists in using the instrument for the design of a building's front line, especially as far as technological choices are concerned.
Particularly in this case, in order to demonstrate the versatility and adaptability of the device, the case of reconditiong of an existing building's front-line has been analyzed, which could occur as a result of compliance with energy saving legislation (e.g. Law No. 373 that, in Italy, regulates the loss of heat from buildings).
In the climatic chamber and after taking account of all the position and the orientation of the various rooms (environmental units) of the building being tested, two different technologies have been studied: plain-glass frames and floated-glass frames.
The so-called "external" parameters have been thereby determined as have the nomographic tables to be used; thereafter, once the values of the input variables are known, the application has consisted in a checkout of environmental performances that can be achieved in the existing condition (plain-glass frames) or in the case of reconditioning (floated-glass frames).
Simulation have made it possible to check for each single envinromental unit the compatibility between the level of performances and a few standards laid down (or advised) by the legislation.
Leaving out the quantitative analysis of all performances, the conclusion can be drawn that the application was very easy and quick in spite of the huge amount of parameters involved.
In particular, in our case, it allowed a quantitative checkout of the variations in envinromental features following the possible reconditioning works of the trasparent outer line.
In some cases it has been demonstrated that this type of reconditioning works - though necessary- would in fact imply worsening certain charateristics.
Thereby other alternative building solutions could be resorted to such as, e.g. a possible enlargement of the window. In this case, too, nomograms demonstrate all their effectiveness and versatility for, after a performances target has been set, it is possible (by proceeding backwards, through a design and not a checkout) to reckon the surfaces of the windows.

4. The application of nomograms in a preliminary project of a building system

The second application shows how the use of nomograms makes it possible to solve a typical planning approach problem, such as e.g. the position of a building in a given lot in a specific contextual situation.
For a clearer explanation of the decision making process and with a view to restricting the number of nomographic tables, a few easily understandable hypotheses have been made that, at any rate, do not challenge whatsoever the validity of the device from a theoretical point of view.
The main hypothesis regards the invariability of the building's orientation: the problem of the positioning of a building thereby comes down to a problem with limited freedom of choice* , owing to the particular typology (on-line) of the building and to the shape of the lot.
Certainly, because the nomograms access variables are represented by the characteristics of the environmental units (geometrical, technological, etc.), for our application to be effected, a few hypoteses are to be made with respect to these characteristics: in this respect "standard" values have been extrapolated from the legislation, both as regards the size of rooms and the ratios between glazed surfaces and floor surfaces.
The application has been very interesting, because, although the orientation of the building's axis was established, a choice had to be made with regard to a further design parameter that is the position of the various living units within the building itself (especially the position of the living and the sleeping areas).
Indeed, for each living unit there are various requirements of comfort and size relationship (also between glazed and matte surfaces). Basically, using nomograms to analyze the two different orientation alternatives for the living and the sleeping areas and examining 4 hypothetical positions of the building in the lot (A, B, C, D in Fig. 2) makes it possible to

* Indeed, in general terms, a building on the ground can be considered as solid body in the plane for the positioning of which three geometrical parameters must be known such as e.g. the coordinates from the centre of gravity and the angle formed by its axis respect to the N-S directrix.

achieve that design solution which first of all complies with the current legislation and secondly meets the various requirements (not only with respect to performance).
The actual application has not been very difficult and has further provided a precise planning choice both as regards the position in the lot and the relative orientation.
It will be certainly possible to check out that choice when the size and the technological solutions for each environmental unit have been throughly specified.
Any rearrangements (that can also be checked out through nomograms) do not necessarily question previous choices but rather can be performed upon the geometrical and technological parameters and in particular upon the size of the window.

5. Conclusions

The methodology that has been worked out is especially characterized by its particular structure which entails the following advantages:
1) the simultaneous evaluation of all the analyzed environmental features;
2) the immediate and comparative visualization of all possible design alternatives;
3) the identification of design solutions that are in line with legislative requirements.
As shown by both before-mentioned examples, the device can be used to solve problems characterized by very different scales, thereby widely demonstrating not only its semplicity but also its versatility.
Further improvements, especially aimed at simplifying the necessary nomographic tables, can be achieved by means of the computerization of the instrument, which is under way.

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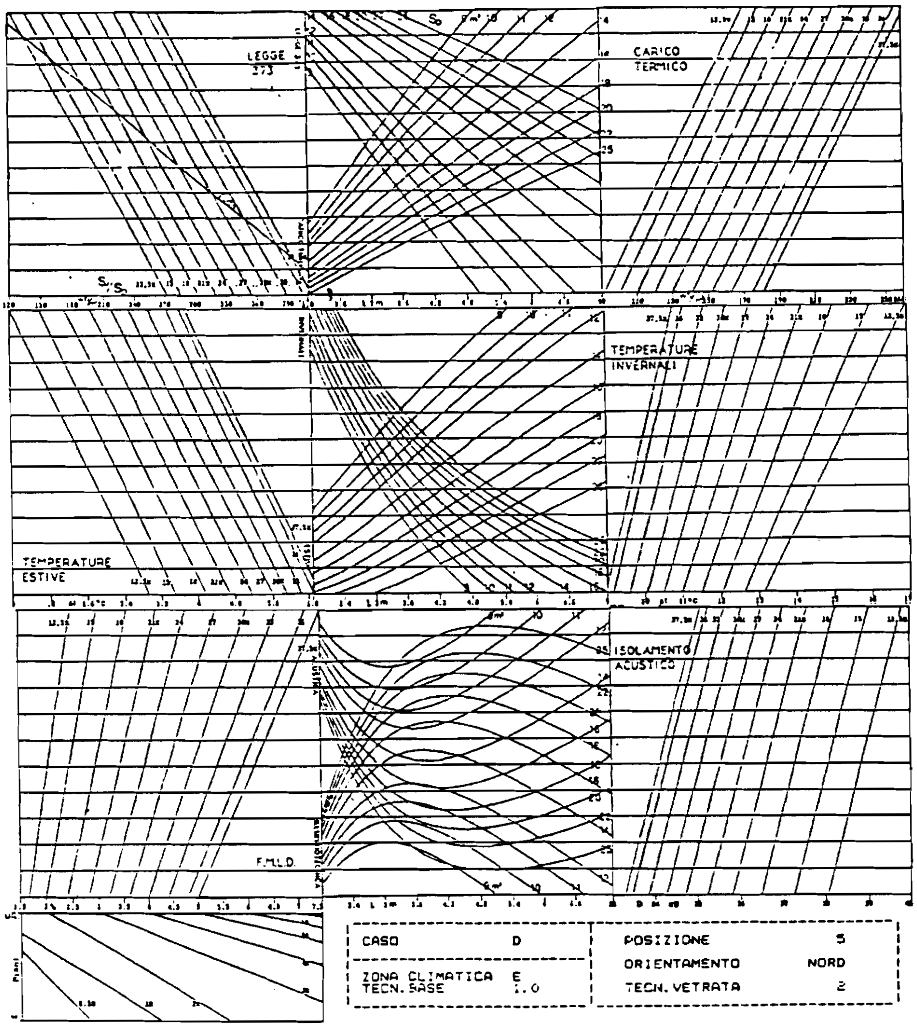
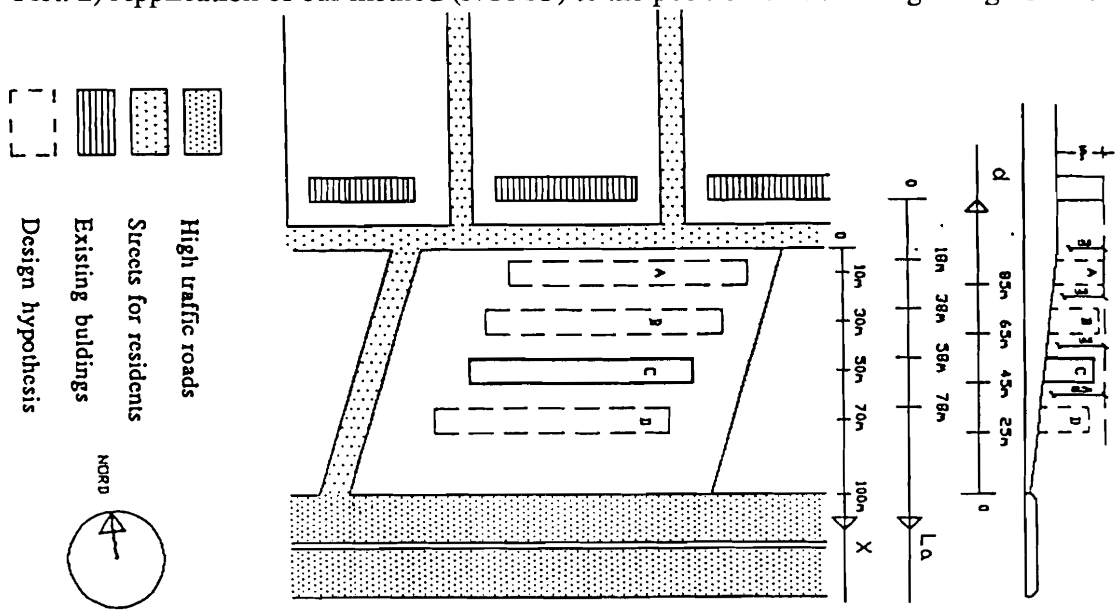
Pict. 1) One of the produced nomographic tables



Pict. 2) Application of our method (NOMO) to the position of a building in a given lot



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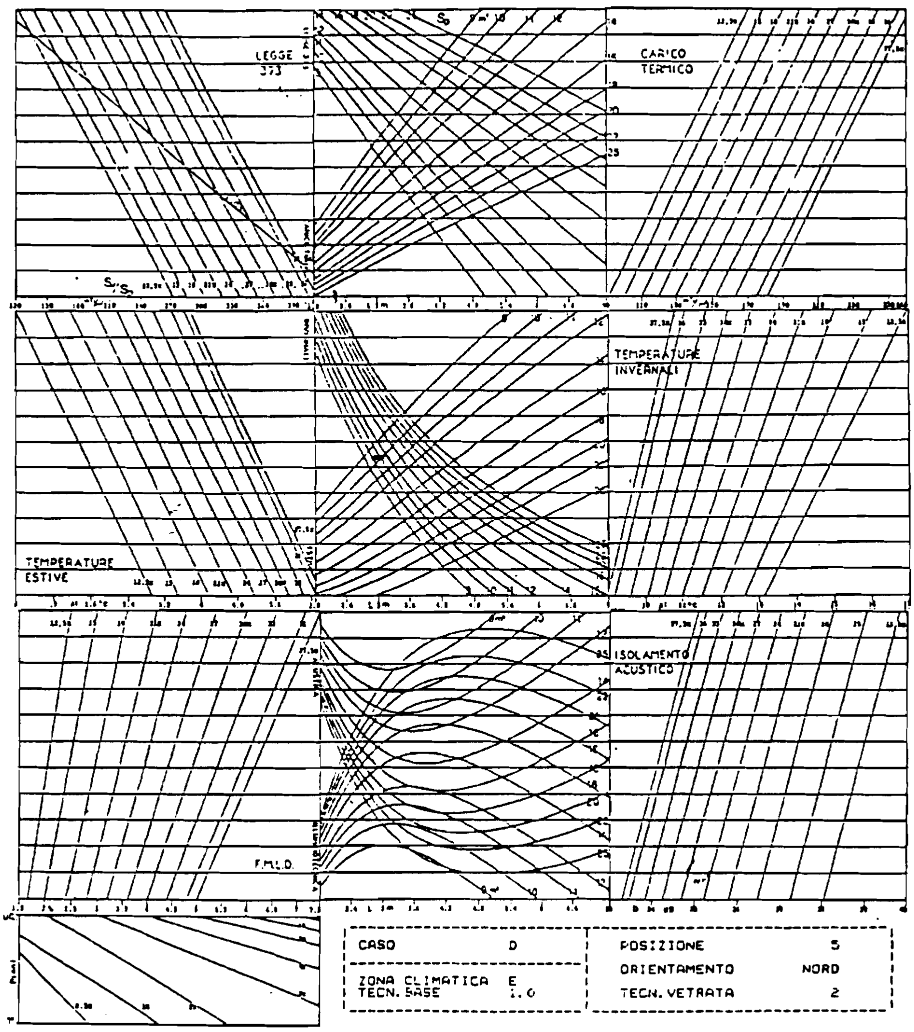

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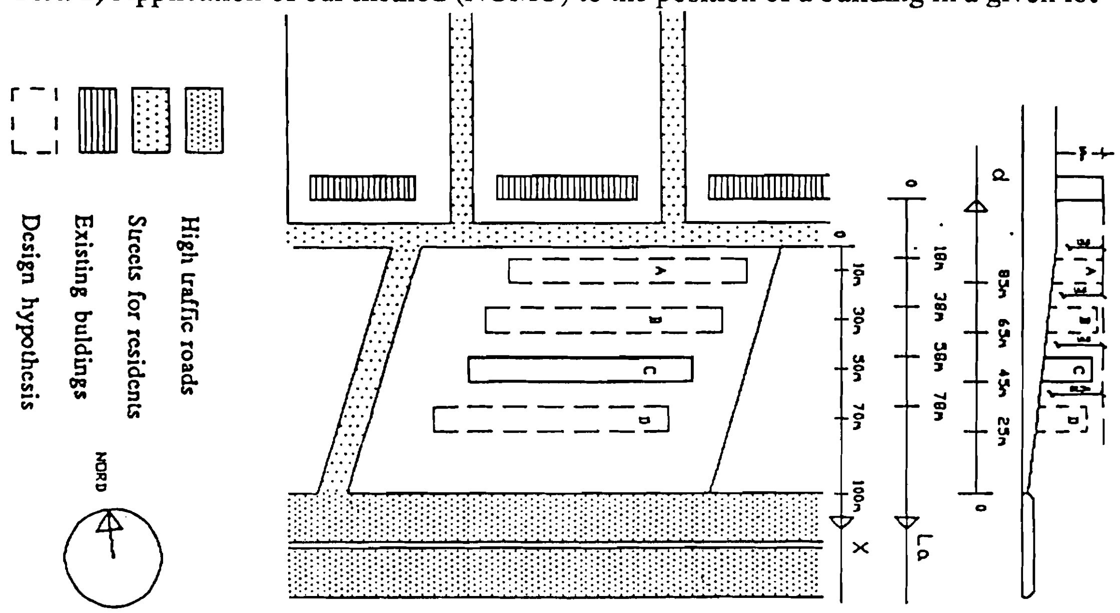

SELECTING MATERIALS AND PRODUCTS: THE POLLUTION CRITERION

Silvia Piardi
Polytechnic of Milan, Italy

I will present to you a work in progress at the Department of PPPE of the Faculty of Architecture of Politecnico of Milan.

Nowadays, the architect has a new big responsibility in his profession: he must be responsible for the impact of his decisions choosing building materials.

It is getting clearer and clearer that those decisions have important consequences on the welfare of occupants, on their health and safety, as well as on global environment.

In Italy, the demand for useful and simple-to-use information about the control of indoor air quality, the environmental impact of the products and the health and welfare of users is quickly increasing.

Until now, commercial and technical information about building products concerned only some of their features; such as dimensions, performances and price.

There is a lack of knowledge about the relationship among these features and the correct use and environmental impact of the products.

Each information is available and sometimes very exhaustive, but seldom interrelated and often hidden in specialized fields: the architect can rarely collate all that he needs.

Our goal is, for each product or family of products, to relate every aspect of its life, from the cradle to the grave. It is necessary to evaluate building products manufactured and sold in Italy, because each country has its own specific building know how.

Our work focuses on:

a) Selecting the relevant information to establish the relationship between materials and the environment;

b) Developing a logical comparison schedule, where the factors are:
   - availability of raw materials;
   - features of the manufacturing process, transport and installation;
   - pollution in indoor air, when in use;
   - potential reuse or recycling.

c) Collecting available information in comparison forms;

d) Obtaining a pre-evaluation of acceptability of building products;

e) The control of our hypothesis testing of some sample products, in different conditions of use. To test all of the products is, in fact, very useful, but too expensive and time consuming.

It is important to underline that the choice of products is strictly related to aesthetical, functional and economical factors, as well as:

a) quantity of material to be used and its quality;

b) features of settlement.

Every decision maker must take on the responsibility of choosing the product according to the specific context in which it works.

It is very difficult, or impossible, to give valid lines or rules in many cases, except for a few noxious products, such as asbestos or lead.

In fact, a good product for indoor air quality can be environmentally destructive, or dangerous for the manufacturers, or noxious during demolition.

Our challenge is to offer integrated information coming from different scientific and technical fields.

Our state-of-the-art software takes two forms.

The first one relates to product life and human life.

We examine each product life phase to discover components that may affect human health.

The second form deals with the general impact of the product on the environment.

Conclusions

The most important thing for the protection of the environment and of the welfare of the people is now, in my opinion, the information on the problem.

The demand for environment friendly products is increasing in Italy, therefore, we have to try to direct our efforts to adjust industrial processes to reduce outdoor and indoor pollution.

The cooperation of architects is vital. The education of a new generation of environment friendly architects is in our hands.

SUBJECTS' ASSESSMENT OF VISUAL WORK ENVIRONMENT IN BUILDINGS

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INTRODUCTION

This paper deals with an investigation of perceived visual discomfort from glare sources in interior contextual settings. The research is being conducted at the Institute of Construction and Architecture of the Slovak Academy of Science. One of the main reasons of establishing this subjective research in the Slovak institute was to test the Western hypothesis that the results in Czecho-Slovakia will be different because people here have not been exposed routinely to high interior lighting levels in comparison to Canada or USA.

An informative overview of the discomfort glare research, its direction and main aim of experiments is given in our poster (see other part of Proceedings). As the whole experiment is rather complex we will concentrate in this paper on the description of the experimental procedure and the analysis of the chosen aspects of results, concerning all three experiments already done. Particular evaluation and explanation of all obtained results are prepared for publication.

EXPERIMENT DESCRIPTION

Size and characteristics of space
Experiments have taken place in a hemispherical artificial sky (8 m in diameter) under standardized overcast sky conditions. The inner reflective surface is covered with special, spectrally non-selective matt white paint. So the uniform environment with luminance gradient 1:3 was prevailing with luminance values from 70 cd/m2 to 210 cd/m2 in zenith. Test space was fitted with indirect light sources and was completely independent from the actual intensity of the glare source. The lights were voltage regulated.

Size and position of glare source
In the experiments I-III a small glare source with solid angle of ω = 0.001 steradian was used. Warm-white fluorescent tubes were used to fit the glare source, which was controled only by the observer using a dimmer controlling knob. The Lutron solid-state dimming device enabled to rise the glare luminance from 70 cd/m2 to 6500 cd/m2 while the illuminance on the work plane was roughly 500 lx all the time. A task luminance was of 125 cd/m2; an ambient surround task luminance was of 60 cd/m2.

During the first step of experiment - familiarization session - the pre-set of glare source was with its central position horizontal to the eye and normal to the direction of work.

Fig. 1
A measurement setting under artificial sky.

During all sets of experiments the position of the observer's body was steady in the middle of the artificial sky space but his head position was without fixation free to move.

METHOD

Subjects Four groups of eight persons in the experiment I (16 males and 16 females) and four groups of four observers participated in the second experiment (7 males and 9 females). Their ages ranged from 19 to 38 years (mean age= 26.5 & 30.5). Each one had finished the secondary school and 75% of them have graduated. The subjects were volunteers, were not paid, and were not involved in vision research. The participants were not informed of the real objectives of the experiment. Each observer was instructed to avoid alcohol or drugs the night before the experiment session and to use glasses during the experiment if needed.

The subjects were randomly divided into four groups of four persons. Each group was assigned to one of the four starting positions considered in this study (JP, JA, JU & JI with the horizontal and vertical displacement of the glare source).

During the experiments some subjects had to be changed so there is some inconsistency of data.

Visual work task To simulate the visual working conditions in an office environment, each subject was given to perform visual work tasks in form of reading and answering simple questions.

Apparatus The measurements of luminances were made with a Minolta luminance meter nt-1°.

Protocol In different parts of experiments both Hopkinson's as well as new developed protocols were used. A general instruction explained the purpose of the experiment, questions about it were answered at this time. The four discomfort criteria (just perceptible JP, just acceptable JA, just uncomfortable JU and just intolerable JI) were introduced and presented in blocks using the latin square method. During the tests there were time limits to perform the visual tasks but usually the person was engaged about 45 minutes with a short break midway to adapt for new glare conditions. The discomfort glare levels and azimuthal positions were presented in different sequences counterbalanced among the four test subjects.

Two perceptual scales were used: S1 to estimate the magnitude of the discomfort attributable to the glare source, on a scale of "Worst Conditions" to "Best Conditions"; and S2 on a light presence scale of "Completely acceptable" to "Completely Unacceptable". The used scales without point rating have the advantage of not directly asking the subjects for their impressions, thus minimizing the experimenter bias.

Procedure Subjects were accepted individually. Before the subjects arrived the ambient luminance conditions were set in the laboratory. During the 5 minutes adaptation phase subjects filed in a form (gender, age, occupation, eye colour, use of glasses or corrective lenses and sleeping lenght of the night before) and because of atypical laboratory environment - they were acquainted with the usual purpose of this space. All instructions in the experimental procedure were taped to be sure that exactly the same instructions for each observer were given. The experiment began when subjects indicated that they understood the instructions and were ready. Subjects were not given feedback on their performance during the experiment.

Experiment I was divided into two parts. In the first part each observer had to set up four levels for Hopkinson's multicriterial scale using the translated original of his protocol. Therefore in the 1.session of this experiment the observers set up the steps in the order of JU, JI, JA and JP. In the 2. session they set up only JA level, while the glare source was placed in the position of 0 degree, i.e. in the central position to the eye and normal to the direction of work.

In the beginning of the first part in experiment II the experimenter pre-set the luminance of the source to equal subject's own selected luminance from experiment I for the commencing discomfort point. The observer was not informed about the reason for the level of the source luminance setting. He/she had to estimate the magnitude of the discomfort attributable to the source on the first perceptual scale, then on a light presence scale. After completion of this magnitude estimation the observer had to set the source to the multi-criterion point to which the experimenter had previously pre-set the source luminance. And again the observer estimated the discomfort on the perceptual scales. Of course the sequence of the starting glare position for subsequent observer and the order of discomfort levels was designed according to the Latin square variations. In the further part the observer was asked to set such glare conditions which he felt to be JP just perceptible, JA just acceptable, JU just uncomfortable and JI just intolerable. During each session they had to perform a visually based writing task which lasted 3 minutes. After the completion the task they have to estimate the discomfort glare on the two perceptual scales again.

In the experiment III the impact of the vertical displacement of glare source was studied.

DISCUSSION

As our experiments consisted from more parts concerning many aspects then also the statistical analysis of the obtained results is rather complex. In this paper we start with the statistics of the common aspects of all three experiments.

The validity of our study is limited by the actual conditions and circumstances in which experiments took place. Most of the participants work usually in areas with daylight and thus may have been somewhat negatively biased toward the experimental settings in the atypical laboratory space under the artificial sky. This conclusion is supported by many comments, even complaints the observers made during experiments. A further limitation can be explained by the characteristics of the sample used in the experiment. We have already mentioned some inconsistency of the data due to the change of some observers. So let us first analyse the sample characteristics.

Figures in our poster presentation show an overview of the setted source luminance levels for the particular steps of the Hopkinson's multi-criterion scale during experiment II. The description is complex i.e. in the figures there are included also the previous results from the experiment I. Each plot of data is divided by the counterbalanced groups of the observers. It is obvious that the variance of the obtained data in four groups has big differences.

As an indicator of the overall amount of variation are standard deviations but in the case of more comparable values the variation coefficients are more informative. In Table 1 are presented the arithmetical means, variation coefficients (CV) and t-test coefficients for the obtained data of 16 observers.

Table 1
Basic characteristics for luminance levels of glare source and perception scales

Obs	Variable	Mean	CV	t
16	L1JP	312.3125000	128.6426416	3.1093889
	L1JA	1039.25	92.0099294	4.3473569
	L1JU	1999.69	62.0634368	6.4450185
	L1JI	3096.81	52.6112904	7.6029308
	S11JP	1.1437500	241.2009726	1.6583681
	S11JA	0.6875000	395.5677302	1.0112048
	S11JU	-1.0312500	-145.4208715	-2.7506368
	S11JI	-2.8750000	-60.4123616	-6.6211615
	S21JP	1.0187500	254.3125473	1.5728677
	S21JA	0.2812500	977.9797771	0.4090064
	S21JU	-0.8125000	-210.6437957	-1.8989403
	S21JI	-2.9687500	-70.2455790	-5.6943085
	L2JP	435.0000000	207.0093520	1.9322799
	L2JA	433.6875000	106.1558670	3.7680442
	L2JU	2122.25	68.4160109	5.8465847
	L2JI	3741.88	44.2457755	9.0404111
	S12JP	2.6562500	73.2970446	5.4572460
	S12JA	1.1562500	227.5754851	1.7576586
	S12JU	-1.1875000	-161.8909497	-2.4707990
	S12JI	-4.1562500	-19.0053614	-21.0466927
	S22JP	2.5625000	88.9536416	4.4967243
	S22JA	1.1250000	252.7218090	1.5827680
	S22JU	-1.6250000	-65.9926480	-6.0612813
	S22JI	-4.0000000	-49.3710441	-8.1019149

High values of variation coefficients emphasize the importance of a thorough sample analysis. The t-tests were conducted to test for the normality of the distribution of the data. These tests suggest that the distribution of data from Table 1 are in most cases normal with the statistical significance of the t-tests where Prob(t>1.753). For this reason parametric statistical analyses assuming normality were in further steps used with more confidence.

A proper attention has been given to test the variance across and within the groups of observers. Table 2 depicts an example of the within-group analysis for the averaged glare source luminance levels with the values for F and t-tests together with the conclusion (> N => no impact).

Table 2
Comparison of the averaged luminance levels within four counterbalanced groups of subjects

		CB=1	CB=2	CB=3	CB=4
L1JP	F	2.399	1.530	4.935	3.242
/	t	0.770	0.400	1.243	0.952
L2JP	>	N	N	N	N
L1JA	F	3.430	1.270	3.299	1.091
/	t	2.095	0.410	1.565	0.228
L2JA	>	N	N	N	N
L1JU	F	1.159	1.477	1.061	1.052
/	t	1.154	0.545	0.194	0.246
L2JU	>	N	N	N	N
L1JI	F	1.378	1.165	1.111	1.757
/	t	0.970	0.891	0.065	1.859
L2JI	>	N	N	N	N

As expected the much greater differences are across the groups. For the critical cases we have calculated the errors using the power function of the t-test. The results indicate that the sample size of four subjects is not sufficient. It is proved also by the high values of the errors from the ANOVA's analyses. So our results can serve only as a pilot ones.

The appraisal values for observers of each group were averaged as an arithmetical mean and in Fig.2 these mean values are plotted against glare criteria.

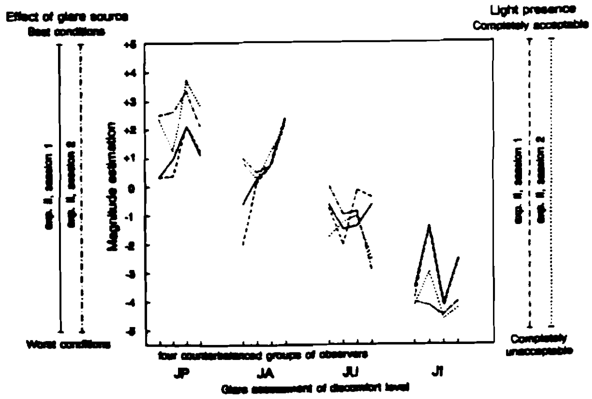

Fig. 2
Comparison of the appraisal values vs discomfort glare criteria.

The mean ratings of the assessment of the discomfort are attributable to the source and on a light presence in the lit space. The common characteristic of these schemes is that the assessments are decreasing for the discomfort glare criteria in sequence from JP to JI. However the variance of four groups' data is impressive (see also t-test values in Table 1 for scales S1JP-S2JI) and again we need to take into account the analysis of the sample characteristics as mentioned above.

CONCLUSION

This paper has reported and examined the chosen results of an experiment concerned with the study on the relationship between subjects' assessment of discomfort glare and luminance levels of discomfort glare sources.

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VENTILATION AND AIR QUALITY

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The objective of my work was to define if there was any correlation between the carbon dioxide, the density of occupancy of space and the relative humidity. Many people believe that carbon dioxide is the first indicator for odour quality or for the body odour qualities. The body odour quality was the first contaminant suggested by previous researchers as the first indicator for the quality of the air.

The procedure was a program of experimental work designed to investigate any correlation between carbon dioxide, occupancy level and relative humidity. A little room with a volume of 154 m^3 was selected because of its situation and construction. The density, time and duration of occupancy were correctly controlled and the series of investigations carried out on air quality on this room. The level of carbon dioxide and relative humidity were measured using an appropriate instrument. The assessment of odour was carried out by the analysis of a questionnaire completed both by the occupants of the room and by a panel of others.

Other measurements were assessed both inside and outside the room, others were assessed by means of panelists who are given questions to determine the possibility of odour and acceptability or unacceptability of the odour. Odour and density and acceptability were assessed by the use of sniffing stations, each of the panelists being called every fifteen minutes to make his assessment. The assessment of odour lasted until all the panelists had recorded that the odour had become unacceptable or until the end of the lecture.

During the lecture, students in the lecture room were also asked to assess the odour by filling out questionnaires. As soon as the lecture was over, the panelists entered the classroom and assessed the odour at the end of the session. The sniffing station has been designed with a potential volume air change of 3.7 L by unit.

This figure number one shows the mean radiant sampling point; as it can be seen, the mean value of the temperature was on each side of the classroom. Number two is the carbon dioxide concentration sampling point; as you can see, there are three points; one is not 0.8 m above the floor, one in the middle 1.8 m above the floor, and the third is not 0.8 m under the ceiling. The carbon dioxide was measured by using an infra-red gas analyzer. This infra-red gas analyzer gives the level of carbon dioxide and absorbency unit. The analyzer shows the correlation between the absorbancy unit and the concentration in parts per million.

This you can see the position and the dimension of the carbon dioxide sampling point in the classroom. This classroom, we can see a manifold with three tops. This is leading to the infra-red gas analyzer, which is the main infra-red gas analyzer; one comes from the corridor, the second comes from the test room and the third comes from the outside. Why compile these three? It is just to follow the way of the carbon dioxide or the variation of the carbon dioxide from the outside and the corridor. We will finish it with the measurement of physical parameters. Now we are starting our psychological objectives.

Panelists were asked to come every quarter hour to give their readings. The first reading was the quarter hour after the starting of the class, the second, half an hour and so on. We can see that panelists were asked to fill out this questionnaire. Numbers on the questionnaire were not given to the panelists; it was just for after the assessment. As well, the panelists were asked to see if the odour was acceptable or unacceptable. There was the numerical scale associating the odour after the assessment.

The analysis of these results shows that the level of relative humidity was not so large to use the relativity as a good indicator and the relative humidity itself was affected by the external, rather than the internal classroom. So, even if the classroom was with a high density of occupancy and the level of relative humidity outside is low, the level of relative humidity stays a bit low.

The carbon dioxide was a big range, but still this variation of carbon dioxide always follows an exponential curve, which have tended to have a constant value after long durations. But if we use classrooms like that one, we can see that the carbon dioxide level after two or three hours varies. If we add more people to that room, the level of carbon dioxide will go with very low variations, which looks steady. We can't use the carbon dioxide as a good indicator; we use the carbon dioxide just for a few hours in the beginning.

The conclusion of our work was that there was no significant range of carbon dioxide concentrated values over which the odour was judged unacceptable by different panelists. Most of the results of the panelists entering an unoccupied test room were more-sensitive to unacceptable odours than the occupants of the room. There was no correlation between the carbon dioxide levels and the density of occupancy. There did not appear to be defined correlation between carbon dioxide concentration level for unacceptable odour and the density of occupancy.

We suggest that more work and the odour field requires much more wide range studies with more details to provide a more satisfactory assessment. The correlation between the density occupation, the carbon dioxide concentration and the body odour acceptability and unacceptability needs more investigation.

SESSION 3B
INDOOR ENVIRONMENT AND USER COMFORT

Questions and Discussion

Question

The most pertinent presentation was the first that we had from Silvia Piardi, when she explained to us the project that she is involved with in identifying the pollution related to building products. I would like to ask if she can give us some idea when some specific results from that investigation would be available. Certainly, one of the things that impresses me is that certainly there are some regional differences, but for the most part, the problems, the issues and materials are increasingly common between countries. Maybe more marble in Italy but then we have got to look around here and we do have lots of marble here. Can you respond to that question as to when?

Silvia Piardi

My answer is very simple. We will publish our work within a year if possible, because we have few resources and few people that work on this.

Question

I noticed from the table in 33A that there is an item that deals with, in case of fire, and the corresponding source of pollutants is simply toxic fumes. I am wondering if materials are also being looked at from other points of view, in case of fire? Aside from the production of toxic fumes, are you also looking at the possibility, in case of fire, of pollutants such as water streams, because as a result of certain types of products used during construction and stored in buildings, there is a corresponding pollution of water streams, not just the air. Is there any work being done in that area?

Silvia Piardi

No we haven't. The indication of toxic fumes is to say that it is important to consider all the factors involved, but we have not studied this problem.

Question

Concerning the control of the formaldehyde, the gas after the construction has started or finished, how long should we be looking for the control of the formaldehyde vapours coming from the siding, which is composed mainly of wood particles and sticks, the glue is mainly formaldehyde and you have this kind of vapour also from curtains and furniture. Is this a such a bad problem, that we should have some kind of ventilation for six or eight months after the end of construction?

Answer (audience)

The real strategy of dealing with pollutants should be source-oriented, basically. Ventilation should not be recorded as a solution of the pollution concentration. I think this has approached its state of the art.

Peter Russell

I think the question might well have recognized that, but still I appreciate his question because, regardless whether you have succeeded or not succeeded in controlling sources, it is how long is it relevant to be testing, and I think that so long as you have got sources such as furnishings, which are semi-independent of the structure itself, then it may be measuring the formaldehyde regardless of when a building might have been put up.

Comment (audience)

If there are permanent sources, permanent emitters, which might be furnishings or which might be, for example, gas cooking, if those kinds of sources are present in an environment, shortened increased ventilation would not solve the problem. The concentration might still be high after two years.

Nadia Boschi

I would like to add more, like I said at the beginning of my lecture, was that we are working together, so today both of us talked about two specific aspects of the research that we are doing. Of course the psychological and sociological factors which we are considering are also part of the indoor environment and when we were talking, if I didn't misunderstand, about ventilation rate and occupation system the first day that the building was finished. We know that the natural ventilation is the best way to take care of indoor air quality. We also know that it is a necessity and a bad habit to start to live in the building from the first day. But we have to deal with an economic factor, that the people who want to build a house, want to rent the space, and have money from the first day, because that is the economic costs. I think personally, that if you are going to use healthy materials, it's very difficult to define what is in healthy materials right now, but in that way you can have a building that you can live in from the first day and if you use and design correctly the mechanical engineering system, you can also save indoor air quality. It's a problem of design.

Question

I know that we can improve the quality of air with ventilation, but since the formaldehyde comes from painting, carpets, almost everything in buildings, how should we plan, since there are no replacement materials for these right now? What should we do to test the air quality?

Nadia Boschi

We know very well that the emission is very high at the beginning and starts to go down over time. There are also some examples that we are talking about from a few days ago that there are some cycles to raise very high temperature and very low temperatures before living in the building. It's a kind of bake out. We have to start to do this in housing as well.

Comment

I think it is an example of a more general question, which appears on some of these papers on indoor air quality, and that is, how do you set the acceptable ventilation rate in buildings or how do you set limits for sources of pollution? Traditionally, I think that we have set ventilation rates by considering body odours. In Victorian times in the U.K., the ventilation rate was set to avoid unpleasant smells from other people. More recently we have looked at the moisture levels in buildings and found that half an air change per hour is about right for avoiding condensation, mould growth, and generally, if you look at the source of concentrations that we are looking at for the major pollutants, then that would also be adequate to reduce the air concentration to an acceptable level.

I noticed that some of these papers on looking at materials have looked at emissions from materials and set some limit, high, low and medium emissions. I would like to know how those criteria are arrived at and what their relevance is in terms of setting either ventilation rates in buildings or what criteria were used for choosing materials to reduce the emissions from the source to acceptable levels?

Silvia Piardi

To know the kind of emission from a material is very important, because if the emission is constant, slow or rapid, the technical interventions are different, as well as if the emission is low, medium or high, referring to available standards and available values we find in international research. If we have material that has constant emission, we can design the ventilation in a constant way.

Nadia Boschi

If I can add one more thing, you are saying, which criteria we are going to use to say why it is high, low or medium. Some data are available. We know everything about radon, or asbestos, but some of the others we do not know but, for example, if we are going to consider wood instead of stone, we have to consider not the material by itself but connected with the laying technique that we are going to use and which kind of treatment we are going to use after laying the floor, for example.

We know in an intuitive way that, to lay a parquet wood floor, it is better to nail instead of using glue, so we can say that if you are using wood, laying with nails is better than using glue, but we don't know anything about the glue so we cannot say that the glue does not work.

Another point is that when you are going to evaluate wood, you are going to evaluate just a material not only connected with the pollutant ratio but also connected with all life cycles from the beginning to the end.

We are concerned about the role of materials; how much energy do you need to have available and if it is possible to recycle that material. Another intuitive factor is, from experience, that the experience of the designer is very important, it has to be connected with the data and research and task, but the task takes a lot of time and we have a lot of data collected in a short time, and we have to start somehow. This could be one way.

Comment

The only really systematic approach that I know to derive logically ventilation rates is by Olif Hanger, and his notion was, as one of his colleagues said, to use a panel of groups and their perception, judgement in terms of the evaluation of the emission of materials and with the units of decibel and all resources of development methods, how you can add up the different emission sources in a building and based on that derived ventilation base, should actually show quite interestingly that in a building with high emission sources, a high occupancy rate, the ventilation rates are higher than in buildings with low emission.

I agree with the notion that pollutants and highly emitted materials should be accepted and then afterwards we should try to find out and with rather high ventilation rates, which have energy implications, and we have thermal comfort implications, try to solve the problem.

For most of the materials, there are alternative ways of reducing the emission at the source and this is a point I want to stress very much, it is rather the way of the future. Backing-out process, a couple of people have recently shown that they have had a lot of problems, they might lead to chemical degeneration of some materials and create site problems.

Question

I would like to know if the research findings that you have on the concert halls is applicable to office meeting rooms?

John Bradley

The results in these halls are really exactly applicable in any other room for speech or music and we have done work in school classrooms. If you go to a concert hall there are a few extra things you have to worry about, that's all. Yes, it definitely applies and we are very interested in the meeting room, classroom end of the problem too.

Question

You said that the change in terms of the sound levels in the room were not very significant. Was the noise produced by speaker, as you compared this to situation, or were the field measurements of actual existing noise?

Sten Ljunggren

We made measurements for 24 hours, one 24-hour period before the glassing over and one 24-hour period after, and there were some other changes, not on the reglassing over. We got a new roof, a new floor in the pedestrian areas and a lot of the sounds come from the trolleys and new floor was smoother than the old one and this implies that sound produced was a little lower.

We have made different evaluations of the tapes that we brought here and we can see we get some different results. We inspect the background sound and the peaks of the sound, but on the other hand, the peaks are produced by sources very close to the microphone, so I don't think they are very relevant in this aspect.

Question

What is the dominant source of noise, is it the people talking or is it the walking?

Sten Ljunggren

It is a mixture, there are lots of people walking and talking here and there were also the trolleys with food and so on, from the shops to the cars.

Question

I was interested in Mr. Décamps' comment that one of the possibilities of reducing noise is perhaps a creation of a quite room within the house. I liken that to one of the things which some people are doing who are very sensitive to air quality, is the creation of one room within a house which is particularly clean and easier to keep clean, than trying to keep the whole house clean.

Can you elaborate on how it is that you are achieving particularly noiseless rooms, within an otherwise perhaps noisy house? What acoustic measures are you taking to achieve that?

Mr. Décamps

A noiseless place would be almost unlivable, but what we need is a place that would be relatively isolated from the others by a classical system. But this place would also present other problems, for example, a mother of a family working at home and the children would be in the normal part of the house, she would not be able to hear her children.

Some solutions to this problem would be for the mother to survey her children with some sort of acoustic system or even a television outside of the noiseless place in order to supervise the children.

SESSION 3C
Strategies for Energy Conservation
Les stratégies d'économie d'énergie

ENERGY CONSUMPTION AND CONSERVATION IN GLAZED BUILDINGS OF SAUDI ARABIA.

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1. INTRODUCTION.

1.1 Many buildings of recent times have large glazed envelopes to accomplish few purposes;

1.1.1 To admit natural day light 'in' and keep undesirable elements like dust, rain, sound 'out'.

1.1.2 To provide panoramic view for out-door visual contact with the building.

1.1.3 To be a source of ventilation for the needed fresh air infiltration.

1.1.4 To act as a decoratioal element.

1.2 In Saudi Arabia, several fully glazed buildings with 100% glass 'curtain walls' on all its four sides and other with large glazed envelopes have been built recently. Several factors have influenced this trend.

1.2.1 Non-existence of building codes/regulations for a satisfactory thermal performance of building materials.

1.2.2 Subsidized energy offered by the Government because vast reserves of natural gas/crude oil exist.

1.2.3 Subtle aesthetic appeal of alien architecture over and above the domestic designs.

1.2.4 Relatively easy availability of new building materials and know-how.

2- WEATHER IN SAUDI ARABIA.

2.1 Saudi Arabia occupies an area of 2.1 million kilometer in the Arabian Peninsula with about 0.75 million square kilometer desert land. The main weather features are;

2.1.1 Climate is hot and dry with essentially desert character.

2.1.2 Annual rain is unreliable, meagre and scanty.

2.1.3 Humidity is variable from low to high.

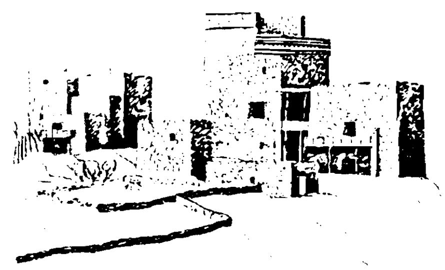
2.1.4 Wide temperature variations occur during the four seasons.

2.2 Weather data of dozen Saudi cities is given in Table 1 covering almost the entire country.

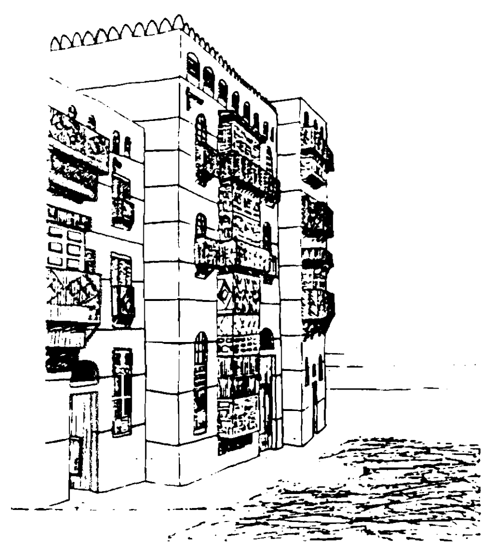
Table 1. Weather chart of some Saudi cities.

City Name.	Mean Extreme Temp., C°. Min.	Max.	Mean Daily Sunshine Duration h.	Mean Relative Humidity, %	Mean Global Radiation, Wh/m^2.
Abha	-0.4	33.7	8.7	57	5824
Bisha	1.0	41.3	9.2	30	7004
Dhahran	1.4	49.0	8.4	56	4729
Gizan	15.8	43.7	8.5	67	5003
Hail	-7.0	43.2	9.4	35	5239
Jiddah	11.4	49.0	8.9	61	5969
Madina	1.0	47.3	9.1	23	6368
Nejran	-0.9	42.3	9.1	33	6936
Qassim	-4.4	49.4	9.3	31	5489
Riyadh	-2.0	48.8	9.2	29	5132
Tabuk	-6.0	45.8	9.1	33	4479
Taif	-1.0	38.6	8.9	41	5429

3- TRADITIONAL BUILDING DESIGNS.

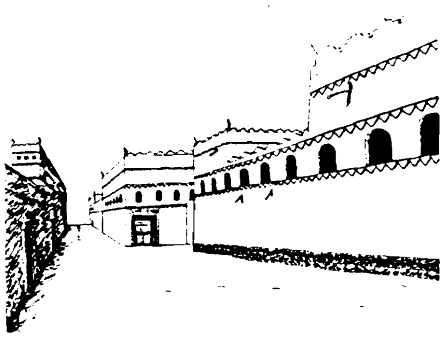


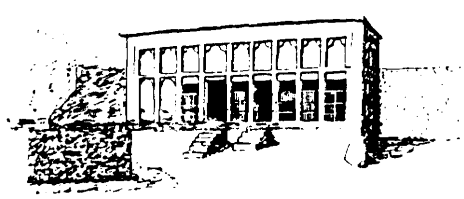
3.1 In olden times, unfired mud bricks were used. The walls were made very thick to achieve insulation. Few windows and openings were provided for energy conservation; see figure 1.



3.2 Where bigger windows and many of them were desired, all were made of wood in local 'mashrabiya' style. These provided diffused light, air infiltration and decoration; see figure 2.

3.3 Some houses were also built with mud, cut stone and coral aggregate. Large doors and few windows were provided. Energy conservation in these cases is achieved through building orientation; see figures 3 & 4.





4- ENERGY CONSUMPTION OF MODERN BUILDINGS

4.1 The modern architecture envisages a bigger glazed envelopes to the extent of 100% glass curtain walls. In terms of energy needs this would mean a high 'heat-gain' viz 'cooling-loss' at the glazings in hot climate.

4.2 In the midst of desert climate, the energy needs for a residential house, office building, shopping arcade etc. follow a general pattern;

4.2.1 Cooling = 70%

4.2.2 Heating = 5%

4.2.3 Lighting plus appliances = 25%

4.3 The data for detached residential base house situated in Dhahran and glazed on two sides with clear single glass panes equivalent to 8% glazed area registered an increase in energy consumption when the glazed area increased to 14.7% (Drs. Said & Abdelrahman); see Table 2.

Table 2. Energy consumption of base house.

Glazed	Energy Needs, kWH.		Energy Requirements, %.		
Area, %.	Heating.	Cooling.	Heating.	Cooling.	Total.
8.0	3283	33449	-	-	-
9.6	3266	33814	0.5	4.1	4.6
11.2	3262	36177	0.6	8.2	8.8
12.8	3234	37589	1.5	12.4	13.9
14.7	3403	38552	3.7	15.3	19.0

4.4 Assuming a steady-state conditions and computing the data for 14.7% glazed area to 100% glass curtain walls the energy needs stand at about 260%, an increase of about 240%.

4.5 The energy needs shall multiply to bigger values for fully glazed buildings in other cities (Table 1) where temperatures around or below 0°C have been recorded in winter, around or above 40°C in summer and mean global radiation is more then 5000 Wh/m^2.

5- MEANS OF ENERGY CONSERVATION.

5.1 In case of buildings glazed with clear single glass panes, the glazed area should be kept to an absolute minimum.

5.2 Insulating units with double glass be used for bigger glazed areas as these reduce the cooling load to around 35%.

5.3 Heat absorbing tinted glasses are other possibilities for building glazing as they absorb 30-35% of incident sun's rays.

5.4 Reflective glasses are suitable for fully glazed buildings since these tend to reflect about 80% of incident sun's rays in certain glass types.

5.5 Solid walls of the building made of hollow glass blocks would keep heat 'out' but would allow light 'in'.

5.6 Sun-breakers should be installed around glazed windows which receive direct sunlight.

5.7 Building orientation should be chosen such that glazed areas remain under the shade during much of the sunshine.

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HEATING OF BUILDINGS BY MICROWAVES

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Introduction

The incentives for introducing microwave technology for heating of buildings relate to a series of common objectives sought in the environmental design of the built environment:

(*i*) **to effect energy savings:** with the gradual depletion of conventional energy resources and the adverse implications of burning fossil fuels on the environment, energy conservation schemes are becoming increasingly essential.

(*ii*) **to improve indoor air quality and comfort conditions:** recently, an increasing number of buildings fail to provide healthy and comfortable conditions to the occupants, thus affecting their well-being and productivity. Unfortunately, some energy conservation measures, e.g. limitation of fresh air supply and number of air changes, inadvertently result in deterioration of the indoor environmental conditions.

(*iii*) **to implement high-technologies in the building industry:** implementation of high-technology products in tempering and control of the indoor environment contributes towards further modernization of the building industry and attaining energy savings as well as improvement of the living and working conditions in buildings (1).

Heating of buildings results in high energy consumption and wastage even greater if one includes all the inefficiencies in energy generation, transmission, and distribution. However, buildings are not always designed to minimise consumption of energy. The reason is that the return on capital is normally marginal and hence it is more "economical" to waste energy in heating than to tie up a large amount of capital in some outdated energy saving scheme.

Most energy saving schemes in low energy buildings rely mainly on thermal insulation and draught-proofing. The thermal inertia of a building is much more difficult to handle. It is still impossible to heat a room without also heating a substantial fraction of its structure, heat that cannot be recovered once the room is unoccupied (although it helps to alleviate condensation in some cases).

Moreover, there is the question of heat losses through ventilation. Do we really need N changes of air per hour, or would it be equally effective and healthy to replace only the CO_2 with clean Oxygen? (dust and other undesirable products, would be removed by using suitable filters).

Consequently, for many non-continuously occupied buildings an "ideal" heating system must provide a high degree of cheap thermal insulation, fast response, and low thermal capacity thus enabling an effective control of the system from "off" to "on".

This paper presents a radically new method for heating buildings by using microwaves. It fulfils, almost completely, all of the basic requirements for an "ideal" system and has additional intrinsic features that no other system can match.

Microwaves

Microwaves occupy the region of electromagnetic spectrum between radio waves and infrared (2); in terms of frequency this range is 1-100 GHz (GHz= Giga Hertz= 10^9 cycles sec^{-1}).

Industrial applications of microwaves are quite common, mainly for heating or drying, with power levels up to 100 kW. To avoid interference between various users, the microwave spectrum has been subdivided into a number of bands, the industrial bands being around 0.915 and 2.45 GHz, the latter more commonly used.

The main advantage of using microwaves is that they can penetrate deeply into the material and heat almost the whole volume simultaneously, in contrast to infrared which heats only the surface, the interior being heated gradually by conduction and consequently being a much slower heating process. This is the reason why microwave ovens cook faster than conventional methods.

For industrial applications, the magnetron is the most efficient microwave generator with around 70% efficiency; the remainder of the energy being dissipated in the magnetron shell which is water or air cooled. There is a slight inconvenience, namely, that magnetrons operate at relatively high voltages, between 4-6 kV, but fortunately the necessary power supply is relatively cheap and very safe. The typical life of an industrial magnetron is about 2000 hrs. Since the present application is only intended for low energy buildings, the magnetron will operate intermittently.

Microwave Heating of Panels

Heating a building or a room by direct irradiation with microwaves is not practical for the following reasons:

(*i*) even under uniform illumination, various parts of a human body would not absorb microwaves at the same rate, resulting in uneven heating and probably discomfort;

(*ii*) similarly, (i) is equally applicable to all objects in a room, with additional possibility that metallic objects could cause sparking and hence represent a fire hazard;

(*iii*) there is some evidence that all high frequency radiation, unless very weak, represent a biological hazard and, therefore, is unacceptable above certain safety limits (of intensity and time of exposure).

Clearly then, the microwave heating method has to be indirect. This can be achieved quite easily by lining selected walls with large panels which are internally heated by microwaves.

Microwaves from one or more magnetrons are injected into the panel cavity at convenient points with minimum power reflections. A metal skin prevents the interaction of microwave fields with the supporting wall. Microwaves travel through lossless thermal insulation into the absorber sheet which forms the other side of the microwave cavity. With a suitable choice of relevant parameters to achieve necessary matching, all microwave energy would be dissipated in the absorber layer, thereby increasing its temperature. Microwave leakage into the room from a microwave absorber layer is prevented by ensuring that the fields in the absorber are evanescent, decaying rapidly towards the outer surface. As an additional precaution, a conductive finish is applied to the surface of the microwave absorber. Thermal insulation, if sufficiently lossless, may fill the whole cavity without any adverse reaction.

For optimum utilization of energy and comfort, the panel temperature would be highest at floor level, progressively falling off towards the ceiling. The overall input power level can also be varied by changing the duty cycle, i.e. the time intervals a magnetron is "on" and "off". Furthermore, hot air from the magnetron cooling circuit can be ducted into the room, thus improving overall efficiency even more.

Clearly, the thermal inertia of a panel is very low because only the thin layer of the microwave absorber is heated. Since panel surfaces are directly heated, air circulations due to thermal gradients are reduced. Energy is also saved by suitably adjusting the vertical heating profile of panels.

The response of this system is almost instantaneous, and it can be electronically controlled and also set to respond to external ambient conditions, thus utilizing energy more efficiently.

Microwave Absorption and Heating Response

The limited knowledge about dielectric properties of of common building materials reveals that they have low absorptivity to microwaves in the 0.915 and 2.45 GHz frequency bands. The amount of energy a material absorbs at radio and microwave frequencies is known as the **loss factor** (ε_r''). The power absorbed by a given material heated by microwaves can be calculated (3, 4) by the equation:

$$P=2\pi f E^2 \varepsilon_0 \varepsilon_r'' \qquad (1)$$

where P is the volumetric power density (Wm^{-3}), f is the applied frequency (Hz), E is the electric field across the material (Vm^{-1}), ε_0 is the dielectric permittivity of the space (8.85×10^{-12} Fm^{-1}), and ε_r'' is the loss factor of the material.

It is clear from eqn.(1) that the rate of energy absorption in the heated substance is linearly proportional to its loss factor and the frequency of the radiation. It must be pointed out that the loss factor is itself frequency and temperature dependent. Water is particularly receptive to dielectric heating and has very high loss factors of 18 and 100 for frequencies of 3000 MHz and 10 MHz respectively. Little is known about loss factors of building materials (5). For comparison, dry sandy soil has poor loss factors of 0.016 and 0.04 respectively (3). However, it is possible to modify a low loss factor material without altering its other properties, by using suitable additives which must themselves have high loss factors. The development of such efficient microwave absorbers is essential for the efficiency of microwave heating of buildings.

The heating (temperature) response of a material per unit time ΔT is given by eqn.(2)

$$\Delta T=P/\rho c_p \qquad (2)$$

where P is the absorbed power density from eqn.(1), ρ is the density of the material (kgm^{-3}), and c_p is the specific heat of the material (Wh $kg^{-1}K^{-1}$)

Clearly, ΔT is proportional to the input microwave power and inversely proportional to the density and specific heat of the absorbing material. Since P in eqn.(1) is proportional to the electric conductivity σ of the microwave absorber, eqn.(2) can be restated as

$$\Delta T=\frac{C\sigma}{\rho c_p} \qquad (3)$$

where C is a constant.

Eqn.(3) may be regarded as the heating response of a microwave panel; it also implies that the microwave absorber should be as thin as possible. However, for satisfactory matching and acceptable attenuation across it, there is a minimum thickness which has to be determined by the field analysis of the complete panel cavity.

Conclusions

Unlike any other existing system, the described microwave heating method meets most of the requirements of an "ideal" system. It can provide the highest possible degree of comfort by suitably setting the heating profile of each panel; offers fast response and is very flexible; is capable of automatic electronic control, taking into account the external ambient temperatures. It uses low thermal inertia panels, which, being integrated with necessary thermal insulation, can result in negligible energy losses from the building. The design of a panel is such that it can be installed without any costly structural modifications.

However, there are also some disadvantages such as the relatively high capital cost of suitable magnetrons. Industrial magnetrons of 3kW or more are comparatively much more expensive, being manufactured in considerably smaller numbers, and hence the price could significantly drop if the demand were substantially increased. Some further reduction in price could be effected by widening frequency tolerances, so that the yield is improved, or even better, by designing a new magnetron specifically for the heating of buildings. In addition, it could be argued that the increased capital cost of the magnetron is offset by low maintenance costs and a substantial saving in plantroom space.

Acknowledgements

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SESSION 3C
STRATEGIES FOR ENERGY CONSERVATION

Questions and Discussion

Question

I can see that all of this nice and fine energy efficient technologies will hit the marketplace and will be implemented in, let's say residential houses, to narrow the question here. However, I am wondering whether you are going to have to change the behavioural pattern of people, are they going to actually use all of this new technology or are you taking this into account, into your data plan or not?

Response

Good question. The program has some part dealing with occupancy patterns but it is not geared primarily to the occupant per se but things like the C2000 commercial buildings program. One of our strategies was to involve tenants through the design process in a much more active way than has happened in the past and when we are looking at what makes homeowners tick; comfort, ease of operation, maintenance, all of those things; those are to some degree taken into account within the programs. In Energy, Mines and Resources, there are other groups that will be dealing with marketing and general occupancy issues as part of a consumer awareness program, but clearly we are concerned about occupant interactions and their attitudes and understanding their trends and the aging population. All of that has to be taken into account.

Question by Hanna Swaid, University of Reading

I have actually two questions. The first one is whether you have some validations of these computer simulations and the second thing is, I think the direction that you are showing is exactly opposite to the findings of the research you mentioned about the surveys in the San Francisco area where people would like cooler temperatures while your results show that the predicted mean is increasing actually. It is already not neutral, it is about 0.2 or 0.3 and it increases until about 1. So actually the direction of your findings or the results of the measures you are taking are actually in opposite direction to the findings by Sheila in San Francisco.

Response

First question was regarding validation. Your question was validation of thermal comfort model or computer simulation for energy consumption. Energy consumption. The validation is that I use a computer model which has been in use for 15 years which is well known in North America. It was very well validated and it is one of two programs; state-of-the-art, dual program called BLAST. That means I did not to have validate this type of program because it is already validated; it is well known. It is distributed in Europe, it is largely used and supported and the matter of validating the program was beyond the scope of this project. I concentrated the validation only on the thermal comfort. You should also take into account that the building I used was a fictitious building built based on standard 90.1 which is not the real building. It is a prototype building, however, we should follow a very strict way to define different parameters and this is the reason why I selected this one. We have some other real buildings simulated in Montreal which is possible too. What I prefer for this particular type of work is to use something which is largely known.

The second question is a very nice question and I will tell you why. Because at this moment, it is a large dispute and a tight community dealing with thermal comfort. Who knows there are different trends. One school is trying to push for their way, as well, there are other schools now coming from Kansas State and they are trying to put under question fungal model and it seems to me a very important element in this situation. Right now the work is being carried out by Lawrence Berkeley dealing with these results and they show fungal model or other models do not deal correctly with real people perception; however, now because you are in this situation where everybody is trying to push his own, I am not saying I am trying to push mine, but as a researcher I am very free to show my point of view. The problem is also maybe the perception of people in San Francisco is different from the perception of people in Montreal. There was very nice work carried out in 1973-75 by Humphey in England and some results were published in a CIB journal whereas they found the neutral temperature or the preferred temperature is not constant but varies in terms of different climates, varies in terms of location, varies in terms of the predominant outdoor temperature. For instance, in Baghdad, you don't have the same preferred temperature as in U.K. or as in Algeria, because there are some customs, some traditions, there are some habitats there, there are some type of operation systems and it seems to me it is an open area and this is nice to be the researcher.

Question

What level of the expenditure, what kind of money is being allocated to this Best program?

Response

I think the annual expenditure of the program is something in the order of 8 million pounds.

Question

Some of that is pretty impressive stuff you have there. Have you actually built one demonstrating the thermally induced air flow strategy?

Response

Not yet. I am trying to compile the issues that can be classified as climate responsive techniques and then my future plan is to really start one by one and see how we could really benefit from that through modelling.

Question
Heather Alt
Atmospheric Environment Service in Canada

I found it was quite interesting that you showed the importance to which energy efficiency measures should fit the outdoor climate of the region you are dealing with. I also found it interesting that you developed the solar model to look at the impact of various measures on energy efficiency or energy use but perchance did you run any of your models to consider how the situation could be transformed under a future, even warmer climate than this greenhouse warming?

Response

I haven't directly dealt with that because the difference is not important. If we take that into consideration then this kind of strategy becomes even more important for us but if we talk about absolute level the model is the same, the concept is the same, maybe the temperature difference on the curve will change by 1/2 degree. This is the issue when you are developing a model because it is part of the data input of the weather conditions so if you account for this then the model will take that into consideration.

Question

Just one cautious point about the evaporative coolant. Unfortunately, in many semi-arid and arid areas, water is a scarce product and just as an example, in the Packard Bell building in California they tried to use a lake for evaporative cooling on grass and as a result the water level of the ground sank drastically and introduced a lot of problems.

Response

I personally agree 100% with you on the grounds that energy usually is scarce in areas where cooling is needed but if we talk about the amount of energy, for instance, water used in cooling on chillers and the waste of others, then we can justify the amount of water especially used in the evaporation. As you see the mister doesn't really consume much water. It is not like running water so practically you might lose as much water or probably less if you have a small air conditioner or something else that has a chiller or cooling tower.

Question

So what the microwave actually does with your conductive metal finish is it actually reradiates out but you are saying there is conductive heat that is generated as well too and that is why the thermal insulation is there?

Response

You mean the metal skin.

Question

No. Your conductive metal finish. The microwave is actually heating that surface up and then it reradiates into the room.

Response

Yes it warms the whole substance.

Question

But your thermal insulation is intended to keep the conductive heat that is generated from moving back through the wall, so the microwave radiation actually breaks down into the two components. Is that what you are saying?

Response

Well, let me describe it again. You inject microwaves, they go through the thermal insulation without being absorbed. Then they arrive at the panel. This panel should absorb all of the radiation. The panel absorbs it, all the volume of the panel is heated and because of that you will have a high surface temperature here and because of that you will have infrared radiation emitted into the building interior. The purpose of this metal skin is that not all of the radiation is absorbed in this few centimeters of the material, then they will not go astray, they will not go into the building, they will be returned, reflected back into this cavity.

Question

Yes, you might even try another reflective layer instead of the thermal insulation layer.

Response

Well then the radiation will not penetrate and arrive at this panel.

Comment

I guess you cannot nail pictures on the wall in this one.

Question

Could you give us an idea of what sort of surface you might need to heat in a room or would the whole of the wall need to be heated in this way or would it be separate panels, do you think?

Response

Well the calculations here or let's say the area needed is exactly as we make calculations for radiant heating from conventional sources so there is nothing special in this case and the design we are doing for this panel is not really intended to get very high temperatures because at least part of them are in the occupancy zone and we don't want that. If somebody puts his hand on the wall, he will get injured by that so we are talking about 40° to 50° C and the area needed for that, as I said, is calculated by usual methods of heating calculations. It is important to mention that because the heating requirements of this space are achieved by radiation in this case, one of the problems of buildings now which is related to ventilation, is that ventilation causes loss of energy. Then if you have the heating provided by radiation and the air is not heated then you can allow more air changes and that is really what occupants want to see, more air changes and more air movement in existing buildings, office buildings and other sorts of buildings. So really with radiant heating you can achieve that but, as I said, this is the same as any other sort of heating which could be achieved by electricity, for example.

Question

As you develop this relatively new technology, are you anticipating other environmental impacts upstream or downstream in terms of manufacturer's impact on other bio-systems in the buildings, disposal systems or handling and sealing problems, in other words, in the context of this conference perhaps there are some interesting questions about here at the beginning point the development of a technology how does it relate to other agenda items?

Response

Well harmful radiation is a problem and those are great interests. We are interested in preventing any leakage of the radiation into the building and obviously there is lots of research on the effects of microwaves on human beings and mice. The point is that this is an innovative thing and we would like to explore the potential of this technology. It is very important and everybody we are collaborating with is signalling to this safety problem but I myself am a bit scared or worried about doing the experiments within a few months because of the radiation effects.

Question

What about the other components or materials?

Response

We are talking about existing materials in the construction industry, with some carbon which would be added to the conventional construction elements. There is nothing new with implications on the environment.

SESSION 3D
New Energy Technologies
Les nouvelles technologies énergétiques

Comprehensive Heat Loss Studies of New Advanced Double Window Glazings

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1. Introduction

The development of high thermal resistant insulating materials has led to a considerable reduction in heat loss through building walls and roofs. The reduction in energy transmission through window glazings remains the major challenge facing the building research groups. While anti-reflective coating material has reduced the radiation heat loss through windows, the problem of convection heat loss through the window air gaps continue to pose a major challenge to the designers of energy efficient window glazing systems. Several efforts have been directed towards the development of vacuum-insulated double window glazings in order to eliminate the heat loss by convection. The major short-coming of a vacuum-insulated glass window is the difficulty in maintaining a perfect seal around the double glazings. Also extreme heat and cold could deteriorate the seal around the vacuum-insulated glass, thereby losing that advantage. All these potential problems associated with the vacuum-insulated glass technology make it less attractive. Therefore a direct approach to solving the problem of convection heat loss through window glazings becomes necessary. This approach must take into consideration the fundamental and physical understanding of the convection mechanisms occurring in the air gap of the differentially heated window glazing system.

Natural convection heat transfer in the air layer enclosed between two differentially heated vertical plates has received a considerable attention in the past. Few examples are the works of Batchelor (1954) and Eckert and Carlson (1961). But these studies were not directly related to building technology. In relation to building technology, Wilson et al. (1959), Brown et al. (1961) and Bowen (1985) have carried out experimental studies to measure heat transmission through double glazings of windows and to determine R-value and U-value of the glazing systems. Because calorimetric (energy balance) technique were used in these studies, no direct investigation of the convection heat transfer mechanisms in the air gap of the double glazings was done.

The aim of this study is to provide a fundamental and physical understanding of the convection heat transfer mechanisms occurring in the air gaps of double window glazings and to develop design criteria which could be applied to suppress the convection and hence reduce the heat loss through the glazings. To achieve this goal, a physical model of a sealed double glazings with various configuration of convection suppressors or barriers installed in its air gap was experimentally investigated to determine the effectiveness of the barriers in reducing the air gap convection. This preliminary study is expected to provide the technical information which could assist window designers in developing energy efficient and condensation-free window glazing systems.

2. Experimental Apparatus

The experimental apparatus shown in Fig. 1, consists of the following: sealed double glazings, a hot/cold box apparatus, and a Mach-Zehnder laser interferometer. The aspect ratio (H/w) of the air gap between the glazings is about 34 and the width of the air gap is 1.27 cm. (0.5 in.). The air gap convection suppressors used in this

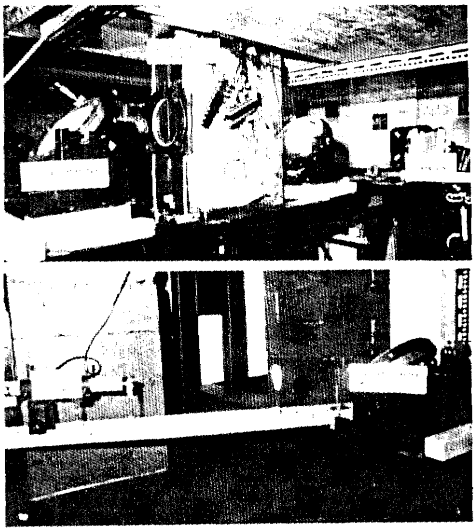


Fig. 1 Hot Cold Box Apparatus integrated with Laser Interferometer

preliminary study were made of plexiglass with a thickness of 0.2 cm. (0.08 in.). The heights of the suppressors are 2.54cm., 5.08 cm., 10.16 cm., 20.32 cm. and 42.6 cm. (or 1 in.,2 in., 4 in., 8 in., and 16.8 in). The hot plate of the hot/cold box was made of two aluminum plates. A nichrome heating wire was carefully installed on one of the aluminum plates which serves as a heating plate and then fastened to the other plate. The cold plate was made of copper with a multiple-pass heat exchanger installed behind the plate. The working-fluid for the heat exchanger is a solution of triethylene glycol cooled in a freezer and run through the heat exchanger by means of a recirculating pump. The Mach-Zehnder laser interferometer consists of a set of optics: two beam-splitters, two flat mirrors, two parabolic mirrors, collimating lenses and a helium-neon laser with a power rating of 5 mW. The optics of the interferometer were arranged as shown in Fig. 1 to produce two beams. One of the beams is a test beam and passes through the air gap of the glazings to be tested. The other is a reference beam which passes through the laboratory room undisturbed. The two beams recombined to produce interference patterns of the convection heat transfer in the air gap.

3. Experimental Procedure

The double glazings to be tested was sandwitched between the hot and the cold plates. The test apparatus was then integrated with the Mach-Zehnder interferometer (Fig. 1). The triethylene glycol was cooled between -25°C and -33°C and then pumped to the heat exchanger to maintain a cold plate temperature which ranges between -10°C and -18°C. The cold glass temperature was maintained steady at -6°C. The hot plate and the hot glass temperatures were kept constant at 24°C and 20°C respectively for all the experiments. Therefore, the temperature difference, ΔT ($= T_h - T_c$), across the air gap was maintained at 26. To investigate convection phenomenon at extreme cold temperatures beyond which our apparatus could support at 1.27cm. (0.5 in.) air gap, the width of the air gap was increased to 1.59cm. and 1.91cm. (0.625 in. and 0.75 in.) in order to increase the Grashof number defined as $(g\beta\Delta T w^3)/\nu^2$ (see Fig.3). When a steady state was achieved at both the cold and hot surfaces of the glazings, the interferometer power was switched on and the interference patterns (see Figs. 2 and 3) of the convection heat transfer in the air gap were recorded on photographic films. The interference patterns were analyzed to determine the non-dimensional temperature gradients dT^*/dx^* on the cold and hot glass plates. These were used to calculate the local Nusselt number (Nu_y) and the average Nusselt number (Nu) expressed as:

$$Nu_y = h.w/k_w = dT^*/dx^*|_{x=0,1} \quad (1)$$

$$Nu = 1/H \int_0^H dT^*/dx^*|_{x=0,1}\, dy^* \quad (2)$$

where h is the heat transfer coefficient of the air-layer, H is the height of the glazings, k_w is the thermal conductivity of air evaluated at the glass surface and w is the width of the air gap. The T^* ($= T-T_c/T_h-T_c$) is the non-dimensional temperature, T_c and

T_h are cold and hot glass temperatures, $x^*(=x/w)$ and $y^*(=y/w)$ are the non-dimensional x and y coordinates.

The average Nusselt number from Eq. (2) can be related to the thermal conductivity, k, of the air in the air gap and the effective or apparent thermal conductivity, k_e, as given by Holman (1981) and expressed as:

$$Nu = k_e/k \tag{3}$$

The effective thermal conductivity can be related to the thermal resistance, R, by the following expression:

$$R = w/k_e \tag{4}$$

The overall thermal transmittance, U, of the glazings can be estimated as follows:

$$U = 1/R_D = 1/(R + R_h + R_c) \tag{5}$$

where R_D is the design thermal resistance; R_h and R_c are the outside surface film resistances on the hot and cold sides of the double glazings respectively, and they can be obtained by determining the film coefficients on these surfaces using interferometer

4. Discussion of Results

Figures 2a to 2h and 3a to 3d present a few samples of the temperature patterns (infinite interferograms) taken during this preliminary stage of an intensive research into the convection heat losses in window air gaps. In view of this, the presentation and discussion of results in this paper will be limited to the qualitative analysis of the temperature heat transfer characteristics (see Figs. 4a to 4d) observed in the interferograms. The discussion will also include the effectiveness of the convection barriers employed to suppress the convection in the

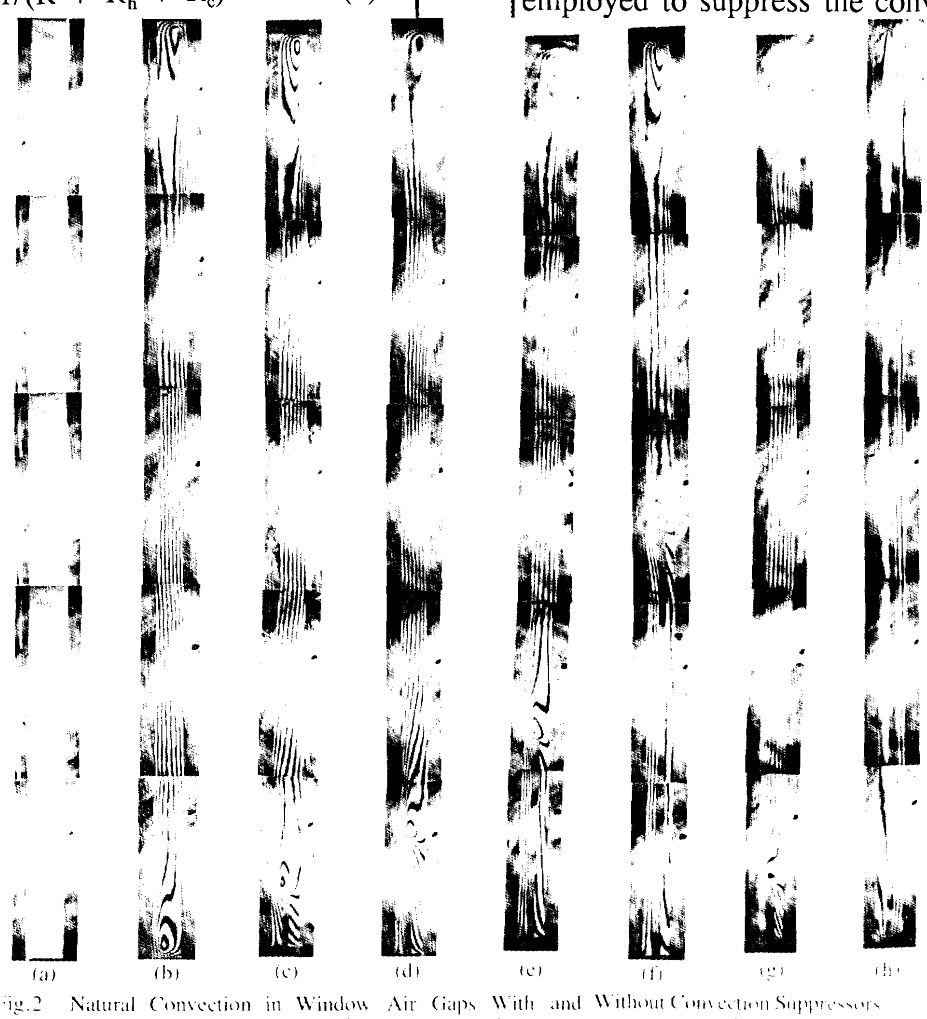
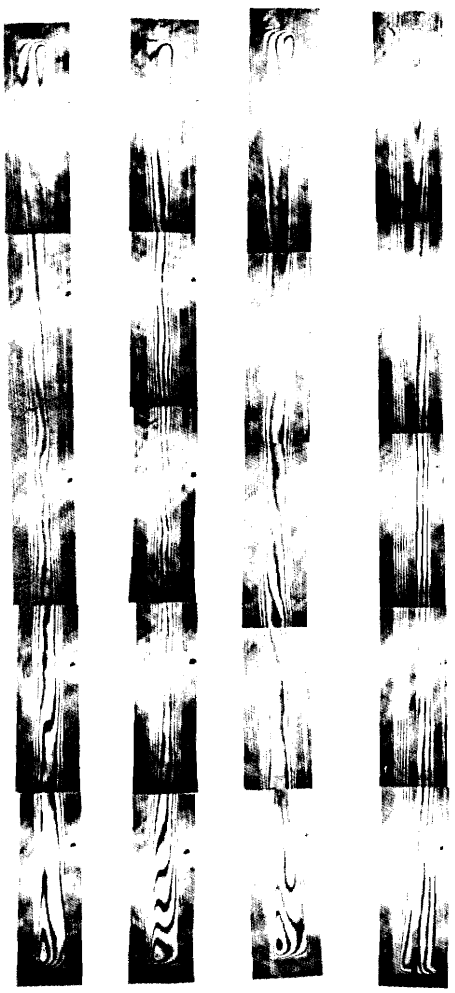


Fig.2 Natural Convection in Window Air Gaps With and Without Convection Suppressors ($\Delta T = 26°C$, $Gr = 9.366 \times 10^{[illegible]}$, Air Gap = 1/2"), (a) No Convection, (b) No Suppressor, (c) 1", (d) 2", (e) 4", (f) 8", (g) 1" Top and Bottom, and (h) Full Partition Suppressors
Note: For case (a) Indoor Temperature equals Outdoor Temperature (ie $\Delta T = 0$)

air gap. A more detailed result will appear in a final report of this study.

The sketches of the local heat transfer coefficients in the air gaps of the double glazings are shown in Figs. 4a, 4b, 4c, and 4d which correspond to the temperature patterns or interferograms in Figs. 2b, 2d, 3b, and 3d respectively. As observed in Fig. 2b, the local heat transfer plot in Fig. 4a indicates that heat transfer in the lower and top sections of the air gap is by convection while conduction heat transfer predominates in the middle section of the air gap. With the introduction of a suppressor



(a) (b) (c) (d)

Fig.3 Formation of Multi-cellular Convection Eddies in Window Air Gaps at high ΔT
(a) $Gr = 2.15 \times 10^4$ $\Delta T = 54$ C
(b) $Gr = 2.33 \times 10^4$ $\Delta T = 58$ C
(c) $Gr = 3.71 \times 10^4$ $\Delta T = 88$ C
(d) Full Partition (Triple glazings)

in the lower section of the air gap (see Figs. 2d and 4b), the convection in that region is suppressed and reduced to conduction. But a weaker convection on the top of the suppressor replaces the latter which has been suppressed. It appears that the original convection at the lower corner has been shifted upward by the suppressor and in the process becomes weakened. This trend persists for all the heights of the suppressors except the full partition. It is interesting to note that the displacement of the convection from the lower section of the air gap eliminates the condensation on the glazings which occurred when a higher ΔT with a strong convection is established across the lower section of the air gap.

A close look at Figs. 3a to 3c reveals the formation of multicellular convection cells in the central section of the air gap similar to those obtained in a numerical study by Lee and Korpela (1983). These multicellular cells occur when a high ΔT or Grashof number (Gr) is established across the air gap This phenomenon is illustrated in Fig. 4c. Introducing a third glazing (full partition) into the air gap (see Figs. 3d and 4d) suppresses the multicellular convection cells and reducing them to conduction.

5. Summary and Conclusions

Interferometric laser technique has been used to investigate the convection heat transfer in air gap of double glazings. To the best of the authors' knowledge, this is the first time such a technique was applied to study heat transfer in building component. Information obtained in this study indicate that heat losses by convection constitutes a major source of heat loss through window glazings at high ΔT across the glazings. And that the convection heat loss can be reduced by an introduction of a suppressor in the air gap of the glazings. This procedure was also found to eliminate the condensation often experienced on the lower section of window glazings.

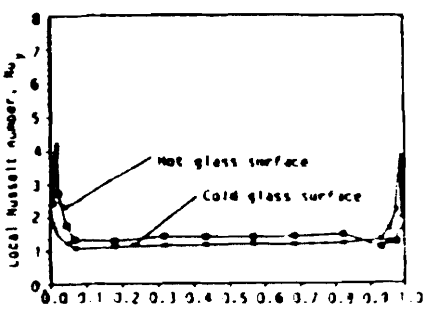


Fig.4a Sketch of Local Heat Transfer Coefficient Without Air Gap Suppressor,(Gr=9.36x10^3)

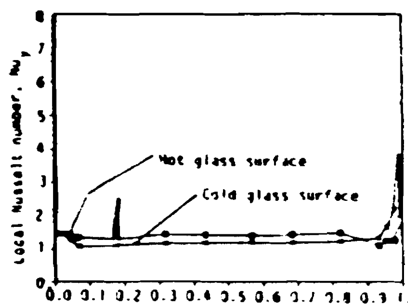


Fig.4b Sketch of Local Heat Transfer Coefficient For A Typical Case with Air Gap Convection Suppressor Gr = 9.36x10^3

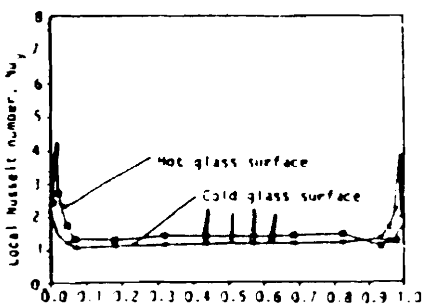


Fig.4c Sketch of Local Heat Transfer Coefficient For A Typical Case of Air Gap Multi-cellular Convection Eddies (Gr=3.7x10^4)

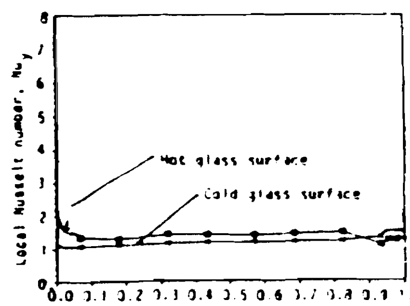


Fig.4d Sketch of Local Heat Transfer Coefficient For A Typical Case of Triple Glazings Used As A Convection Suppressor (Gr=3.7x10^4)

6. Acknowledgement

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DESIGN AND DEVELOPMENT OF HEALTHY, ENERGY EFFICIENT OFFICE BUILDINGS

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For the past 20 years our firm, Theodore Sterling and Associates, has provided consulting services, specializing in indoor and outdoor environmental quality ues. Before presenting a case study of the design of an energy-efficient livable office building, I want to first set the stage.

Some of the stage has already been set in the plenary session this morning very well. I would like to cover some of those topics very quickly. Our role in the design of this and other buildings has been to provide input based on the knowledge that we have developed over the years of indoor air quality problems in existing buildings. Our staff is frequently called upon to deal with problems of sick buildings. These are buildings where occupants are reporting a high frequency of health and comfort complaints.

We have evaluated by now, I guess, some 40 million square feet of problem buildings. You saw a similar slide of this this morning, but one thing that was not mentioned, is that primarily there are complaints. Complaints of lack of fresh air, stuffiness, poor temperature control and unpleasant odours, which then are accompanied by the symptoms that are defined by the World Health Organization as the sick building syndrome or building-related illnesses of eyes, nose and throat irritation, headaches, fatigue, nausea, dizziness and skin irritation.

Sick building problems first came to light in the 1970's with the introduction of technology for energy efficiency in buildings. Often sick building problems have been blamed on energy efficiency but today there is really no reason why a building can't be both energy efficient and have a healthy environment.

While energy efficiency and energy management technologies were being refined, the 80's and 90's have seen an increased awareness and focus on environmental results of technology. New demand-side management, energy efficiency programs introduced by many utilities, including the utility here in Québec, and government bodies, have reintroduced potential for repeating the era of the sick building, unless these new programs take a lesson from the past, and begin to balance energy efficiency with environmental health.

I want to now present our case study of a project which has attempted to balance environmental energy issues in the design process. Our case study is the Jack Davis Building, now under construction in Victoria, British Columbia. The building will be the headquarters of the British Columbia Ministry of Energy, Mines and Petroleum Resources. The building is intended, not only to provide a flagship of energy efficiency, but also to demonstrate that livability and comfort need not be sacrificed.

The ideal strategy for achieving an energy efficient liveable building is for the environmental and energy consultants to begin working with the design team at the program and conceptual stages of the project. Energy consultants, of course, are often included at this stage, however, environmental consultants are rarely called upon until well into the design process or more often, until the building is constructed, occupied and problems are already occurring.

In the Jack Davis Building, we were brought in as the environmental consultant early enough to assist development of the building program and to review design decisions that could influence the ultimate liveability of the building, as they were being made. Specifically, our role was to formulate a program of environmental goals and objectives for the design, review the schematics to evaluate whether the environmental objectives had been reached, inspect the building after construction and test building performance relative to the environmental objectives, provide an ongoing program of indoor air quality and building performance assessment. Although our input will encompass all phases of the design and development process from program through acceptance, I am going to limit this discussion to the program and design phases of the project, since the building is now under construction.

Initially a design brief was prepared by the design team, which included detailed criteria for the building requirements. An integral part of these criteria were environmental and performance goals. These goals encompass heating, ventilation and air conditioning, illumination, architecture, commissioning, operation and maintenance.

Inadequacies of HVAC systems have been identified as a primary cause of liveability and comfort problems in the majority of so-called sick buildings. Just to give you an example, some 52% of approximately 1500 buildings that Health and Welfare Canada investigated, the problem was found to be either inadequate ventilation or problems with the ventilation system.

Because these problems play an integral role in creating a liveable environment, the design team focused most attention on establishing acceptable performance goals. Goals were established for ventilation, thermal control, indoor air quality, filtration and energy management.

Many of the HVAC design criteria are based on ASHRAE standards; that's the American Society of Heating, Refrigeration and Air Conditioning Engineers, and guidelines. Especially the new ASHRAE standard 62, 1989, which is shown here, Ventilation for Acceptable Indoor Air Quality. I had the pleasure of being on that committee, which met for about ten years before we finally ended up with a consensus decision.

The ventilation goal for this building is 40 cfm, cubic feet per minute, per occupant at 70% ventilation effectiveness, that is, the ventilation effectiveness is 70% of the air that is brought into the building actually gets to the occupants, which results in about 28 cfm per occupant, which is about 8 cfm higher than the ASHRAE standard. The humidity goal is 30 to 60% relative humidity. I am not going to get into the background for these standards, because we don't have time today.

The energy management goals were based on criteria of the B.C. Hydro Power Smart Program of 45 000 BTU's per square foot per year. In the resulting design, this goal was achieved without compromising the ventilation goals by incorporating an economizer cycle. B.C. Hydro Power Smart Program is providing a subsidy to implement much of the innovative energy management technology in this building.

We also developed criteria for lighting levels, illuminance, spectral quality, daylighting and task lighting were addressed. Goals for illuminance were established based on the Illuminating Engineering Society and the Canadian Standards Association recommendations. The goals are 50 to 70 foot candles for general office areas and 30 to 50 foot candles for video display terminal workstations.

No specific targets were set for spectral quality, daylighting or task lighting, however, the design team determined to address these issues qualitatively and within the building budget. For example, high quality parabolic lenses have been included and daylighting is to be achieved throughout the interior.

The overall architectural goal was to meet or exceed previously described environmental goals wherever possible by the architectural design of the building, through careful consideration of the envelope and glazing, configuration and massing, interior planning, materials and acoustics. Within this framework, the resultant design included the following features: for ventilation, all windows above the ground floor are operable. To some of you this may seem like a revolutionary concept, but I assure you, it is a process of building evolution, not revolution.

For illumination, the glazing and building configuration allows daylight to penetrate far into the core office space. For indoor air quality, construction and furnishing materials will be low off-gassing and non-toxic. To achieve this, manufacturers and suppliers have been required to provide material and content information.

The end result has been this building. If you have the book of abstracts, you won't see it in there. The Jack Davis Building has been designed to meet the liveability and energy goals included in the design brief. As a result of the integration of environmental considerations into the design process, many characteristics of added liveability and occupant well being have been incorporated into the final design.

As I have stated, all windows above the ground floor open, that's all the lower windows here. Daylight access is provided to all areas using a combination of architectural light shelf and plate configuration, so above this sill is the light shelf on each floor.

All fluorescent fixtures have been equipped with parabolic diffusers to reduce glare on the work surface and computer screens and to improve overall quality of illumination. Cooling is provided through HVAC economizer operation and evaporative cooling, allowing outside air ventilation rates far in excess of 40 cfm per person, with minimal energy consequences.

Potential for contamination of the office work space by laboratories and the parking garage underneath, was eliminated by careful placement of exhausts for these special use areas. The building's outside air intake locations avoid sources of contamination. In addition, outside air is brought in at each floor and the mechanical systems for each floor are independent. These features provide a high level of occupant control both during and after normal working hours.

High efficiency filtration systems were included to control particulate levels. Evaporative cooling was provided to achieve economical cooling, to reduce CFC use, and to provide humidity control within the criteria developed.

Finally, we selected low emission finishing materials. Although energy simulations indicate the building energy demand will be on target, until the building is constructed and commissioned, there is no way of confirming that both liveability and energy goals will be met.

The creation of a healthy building does not end with the design, but continues through construction and operation during the life of the building. Because of that, we also developed criteria for commissioning and maintenance, plus ongoing monitoring throughout the life of the building. For this project, the process will include commissioning, maintenance programs, operation staff training, pre-acceptance indoor air quality evaluation, periodic indoor air quality audits, pre-occupancy testing and post-occupancy indoor air quality evaluations.

While some may consider the addition of environmental consultants to the design team is unnecessary, I am going to leave you with this thought.

EARTH TUBE HEAT EXCHANGERS

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Introduction

The use of earth as a heat source or natural air cooling system in combination with buried pipes is a very old concept.

Nevertheless, there are a few studies about this subject and particularly, under moderate climates, we meet in European countries.

The most interesting publications on this subject come from other countries like India, N.K. Bansal, and M.S. Sodha (1), R.R. Sinha (2); or U.S.A., C.E. Francis (3). We can also mention Costic's Study (4) and Esim's Study (5) from France.

So two reasons led us to develop a study about earth tube heat exchangers:

- the lack of experimental results in our countries to know accurate possibilities of this system for heating and cooling;
- a simplified design tool that anybody can use and which is the object of future works.

1 Experimentation

1.1 Situation of Experimentation

This experimentation has been realized on two identical timbered houses which are built near the city of Toulouse in the south of France.

To realize a comparative study about thermal comfort, only one of these houses is equipped with an earth tube heat exchanger.

1.2 Description of Experimentation

1.2.1 Description of Air Duct

One part of this air duct is directly buried under the house, the other part is underground situated on a private garden of the same house.

Main characteristics of earth tube heat exchangers are indicated in Table 1.

1.2.2 Measurement System

It is composed of a microcomputer which works in real time and takes measurements every hour.

During this experimentation, we only measured parameters as dry bulb temperature and relative humidity of air.

- Measurement implantation inside tube or in soil near it is shown in Fig. 2.
- Same measurement implantation has been realized inside these two houses. Figure 3 shows experimentation relative to house (N°14) equipped with earth tube heat exchanger.

1.3 Experimentation Conditions

1.3.1 Meteorological Conditions

It was a very hot and dry summer climatic sequence, Figure 4.

During this measurement period, average value of outside air temperature was about 26°C and at the end, temperature had easily reached 37°C on several days.

Relative humidity varies on a great scale of amplitude (between 20 and 70%) and it takes an average value of 40% for total measurement period.

1.3.2 Working Management Conditions of Air Duct Flow Rate

During the measurement period we tried to vary, Figure 5, as much as possible, air flow rate in earth tube heat exchanger.

At the beginning of the measurement period, the fan is stopped for the night, and during the day, it is given different values ranging from 306 to 450 M3/h. In contrast, at the end, the fan is running night and day.

TABLE 1: MAIN CHARACTERISTICS OF EARTH TUBE HEAT EXCHANGER

TUBE NATURE	PLASTIC (P.C.V.)
DIAMETER VALUE	OUTSIDE = 0.20 Meter INSIDE = 0.19 Meter
MEAN THICKNESS VALUE	0.005 Meter
THERMAL CONDUCTIVITY OF TUBE	Lambda = 0.2 W/m. ^{o}K
AVERAGE EARTH DEPTH VALUE	Z = -2.5 Meters
LENGTH OF BURIED AIR DUCT	- OUTSIDE OF HOUSE = 33.5 Meters - UNDER HOUSE = 8.5 Meters
LENGTH OF FREE AIR DUCT	- OUTSIDE HOUSE = 1.50 Meters - INSIDE HOUSE = 4.5 Meters

2 Results

2.1 Thermal Behaviour of the Earth Tube Heat Exchanger

2.1.1 Temperature Evolutions

a) For the total measurement period, entry and exit air temperature evolutions of earth tube heat exchanger are shown in Figure 6. We take into account flow rates values and meteorological conditions and we select two interesting sequences.

The first one is relative to the beginning of the measurement period (days 16 and 17 of July) and presents similar outside air temperatures. Moreover, fan is stopped during the night, Figure 7.

The second, situated at the end of the measurement period (days 20 and 21 of July), is characterized by extreme outside air temperatures and by the fact that air fan runs all day long, Figure 8.

Figures 7 and 8 show that flow rate value has an important influence on air exit temperature of earth tube heat exchanger.

For great values of flow rate (450 M3/h), exit temperature of air duct is obviously higher than for low ones. This phenomenon increases when fan is running all day and with high values of outside air temperature (Figure 8).

In this case, soil temperature is increasing and this phenomenon limits its air cooling power (Figure 9).

In conclusion, similar cases need to have a good working management to avoid soil saturation of air-earth exchanger system.

b) For day 14 of July, Figure 10 and 11 show air temperature evolutions in tube using two different parameters:

- The first one is the time, Figure 10;
- The second is the distance from the beginning of tube, Figure 11;

As soon as fan is running (Figure 10), air temperature in tube becomes very different. Strongest amplitude during the day is equal to 12 ^{o}K and corresponds to highest outside air temperature values.

If we consider, now, Figure 11, we can see that air temperature in exchanger decreases rapidly at the beginning of duct and more slowly further on. This is a normal behaviour of heat exchanger because at the beginning of tube we meet highest differences of temperature between soil and air in the duct.

2.1.2 Relative Humidity Evolutions

Figure 12 shows relative humidity evolutions inside tube during measurement period.

We can see that relative humidity increases between entry and exit of tube. This corresponds only to the decrease of ambient air temperature in tube because earth heat exchanger is made of plastic elements and total system is waterproof. So, there is no risk of water infiltration.

Nevertheless, as this climatic period was very dry, air condensation in tube did not appear but it cannot be a general result.

2.1.3 Cooling Energy Possibility

Energy extracted for air cooling dwelling equipped with earth heat tube exchanger has been calculated with aid of the following formulation:

$$Ø = M * Cp * (Tref - Ts) * TT$$

Where:

- Ø = air cooling energy in kWh;
- M = air flow rate value in kg/s;
- Cp = specific heating capacity in kj/kg. ^{o}K;
- Ts = air exit temperature from tube in ^{o}C
- Tref = reference temperature in ^{o}C to calculate cooling energy possibility of tube
- TT = Time step = one hour

Cooling energy extracted from the tube is indicated, day by day, during the measurement period (Figure 13).

Highest hourly values for this period can reach 1.5 kWh and total value 119 kWh. But this result was obtained by using outside air temperature as calculation reference. So, if we choose a lower reference temperature value as inside comfort temperature of dwelling, cooling possibility of exit air decreases rapidly.

Figures 14 and 15 show this difference and Table 2 gives cooling energy value of air in terms of reference temperature calculation.

- In the first case, Tref = outside air temperature of moment;
- In the second case, Tref = 25^{o}C.

So to increase this cooling power, it seems necessary to have an air exit temperature value from the earth heat tube exchanger as low as possible. This factor depends on various parameters: surface area and length of tube, water contents of inlet air, dampness and temperature of earth, air velocity, ... all parameters on which we are going to work with to develop a new experimental and theoretical study.

2.2 Comparative Study About Comfort Conditions of Houses

2.2.1 Resulting Temperature of Living Room

Resulting temperature has been calculated using the following formula:

$$Tres = (Tamb + Tpar)/2$$

Where:

- Tres = comfort resulting temperature;
- Tamb = inside temperature of room;
- Tpar = $\sum_{i=1}^{n} Si.Tsi \ / \ \sum_{i=1}^{n} Si$

Where: Si = surface of each wall;
Tsi = surface temperature of each wall

Figure 16 shows results obtained for living room in the two dwellings. For the measurement period, it appears an average difference of 1.5^{o}C between resulting temperatures of these two rooms.

TABLE 2: COOLING POSSIBILITY OF TUBE EXIT AIR FOR DAYS 20 AND 21 OF JULY

CONDITIONS	DAY JULY 20	DAY JULY 21
FLOW RATE (M3/h)	450	306
REFERENCE TEMPERATURE CALCULATION	COOLING POSSIBILITY OF AIR FROM TUBE	COOLING POSSIBILITY OF AIR FROM TUBE
- Air outside temperature of moment	22.06 KWH	18.59 KWh
- Comfort temperature of dwelling in summer = 25°C	7.21 KWh	6.16 KWh

2.2.2 Relative Humidity Evolution of Living Rooms

During the total measurement period, relative humidity of living rooms of houses is between 40 and 60% (Figure 17).

For the house not equipped with heat exchanger, relative humidity is constant and takes an average value of 55%.

In contrast, for the other house, relative humidity varies. At the beginning of the period, it climbs up to a value of 60% and decreases at the end to 40%. This behaviour is easily explained if we consider the values of the outside relative humidity, which is very low at the end of the measurement period (Figure 4).

In conclusion, these relative humidity values do not bring any risk of uncomfortable conditions.

Conclusion

In conclusion, this first study points out advantages of this system.

We have seen that it has a sufficient potential for conditioning outside air, even if it reaches very high values during the day.

Nevertheless, this system needs a good running management of fan and must have an optimized conception.

This is the aim of our future work.

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MODELE POUR DIMENSIONNER DES SYSTEMES DE VENTILATION NATURRELLE DES EDIFICES INDUSTRIELS

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Je vous parlerai du dimensionnement des systèmes de ventilation naturelle des édifices industriels dans lequels il y a des sources de chaleur. La ventilation est toujours importante, mais elle est plus importante en climat chaud, pour:

- la santé des travailleurs;

- la qualité et la quantité de la production;

- la reduction des accidents du travaille.

La ventilation peut être faite mécaniquement, naturellement ou par des systèmes mixtes. Cependant, il est presque impossible de ventiler mécaniquement des grands édifices oú la génération de chaleur est aussi grande.

Quelques fois, le système doit être mixte:

- ventialtion mécanique aux points oú la chaleur est produite; et

- ventilation naturelle pour le renouvellement générallé de l'air de l'enceinte.

Je n'ai étudié que la ventilation naturelle par effet cheminée. Ce phénoméne se produit quand l'air de l'intérieur d'un édifice s'échauffe, s'élève, rencontre des ouvertures aux points hauts tandis que l'air frais de l'extérieur peut rentrer par des ouvertures localisées aux points les plus bas.

Le rénouvellement de l'air d'un hangar, par éffet cheminée est en fonction de:

- la différence de température causée par la génération de la chaleur;

- la distance verticalle, H, entre l'ouverture d'entrée et l'ouverture de sortie de l'air;

- les dimensions de cettes ouvertures (d'entrée et de sortie); et

- d'un coefficient, que nous appelerons Ko, complexe, mais dont, pour dessiner des édifices il faut seullement savoir la valeur.

Pour dessiner des édifices qui ont des sources de chaleur, en climat chaud, et pour arriver a des bonnes conditions de ventilation, j'ai étudié l'application de la formule pour calculer l'effet cheminée selon plusieurs auteurs. Les résultants étaient considerablement différents. J'ai vu aussi que les uns considèrant et les outres non l'avantage d'avoir Ae>As ou As>Ae.

Alors, je suis decidé a faire mes expériences. On a construit des maquettes, pour travailler dans un laboratoire, en éssayand une centaine d'hypothèses, oú on a varié:

- le potenciel, la quantité et la position des sources de chaleur;

- le position et les dimensions des ouvertures d'entrée de l'air - Ae;

- la dimension de l'ouverture de sortie de l'air - un dispositif spécial localisé au sommet - As;

- la hauteur de la couverture, et en consequence, le volume d'air et la distance H.

Pour dévélopper des études avec des maquettes, on a appliqué la "Théorie de Ressemblance" et "L'Analyse Dimensionelle", qui permettent la correcte construction de la maquette et les relations entre les résultats rencontrés dans l'échéle reduite et la réalité, en employant certaines formules.

On a enregistré des températures en plussieurs points de la maquette, hors d'elle, et des températures et vitesses de l'air en plussieurs points de la sortie.

Comme je conaissais la vitesse moyenne de l'air qui sort - v. - et les dimensions de cette ouverture

- As -, j'ai déterminé le flux de la ventilation - $ø_{ch}$.

J'ai calculé, en employant des formules d'autres auteurs, le flux d'air pour les conditions representées en maquette et j'avais trouvé les résultats et faite des comparaisons avec les résultats mesurés - en rouge. Ici, nous pouvons le voir, avec ces exemples, la raison de mes études.

Ici, nous pouvons voir le résumé des résultants comparatifes:

1. Pour ceux qui considèrant seulement:
   ....Ae/As = 1
   Van Straaten et Baturin
   calculé = 68% du mesuré
   (en moyènne);

2. Pour ceux qui considèrant
   ....Ae/As > 1
   Randall/Canover, Ashrae, Toledo, CSTB, Daly

   a. Quand .... Ae = As
      calculé = 86% du mesuré
      (en moyènne)

   b. Quand As/Ae > 1,
      l'acroissementément du flux est:

Ae/As	2	3	4
Acroissement calculé (%)	27	34	37
Acroissement mesuré (%)	9	15	18

En employant les formules de conversion, il a été possible, pour quelques facteurs d'échéle, de déterminer, pour chaque expérience quelques cas de représentation des édifices en échéle naturelle.

Comme je conaissais les valeurs de toutes les variables mois du coefficient K, que j'appele Ko, il a été déterminé par la formule basique de Emswiller:

øch = K A I H Δt -->
Ko = øch / A I H Δt

pour la centaine de cas essayés. On a fait 19 groups d'expériences. Chaque groupe a eu 4 ou plus d'expériences, toujours pour:

Ae/As = 1, Ae/As = 2, Ae/AS = 3, Ae/AS = 4.

Il a été possible d'observer que quand la chaleur est grande et la maquette la plus petite, les resultats sont a normals - courbes chatains - et je ne les considére pas.

Les valeurs de Ko sont apresentés dans ce graphique:

L'expression analytique de cettre courbe, quand x = Ae/As et
i < x < 4:

$$Ko = 0.00i\ (-2\ x^2 + 19\ x + 122)$$

Comme il faut dimensionner le système de ventilation et non calculer le flux j'ai donné a la formule la forme suivant:

$$A = \frac{øch}{Ko\ \ I\ \ H\ \ \Delta t}$$

Dans la formule:

A = dimension de l'ouverture d'entrée (ou de sortie) de l'air, la plus petite;

Δt = (ts - te);

Ko = coefficient dont la valeur varie selon Ae/As.

J'ai des bons résultats quand j'applique ce modèle pour dimensionner des systèmes de ventilation naturelle a quelques édifices industriels oú la chaleur est une grande problème.

Le bien dimensionné système de ventilation naturelle peut être un facteur d'un certain confort, de santé et de bon rendement au travail, mais peut être aussi un recours pour rationaliser l'usage d'energie.

SESSION 3D
NEW ENERGY TECHNOLOGIES

Questions and Discussion

Question

I would like to know whether comfort and satisfaction in theory varies in time? If in 1950 the degree of satisfaction of all occupants in an office building would be the same as the analyzed factor in 1990. Does the tolerance in the population vary with time? Are we more or less demanding than before?

Mohamed Boubekri

I don't proclaim to be an expert in the area of environmental psychology, because all what I have shown you today is borrowed from that science. I know one thing, first, a human being is never satisfied with what he or she has and the more we have, the more we want.

In the field of lighting for instance, the desired indoor illumination levels have increased over the past. We went from 30 to 40 to now perhaps we are recommending 50 or 60 foot candles or 500 lux, which means that perhaps we always want more. So perhaps to answer your question, 10 or 20 years ago we were content with much less than what we have now.

There are so many things that we have not examined here, for instance, the question of whether the person comes from northern or southern latitude. The appreciation of sunlight is very much different. Now the way we have gone around this problem is the entire experiment was done in a thermally comfortable environment. The space was air conditioned so at least the thermal effect caused by various sunlight penetration was not there; it was eliminated because the thermal indoor environment was comfortable.

Question

Have you applied these techniques to real buildings as well as to test buildings?

I. Meroni

No, we have only experimented with this system in small cells. It will be particularly important to have the possibility to test these components in a real building and this is the aim with the next research with my institute in the near future.

Question

The control was through a computer, or you are suggesting control through ordinary small thermostats?

I. Meroni

Yes, instead of using a computer, a lot of these components are very sophisticated, because using an electronic interface will give all the input necessary to optimization of the functionality of all these kinds of systems. With a factor it can cause a lot of problems for a lot of the systems tested, because the teletronic path was particularly delicate. The next step would be to improve the electronic sheet, integrating these components and simplifying integration on a real building in construction.

Question

What are your insulation overall conditions, since you have made this operation outside on the room with very cold windy conditions. What is your overall insulation envelope to conduct this type of experiment?

Mr. Athienitis

On the floor we have quite a high amount of insulation, it is about 5.6 RSI and on the ceiling 3.7 and on the walls it is not as much as on the other surfaces, it is only about 2.4 RSI.

Question

For practical purposes, most of the time when we are using radiant heating strategy, most of the time we are using films that we can put easily on ceilings. You were talking about panels, is this approach of using panel radiant outlets a practical one for construction purposes or is it for experimental purposes?

Mr. Athienitis

No, this is a commercial system. It is being sold by a company that gave us the system and this ceiling system is installed usually for perimeter heating in office buildings. These are things that look like false ceilings. They can easily be fit into a false ceiling and most people would not even recognize that they are radiant ceiling panels when they walk into an office.

Question

Is there a reason why you did not use the film type of radiant heating or is it because it was given to you as a panel?

Mr. Athienitis

When you have something free and you can do your job, it is the best way to do it.

Question

Would you just run that house through the loop on a Toronto summer day?

John Timusk

On a summer day, the first thing you have to do is open a window so that you do not draw air through the walls. You want to have as much resistance as you can. You mechanically switch over the heat pump so that you are now exhausting hot air to the outside. The heat you need for domestic hot water is taken out of the internal circulation loop. We have switched that around so that we draw air at living room floor level, pass it over the evaporator and cool air is exhausted at ceiling level upstairs in the bedrooms. The circuit is completed by means of doors in the stairway. We would not recommend exhausting air through the wall. One would be tempted to do that and we have to remember that indoor air is more polluted than outdoor air. We would not want the thermal insulation turned into the equivalent of a vacuum cleaner bag or a furnace filter.

Question

Could you explain how that system would work in relation to stack effect with the difference in pressures at the bottom and the top of a building?

John Timusk

In order to overcome stack effect, you need to maintain a negative pressure which is high enough so that you maintain a negative pressure over the entire envelope, which, in turn, means that the house has to be very tight, so that we maintain the negative pressure at a prescribed exhaust rate. Thereby depressurize the house to the point where we overcome wind pressure and stack, but there is an advantage for more flow through the lower part of a wall than the upper part of a wall. Also, under windy conditions, more flow through the windward than the leeward, but again, measurements in our test house indicate that even under windy conditions in open country we were not exfiltrating air through the upstairs leeward openings in the walls.

Question

I would like to ask a little about sensibility for air leaks in the building. How careful do you have to be with air tightness of a building envelope?

John Timusk

Extremely. You are looking at two conductors in parallel, one is the air leakage opening around windows and so on, the other one is in a spun bonded polyolefin, which forms your control membrane. Air is not obedient, it only obeys physics and it comes through the easiest path, so we must seal off those. In the future we are looking at isolating the wall alone, not depressurizing the whole house, bypassing many of the other leakage openings.

Question

Have you used this system for the roof? You mentioned earlier that you used a lot of solar radiation on the walls, but if you have it on a roof, it would be heated much more than the walls.

John Timusk

We have not looked at it in our latitudes and our conditions. We are getting several times more heat. Theoretically it would be captured by the walls, without having to go to the roof, so that even with low thermal efficiency heat collector efficiency in the walls, we would satisfy it.

In Sweden, the logical position would be to go in that roof and particularly the sloping roofs in the storey and a half houses.

Question

In Sweden we have this system also, and we discuss very much about the indoor air quality problems and some people are afraid about formaldehyde and organic emissions from the glass fibre in the insulation and you will add that to the supply air. Have you made any investigation of this?

John Timusk

We have done a small amount of work, going back on historical records. All of the Canadian houses have basically been breathing through the insulation. Naturally, air leakage happens through the insulation, we recognize the problem, we are basically breathing through the thermal envelope and we have to be very careful about what we put in and there is one possibility that the air we will recover goes directly to the heat pump, it is not used for breathing. So we have that option open, but so far historical evidence shows that there are no fibre problems and there are no formaldehyde problems or mould and mildew problems associated with it.

We are using ordinary glass fibre. We have seen no evidence of any fibres being picked up. The velocities are extremely low and again the deviation from old buildings is that, what we do now is under very carefully controlled conditions so we don't have the same problems that we might have had in the old days. If anything, we are improving on natural ventilation.

Question

I assume then, for existing homes, we cannot use that technology unless you do extensive renovations.

John Timusk

Yes, you can, we are working on it. We are working on an add-on insulation, dynamic wall retrofit, in which case, you would not depressurize the house, you would look at one wall alone at a time.

Question

The second thing, which you skipped over, is the question of filtering radon.

John Timusk

We are not filtering. There are two strategies for excluding radon from a house. Pressurizing the space under the floor slab, pushing it back into the soil, or having the space under the floor slab under a slight vacuum so you draw house air into that space. Traditional ways, both are very energy wasteful. In this case, we are coupling this with heat storage.

Question

Do I assume that you would have some kind of a membrane under your storage?

John Timusk

No, we are excluding the radon-containing air from entering the house.

Question

The last question deals with the mechanical system in itself. Obviously you are getting your energy on sunny days and on cloudy days you are gaining it from your storage. Is the system automatic, how does that work?

John Timusk

We have done everything in the house, except for the under-slab storage, and that is on paper right now. It would have to be controlled by micro-processor.

Question

Does that kind of micro-processor exist?

John Timusk

Very simple crude technology, in comparison with the automobile, which has more sophisticated equipment.

Question

What ventilation is given in this project to minimize the effect of wind flow conditions around buildings and wind induced heat losses?

Mr. Sterling

There was minimal consideration given; there was consideration given particularly about pressurization and what will happen with an unsealed envelope. We don't know, this building will be a test situation. We intend to monitor varying pressurization both around the different facades of the building and also the stack effect. We are not sure what is going to happen to the neutral pressure point. Essentially, it is a type of project that a lot of detailed monitoring has not been done on, so the predictions are very difficult to make. Hopefully, this will begin to give us the ability to make predictions about buildings that are not sealed and do incorporate operable fenestration.

Question

Just for information, there is a building in your city that is probably at least 15 years old, it is a high rise with operable windows, so you might be able to answer that question if you study that building.

Mr. Sterling

I didn't say that there aren't buildings with operable windows. What I am saying is that it is essentially a lost art. For the past 15 years approximately, engineers and architects have not built buildings that are not sealed and there is very little data available about non-sealed buildings and how they perform. I think that is a problem that really should be addressed to the building research establishment in North America and Europe. The Europeans do have more information about operable windows than we have, but they also don't incorporate the same types of mechanical systems.

Question

But we have a good example to study and that is the Stanza Building. The second point is, my experience has been when you have a building that is a bit unusual that not only do you have to have a training program for your operations staff, but it's very helpful for the function of the building to make sure that as many people who are interested who work and use the building are fully aware of its capabilities.

Mr. Sterling

The staff will be trained. In fact, we have been working very closely with the new design committee on this project and the intention is that the staff occupying this building will be educated as to how it functions, what the pros and cons are, opening the windows. The effect of opening and closing windows will be monitored on this building, both in terms of comfort and energy performance.

Question

What kind of measures can be taken as far as fire safety is concerned?

Mr. Sterling

It meets the National Building Code of Canada. The building was designed within the constraints of the National Building Code as modified by the British Columbia Building Code and by the city of Victoria.

Question

Many of the things introduced on the sick building problem are ventilation and moisture problems and beside that, we have experienced that emissions from materials have great influence. What kind of consideration have you made when you have chosen materials for furniture and other equipment in the building? Have you any laboratory tests to measure the emissions?

Mr. Sterling

We are not undertaking specific laboratory tests for the materials that are going into this building. We have a very high ventilation rate. For people and for emissions it is designed to exceed the ASHRAE standards for people and, in a sense, the standard of 28 cfm is intended to allow us some flexibility in incorporating materials into the building throughout its lifetime, because a building is dynamic, it's not static. It's going to change, people bring things in, they move things around, new equipment changes, office technology changes, so we have allowed some flexibility there. As far as materials go, we have requested the suppliers to provide materials information sheets. That is all we have in Canada that we can specify. All materials that are available in Canada for construction have what we call WHMIS sheets, workplace hazardous materials information sheets, so we have some information about what materials are going into the building. Hopefully, as this process continues, and we don't see this as being an isolated case, architects will begin to specify information, that information be provided about materials and then that information will find its way into traditional building projects so that decisions can be made without having to go to the extent of doing emission tests for materials.

Question

How do you ventilate a building with operable windows? How do you deliver appropriate ventilation to everybody else on the floor? When I open my window on my space and short circuit the system?

Mr. Sterling

You won't be short circuiting the system.

Question

I must, I am lowering the pressure in my area. I am just going to encourage the vents to deliver it all to my space, unless you shut me off. By opening the window you cut off the supply valve.

Mr. Sterling

This is exactly what the argument has been in the past, that you cannot have a building that is not sealed, because it will by changing pressurization cause short circuiting. I am not necessarily convinced that won't happen in this case. I would like to mention to you one study that we did that was published in the Canadian Journal of Public Health and was followed up. We did survey questionnaires and measurements in two buildings, one with operable windows, one with sealed windows and the same type of occupancy loads. The building with operable windows had poor air quality, poor heat distribution, poor ventilation, poor lighting, had no complaints. The building that was sealed had perfect conditions as far as measurable conditions went; 90% of the occupants complained of eye irritation, headaches, nausea, fatigue. We find that in varying cases in other case control studies that we have done.

Building occupants want the ability to control their conditions. I think, from energy perspective, we need to consider that in the development of comfort standards, because people are willing to put up with slightly poor environmental conditions if they have some ability for individual control.

Cliff Shirtliffe

I would like to make one comment on predicting the future. A few years down the line we will be hearing papers on how to prevent the opening of windows in buildings for three reasons. One is the time when the snow leaves the grass and the grass moulds are in tremendous quantities and those moulds get in the buildings through the windows and you can't get them out. It takes a very good cleaning to get them out. The second time is when all the fir trees are giving off their pollen, and especially the tamarack trees that so many people are allergic to, those get in. The third is the ragweed season, when they get in through the windows and the ventilation system, filtration system can't do anything about it. It will be interesting to see what happens in the future.

Question

Did you make any correlation between the economical or efficient pipe size from the length and the diameter with respect to the fan power?

Dr. Romeu

Yes (answer given in french)

Question

Did you check what the efficient depth you can go with these pipes?

Dr. Romeu

2.5 metres. (answer given in french)

THEME 4
GLOBALIZATION
KEYNOTE ADDRESS

Jacques Rilling
Directeur scientifique, Centre scientifique et technique du bâtiment, France

Let's first begin with what occurs in European communities with respect to technical legal aspects related to building and the construction industry. For the European community, the problem has been to remove technical barriers to trade. That is something which is a common problem in a lot of the regions of the world. The rule for decision making at policy level, particularly in the EC commission and the Council of Ministers in European communities was, until 1987, the rule of unanimity in decisions. On the other hand, the basic philosophy for technical aspects was to accomplish unitization of standards. These two rules made the problem impossible to solve, so people decided in the middle of the 1980's to change the rules, and they have been changed, into first, a rule of qualified majority for decision making. That means that the normal democratic system applied a lot of the time in a European community, that means also that some countries sometimes have to use rules that they have not accepted and they have to accept the law of democracy of measuring. It's not always easy to explain to people in other countries and to electors.

The change on the technical philosophy was to consider more harmonized standards and more mutual recognition of local standards, instead of complete unitization of standards.

As far as the construction industry is concerned, this concept started to be implemented through a European community law. We called these laws directives in Europe, so you will have the opportunity of hearing the European community English.

There was a construction product directive published in December 1988, a law defining the technical rules for the market and construction products. These directives have interesting features; the first one is that its technical basic philosophy is based on the twin concept of the requirements on one hand and performances on the other hand. I will come back to that point.

Some points will be implemented in three major ways. The first way will be to produce harmonized standards on products. Initially this was for products only, products on the market and circulating through the more European market. It was also necessary to consider building elements and building as a whole and it's making some kind of mess.

The second way, specific procedures of technical assessment have been defined. It will be used for innovative products, for which it is still very difficult to define harmonized standards. This concept is the concept of European technical approval and this will be managed through a network of institutes gathered in an association called EOTA, European Organization for Technical Approach. Clearly this concept of technical approach is some of the concept of agrément.

The third element is labeling process, EC mark, which will be a passport for the product to be allowed to circulate within the EC countries. What is interesting is that the EC mark will be used and is the responsibility of manufacturers with a set of possibilities for certification of this EC mark. This can be controlled by the public body, with a lot of possibilities to make sure that this certification is something which is clearly good.

I would like to make some personal comments on this process. If one sees that from the ground level, from inside the process, this looks terrible. Taking comparison, it is something like observing a fluid, a strong flow of fluid, from inside the fluid, moving with the fluid at the level of molecules, you see everything, everywhere. Fortunately, human beings are able to move mountains if they think it's needed and it's useful. I am quite convinced that it will succeed.

If we look at that process from some distance, but not really from the moon, to keep realistic, it appears that rationalizing techniques, and the concepts we hide behind all these techniques, are very familiar major scientific concepts, the concepts which have been used in CIB in many technical subjects.

The first step is the qualification of human and technical requirement, the second step is definition of performance, with measurements or evaluation tools.

The construction product directive defines six basic requirements, the so-called essential requirements, mainly related to health and safety. The first one is mechanical resistance or structural safety of product, the second is safety in case of fire, the third is health and environment, the fourth is protection against noise and the fifth is energy conservation, the only one outside the field of purely health and safety aspects.

I would like you to notice that there is no mention of any question of cost effectiveness; that's a problem of economy and market. There is no jointly explicit mention in the six essential requirements of durability of buildings or construction. Nevertheless this is in the wording of the directive in general and there is some reference to that point. It is also to be noticed that these essential requirements are applicable to building elements and building as a whole. There must be connections to specific performances of building products, the products which will be circulated on the market.

This last aspect of the question leads to the production of so-called interpretative documents. These interpretative documents split each essential requirement into a consistent set of performances to be met by building elements and building products. The important words are consistent set of performances; you can imagine the work behind that.

Clearly this performance concept, which has been the cause of CIB work since the 1950's, is therefore the essential concept of the EC harmonization. No other member states of the EC countries has that built into their own building code. We all have part of performance based system and part of non-performance based system, but the rule now in Europe is performance and we have to find a way to put that into operation.

We are in some way building a detailed prime work of reference and rule for products on the market, so this is not restricted to European communities. I would nevertheless, declare myself to conclude that this reference system will be ready for use by the whole world after being implemented for Europe. It would be good to be successful in Europe.

We will settle and get that way quite an interesting basis for world wide extension. It will be some part of the open science that has been mentioned by George Seaden yesterday.

On the other hand, the easy decisions led to a large learning process; we are learning from each other at the European level. I suspect that the extension of such a performance frame to other parts of the world would require also, a learning time consuming process, so don't dream.

I don't know if the open science concept has been used in non-European countries to take advantage of the results we are obtaining now in Europe. I don't think its unreasonable to think that you, from America or Asia are sufficiently informed in that to put that in your code at the same time as we are putting that in our system, but I can testify that this European process, using world wide products, is taking advantage of the production of other parts of the world.

We have met quite a science problem with certain essential requirements. Fire safety; it appeared that for the so-called reaction to fire tests system, we had in Europe three major groups of consistent tests, but completely inconsistent with each other. It proved impossible to solve the problem of harmonizing these different tests' philosophy. So we are now trying to enter a new way, a forced way, a known used way in Europe to find the solution to that problem. We found this in the United States.

This is an example of what we have to do at the world level in general, try to use the science produced by others and offer our science to others. This was mentioned by George Seaden yesterday as well.

This leads me to my second point, namely the necessity to develop a common cultural basis on building science and building performance definition. The EC harmonization process showed that it may take decades to get to partial agreement on technical definition for everyday technology. The name of CIB is International Council of Building Research for building research and documentation; the important word here is documentation. I am not discovering anything in saying that knowledge dissemination is important; this is built in the CIB system.

My feeling is nevertheless that we should do more on that aspect. CIB working groups and task groups clearly played the role of venues for knowledge production and exchange. It is interesting to notice that CIB membership changed substantially in the last decade. More and more educational bodies are involved, universities, architectural schools and so on. It is certainly an excellent trend, very helpful to the implementation of the open science concept and for all the dissemination of knowledge.

I am nevertheless a little concerned by the relatively low participation of developing countries' universities to CIB. We might be missing something definitely vital for the future.

My third point will be briefly outlined, because it gave raise to extensive exchanges in the sessions yesterday and Roger Courtney made a very clear presentation of the problem in his talk yesterday morning.

Global climate change, greenhouse effect, ozone layer problem and so on, are affected by our technical policies. Buildings may be responsible for one third to one half of the greenhouse gas production related to energy consumption. We never had, from a technical point of view at least, such a world wide challenge to face. We all are just starting to think and take the first actions. Should we recommend CIB to tackle the problem with a high priority and to organize a significant part of its current work in a suitable way to help progress together in building industry and building research and environmental protection and global changes problems?

Looking at these world wide environmental problems, leads me to my last point. I suppose most of you will have an idea of what will happen in the next century. OECD and the eastern European countries have a total population of a little more than one billion individuals, and will remain more or less stable over the next one hundred years. Most OECD countries, mainly developing countries, should see their total population being raised by a factor between two and three, getting up to about ten billion individuals and hopefully they should get much better life conditions and much higher economic production.

This is inducing a major trend towards environmental impact and global change on the planet. Evaluations have been made of that and it's really impressive. These are certainly major challenges of the world for the next decades and maybe the most major challenges that human kind has ever faced. Are we ready to face it and to make the good choice, helping these countries to share our knowledge, to produce their own rules and technical culture? That is the only way, in my opinion, which could be used to get good results.

I am a little concerned if I rely on the few representatives of eastern and central European countries and developing countries today, or at least at CIB congress this week. I have some doubts on our CIB efficiency; you might feel guilty, but we are all guilty.

I agree with a statement made by George Seaden yesterday; the situation of these countries will be dominated by financial aspects. We all know that, but my opinion is that CIB policy should help overcome this aspect and make sure that technical knowledge and culture will be able to develop normally in these countries, even if they lack financial support.

THEME 4
GLOBALIZATION
KEYNOTE ADDRESS

John Redfern
Chairman, Lafarge Canada Inc., Canada

It is a pleasure to welcome each of you to Canada and to the magnificent city of Montreal. Montreal, as you are finding out, is more than one of Canada's largest cities; it is a centre of history, culture, industry and commerce. Since 1992 marks the city's 350th birthday, it is really an ideal place to bring together the world's leading researchers and practitioners of the many arts and sciences of construction.

The theme of today's session is globalization, one of the five themes for the building congress. Globalization is an especially important topic because it is the only one that provides context to each of the other themes. That is to say, the globalization of our industry has important implications for how we develop and employ new construction materials and systems. It affects how we address the need to rehabilitate and restore the infrastructure of many nations. Our approach to globalization also has implications for the world's environment and, of course, globalization is a major issue with respect to the ways we use computers and transfer information.

Predications have been made that the 1990's will be the decade of globalization. To many, this is already the case and there are plenty of examples to illustrate this point. It is not unusual for multi-national businesses to obtain raw materials on one continent, use them to manufacture products on a second and market those products to customers on a third. The situation is the same in matters concerning the environment. In just a couple of weeks, world leaders will gather for a summit in Rio to address global environmental impacts, both from the activities of developed nations and from the industrialization of the developing world.

None of us can ignore the global marketplace. Even those who operate locally must still compete against international competitors, standards and potential. This is what forces productivity and efficiency. This is why everyone gains.

Certainly, globalization is occurring on the economic front. As we meet, the nations of Europe are actively preparing for an economic union while those on this continent are striving to remove trade barriers by completing a North American Free Trade Agreement. And so it is with politics. The world community as a whole is currently coming to grips with a remarkable political transformation of Eastern Europe and what that transformation will mean to the rest of the world.

Now, today, I do not profess to be an expert with universal truths, my only knowledge comes from my personal experience in the building materials field. I will have to leave it to you to extract from my Lafarge story what might be of value for your particular situation. Hopefully, by hearing the actual events of one group's actions, you can observe that globalization is in progress and working.

Our industry is globalizing. We have seen enormous growth in tonnages of imports and exports of all sorts of construction materials. The companies that dominate our industry do business on every continent. Impacts of research projects or innovation or engineering accomplishments are global in scope.

I want to talk to you about what the globalization trends have meant to us at Lafarge. I will do that in three ways: I will address the process of growth and globalization through the experience of Lafarge Coppée; I will focus briefly on our activities here in North America; and I will look at what the challenges of globalization bring to our company as we position ourselves to compete for opportunities in the rebuilding of Eastern Europe.

During the three and half decades I have spent with Lafarge Corporation and its predecessor the Canada Cement Company, I have seen remarkable growth and expansion. Lafarge Coppée, our parent organization, is today among the world's largest and most diverse producers of construction materials. We are market leaders in many sectors. Lafarge's history spans more than a century and a half. Our first enterprise started in 1833 when three 15 ft. vertical lime kilns were fired up in the tiny southern France hamlet of Lafarge. Today we have 500 subsidiaries operating in some 30 countries and employing more than 35 000 workers. In 1990, our revenues totalled $6.3 billion and we produced some 41 million metric tonnes of product.

Lafarge has always operated with several basic philosophies which have contributed to our ability to survive and grow worldwide. First, we believe in our employees. As far back as the late 1880's we were being recognized for our program for providing free benefits to our workers. Benefits such as medication and hospitalization, schooling and housing, pensions and saving plans. Today these sound routine, but in 1889 they were quite progressive.

Second, we have long been innovators committed to research, product improvement and new product development. We opened our first laboratory in 1887. That facility was instrumental in changing the company's focus from lime to cement products. Today our laboratories here in Canada and in Europe are on the cutting edge of scientific advances in developing building materials that are lighter, stronger, more versatile and energy efficient. These will be the materials for building in the 21st century.

Third, we have been adaptable, despite wars, depressions and other setbacks. We have always managed to expand, modernize and recognize the need for our products. We know that after each setback comes a surge. In the aftermath of World War II, Lafarge doubled its production in one decade.

The lynch pin of our corporate culture and management style that resulted are the ethical and moral guidelines embodied in the company's mission and guiding principles drawn up several years ago by Lafarge employees worldwide. Our mission is simple and straightforward: "To be the very best in every field we enter." We strive to serve the needs of our customers, our employees, our shareholders and our host communities. While these fundamental principles reflect the company's basic approach to business and management, Lafarge is committed to ensure that all employers, whatever their business unit or country of operation, understand and follow them. We regularly conduct training programs at all levels of the company to keep the principles active and on the mind of every employee.

Lafarge Coppée has always focused on the importance of developing a global strategic approach. Our statement of mission and guiding principles is but one key example of how the company has been able to sustain and increase its role as a key international player. To be a global player, one has to want to be a global player and make that a goal. Lafarge has set such a goal. It fits well with our long term planning and we are fortunate that in our areas of business, the technology and equipment are universal. The company's overall strategic orientations have long been focused beyond the borders of France. We contribute to our success by thinking internationally, starting with an international advisory board and extending down to hiring new employees who are looking for international careers. We constantly monitor the key markets around the world as to volumes, prices, suppliers and trends. We make sure that our strong financial group knows and interacts with the major financial players in markets. Our key management team members have had multi-country careers. We use the strength of the group to assist each segment and we add the strengths of each segment to that of the group.

Lafarge has been a presence here in North America since the 1950's but our merger with the Canada Cement Company in 1970 made us a major player in the North American market. By the 1980's we expanded into the United States, where today we are among the nation's largest corporations. Our North American organization, Lafarge Corporation, is now the number two player on the continent, providing nearly 14% of the total clinker capacity. In 1990 Lafarge Corporation generated revenues totalling $1.6 billion with some 16 plants, more that 90 terminals and in excess of 85 000 employees and processing more than 15 million tonnes of cement capacity.

We also own Cistec Environmental Corporation, our waste management and co-processing division. The key component for the future is the potential for cement kilns to recycle and reuse hazardous waste as fuel. We consider co-processing technology to be necessary for the cement industry, and a kiln's ability to provide a safe, practical and effective solution for waste as being essential for a sustainable environment, which we all are striving for.

An example of our global view and innovative ability was the financial structure created for our North American operations in the early 1980's. This was before the Free Trade Agreement. When we put our Canadian and U.S. operations together into Lafarge Corporation, we wanted to do so in a manner that would allow us, as much as possible, to operate as if there was no border.

Operationally, we have succeeded by having regional structures operate in logical market groupings, rather than national boundaries.

Financially, we have succeeded by designing a structure with one group of shareholders, but within which American shareholders may hold designated American stock and Canadian shareholders may hold designated Canadian stock, both having equal rights and dividends.

Although the past couple of years the markets have been difficult, I am convinced that we are well positioned to grow and expand. We expect to see significant opportunities throughout the 1990's, particularly as the housing construction market rebounds and as the U.S. and Canada address the challenges of replacing and upgrading infrastructure.

We, at Lafarge, are proud of our company and pleased with our performance over the years. But probably the greatest challenge for the next few years is in Eastern Europe. We intend to be important players in the effort to restore and rebuild the nations of the former Soviet block. Lafarge has been involved in Eastern Europe since early 1990 and we are building significant production capacity in the region to be prepared to respond to demands for high quality building materials.

Our Carsdoor plant, in what used to be East Germany, is a good example of what I am talking about. It is a facility with an annual production capacity of 4 million metric tonnes. Since acquiring it, not only have we upgraded the physical facility, we have also retained the entire work force, placing special emphasis on those in management positions.

A similar effort has been underway in Czechoslovakia, where last July we acquired a 40% stake in the Cheskovitza Cement Plant. The plant, which was last modernized in 1987, has an annual production capacity which can easily be expanded to some 850 000 metric tonnes. Our goals at this facility are to provide technical and sales expertise to plant officials, to vertically integrate the plant by adding a ready-mix concrete operation and to streamline the operating staff.

Adding further to our strength in the region, is Lafarge Coppée's facility in Turkey. With annual cement output of some 25 million metric tonnes, Turkey now ranks among Europe's leading manufacturers. In 1989, Lafarge acquired Istanbul's Aslam Cemento, the country's very first and today, its largest cement plant. Operating at full capacity we expect the facility to manufacture more than 1.2 million tonnes of cement annually. The plant will serve Turkey's largest and fastest growing cement market and contribute to our export capacity as well.

With these newly acquired facilities, as well as the capacity we have elsewhere in the region, such as Austria, Lafarge is positioned to be a leading player in the effort to rebuild Eastern Europe. We find this the most exciting challenge.

I thank you for having invited me to be with you this morning for this discussion and allowing me to share our globalization experiences with you. We at Lafarge look forward to greater involvement and participation as this global trend continues to unfold.

SESSION 4A
The Impact of the Globalization of Markets
L'incidence de la mondialisation des marchés

A METHODOLOGICAL APPROACH FOR IDENTIFYING POTENTIALS IN THE GLOBAL CONSTRUCTION MARKET

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1. Introduction

The scope for international construction contracting is of growing importance in the global market place. In recent years, construction firms from both the industrialised and developing countries are actively engaged in international contracting activities. International contracting is, however, a business activity undermined by high risks and uncertainties. To venture overseas, the international construction firm needs to have information pertaining to the global market place. Coherent information which pertain to the global construction market are, however, widely dispersed and not currently available under a single information system. International construction firms do not have an easily accessible information system which allows them to compare the construction markets in different countries. In view of this lacuna, the objective of this paper is to build a graphical model of the global construction market which will provide information pertaining to the construction industries of all the countries in the world. This information system uses statistical data relating to Construction Value Added (CVA) (US$m) for each country over a 15-year period (1970-1984). Statistical data for 180 countries were collected and analysed (Low, 1990). The analyses consist of comparing :

- The absolute size and linear regression of CVA in each country.
- The relative growth and linear regression of CVA in each country.
- Each country percent share and linear regression of the global construction volume.
- Each country relative growth of the percent share and linear regression of the global construction volume.

This paper should be read in conjunction with the two attendant posters. The results of these computations, presented in graphical and tabular formats in the original analysis, are discussed below.

2. Regional Percent Shares

The regional analyses model the average percentage shares of world CVA between 1970 and 1984 for 19 global regions where the domineering size of the markets in North America, Europe, the USSR and East Asia is clearly noticeable. The apparent disparity between regions in the north and those in the south can also be observed. In contrast, the average annual percentage growth of CVA over the preceding year between 1970 and 1984 for the same 19 global regions, shows a reversal of this domination. Here, the regions in the south now commands more attention than those in the north. Read together, these findings illuminate the global relationship between absolute size and growth trends at regional levels. This again invokes the north-south phenomenon where there is greater concentration of regions with higher growth trends in the southern hemisphere. This observation seems to suggest the determined efforts put in by the predominately developing countries in the south to generate economic development through a policy of rapid investment in construction programmes over a short-term period. From computations of current market prices between 1970 and 1984, the world average annual percentage growth rate was found to be approximately 9.75%. It can be seen from the analysis that 10 regions have average annual growth rates greater than the global growth rate. In contrast, there are 9 regions that have their average annual growth rates falling below the global growth rate.

3. Regional Contributions to Increase of Global CVA

The absolute size and relative growth of each region are two important criteria that management must consider in adjudicating the attractiveness or otherwise of each regional market. In considering the global construction volume in its entirety, these criteria do not, however, reflect the contributions made by each region towards the global volume increase over a specific time period. Between 1970 and 1984, at current market prices, the world CVA has grown by approximately US$518275m. This increase can be attributed to the respective growth in each of the 19 regions over the same time period. In similar vein, the increase in construction volume between 1970 and 1984 for each of the 19 regions can be calculated. By dividing each regional growth in volume by the global increase in volume, the percentage contribution to the increase of world CVA by each region can be obtained. The computed results for all the 19 regions show that North America provides the largest contribution to the increase of world construction volume between 1970 and 1984 (at 25.59%). Read together, these findings yield some very interesting results. For example, while the growth rate of North America is only 9.38%, its contribution to the increase of global construction volume over the same time period has been significant at 25.59%. On the other hand, while West Asia has the highest growth rate (22.74%), its contribution to the increase of global construction volume is only 5.66%.

4. Countries' Percent Shares & Growth Rates

The average percent shares of world CVA for 180 countries between 1970 and 1984 are also computed. The disparities in size between countries in the northern hemisphere and those in the south are again apparent. This contrasts sharply with the corresponding growth trends which shows the average annual percentage growth of CVA over the preceding year for the same number of countries over a similar time-frame. In this instance, countries in Africa, West Asia, Central and Caribbean America now occupy positions of greater prominence than those elsewhere in the world. These can be seen in greater detail in the analysis which categorizes the average annual percentage growth rates of each country into 6 ranges. As can be seen, although there are more developing than developed countries, there appears to be many developing countries with exceedingly high growth rates compared to those of the developed countries. Read together, the findings appear to suggest that although most developing countries in the southern hemisphere have small construction volumes in relation to those of the developed countries in the north, the former have grown persistently at a faster rate than the latter.

5. The Top Twenty Countries

Further analyses, extracted from earlier computations carried out elsewhere by Low (1990), have classified and ranked the top twenty countries according to their regressional trends of CVA. As can be seen, a total of eleven developed countries, four developing countries and five oil-producing countries go to make up this group. The performance of time series analyses on the CVA for each of the twenty countries has also indicated relatively high coefficients of correlation, the majority of which are in excess of 0.90. The results would seem to suggest that the largest growing markets are, in the main, to be found in the developed countries by virtue of their higher absolute trend growth rates.

Further analyses, derived as before, have also classified and ranked the top twenty countries in accordance with their regressional trends of CVA indices. There are a total of twelve oil-producing countries and eight developing countries in this group. The absence of developed countries among the top twenty countries ranked by their relative trend growth rates is significantly noticeable. Although the developed countries are much larger markets, the results here would seem to suggest that their relative rates of growth are nevertheless less impressive than those of the developing countries. The findings also suggest that between 1970 and 1984, the construction industries in the developing countries and, in particular, the oil-producing countries, have grown at a faster pace than their developed counterparts at the global level. Their respective correlation coefficients are significantly high enough to warrant confident interpretations to be made accordingly. The domination by oil-producing countries in this category is noticeable. This perhaps explain why there has been a hive of international construction activities in the 1970s in the Middle-East where most of these oil-producing countries are located. The intensification of construction activities during this period of time would appear to be fledgling efforts channelled towards the various development programmes in these countries. This may have, therefore, accounted for the rapid rates of growth experienced here.

The top twenty countries are again classified and ranked in accordance with their regressional trends of global volume percentage which measure the absolute rate of change for each country's percentage shares of the world construction volumes over the 15-year period from 1970 to 1984. A total of two developed countries, eight developing countries and ten oil-producing countries goes to make up this group. In the light of their generally high correlation coefficients, this would seem to suggest that the developing countries' percentage shares of the global construction volumes grew at a faster rate than most other developed countries, apart from Japan, which ranked first. These analyses showed that both the absolute volume and absolute percentage share of the global volume in the Japanese construction industry have grown at an extremely rapid rate.

The large concentration of developing countries and oil-producing countries in the last grouping above has undoubtedly reflected the growth significance of their percentage shares in the world construction market.

Earlier computations undertaken by Low (1990), have also classified and ranked the top twenty countries according to their regressional trends of global volume percentage indices. The grouping here reflects a total of eight developing, non oil-producing countries and twelve developing, oil-producing countries. There is no developed countries within the top twenty countries of this group. Again, their coefficients of correlation suggest a relatively high closeness of fit, the majority in excess of 0.80. The findings therefore reveal a preponderant content of oil-producing countries with their consistently growing rates of share of the world construction volume between 1970 and 1984. A joint consideration of all these findings can enable the following observations to be made for the period studied:

- Developing countries which reflect high regressional trends of CVA indices appear to have similarly high regressional trends of global volume percentage indices. It seems that the increasing growth rates of these developing countries' CVA indices have paralleled the increasing growth rates of their global volume percentage indices.
- In considering the top twenty countries alone, both the regressional growth rates of CVA indices and the regressional growth rates of global volume percentage indices for the developed countries seem to be much lower than those of the developing countries. The pronounced absence of developed countries in two of the above categories is noticeable.
- However, when considered in absolute growth terms, the developed countries' larger construction markets tend to reflect higher regressional growth rates of CVA than those in the developing countries.
- On a ranked basis, countries appear to offer better market potentials if their volume increases in both absolute and relative terms over a period of time are greater than the corresponding global aggregates in similar terms.

In the earlier computations carried out elsewhere by Low (1990) and by iterating the basic information system further, the following additional findings were also revealed:

- Based on the rankings of each individual country's VA by construction on a global basis, both the smaller and poorer developing countries have a tendency to feature at the lower end of the spectrum.
- When the CVA for different countries are ranked accordingly in their respective geographical regions, the ranked position of each country in absolute terms tends to remain relatively consistent in that region. For examples, while Japan has been featured constantly as the largest

market in East Asia, the United States, likewise, has also consistently retained its position as the country with the largest construction volume in North America.
- With some notable exceptions, the percentage shares of the world VA by construction for most of the countries also appear to be relatively consistent over the time period considered.

6. Correlation Coefficients for CVA & CVA Indices

As noted earlier, because CVA indices, using 1970 as the base year, are derived in the main from CVA, a single set of correlation coefficients was applicable in both instances after their respective regression analyses were performed. The findings revealed that more than 62% of the 180 countries considered have correlation coefficients of less than 0.90. This means that only slightly more than one-third of all the countries considered have a correlation coefficient high enough to warrant confident forecasts to be made based on their respective linear regression formula, y=a+bx. Forecasts with high level of confidence are taken here to mean those derived from regression analyses which yield correlation coefficients in excess of 0.90. This contention must, however, be interpreted within the confidence intervals of 95% adopted for the analysis.

On the other hand, the above computations have also shed some interesting findings when all 180 countries are ranked in descending order of their regressional trends for CVA in US$m. As the rankings show, the larger and richer countries appear to have regressional trends in CVA terms which are significantly greater than those of most other smaller developing countries. Although this logic seems obvious enough, the rankings obtained from this analysis can still help to indicate the extent of the intervals between various countries. By way of illustration, the regressional growth rate in absolute volume terms in the USSR (i.e. US$3176.67m) appears to be one-third that of the United States' (i.e. US$9034.72m) and half that of Japan's (i.e. US$6304.84m). The United States, by far, provides the highest regressional trend in CVA terms, a figure which has yet to be surpassed by any other country.

Other computations were carried out which rank all the countries considered in descending order of their regressional CVA after these have been converted to indices using their corresponding figures in 1970 as the datum. This has the effect of transforming the absolute measure described above into a relative measure for indicating the extent to which the regressional trends for CVA in volume terms have changed over the same time period. Upon transformation and after regression analyses were carried out for every country, the rankings have subsequently revealed findings which are substantially different from those reflected above (Low, 1990). The analysis here shows that most of the countries at the upper end of the scale now tend to be developing or industrialising entities. Considered jointly, both sets of analysis seemed to suggest that the developed nations tend to have larger construction markets but their relative rates of growth in volume terms are generally lower than their corresponding counterparts in the developing countries. Likewise, the construction markets in the developing countries tend to be smaller under comparison with their counterparts in the developed countries but their rates of growth in volume terms may be substantially higher (Low, 1990a).

Attempts were also made to place the two data sets, relating to CVA for 180 countries, into perspective with their corresponding correlation coefficients. As the results show, countries which have high regressional CVA trends and high regressional CVA indices trends tend to yield higher correlation coefficients for the few isolated cases depicted. The investigations revealed that because of their higher level of stability, developed countries appeared to have higher regressional CVA trends (as indicated by the value of b in the linear regression formula, y=a+bx) with correspondingly higher correlation coefficients. Similarly, the findings also indicate a tendency for some of the higher correlation coefficients to be related with higher CVA indices trends. A majority of the countries has, however, remained concentrated at the upper ends of the correlation coefficient axes in both sets of data. A considerable number of cases had also returned substantially low coefficients of correlation. Nevertheless, regression functions with low r values are still meaningful because of their usefulness in demonstrating the non-linear absolute and relative growth of the construction volume in a particular country which merit further investigation to uncover the cause of this non-linearity. This can, in turn, give ample warning to the market researcher over the use of forecasting techniques to project future volume and growth as these may not necessarily be accompanied by a high level of confidence.

From the clustering effects shown in both sets of data, two phenomena may be observed. Firstly, there are countries which fall towards the extreme ends of the vertical axis in the regression analysis. Secondly, for some countries, a high regressional trend of CVA may not necessarily generate a correspondingly high regressional trend of CVA indices, and vice versa. These findings would seem to support earlier propositions which suggest that :

- Countries which have large construction markets may not necessarily display exceedingly high growth rates. As pointed out earlier, these are normally developed countries.
- Countries which have small construction markets do often experience high rates of expansion in their construction activities. Developing countries usually fall within this category.

7. Correlation Coefficients for Global Volume Percentage & Associated Indices

As the preceding analysis has already shown, a single set of correlation coefficients was similarly obtained here for both the regression analysis of global volume percentage and the regression analysis of global volume percentage indices because the latter have been derived fundamentally from the former. The results of this set of correlation coefficients are grouped accordingly, as before, and plotted against the grouped cumulative percentage total. These revealed that more than 78% of all the countries considered have correlation coefficients less than 0.90. This implies that less than 22% of all the countries considered have correlation coefficients high enough to allow forecasts to be carried out confidently. In considering the data between 1970 and 1984 alone, it would appear that the majority within this band (i.e. correlation coefficients between 0.90 to 1.00) is made up of developing countries. This would seem to suggest that in between the 15-year period considered, the growth rates of the construction industries in the developing countries have increased at a faster pace than most of the other developed countries. To the extent that this is true, this would mean that the percentage share of the world construction volume in the developing countries has been growing steadily.

Earlier computations carried out elsewhere by the writer have also shown a preponderant clustering of developing countries among the upper echelons of all rankings relating to global volume percentage variables (Low, 1990). When ranked in descending order of regressional global volume percentage, apart from Japan, there is a domination by developing and newly industrialising countries among the higher hierarchy. Similar results were also obtained for the regressional global volume percentage indices where there was a significant presence of developing countries and territories towards the top of the ranking. Viewed from a zero-sum perspective, it can be conjectured that the growth in percentage shares in the developing countries would correspondingly lead to a proportionate reduction elsewhere along the same line in the developed world. As noted from the computations carried out by the writer elsewhere (Low, 1990), the persistent growth in percentage shares in the developing countries between 1970 and 1984 have enabled the following observations to be made :

- There has been a gradual reduction in the percentage shares of global construction volume in the developed countries.
- There has also been a dramatic reduction in the percentage shares of the world construction volume for the socialist countries of Eastern Europe.
- The percentage shares of global construction volume in the socialist countries of Asia have remained relatively unchanged.

In effect, the percentage shares of the world construction volume in the developing countries over this period of time have appeared to increase by almost two-folds.

It must be pointed out again that the high correlation coefficients (i.e. r between 0.90 and 1.00) referred to earlier have helped to provide not only an indication of the extent to which growth in the regressional percentage shares of the world construction volume for the developing countries has increased, but also an affirmation of their consistent efforts directed to achieving a high rate of construction growth as a means to industrialisation and development. The analysis also attempts to place the next two data sets for 180 countries into perspective with their respective coefficients of correlation.

The sharp contrast between the distributions in the two data sets above is clearly discernible. While the distributions in the first set clustered around the origin of the horizontal axis, these have also appeared to be concentrated at the upper end of the vertical correlation coefficients' axis. On the other hand, the second data set shows a distribution which indicates that some of the countries with high regressional global volume percentage indices trends tend to have higher coefficients of correlation. On the other hand, both data sets also show many cases with low regressional trends and low correlation coefficients.

Turning now to the analysis which deals with the global volume percentage regressional trends, it does not seem unreasonable to postulate that the changes in percentage terms for each country are, not unexpectedly, both small and gradual. A sensitivity analysis carried out by the writer earlier elsewhere in this study using global VA by construction for 1984 had revealed a shift of ± US$7220.52m for every percent change in global volume percentage in either direction (Low, 1990). As a result of this extremely delicate sensitivity, one would therefore expect the percentage share of the world construction volume in each country to be relatively constant over the years. This perhaps explains the straight-line tendency in the first data set, where apart from the larger developed countries such as the United States, Japan, the USSR, West Germany, France, Italy, and the United Kingdom, most other countries have less than one percent share of the global construction volume. Earlier computations carried out elsewhere which expressed the estimated VA in construction of each country as a percentage of the world VA by construction between 1970 and 1984 for 180 countries have lent support to this proposition (Low, 1990). It can be seen from these computations that there has not been any radical increase or reduction in most countries throughout the 15-year period considered. This tendency would, therefore, yield a narrower and lower range of regressional trends for global volume percentage, thus accounting for the predominately straight-line distribution in the analysis for the first data set.

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GLOBAL CONSTRUCTION INDUSTRY

Professor Paul Strassman
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One of my impressions here is that the globe has gotten a lot smaller. It seems to consist now mainly of Europe and North America. Five years ago people were talking about the Pacific Rim. Ten, fifteen years ago it was the mid-East and Latin America.

I think the real globalization of the construction industry actually took place in the 1970's with that big Middle Eastern boom, when building there increased 5 times and overseas construction, especially for European countries, Germans and others, went up something like 10 times. Then in 1982 and 1983 that market collapsed, went back down to a fifth, although at the same time, the world international building, going by these ENR data, only went down by something like a half. So I think that some of the urging for companies to become globalized or internationalized seems perhaps to be primarily for latecomers.

The globalization that took place then was that a lot of construction firms ceased to be simply national firms which happened to have some sites abroad because they were building something special, military bases, or perhaps some special contract for the World Bank or building factories for their own national companies. But they came to learn in the course of the 1970's to be truly footloose, to work jointly with firms from other countries, especially in the Middle East to begin with, recruiting labour from the Far East, from Pakistan, Korea and the Philippines, and the Koreans came in (the Koreans having had their experience building overseas initially in Vietnam during the war there) and so then we began to get highly specialized firms. Some firms specialized in procurement. Some firms especially skilled in financial engineering were tied in with banks and government agencies.

The construction management and fast track working was also stimulated by the inflation that began to accelerate a great deal in the 1970's and, of course, some of the overseas building went on because some of the petrodollars were recycled in Latin America. Something strange is that none of this was predicted. In 1970 it was predicted that the biggest market would be in Latin America; the Middle East was not foreseen. In the late 1970's the collapse of the Middle East was not foreseen, just as the collapse of the whole Eastern European planned economies, that was not foreseen.

From Dr. Ravara, we heard that in Portugal now there is an opportunity and a need to associate with engineers and building firms in other countries, in order to learn a variety of things so that after that, the Portuguese building industry would be able to fly without a net, as he put it. So then the question comes up, once they have learned how to do that, what is there left for any global contractors to do in Portugal? Is this only a temporary thing? After all, the buildings are not part of international trade. They have to be built locally, primarily with local materials and with local workers, and so therefore what does a foreign firm really have to offer?

From Dr. Kibert we heard a lot of a kind of scolding of the American construction industry - a lot of it, I think, very well put and valid - for low research and development, especially for an adversarial spirit, and lots of things that ought to be done that are not being done and otherwise American firms would fall behind and would not really be competitive. But I don't think that adversarial spirit is going to be changed and the low research and development is partly due to that adversarial spirit. Sometimes they found when the Commerce Department would go to South Asia to try to explore possibilities and would go with some executives and technicians of American construction firms, afterwards they were supposed to write up their reports but most of these tended to be quite useless and uninformative because the firms considered what they had learned to be proprietary information.

And so one thing lacking in the United States and in Britain, I have the impression also, is some of that teamwork, working together, firms and governments and banks (what we call in Japan, incorporated) and the French have something similar. This kind of mutual trust and collaboration of firms and government is just simply not part of the American way of doing things. Under the Reagan administration, the industry hoped things would be different because there was just from Bechtel alone, there was Schultz, who had been president of Bechtel, Secretary of State, Wineberger, Secretary of Defence came from Bechtel. The Deputy Secretary of the Environment, Kenneth Davis, came from Bechtel and so they thought they would be in. There was a book written by McCartney, "The World's Most Secret Corporation - How They Engineered the World" but actually, the odd thing is that once these people got to be in the government, they kept on being adversarial and competitive in the other sense of the word, not in the adversarial sense rather than in the efficiency sense, and what the Reagan administration wanted to do was even to abolish some construction industries-serving activities, for example, they wanted to abolish the Export/Import Bank, as being competitive with private banking. They wanted to abolish some government insurance supports. They wanted to abolish the commercial service, all of this and they did not really want it and I don't know if that is ever going to change.

In a paper by Thomas Vonier, who is not here, but maybe you have seen the poster outside. He mentions what could be done to make American firms fit in in Europe in the future and he mentions, among other things, that it is in only those areas where there is a unique technical ability (and he has the word extraordinary) where extraordinary skill is involved, and maybe extraordinary speed is needed or where it seems to be especially risky. These are the areas where are the extraordinary skills and it is in the area that Dr. Kibert mentioned, namely for the United States, in use of computers, integrating computer design and constructability and a lot of these sorts of things, and it is exactly in the things which are unusual where perhaps, even in Portugal, foreign firms can later come in.

The odd thing in globalization is, an inventory principle is involved, last in, first out, that the international companies in the Middle Eastern boom that were last in were the Koreans, the Brazilians, Tunisians in North Africa and then they were the first out there. Their share of the international market went down or their total volume went down by something like 90%, while industrial countries, their international work as that market collapsed went down by something like 50% and, well, why is that? Because they were doing the most conventional sorts of things. They were doing the sorts of things which Arabian and Libyan contractors could themselves most easily learn. So, it is the unusual things, the risky things, the large scale things, the novel things, this is where firms are likely to be having a competitive advantage internationally and in this connection I note the following. The countries which have had this kind of integrated teamwork type of research, and lots of government encouragement for research and development, and namely the French, the Japanese and the Italians, their share of the world market, using these defective ENR figures, which have a lot of omissions and some double counting, but nevertheless, with a big margin of error, the share of these countries from about 1980 to about 1990 went up from about 10% of the world market to a third and more but at what expense? Not at the expense of the largest American firms: Kellogg, Bechtel, Carsons Floor, Lumbers Crest and these largest firms. If you compare the six largest American firms with the six largest French, Japanese and Italian, it continued to be about two and half times as much of the market. So the largest firms were the ones who were doing exactly the sort of thing, who were already internationally competitive, and were doing these sorts of things, while it is the smaller firms who were also the last ones to come in. They are the ones who don't have these sorts of highly specialized skills and also the international networking capability which it takes to be truly globalized.

I was going to say something on Mr. Bowen's paper, but I didn't find anything to disagree with. It is a lot easier and more fun to disagree. I have two extreme examples, that one time I made a comparison of something like 80 contractors building a very small 25 m^2 house, which cost about $3500 and it turned out that the costs stayed more or less the same as pricing this house in the very standardized design in about 8 countries, with about 80 construction contractors, where wages would be, in the cheapest countries, Pakistan and Sri Lanka, $2.00 per day and Latin America and North Africa, maybe $10.00 per day for unskilled labour. But, somehow or other, the contractors with the higher labour costs found ways within their own country to use the labour more efficiently and there was not any way of predicting exactly how they would do that, but it turned out that, insofar as labour costs went up, they would substitute other ways of doing things, so that it is certainly true that one cannot simply go by inputs and use a cookbook formula.

The other extreme was a plant in Michigan being built by the Japanese firm "Kajima", which is a half-billion dollar plant a little bit south of Detroit, which they were building for Mazda. And so that wasn't very far from us so I drove there and wanted to find out if they use any of their many patents with their much more research and development, which the Japanese firms do compared with Americans, and the manager, I think his name was Toshia Muki, told me "No they weren't using any of the patents." So I asked him what do they do differently and they said "we don't do anything differently here." They built an almost identical plant in Japan. The only thing they do differently is in Japan if they see some worker who is not working well, they can say to the subcontractor to fire him and he is permanently gone, but in Michigan you have a lot of trouble on your hands and even if he is fired, some other subcontractor will hire the same worker and also they do not have as much clout with the material suppliers as in Japan. He said mainly that means they spend a lot of time working at night, working week-ends, in order to stick to the schedule. So then I asked does it mean it is cheaper to build here or cheaper in Japan. He looked at me kind of funny. Later I concluded he must have felt, what a dumb question for an economist to ask, because he said well look, at 250 yen to the dollar, it is cheaper in Japan; at 150 yen to the dollar, it is cheaper here; so 200 yen to the dollar is about the break even point.

Well, finally, the last thing that I will mention is that what prices are ultimately depends on whether the industry is competitive or not competitive. And on this my British co-author Gill Wells and I, we never could agree, because I said the industry is fiercely competitive. Look at how easy it is to enter, look at how many firms go bankrupt, it must be fiercely competitive. And she said the whole point of the book is to show that competition is a myth, because design, construct and negotiated contracts avoid competition, construction management avoids competition, there are bribes all over the place, there is financial engineering and government pressures. How can you say there is any competition anywhere? So if you look at the book and you think it is kind of schizophrenic, that is why. So I said to her, why don't you write the introduction and I write the conclusion, so don't read both, read only the conclusion, and I concluded that, okay, sometimes they get high profits but they have to have the high profits, in some cases, in order to offset the risks elsewhere, and that essentially competition is not about who gets the contract but competition limits the price that one of the competitors can actually charge to get the contract.

How the North American Building Industry Can Improve Its Prospects in Western and Eastern Europe

Thomas Vonier, AIA Consulting Architect
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A prolonged low-cycle in North American construction activity and an apparent growth of opportunities in Western and Eastern Europe has caused many North American design and construction firms to look overseas for sources of new business. But only a few such firms have anticipated fully the challenges inherent in competing with well-established foreign companies in sometimes unfamiliar and often difficult surroundings. Few firms are adequately prepared to meet these challenges, or to make the investments needed to compete effectively in Europe.

If product manufacturers, design professionals and construction companies based in the United States and Canada expect to participate in the rebuilding of Eastern Europe, or hope to capture a share of the established West European markets, they will need to make significant changes in approaches and outlooks. Key rôles also can be played by national federal governments, including: active reform of domestic building standards; revision of international agreements and regulations governing the practice of various design disciplines; and strengthening of national policies that affect building technology innovation and incentives to export.

Characteristics of successful American entrants in European design and construction markets

Cases studied during 1990 and 1991 revealed that a number of factors, often in combination, are decisive in determining the success of foreign ventures:

- The presence of company principals with strong personal ties, including family relationships, in the project host-country, and often to clients who are active in the host-country;

- Willingness and ability to risk delays in fee payment, to accept payment in forms other than readily-convertible currency, and to forego near-term profits in the interests of building long-term relationships;

- The availability of committed firm personnel who can obtain professional credentials, licenses, work and residency permits from the project host-country;

- The availability of substantial cash reserves to establish and finance continuing operations, to support the cost of communications with the parent organization and to sustain efforts in periods of lean activity; and

- The possession of unique or innovative technical ability and knowledge that have high market value.

The importance of technical innovation

American corporations and design professionals who have succeeded in international competition have used innovation as a fundamental strategy. Innovation — the process of developing new inventions and ideas into products and technologies that achieve commercial use — has, after all, allowed many foreign competitors to gain or maintain commercial advantages in North American markets. An innovation in building design, construction or management can be considered significant *if*:

- It produces order-of-magnitude benefits in such areas as initial and operating cost reduction, speed and ease of construction, life safety, environmental quality or other critical aspects of performance;

- It employs new or previously unused materials, techniques and principles;

• It permits the realization of objectives that previously could be only contemplated;

• It confers upon those who adopt it significant and lasting competitive advantages, particularly across national boundaries; and

• Science-based research and development, as well as disciplined marketing endeavors, were required to bring it about.

Assessed against these criteria, few recent developments in American architectural design and building technology can be described as significant innovations. Greater attention to innovation is necessary for successful competition in foreign markets.

Conditions that favor design and building technology innovation

Several factors, no single one of which alone is sufficient, must in some measure be present:

• The emergence of new needs, requirements and opportunities, or the disappearance of traditional markets and resources;

• The development of new applications methods and technical knowledge, or the development of new materials and new properties of existing materials;

• Extraordinary collaboration among diverse disciplines, including close allegiances among design, manufacturing and marketing disciplines; and

• The presence of significant incentives and support without barriers to market entry.

The present climate for building innovation

A variety of challenges and opportunities will exist for building innovations in the decade ahead:

• A new generation of technical demands and functions has arisen in office buildings, engendered mainly by the advent of electronic information systems. New computing and communications technologies require a high degree of building systems integration.

• Environmental and health costs associated with current approaches to building are coming into question, leading to greater pressure for the development of new design approaches and the use of environmentally-benign resources for building.

• The scarcity of capital, the expanding costs of development and rising expenses for operation and maintenance are creating growing pressure on buildings to perform as economic assets.

• The performance of certain building components and sub-assemblies has improved from many standpoints, but overall building performance has not kept pace.

• Powerful new design tools are emerging, permitting the integration of previously disparate disciplines and allowing designers to achieve new understanding of and refinements to design alternatives.

An agenda for building industry action

Several immediate steps could help the North American building industry to improve its ability to compete more effectively abroad:

• ***A "summit" among national building association executives and officers from the industrialized nations***: A range of important issues now exists — related to international trade in professional services, reciprocal foreign licensing and international professional relations — that warrant convening of a well-organized, clearly defined business forum among leaders of the key professional societies and building trade associations in the principal industrialized nations. The forum would serve to identify issues, to take concerted action on key matters and to lay the groundwork and establish agendas for future dealings. Bilateral and multilateral agreements could be reached regarding cooperative ventures and exchange programs.

• ***Action and lobbying programs directed toward foreign commercial services and other parts of the federal government charged with promoting exports***: Promoting the export of architectural and engineering services, building technologies and construction services should have higher priority for the US and Canadian foreign commercial services. These services and other elements of federal government responsible for advocating the overseas interests of American businesses should become more active in seeking opportunities to tie foreign aid, international development support and technical assistance programs to the use of lending-country architectural and engineering firms.

• ***Technical assistance to building industry institutions in the developing Eastern European market economies***: As Eastern Europe seeks to overcome a legacy of four decades of socialist central planning, they will need to restructure their public institutions; not least among these are the organizations concerned with building and design. Much of the rebuilding in these countries will be accomplished with foreign investment, much of it supplied by and through North America. Design professionals from the US and Canada can assist architects and political leaders in these countries by providing advice and technical assistance on key development matters, including infrastructure and building programs.

• ***Professional and intern exchange programs at the national level***: Many universities have long-established foreign study and faculty exchange programs, but there are relatively few (if any) such opportunities supported for mid-career professionals and association managers at the national level. Exchange opportunities, supported by counterpart professional societies, provide enriching experience for established professional association managers and young people who show promise for professional leadership. Such programs could lead to long-term relationships and professional and institutional rewards.

• ***National focus on building design and technology innovation***: Curricula in North American schools of architecture and engineering could approach the teaching of innovation as a creative and disciplined process, with clear precedents and requirements. Closer alliances between design schools and business schools could encourage interchange on the theory and rôle of innovation as applied to buildings. Schools of industrial design have much to offer, because industrial design is more deeply concerned with the processes of manufacture and the disciplines of market research.

Conclusion

With few exceptions, the North American building industry is today characterized by a number of factors that diminish its prospects for successful participation in European markets: Over-emphasis on short term, incremental improvements in existing domestic technologies and product lines; poor capitalization and increasingly marginal design and production facilities; reductions in research and development budgets and staff; absence of national leadership and cohesion; and reliance on advertising and protectionist measures as substitutes for genuine market research and product redesign.

If our building industry hopes to participate in European markets, these patterns will have to be reversed — and quickly.

Répercussion de l'économie de marché sur le développement quantitatif et qualitatif du bâtiment tchéco-slovaque

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Introduction

Le congrès mondial du bâtiment s'occupe de problèmes plutôt techniques: des metériaux, procédés et systèmes nouveaux, de la réhabilitation et restauration, de l'environnement, de l'informatique et de robotique. En outre il existe un thème appelé "mondialisation" orienté vers les conséquences des innovations techniques et économiques sur l'industrie de la construction.

Pour les pays d'Europe Centrale et Orientale le phénomène de la mondialisation s'identifie aux changements politiques, économiques et sociaux, lesquels automatiquement ne tardent pas à influencer l'évolution de l'économie nationale y compris le secteur BTP.

La mondialisation tout à coup a apporté plusieurs problèmes, jusq' à présent inconus.

1. Présentation (en bref) d'un système planifié dans le secteur BTP

Le système planifié n'était pas du tout efficace en ce qui concerne la production du secteur BTP et son activité. La propriété collective n'a pas poussé du tout les maîtres d'ouvrage, les maîtres d'oeuvre et les entrepreneurs à exécuter les constructions dans les meilleures conditions. L'Etat a privé les entreprises de tous ses moyens financiers (p. ex. bénefices et amortissements) et d' un autre coté, il les a redistribué sous forme de subventions, de dotations, sans aucun liaison avec l'efficacité de l'activité des entreprises et de leurs besoins. Dans cette situation un seul (le plus important) rôle des directeurs (tous nomenclatura) était de maximiser ces "dons". Et l'Etat était génereux surtout pour les "fidèles". Ceci explique que p. ex. en BTP il y avait 600 mille personnes emplyées (4,3 % de la population) et une production de 19,2 % du PNB alors qu'il manquait toujours de logements, d'écoles, d'hopitaux et que l'habitat et infrastructure étaient dans un état catastrophique....

De cela on peut conclure qu'en général le système planifie:

- a donné des certitudes aux entreprises;
- a fondé (puisque le plan avait force de loi) des disproportions dans la structure de la construction: répartition anormale de 38 % de l'activité pour les bâtiments et de 62 % pour le génie civile; la proportion de nouvelles constructions étant elle aussi tout à fait anormale (78 %) par ropport aux réparations (22 %);
- a forcé les entreprises du bâtiment à assurer des activités qui n'avaient rien à voir avec la construction (un tier des travailleurs occupés hors de la construction, à l'entretien, la fabrication de matériaux etc.);
- a entrainé l'exécution des chantiers dans des délais 2 à 3 fois plus longs, immobilisé des milliards de couronnes en travaux non achevés, accepté la mauvaise qualité de la production et une productivité ainsi qu'une rentabilité extrémement basses.

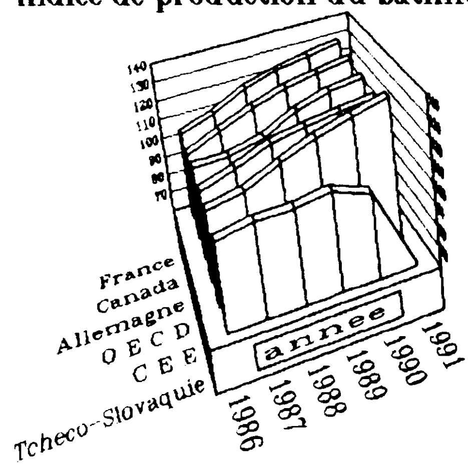
2. Conséquences de la mondialisation

La réapparition du marché de la construction apporte au point de vue du secteur BTP certaines conséquences positives (meilleure souplesse de planification, stimulation économique, hausse de la qualité etc.) mais en même temps certaines conséquences négatives.

Parmis celles-ci les plus importantes sont:

- chute de CA des entreprises de BTP (baise de 30-40 % entre le début 1989 et 1991) et

Indice de production du bâtiment



[Main Economic Indicators OECD, No 3/91]

● licenciement des travailleurs (surtout en Slovaquie où 70 mille personnes furent licenciées la fin 1990 - début 1991).

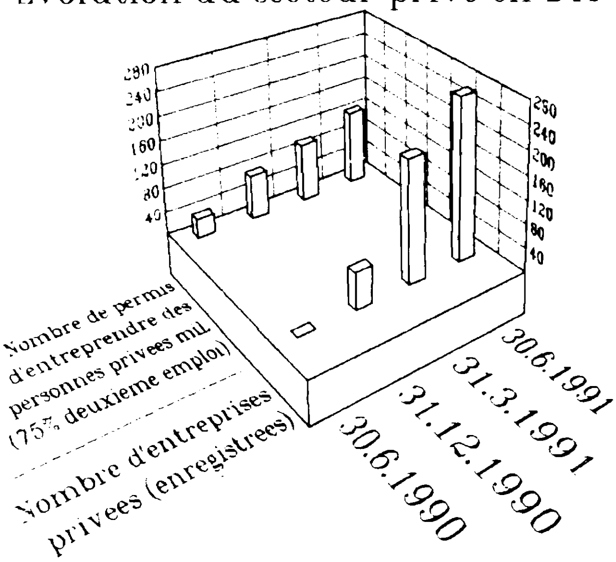
3. Comment veut-on maîtriser la situation

Le premier but du nouveau gouvernement était la "réinstallation" du marché. Cet objectif peut être atteint par deux voies:

● démonopolisation "forcé" (p. ex. en 1989 97,5 % de la production exécutée par les entreprises de plus de 1 000 travailleurs) des entreprises - monstres: en 1989 il y avait 55 entreprises sous tutelle des Ministères de la construction (moyenne de 6 000 travailleurs), au 1. 7. 1990 c'était plus que 230 entreprises (moyenne de 1 200 travailleurs) et en 1991 il y en a 600 (moyenne de 450 travailleurs) et

● soutien à la privatisation, à la fondation d'entreprises privées: si en 1989 pratiquement aucune entreprise privé n'existait en secteur BTP, en 1990 il y en avait 60 et à mi-1991 déjà 270. De plus, presque 120 mille personnes priveés ont l'autorisation d'exercer une activité à titre personnel dans le secteur BTP (la plupart comme activité secondaire).

Evolution du secteur prive en BTP



A présent commence le processus de la "grande" privatisation où presque toutes les entreprises de BTP se transforment en S. A. et où les actionnaires sont surtout les citoyens (ceux-ci peuvent recevoir à bon compte des actions grâce aux coupons distribués par l'Etat ou, ils peuvent les acheter directement).

On estime que de cette manière, les citoyens pourront acquérir 43 % de la valeur des entreprises de BTP, le reste étant vendu aux sociétés tchéco-slovaques ou étrangères. La participation de l'Etat sera plutôt exceptionnelle.

4. Perspectives du développement du secteur BTP

Le secteur BTP est considéré comme un indicateur hautement sensible de la situation économique du pays. Nous serions donc actuellement dans une phase de récession profonde...

Malgré tout on croit la surmonter pour les raisons suivantes:

● il manque des bâtiments et de l'infrastructure;

● les arriéres en réparations sont éstimés à 400 milliards de courronnes ce qui représente 4 ans de travail des capacités de BTP existantes;

● il existe des possibilités réelles d'exporter des capacités, surtout à l'URSS;

● on peut régulariser le chômage à l'aide d'investissements nottament en TP;

● il existe un intéret réel à l'étranger pour réanimer l'économie tchéco-slovaque par des investissements importants.

La prévision à court et long terme: la baisse de la production de BTP continuera en 1992-93. On prévoit une certaine stabilité pour la période 1994-95 et ensuite une legère hausse. Nous prévoyons de réatteindre vers l'an 2 000 le niveau d'activité des années 1980.

Soviet Investment Policy and Cooperation with The West in the Construction Industry

by Professor, Dr. Jakov A. Rekitar
Academy of Sciences of the USSR, Chief of Department
President, Association for International Economic Cooperation of Investors and Construction

The involvement of foreign enterprises in the USSR construction industry will develop based upon the following factors:

1. State funded construction contracts will diminish to 40 - 75% and private contracts will increase accordingly.
2. The limitation of state expenditures will be overcome by private enterprise funding and bank credit.
3. A competitive atmosphere will develop in design and construction amongst the different forms of property owners - state, cooperative and private.
4. Economic incentives will strengthen the construction process by offering bonuses for good work and penalizing non-performance of contract conditions.

The investment by private enterprise will be significant in 1991-1992. Centralized investments will decrease by 16-22% and private investment will grow, correspondingly, by 2% and 3%. In the national economy as a whole, the total volume of 1991 capital investments will decrease by 6% - 8% compared to 1990, including drops of 9% for industrial construction and 4% for non-industrial. Stabilization and a gradual withdrawal from the economic crisis are expected beyond

1992-93, and with the introduction of new market mechanisms, the recovery will accelerate. The market changes that will positively impact the construction industry include the following:

- Placing of orders for construction of projects on a competitive basis, with selection of a contractor through bidding;
- creation of a developed market infrastructure (networks of building exchanges, tender companies, commercial information centers, etc.);
- creation of a market of building materials and equipment with provisions for commodity producers to offer their products at exchanges and auctions;
- bidding of unfinished projects including laid up ones, especially in the economy's public sector.

One of the most perspective forms of economic cooperation between East and West is the establishment of joint ventures on the USSR territory. Now, after adoption of the President of USSR Act, vast opportunities for further cooperation can be found. As for construction, there are infrastructure projects, road building, sport facilities and tourist complexes, administrative buildings, a number of industrial plants, restoration of historic buildings and town centers, computerization of cost engineering, and designing, production of effective construction materials (especially cladding and insulating materials), and so on.

It is interesting that in 1991 almost 90% of production and non-production projects were not provided with building materials in accordance with their planned needs. There were incomplete deliveries to building sites of prefabricated reinforced components (up to 20%), steel components

(10%), brick (29%), sawn timber (40%). Demand for finishing materials was not fully covered. The level of provision of construction projects with glass, paints and linoleum constituted 69%-79%, with facing tiles - less than 50%.

It should be noted that small and middle sized companies were the leaders of joint venture projects, while larger Western firms took, as a rule, expectative positions. Multilateral partnerships on a company level seem to have great possibilities. A vast potential for cooperation on industry and company levels concentrated on commercialization of Soviet technological developments; with an emphasis on trade of technology.

To improve the process of international technology trade, we intend to develop, and use more actively, other forms of technological cooperation, and in particular to widen direct scientific relations of Soviet research and engineering institutes with similar foreign partners.

Joint entries to the third country markets have involved deliveries of plant and equipment, as well as different services for industrial projects. Depending on specific situations, joint activities may be organized as subcontracting, consortia and joint ventures. When implementing reforms in the USSR economy, and in particular in international economic relations, the need for engineering services becomes more urgent both for Soviet and foreign companies.

A large economic potential is contained in leasing operations - an effective form of investment policy.

Cooperation in the design sphere is very important. The gap is illustrated by the fact that in the USSR 1.8 times more designers are employed than in the USA when sums of investment in the countries are approximately equal. At the same time, designer labor productivity in the USSR is 5 times less than in the USA, and capital-labor ratio in the design is 7 times less. The design work automation degree in the USSR is in the rage of 15%-20%, while in leading capitalist countries - 60%-70%. In 1991 there were 120 CADD systems in the USSR - in the USA 3,000. In USSR there are 48 CADD centers for collective use in the country, when minimum 120-150 are required. Also, there is not enough design software data bases.

It should be stressed in conclusion that perestroyka, although it is an internal problem of the USSR, inevitably effects international labor division processes, increases the scales of international economic relations making them more wide and diversified, provides for lowering of international tensions and leads to better understanding between USSR and other countries.

SESSION 4A
THE IMPACT OF THE GLOBALIZATION OF MARKETS

Questions and Discussion

Question

I would like to ask you a question, which is related to my speech this morning. What is your opinion on the feasibility of such a process as you are describing for Portugal, without any help from other countries of Europe? Do you think you would have been able to do all that work, all those changes, without having some support from other countries in the European community?

Dr. Ravara

No, the help from the EC bodies and the EC community is, in fact, essential and as I mentioned is a well established policy of the EC to reduce inequities, because the only way to have a global market is not to have very sharp differences in development between its members. An interesting feature of this attitude and of this policy is, as is well known, that although there are significant inputs, they always require a correspondent, a parallel national input, so in global terms, for instance, for the roads, for the public works activities, the input from the community represented never more than 20% in global terms. This kind of attitude and policy is mobilized very much, but it would not be possible, of course, at the same rate without these integrations.

Question

I noticed with interest, that you identified the LNEC mark of quality and it's in capital letters. I am assuming that this mark of quality is some sort of symbolic way of recognizing people in the construction business as being given the blessing from your civil engineering department as meeting a certain standard of expertise as well as the production of materials.

Dr. Ravara

It corresponds to the quality of work; in our case the problem was the following. In our experience we have in many countries, many technical legal administrative procedures for quality assurance for different places of work. Some procedures for design assurance, construction assurance, several procedures for products and components, but there was no integrated procedure to guarantee quality of the final product. Therefore we have, very often, the case of poor quality with good projects or poor quality with good construction but lack of quality in project. We devised a global certification procedure that involves three entities: the owner of the work requires the mark of quality for his work, the LNEC has a certification body, but the fundamental is the action of the general quality managers. Those are private firms, a bit similar to what there is in other countries, who are responsible to coordinate all the actions, gathering all the phases to guarantee or implement the quality control plan.

Then at the end of the process, they are qualified by LNEC to act on that purpose and the owner of the work is certified with the quality mark.

Question

Is there a legal requirement in Portugal to obtain such mark of quality for construction?

Dr. Ravara

Yes. As I mentioned, this was presented in level 65 quality and management symposium.

Question

Could you give us an example of what is a favourable condition? You make reference, in your presentation, to the fact that there were favourable conditions granted until 94-95.

Dr. Ravara

Yes, this importance from EC, the favourable conditions is that this input, this significant financial resources, will continue and we will cover programs at least until 94-95.

Question

It is mostly financial conditions which are favourable.

Dr. Ravara

Yes, indeed, this fact is the financial conditions by EC.

Question
John Fernlord
Construction Cost Consultant

You mentioned in one of your slides that you are participating in the EEC standardization process, at the same time keeping in mind the characteristics of your local industry. Can I ask specifically, what characteristics you want to keep in mind and what compromises you have made or are going to make to maintain those characteristics?

Dr. Ravara

If you participate in the draft panels, you must arrive at a common draft, but that reflects interests of all. So I spoke in very general terms. To give you an example, it is important to have a device and to have a general model of seismicity that integrates well the seismicity of Portugal and other countries, the activity of classes of steel. It is a compromise and it must be something that does not forget, and the only way to assure this is to be present and to participate as much as possible.

SESSION 4B
Housing Accessible to All: A Pressing Need
Le logement à la portée de tous: un besoin pressant

A DESIGN PROCESS TO IDENTIFY APPROPRIATE BUILDING CONSTRUCTION IN DEVELOPING AREAS

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1. INTRODUCTION

This paper is written with the intention of drawing the attention of Development Agencies and the Professional Consultants who advise them to the advantages of considering all the "Alternative Construction Methods" that are available and utilizing the ones that on analysis are shown to be "Appropriate."

This paper sets out the Criteria for Development that the DBSA considers essential, defines Appropriate Construction and Alternative Construction methods in the context of development and recommends an approach to the design of buildings in developing areas.

An integral part of the design process proposed is the identification of what is available locally and the integration of this into the overall concept.

2. CRITERIA FOR DEVELOPMENT

The problem common to all areas of the World where development is taking place is "how does one use the resources available for development to the maximum advantage".

It is a belief of all in the Development Bank of Southern Africa that a building or project is appropriate to the development environment when it:

- is affordable[1]
- is acceptable to the end user
- is appropriate to the brief
- addresses the needs of the community
- makes maximum use of local resources.
- contributes to the community in economic terms.
- is such that the community's resources are sufficient to operate and maintain the facility provided.

While it is difficult to produce buildings that satisfy all the criteria listed the possibility of doing so is increased by considering all the "Alternative Construction Methods" that are available together with all the other relevant factors such as locality, climate, economics, resources, aesthetics and most importantly, the people and their ability to sustain the proposed development.

The development of an appropriate building design for a community can only be achieved by consulting the people whose active participation and involvement is a prerequisite for the successful implementation of any project.

3. APPROPRIATE CONSTRUCTION

What is Appropriate Construction? In the context of development appropriate construction can be regarded as any building medium or method that can be utilized to construct buildings that meet the development criteria.

4. ALTERNATIVE CONSTRUCTION METHODS

4.1 What are Alternative Construction Methods?

In this paper Alternative Construction Methods are considered to be <u>all</u> the choices of construction methods open to one when considering the design and construction of a building. These alternatives are:

- Conventional
- Traditional

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[1] Affordability levels can be determined by statistics that will indicate 'ability to pay'. However the statistics can be made meaningless by attitudes that determine 'willingness to pay'. Both the 'statistics' and the 'attitudes' should be determined in consultation with the potential beneficiaries of a development project.

- Innovative

  * Labour Intensive
  * Industrialised

4.2 Traditional construction

Where a traditional building method or technique is no longer employed in the normal course of events but has lingered on in rural areas where it is still familiar and available it should be considered for use in modern buildings.

This can include

- building in stone
- wattle and clay methods of construction
- mud brick construction
- thatched or leaf roof coverings
- beaten and polished earth or dung floors
- post, lath and plaster construction, etc.

4.3 Conventional construction

Conventional construction is current building practice which is familiar to all in the developed regions of Southern Africa. In its simplest terms it is:

- cast **in situ** concrete foundations
- cast **in situ** concrete surface beds
- walls constructed of clay bricks, cement bricks or concrete blocks, laid in mortar
- timber roof construction clad with
- steel or fibre cement roof sheets, clay tiles, concrete tiles, fibre cement tiles or slates.

In Southern Africa, timber frame construction is not yet carried out on a day to day basis and is still sufficiently unfamiliar to the average builder to be regarded as an Innovative construction method.

4.4 Innovative construction

Innovative construction is the use of unusual methods to achieve a satisfactory end product. The driving force behind the development of these construction methods is usually the desire to:

- simplify the building process
- reduce the number and the level of the skills required
- reduce the construction time
- reduce costs

Included under this description are building methods, systems and techniques that range from sophisticated industrialised methods where a whole structure or major components of it such as wall panels, roofs, floors, etc., are prefabricated (and possibly pre-finished) in a factory or produced in a casting yard, to labour intensive, site based operations that use the most basic building materials and tools.

4.4.1 Labour intensive construction

Labour intensive construction should be seen as part of the mobilisation of local resources. Intensive use of labour does not only mean the employment of large numbers of unskilled labour by construction companies. It also means construction carried out by small contractors, emerging entrepreneurs, community self help and mutual aid construction all of which can be carried out without the aid of sophisticated plant or equipment.

While the employment of any of these construction methods has obvious economic benefits for the community it has equally important benefits for the project. Involvement in the building process reinforces the consultative processes utilized to arrive at an appropriate design and assists the community to identify with and take ownership of the project.

Experience has shown that it is virtually impossible to introduce labour intensive construction methods to a project at implementation stage. In view of this if a decision is taken that labour intensive construction should be used, the project should be designed, documented and managed with a conscious attempt to maximise the use of labour and minimise the use of capital intensive mechanical plant.

4.4.2 Industrialised construction methods

Industrialised building makes use of predominantly unskilled labour although obviously not to the same extent as labour intensive building methods.

Industrialised building can produce buildings more quickly than many of the other construction methods at the same cost or less than that of conventional construction of a similar standard.

Lightweight industrialised building systems are easily transported to the remoter areas and can provide accommodation quickly. This medium generally uses less labour than heavyweight industrialised building systems and is built so quickly that training opportunities for the local populations are minimal.

Heavyweight industrialised construction produces durable buildings and it has been used successfully to produce a wide variety of buildings. When on-site casting yards are established local people can be employed in these and of course, in the erection process.

5. COMPARATIVE COST OF ALTERNATIVE BUILDING METHODS

In a large area such as Southern Africa the cost of any particular building method will vary depending on a number of circumstances such as, the locality where it is intended to build, the distance from suppliers, the skills available and what particular resources are available in the area.

In view of this it is essential that the professionals charged with responsibility for costing the alternatives have or obtain extensive information on local conditions and circumstances and that armed with this knowledge they carry out objective cost/benefit analyses relating to the alternatives under consideration.

6. CHOICE OF ALTERNATIVE BUILDING METHOD

In projects that are undertaken to assist in the development of Southern Africa the design of the building and the materials and method of construction chosen must be appropriate. To be so they must comply with the Development Criteria listed in Section 2 above.

The next Section of this paper deals with an approach to the design of buildings in developing areas that is intended to ensure that the correct alternative building method is chosen and that the resultant buildings meet as many as possible of the criteria listed.

7. PROCESS FOR DESIGN OF BUILDINGS IN DEVELOPING AREAS

Poster 1 attached illustrates graphically the basic design process, with the additional considerations that should be examined in designing for development these are:

NEED

Recognition and proof of need.

- in development no need is simple. A school may be identified as the community's major or primary need but the primary need of an underpriviledged community is part of a network of needs that is common to most such communities.

  The designer should identify the additional needs that exist, and in consultation with the community, he should determine how many of these can also be satisfied by the appropriate design and implementation of the primary need.

INCEPTION

Initial steps to satisfy this need eg. selection of site and contact and discussions with design professionals.

BRIEF

Description of the project derived from the above. Establishment of standards:

- In rural areas lower standards of building and of services may be acceptable. In urban areas it is likely that the local authority will demand a higher standard. In either case the views of the community should be sought and agreement reached at the earliest possible stage.

ACCOMMODATION SCHEDULE

Translation of brief taking into account areas, volumes, function and special requirements

DESIGN

The design of the form of the building taking into consideration all of the above plus site conditions, cost constraints, time available for design, time available to build, specification of the materials, structure finishes, etc.

AFFORDABLE/ACCEPTABLE

The issues of affordability and acceptability should be addressed at the earliest possible moment and all subsequent decisions checked against these two criteria.

There is no point in proceeding with a project no matter how desirable i.e. no matter how acceptable to the community, if the project cannot be made affordable to the community or more importantly if the community is not willing to pay the ongoing costs of the facility.

Similarly there is no point in proceeding with a project that the community will not or cannot accept. If this is the case, it does not matter how efficient, cost effective or affordable a project is. It will not be a success.

SITE/ALTERNATIVES

For a variety of reasons the sites chosen for development projects may not be the most suitable. It is advisable therefore to take a critical look at the site before conducting the technical investigation that would form part of any design process:

- is the location of the site the most suitable for:

* the purpose
* the community or communities that are affected by the project
* economic connection to the existing infrastructure and services
* future expansion
* integration with other developments

- will the topography or geological conditions of the proposed site add to the cost of the project or make construction unnecessarily complicated.

- are there alternative sites available and have their advantages and disadvantages over the site chosen been considered.

Successful development implies that resources be used optimally. In view of this it is sensible before embarking on a new project to determine if there are any existing buildings that could satisfy the requirements of the development project.

Unused industrial buildings can be converted and upgraded for a wide variety of uses. A community library or a clinic can be accommodated in one or more units of a commercial shopping centre. Dilapidated buildings that are structurally sound can often be upgraded at a considerably less cost than building anew. If the upgraded building cannot accommodate all of the proposed development it can very often form a characterful core to a new development.

AVAILABLE RESOURCES / PERFORMANCE AND MAINTENANCE

The use of local labour, contractors or entrepreneurs, local materials or locally manufactured components can be crucial to the development impact of a project and of course the availability of these resources will to a great extent determine the community's ability to operate and maintain the facility provided.

In assessing the availability of local resources the following questions should be asked.

LABOUR

- What labour is available
- Does it possess traditional skills
- Does it possess contemporary skills
- Is it unskilled
- What training is available
- What training can be made available
- Are there entrepreneurs or small contractors who can assist in this process.
- What level of support will be required to develop their capacity

MATERIALS

- What is currently used
- What has traditionally been used
- Are there untapped materials at hand
- Are these exploitable by local entrepreneurs
- What is imported at present
- Can local alternatives be substituted

COMPONENTS

- Are components made locally
- Can the manufacturers be assisted or encouraged by the new development
- Can the development be used to help establish local entrepreneurs
- Has the community the ability to manufacture components from:

* local materials
* imported materials

APPROPRIATE CONSTRUCTION

All the different methods of construction should be considered in the design process taking cognisance of all the other items listed and illustrated graphically.

8. DESIGN AND CONTRACT DOCUMENTATION

Having determined the appropriate construction medium taking cognisance of the community's needs, affordability levels, preferences, and of the availability of local resources, the design of the project and the contract documentation should be compatible with the intended method of implementation.

A major contract can be split into several smaller ones which can advantegeously be priced and implemented by small contractors. However this will not happen if the normal approach is taken to the production of bills of quantities and other contract documentation. Simplified documentation suitable for small or emerging contractors should ideally be used.

9. CONCLUSION

The application of the design process outlined above should result in acceptable buildings that meet the development criteria. However to achieve this it is necessary that the designers are prepared to design projects around, and work within the limitations imposed by the performance of the building methods that are identified as suitable.

D MACLEOD

EFFECT OF GLOBALIZATION ON AFFORDABLE HOUSING

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Housing is rated as a basic necessity. It enhances productivity through better quality of life. It ensure social harmony.

The Problem

Bombay is the principal commercial city in the country. The housing situation in the city is grim. Fifty percent of its population of 8 million lives in slums. The claim of slum dwellers on residential space is limited to 16.66% of the residential space in the city. It means that 83.34% of the living space has been offered to 50% of the population. In fact, it has been observed that roads occupy more space in the city than the space made available to slum dwellers. Annual output of housing in the formal sector is much less of the identified demand. Against the demand of 80 000 units, the annual construction is 20 000 units.

Symptoms

The deteriorating housing situation in Bombay is reflected in overcrowding. The number of households per dwelling units has increased from 1.03 in 1971 to 1.06 in 1981 and to 1.10 in 1991. A similar trend was also observed in respect of the number of persons per dwelling unit. The slum population in Bombay has grown from 38% of the population to 50% at present. Sanitary conditions are far from satisfactory. The annual investment of Rs.500 million for housing for the whole city and Rs.25 per capita is very low at any standards. Survey on affordability revealed that 40% of the people are unable to own a house constructed in the formal sector. User involvement as a cost reduction measure has not been attempted. The poor cost recovery of housing services rendered has been observed. Local authorities have been recovering only 74% of the cost of services provided.

Causes

The local administration faced severe resource constraints. Property tax is the main source and is based on controlled rents. Thus controlled rent reduced the revenue of the local government. Available data indicates that property tax, as a percentage of Bombay City's income, declined from 31% in 1974-75 to 21% in 1982-83, to 17% in 1983-84, to 13% in 1984-85 and to 10% at present. Restrictions on the use of land under the urban Land Ceiling Act added to shortages and cost push. The price of land at various centres of the city has moved up 8 to 10 times as a result of the imposition of the Land Ceiling Act. The Zoning System, the FSI and the Tenement Density Provisions introduced under the Development Control and Building Regulations have curtailed buildability and reduced housing production to a large extent. As many as seven agencies have been found to be involved in the provision and administration of housing.

World Bank Aided Project

The World Bank's intervention to the housing provision in Bombay under the Bombay Urban Development programme is reviewed here.

World Bank participation brought to light the inadequacies of the policies of the agencies responsible for the provision of housing in Bombay and observed that they did not address issues such as cost recovery, provision of tenure to households and local government's managerial and financial capacity to maintain and service improved neighborhoods.

1. Land Infrastructure Development - about 60 000 residential plots including community facilities, core housing and house expansion loans on 374 ha. of land benefiting about 300 000 people.

2. Slum Upgrading Programme - upgrading about 300 ha. of slums in Bombay including improved infrastructure services, home improvement loans and community facilities.

3. Maintenance Services - provision of equipment and civil works for improving the maintenance of roads, drains and services, and collection and disposal of refuse.

4. Strengthening Project Implementation - including strengthening of staff capacity for administration, estate management, accounting, providing expertise in urban planning and management, quantitative techniques in urban planning, use of computers, project management and finance.

These schemes are found to have the following benefits:

1. The scheme removes the element of interest subsidy enjoyed by the beneficiaries under various existing schemes of the government. The interest rates have been raised from 5 to 7% to 12% per annum.

2. The cost recovery has been raised to 94% against 74% as in the earlier case. The project has been found to be self-supporting. Besides, it also enabled the set up of a revolving fund for continued operation of this programme.

3. The project had a built-in system for cross-subsidizing the development costs. Higher income groups have been asked to provide a substantial part of the development cost. This eliminated the need for government subsidy.

4. Higher ratable value for the housing units constructed under the scheme enabled the local governments to recover higher taxes from the users. This has improved the resource position of the government.

Limitations

The scheme is land intensive in nature. Bombay City faces an acute shortage of land. Questions will be raised about the viability of the scheme in the long run, when the implementing agencies will have to formulate and execute plans independently. Finally, a further question will likely come up; if the scheme will be cost effective in the long run?

Replication of this project may be considered in the light of assessing these issues in proper perspective.

References

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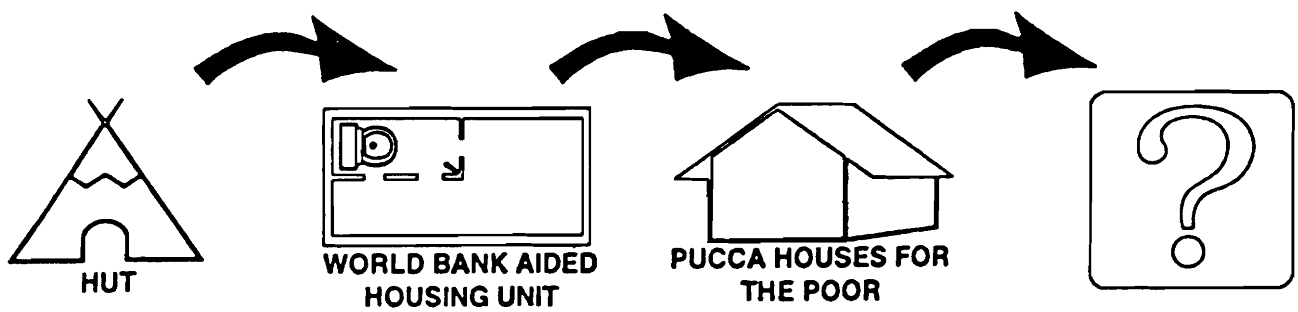
3. Report of the Bombay Municipal Corporation - various issues.



IMPACT OF GLOBALIZATION ON AFFORDABLE HOUSING

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Grim Housing Situation

Housing has become one of the most complex problems of modern times. As per the estimates of the United Nations, in 1991 there were one billion homeless in the world and if urgent measures are not taken by 2001, the number of the homeless population will increase to two billion.

At the country level, as in India, it has been estimated by the National Buildings Organization that, in 1991, the shortage of housing was of the order of 29 million - 9 million in urban and 20 million in rural areas. By 2001, it has been projected that the shortage of housing will be some 40 million - 10 million in urban and 30 million in rural areas.

Global Cooperation

It is being increasingly recognized that affordable housing has to be accorded high priority by the world community to improve the quality of life of the masses. Over the last four decades, largely at the insistence of the United Nations, international cooperation for improving housing and environmental conditions, particularly in developing countries, has been growing.

Global Action Programme

For achieving affordable housing, outlines of major thrust areas have been presented in the paper, along with two case studies of the impact of appropriate technologies for housing for improving:

i) Traditional Mud Housing Technology for building more durable houses; and

ii) Conventional Cement Concrete Technology for optimizing the use of cement in housing constructions.

1) Social Housing: In the context of widely varying social and economic conditions, as well as geo-climatic conditions, appropriate guidelines are required to provide countrywide assessment of:
   a) social housing needs;
   b) minimum housing standards; and
   c) future housing requirements.

2) Housing Economics: The economic aspects have far-reaching consequences on housing affordability and these mainly concern:
   a) housing finance mobilization;
   b) employment generation through housing; and
   c) contribution of housing to national economy.

3) Technology Development: Technological developments for achieving affordable housing have to evolve to ensure:
   a) improved use of indigenous building materials;
   b) appropriate construction technology; and
   c) skill formation for cost-effectiveness.

4) Technology Transfer: To facilitate transfer of technology, mainly to promote utilization of results of research in practice, stress has to be put on:
   a) dissemination of technical know-how;
   b) adoption of innovative and new technology; and
   c) feedback of experiences to resolve local problems.

5) Housing Policy: A national housing policy is necessary to promote affordable housing in the context of new and emerging issues of global concern pertaining to:
   a) sustainable development;
   b) environmental control; and
   c) conservation of nature.

6) International Approach: For tackling some common problems, particularly in the development of appropriate housing technologies, it has become imperative to promote:
   a) South-South cooperation among developing countries;

b) North-South cooperation for achieving technological advances; and
c) international cooperation through United Nations and its specialized agencies, as well as the non-governmental organizations.

Impact Case Studies

Two illustrative case studies are briefly mentioned to highlight the impact of globalization on technologies for achieving affordable housing in developing countries.

a) Improved Mud Housing Technology

A vast majority of houses, especially in rural areas, have mud walls and thatch roofs which are built at an affordable cost. However, the mud houses lack durability and resistance to heavy rains, floods, cyclones and earthquakes, etc. They are easily destroyed by fire. Improved mud housing technology has been developed in some countries. There is a great need to promote global cooperation, particularly through South-South cooperation to achieve affordable housing.

b) Advancement in Conventional Cement Concrete Housing Technology

Cement is a costly and scarce building material, the production of which is capital as well as energy intensive. However, the use of cement for housing construction has become popular. Therefore, to build durable houses at affordable cost, the use of cement should be optimized. Great advances have been made in developed countries which need to be appropriately transferred to developing countries. These include the technology of: strength mix concrete; ready mixed concrete; light weight concrete; pre-stressed concrete; prefab concrete construction; ferro-cement, etc. North-South cooperation would have great advantages in adopting advances in cement concrete technology for affordable housing.

LA CONCEPTION INTEGREE DU LOGEMENT A COUT ABORDABLE

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Le but de ma communication est de vous présenter les possibilités de recherche que nous mettons de l'avant, pour contribuer à répondre aux besoins que nous avons tous de produire des logements à coûts plus abordables. Il s'agit de ce que nous appelons la conception intégrée du logement. J'aimerais suggérer des modes de coopération possible.dans la recherche et le développement dans le cadre de cette perspective. En conclusion, je donnerai des exemples de résultats pratiques obtenus dans ce contexte par une université montréaise avec laquelle nous collaborons et qui nous a inspirés dans certains aspects de cette perspective.

Les difficultés économiques que nous connaissons actuellement à l'échelle mondiale touchent partout le secteur de l'habitation de façon un peu différente selon les conditions démographiques, sociales et économiques d'une région mais aussi avec beaucoup de similitudes. Au Canada comme au Québec, au plan démographique, en raison du faible taux de natalité, nous connaissons une croissance lente et un vieillissement de la population, ainsi qu'un ralentissment du rythme de formation nette des ménages, qui est à la base de la demande de nouveaux logements.

En conséquence, les mises en chantier annuelles devraient être en baisse dans l'avenir prévisible. La diminution de la taille des ménages et l'immigration sont les principaux facteurs actuellement qui créent la demande nouvelle. A ces tendances s'ajoutent l'évolution des moeurs qui entraîne aussi une diversification des ménages et notamment, la croissance du nombre de personnes sans famille et des personnes seules.

Sur le plan socio-économique, au cours de la décennie 80 le revenu moyen des ménages est demeuré à peu près stable en termes réels, tandis que nous avons assisté à l'accroissement du taux des dépenses pour le logement, qui est passé d'environ 25% par rapport au revenu dans les années 70, à environ 30% aujourd'hui. Le coût d'acquisition d'une nouvelle maison a également augmenté plus que le revenu de l'acheteur, d'où la plus grande difficulté d'accès à la propriété. Les conséquences pour l'industrie? Baisse et diversification de la demande locale dans un contexte où la mondialisation des échanges et des techniques font craindre une concurrence qui viendrait des pays les plus performants. Même si nous savons que le marché de l'habitation de par sa nature est moins facile à envahir que d'autres. A ces préoccupations d'ordre économique s'ajoutent des sérieuses préoccupations sociales dans la mesure ou nous constatons deux phénomènes parallèles, d'une part, les ménages à revenu moyen ont plus de difficultés à défrayer les coûts du logement et d'autre part, en raison de l'augmentation de la disparité des revenus, plus de ménages démunis ont de graves problèmes d'accessibilité financière au logement., ce qui accroît les besoins de logements sociaux alors que les fonds publics disponibles sont de plus en plus limités.

L'objectif donc de développer des formules permettant de rendre les logements plus abordables sans dépendre de la part des fonds publics prend une importance primordiale dans nos sociétés, autrement nous risquons de voir se multiplier les problèmes sociaux liés au logement et la qualité des logements régresser. Comment faire? En produisant de manière plus efficace. En améliorant l'usage des techniques et la gestion du développement pour contrôler les coûts sans pour autant réduire la qualité. C'est ce qui a été fait pour la plupart des biens de consommation et il faut se demander pourquoi ne pas appliquer ce principe au domaine de l'habitation. En réussissant à produire plus efficacement on fait d'une pierre deux coups: la performance de l'industrie et sa compétitivité sont améliorées et des logements plus abordables pour les ménages sont construits.

Le critère de base demeure le même. Améliorer le rapport qualité prix, règle d'or dans toute production industrielle, et également bien adapter un produit à la demande. Les retards technologiques dans le secteur du bâtiment sont bien connus. Effectivement, la croissance des coûts du logement, semble indiquer que le rapport qualité prix est plutôt stable ou ne s'améliore pas spontanément. Il y a plusieurs explications à cet état de fait: faible niveau des activités de recherche et développement, fractionnement des entreprises, division du processus entre la fabrication et la construction, industrialisation encore modeste, réglementations multiples etc. Mais il y a là un paradoxe car l'industrie du bâtiment est aussi un secteur industriel en pleine évolution technologique. Il y a un réel foisonnement de matériaux et d'équipements nouveaux qui témoignent de l'évolution rapide du secteur: spécialisation des matériaux connus, développement de matériaux de synthèse, recherche et développement multiples sur les aspects thermiques, acoustiques, opérationnels, ainsi que sur l évolution de l'équipement en vue introduire l'automatisation dans le bâtiment, les télés-commande, etc., tout en ne laissant pas pour compte le raffinement de la recherche du confort intérieur. Il suffit de voir les posters présentés dans le cadre du présent congrès pour montrer que la recherche et le perfectionnement technologiques évoluent actuellement dans toutes les directions. Cependant, nous constatons aussi que la pénétration des nouvelles technologies demeure lente dans le domaine du logement. Les transferts technologiques entre les centres de recherches et en particulier, la petite entreprise de fabrication et de construction ne se fait pas facilement. Nous hésitons encore à introduire des changements dans le logement, l'une des raisons majeures étant sans doute que les résultats à court terme ne sont pas suffisamment probants aux yeux à la fois des usagers et des industriels.

C'est à partir d'une réflexion sur cette situation, que nous avons mis de l'avant l'approche de conception intégrée. En effet, tout procédé nouveau, toute technique nouvelle qui vise à réduire le coût du logement, pour être jugée efficace doit permettre d'abaisser le coût du produit fini, du logement dans son ensemble, y compris le coût d'entretien et d'exploitation dans le temps, tout en ne réduisant pas la qualité. Or, si la performance doit être évaluée d'une façon globale, en intégrant toutes les composantes et toutes les opérations, il est logique de penser qu'il faut concevoir le logement comme un tout afin d'optimiser véritablement sa production. De là l'idée de tirer avantage des progrès technologiques en vue de rendre le logement plus abordable, d'adopter une démarche de conception intégrée, c'est-à-dire une approche systémique du logement qui permet d'harmoniser et d'optimiser toutes les composantes. Le choix systématique des meilleurs gammes de produits et d'équipement compatibles ainsi que des méthodes de fabrication et d'installation les plus appropriés, sans négliger aucun élément et aucune étape, s'inscrit aussi dans cette perspective.

Logiquement, il est possible de réaliser des économies à chaque étape ou procédé, et c'est la somme des petites économies partout qui assure l'efficacité. Il n'y a pas de solution miracle ou un seul procédé qui peut avoir une incidence sur le reste de l'exploitation. La conception intégrée vise donc non seulement à optimiser le rapport qualité prix dans le choix des composantes, mais aussi à tenir compte des autres critères d'importance actuelle. Et la conception intégrée permet justement d'intégrer l'analyse et l'application des ces différents critères parmi lesquels, notamment la souplesse et l'université d'accès, puisque le logement doit pouvoir maintenant s'adapter à une grande diversité de besoins et de situations.

En particulier, il doit pouvoir être habité par des personnes affectés de limites physiologiques. L'adaptation doit pouvoir se faire facilement par des moyens simples et donc, cette adaptation doit être prévue dans la conception initiale de façon à éliminer les obstacles et à faire en sorte que l'adaptation puisse se faire facilement le moment venu.

Un autre critère extrêmement important dont il est beaucoup question dans le cadre de la présente conférence, demeure l'environnement et l'efficacité énergétique. Les dispositions dans ce domaine seront de plus en plus imposées par des règlements, mais elles peuvent aussi être perçues comme de sources d'économies. Economies dans l'exploitation du logement, mais aussi économies au départ par le choix d'équipement et de matériaux simples et efficaces. A ce niveau, il faut se préoccuper d'optimiser à la base. Les exemples sont nombreux: prenons le choix des types de matériaux, par rapport à leur performance acoustique ou le besoin de ventilation et la nécessité d'accroître l'étanchéité des logements. Ce travail d'optimisation doit se faire au conception et la notion de conception intégrée attire l'attention sur la nécessité de cet étape au moment de la conception.

Autre critère, la qualité de la conception et la satisfaction des exigences de confort des usagers. La qualité est de plus en plus recherchée et se trouve à la base du maintien de la valeur d'une propriété. Une bonne conception peut aussi être une source d'économies. Il faut aussi choisir de l'équipement de qualité qui répond pendant longtemps aux besoins de confort des occupants et à leur besoins réels.

La conception intégrée suppose donc une approche pluridisciplinaire qui entre autre associe le design, la technique, l'analyse socio-économique des besoins, l'analyse du marché. Elle suppose donc l'association des différents intervenants pour tenir compte des nombreuses préoccupations de chacun.

L'approche de conception intégré devrait débouchée sur une industrialisation plus poussée de la production du logement. En revanche, conception intégrée ne signifie pas nécessairement production intégrée, c'est-à-dire de modules entièrement assemblés en usine. La démarche consiste plutôt à explorer la possibilité d'associer différentes techniques et procédés industrielles dans des systèmes ouverts tout en respectant le partage entre usine et chantier qui donne les meilleurs résultats. C'est donc un système ouvert qui peut même faire place à l'auto-construction. Les outils informatiques qui sont en voie d'être mis au point dans les domaines de l'architecture et de la construction pourraient soutenir cette démarche. A l'heure actuelle, des logiciels existent pour différentes opérations: études volumétriques, choix d'options, estimations, expertises techniques, productions de plans. Il s'agit comme c'est la tendance actuelle, d'intégrer progressivement ces outils pour qu'ils servent à optimiser, et donc à fournir une base à la conception intégrée.

En conclusion, j'aimerais présenter l'exemple d'une conception intégrée. Le concept appelé «maison évolutive», développé par l'école d'architecture de l'Université McGill, sous la direction des professeurs Libzinski et Feadman. Ce concept a donné lieu à la réalisation de plusieurs projets immobiliers dans la région de Montréal en 1991. En fait, six cents soixante unités ont été construites dans dix-neuf projets de la région et vendues à des prix variant entre soixante-neuf-mille et quatre-vingt-quinze mille dollars tout frais inclus. Le succès du concept paraît démontrer l'intérêt d'une démarche de conception intégrée, puisqu'il a d'abord été élaboré à partir des résultats d'un sondage portant sur les besoins des consommateurs et les préférences des acheteurs de maisons.

Nous avons établi des principes de base conduisant à des économies possibles, et nous avons élaboré un concept d'ensemble à partir de ces principes.

Les principes étaient les suivants: une maison étroite de 4,25 m, une aire de plancher correspondant aux besoins d'environ $100m^2$ répartie sur deux étages, la simplicité des techniques de construction, le choix des composantes disponibles les plus performantes et la flexibilitié des volumes intérieurs de façon à permettre en option à l'usager de compléter des éléments «à faire soi même». De ces principes, ont découlé le concept appelé «maisons évolutives» et sa diffusion auprès des promoteurs a permis la réalisation de projets au cours de l'année 1991, comme je l'ai mentionné.

Enfin, une évaluation par sondage des résultats a été réalisée par l'Ecole d'architecture visant à connaître le profil des acheteurs et leur degré de satisfaction, ainsi que les coûts réels obtenus. Nous avons constaté que l'avantage principal de l'expérience demeurait le prix inférieur des unités par rapport au prix courant obtenu non seulement par la réduction de l'aire de plancher, mais également par la rationalisation des techniques de construction, puisque le prix a pu être ramené à 400 $\$/m^2$, coût considérablement inférieur au coût habituel. Le coût de construction d'une unité constaté a été en moyenne de quarante-cinq mille dollars.

Je vais donc vous présenter quelques diapositives de ce projet.

Voici le prototype de l'Ecole d'architecture de McGill, construit et présenté en démonstration sur le terrain en 1990. Nous voyons maintenant le plan d'unité qui a été réalisé en 1991. Alors nous voyons qu'il s'agit essentiellement d'une maison étroite qui peut être construite facilement entre autre parce que le volume intérieur est complètement libre, n'a pas de contraintes de structures, de sorte qu'il est possible de construire et de compléter l'intérieur plus tard. Nous verrons quelques exemples de réalisations qui montrent la grande diversité de traitements architecturaux que le concept permet. Voici un exemple dans la région de Montréal, un autre style architectural. Nous voyons ici que le concept peut se construire en quelques unités, ou en bandes plus importantes comme celles-ci, ou encore simplement en maison double. Un aperçu d'un intérieur. Ce graphique montre le partage des revenus des ménages qui ont acheté ces maisons. Si nous considérons d'après les calculs qu'une telle maison est accessible à un ménage ayant un revenu minimum de trente mille dollars, on obtient effectivement dans les faits une bonne proportion des ménages qui se situent entre trente et quarante mille dollars par année, soit un revenu inférieur à la moyenne, qui est actuellement autour de quarante mille. On trouve aussi par ailleurs des ménages à revenus plus élevés qui s'intéressent à ce concept, ce qui démontre aussi que les maisons produites suivant ce concept ont aussi un attrait pour des ménages à revenu supérieur. Il s'agit donc d'une solution qui rend véritablement l'accès à la propriété plus abordable pour un éventail étendu de ménages en ce qui a trait au revenu.

PROJET DE DEMONSTRATION DE LA VILLE DE MONTREAL: "LOGEMENTS ABORDABLES REPONDANT A DES BESOINS NOUVEAUX"

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Cette présentation est axée sur le projet de démonstration "L'Art de vivre en Ville" que la Ville de Montréal a mis de l'avant avec la collaboration de la Societé d'habitation du Québec et la Societé canadienne d'hypothèques et de logement.

Contexte du Projet de Démonstration "L'Art de Vivre en Ville"

La politique d'habitation de la Ville de Montréal a comme objectif, entre autres de "promouvoir une appropriation croissante de l'habitation par les Montréalais". Pour ce faire, la politique propose des mesures pour favoriser l'accession à la propriété tant individuelle que collective.

L'abordabilité de l'habitation croyons-nous, peut être traitée de plusieurs points de vue, selon la catégorie de la population à laquelle elle s'adresse et selon les besoins qu'elle vise à combler. Le tableau, intitulé "Approches à la notion d'abordabilité et projets de démonstration de la Ville de Montréal" fait état des thèmes mis de l'avant par la Ville de Montréal dans son projet de démonstration en regard de la préoccupation de favoriser l'émergence de logements abordables.

Pour assurer une offre de logements qui répondent aux besoins et aux capacités financières des ménages, la Ville de Montréal s'est engagée dans plusieurs initiatives. Au moyen, entre autres, de projets de démonstration, la Ville veut stimuler la recherche et le développement de produits résidentiels qui recontrent les besoins spécifiques des ménages qui veulent vivre dans les quartiers centraux et qui auraient alors les capacités financières de devenir propriétaires de leurs logements. Le développement de tels produits raffermira la fonction résidentielle dans les quartiers centraux et utilisera le potentiel important que représentent les terrains demeurés ou devenus vacants. Il améliorera aussi l'environnement en complétant la trame urbaine existante.

Thèmes Retenus

Les thèmes retenus pour le projet de démonstration sont les suivants:

Thème A: Logements pour familles acheteuses d'une première maison

Ce thème répond au sous-marché de ceux qui cherchent à Montréal une première maison à prix abordable. Ce projet vise à démontrer les possibilités de construire dans les quartiers centraux des logements accessibles aux premiers acheteurs.

Thème B: Logements pour familles avec adolescents

Dans les logements conventionnels, la cohabitation des adolescents avec leurs parents est parfois difficile, dans un contexte où les adolescents peuvent demeurer de plus en plus longtemps à la maison pour causes d'études ou de contexte économique plus difficile.

Ce thème répond au sous-marché de ceux qui habitent avec des enfants adolescents ou jeunes adultes. Ils sont généralement des deuxièmes acheteurs et les enfants sont des utilisateurs de services offerts au centre-ville (CEGEPS, lieux de culture, lieux de loisirs, etc.).

Thème C: Logements pour familles dont un parent travaille à la maison

Ce thème répond au sous-marché de ceux qui ont besoin d'un lieu de travail incorporé à leur logement ou à leur immeuble résidentiel. Ce genre de logement permet à un des deux adultes des ménages avec enfants de travailler à la maison tout en recevant une clientèle extérieure.

Dans le cas des thèmes B et C, l'abordabilité tient surtout au fait que les logements, de par leur flexibilité et la polyvalence des espaces qu'ils offrent, constituent en soi un investissement pour l'avenir ou peuvent servir, dés leur première occupation, à partager les coûts d'immobilisation. Les parties du logement servant à satisfaire les besoins identifiés peuvent en effet, lorsque ceux-ci on cessé ou ne se sont pas encore manifestés, être louées à d'autres occupants.

Thèmes D: Développement viable: La Maison Verte

Il s'agissait de concevoir et de réaliser une maison qui soit à la fois économique à l'usage et écologique. L'économie passe ici aussi par des choix de société en préconisant des comportements sains.

Le Concours D'Idées D'Architecture

Les trois premiers thèmes que nous avons mentionnés précédemment et qui furent retenus pour le projet de démonstration (thèmes A, B et C), ont fait l'objet d'un concours national d'idées d'architecture sanctionné par l'Ordre des Architectes du Québec et pour lequel plus de cent cinquante (150) firmes d'architectes ont soumis près de deux cents (200) projets. Le concours s'est terminé à la mi-octobre 1992 par l'attribution de neuf prix et six mentions. Les projets gagnants et quelques autres qui proposent les idées jugées les plus intéressantes feront prochainement l'objet d'une publication.

Etant donné que la démonstration implique la construction des projets sur un site réel, un terrain spécifique était imposé pour chacun des trois thèmes du concours. L'intention de la Ville est d'y construire un projet de démonstration répondant au thème choisi.

Caractéristiques des projets gagnants:

Les projets retenus proposent des solutions architecturales novatrices, adaptées aux besoins des clientèles cibles: accès à une cour ou `a une terrasse privée, fenestration abondante, et surtout, possibilité d'adaptation des logement aux besoins changeants des familles.

Thèmes A: Logements pour familles acheteuses d'une première maison

Les quartiers centraux sont déjà dotés de parcs et de services dont peuvent bénéficier les familles qui achètant leur première maison. Les parents bénéficieront aussi de la proximité des lieux de travail et des commerces du centre-ville.

Le projet retenu, conçu par Richard de la Riva et Georges Lagacé, architectes, offre pour chaque logement un accès à des espaces privés, terrasses et cours qui communiquent avec un "sentier" paysager commun à l'arrière. Le prix des unités devrait les rendre accessibles à des familles de premiers acheteurs gagnant entre 35 et 45 000 $ par année.

Thème B: Logements pour familles avec adolescents

Pour les familles avec adolescents, le retour en ville permet de se rapprocher des collèges et universités, lieux de travail, équipements récréatifs et culturels, transport en commun. Ces familles ont des besoins spécifiques en termes d'insonorisation (le système de son!).

Les critères de design privilégiés ici sont l'intimité et la flexibilité. Le projet, conçu par les architectes Tétreault, Parent, Languedoc et associés, comprend une aire pour les parents et une autre pour les adolescents, chacune avec accès à la terrasse. La forme en équerre du bâtiment permet l'utilisation maximale d'un terrain tout en profondeur, ainsi qu'un meilleur ensoleillement des logements.

Thème C: Logements pour familles dont un parent travaille à domicile

Pour les familles dont un membre travaille à domicile, la proximité du centre-ville, c'est aussi la proximité des réseaux de contacts, d'information et de services. Ces familles ont besoin d'un espace de bureau ou d'un atelier qui laisse en même temps la surface habitable nécessaire à la vie de famille.

Dans ce projet, conçu par Kit Wallace, Architecte, et son équipe, certains espaces de travail sont adjacents aux unités de logements, d'autres sont isolés. Tous les bureaux ont une entré distincte de celle du logement. Par exemple la cour arrière sert d'entrée pour plusieurs bureaux.

Le Quatrième Thème: La Maison Verte

Ce thème n'a pas fait l'objet d'un concours d'idées d'architecture à cause de son trop grand contenu technique. Il fut développé en partenariat avec l'Association provinciale des constructeurs d'habitations du Québec (APCHQ) et exposé à son salon de janvier (salon Expo-habitat). Il devrait être construit sur le site à la fin de 1992, pour être visité en 1993.

La Maison verte est un projet d'habitation de six logements qui a été conçue pour utiliser au mieux le terrain, une ressource recherchée et unique. Pour compenser la dimension réduite des logements, on les a aménagés de façon flexible et adaptable. Ils coprennent des éléments mobiles (comptoirs, partitions) qui permettent d'adapter l'espace pour en tirer profit au maximum, selon les besoins de moment.

On a aussi prévu des espaces collectifs (ateliers, espaces de travail, lieux communautaires, rangement, buanderie, ...) qui assurent une qualité de vie intéressante. Le bâtiment entoure une cour intérieure protégée et face au sud, ce qui crée un microclimat. L'orientation face au sud assure d'ailleurs en apport énergétique solaire passif. Le toit est utilisé comme terrasse et jardin cultivable.

A l'intèrieur de la maison verte, la préoccupation environnementale est partout évidente. L'organisation des cuisines favorise la gestion des déchets domestiques. Les déchets organiques seront traités par compostage et utilisés dans le jardin. On économise l'énergie et les ressources en utilisant des appareils électro-ménagers compacts et efficaces, des lumières fluorescentes compactes, des dispositifs pour une utilisation efficace de l'eau et des systèmes de chauffage alternatifs, dont un apport en énergie solaire passif. Dans l'ensemble, on a essayé d'utiliser des matériaux qui ont un impact moindre sur l'environnement. On a aussi eu recours à des techniques de construction plus performantes: ex.: insonorisation.

Etat D'Avancement du Processus de Démonstration

<u>Construction des Projets</u>

La construction des unités types pour fin de démonstration des thèmes A (maisons pour familles acheteuses d'une première maison) et B (maisons pour familles avec adolescents de même que de la maison verte est prévue pour l'automne 1992. La construction des unités types du thème C (maisons pour familles dont un parent travaille à la maison) est prévue pour le printemps 1993.

Dans tous les cas, la Ville procédera par appel de propositions sur invitation. Les soumissionnaires proposeront un prix d'achat du terrain su lequel ils s'engageront à construire les unités types selon les esquisses fournies et en ayant recours aux services des architectes concepteurs. Les autres unités de logement seront construites selon l'absorption du marché.

<u>Communication</u>

La communication est un élément très important du processus de démonstration.

Celle-ci est déjà initiée avec la diffusion des résultats du concours qui a débuté avec des expositions publiques des projets gagnants et qui se poursuivra avec la publication en juin prochain du document du concours, présentant les projets gagnants et quelques autres projets jugés méritoires. Les maquettes des projets gagnants seront exposées tout l'été à "Images du futur" dans le vieux port de Montréal.

La seconde étape importante du processus de communication se réalisera lors de la construction et la vente des unités à construire sur les sites choisis.

Enfin, après construction d'unités de démonstration pour chacun des trois thèmes, des visites seront organisées pour le public en général et pour les professionnels de la construction.

Des relations de presse constantes seront entretenues à chacune de ces étapes afin d'assurer la plus grande diffusion possible à ces projets de démonstration.

TABLEAU I

APPROCHES A LA NOTION D'ABORDABILITE ET PROJETS DE DEMONSTRATION DE LA VILLE DE MONTREAL

APPROCHE	MOYENS	PROJETS DE DEMONSTRATION DE LA VILLE
Subventionner l'habitation	Programmes d'aide municipaux, provincaux et fédéraux	
Diminuer le coût de production	Par le produit directement (matériaux, méthodes de construction, design, surfaces, densité.	Logements pour familles acheteuses d'une première maison (thème A)
Diminuer le coût d'utilisation	Par le contexte (banlieue ds ville)	
	Par une conception gérant l'énergie et les économies en général	La maison verte (thème D)
	Par une préoccupation de l'entretien à long terme	
Augmenter le potentiel d'utilisation	Par la flexibilité	Logements pour familles avec adolescents (thème B)
	Par la multi-fonctionnalité	
	Par l'adaptabilité aux besoins changeants	Logements pour familles dont un parent travaille à la maison (thème C)

Strategies for Improving Quality and Maximizing Economy in Housing Projects of Turkey

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1. Scope and Introduction

The problem of consumer dissatisfaction with the overall quality of housing construction is a long standing one even in many technologically sophisticated countries. The intensity of this issue consistently arises during the early phases of occupancy when building systems and materials do not perform as expected by the occupants.

The situation is even more frustrating in the case of developing countries where people experience longer construction periods during which all their earnings have been completely depleted and in return what they obtain is generally a poor quality housing unit which urgently needs some major investment for upgrading the quality so that normal living standards could be maintained.

In the context of developing countries; where economies can be characterized by scarce resources, the slow and insufficient inflow of capital allocated to construction works usually causes the employment of low quality materials and workmanship. At the first instance, this deceiving solution may appear as a satisfactory result , but when the maintenance and repair costs start displaying an increasing trend beginning from the very early years of occupancy, occupants realize the fact that in the long run, low quality housing is actually very costly.

The scope of this paper is to examine the above mentioned shortcomings of low-quality housing projects and to propose strategies for improving quality and maximizing economy in affordable housing projects.

2. Managerial Aspects of Bidding Strategies

The number and homogeneity of share-holders that constitute a housing cooperative is an important factor in achieving its objectives. It is observed that small scale cooperatives composed of members displaying identical social and economical levels are more satisfactory than the others. In a recent survey, it has been reported that the factors such as; previous experience of the contractor, number and economic homogeneity of the share-holders affect the completion time of housing projects at a rate of 42%(1).

In the financing of urban housing projects, in addition to limited personal savings of of low income groups being involved, loans supplied by the central government and/or local administrations are also utilized. But due to high rates of inflation being experienced, the governmental support in the overall financing mechanism is exhibiting a decreasing trend. Thus supplementary resource creating or cost reducing methods, such as; cross subsidization, usage of rental incomes obtained from commercial units of the project as a resource, measures for reducing construction costs should be imported in the financing system(2).

Among the vast variety of bidding techniques employed, the most frequently used ones could be listed as; construction by force account, unit price and lump sum contracts. Each method caters its own specific advantages and disadvantages. Thus, no general solution could be derived except the fact that, sufficient supervision and control mechanism should absolutely be maintained regardless of the bidding system being selected. Also, within the decision making process of bidding systems; the purchasing power of cooperative share-holders, the scale of the housing project, construction method and its duration , organizational structure of the cooperative should be considered for to eliminate potential disputes between the contractor firm and the cooperative.

3. Appropriate Technology and Material Selection

Especially in big housing projects, it could be possible to reduce construction costs by the production and procurement of various construction inputs directly. In even bigger projects, by making use of the flexibilities concerned, appropriate technology selection and application could result in further reductions in construction costs. Thus, with the application of industrialized construction technologies in housing sector, considerable reductions in construction costs together with higher quality housing units could be obtained in relatively shorter construction periods when compared to conventional construction systems.

Until recently, it was believed that better quality products have higher costs. In most housing cooperative constructions, it has been observed that, the repair and maintenance process of dwelling units have shifted to very early years for to compensate the direct and indirect costs associated with poor-quality in constructions, which brings additional and unnecessary expenditures to low-income households who are already suffering from financial bottle-necks(3).

As an alternative to conventional construction methods, industrialized technologies have been developed. With the introduction of these new systems, considerable economies could be maintained provided that they have been implemented within proper project scales. In a research conducted for to examine the trade-offs between construction technologies revealed that; conventional method is the most economical solution upto a production amount of 400 housing units due to the fact that it has the least initial investment requirement. Within 400 to 3500 housing units tunnel formwork system and above 3500 housing units panel prefabrication system appears to the most economical solutions as compared to their total construction costs (4).

4. Results and Recommendations

The results that could be derived from this research are summarized below:

i)In the financing of housing for low and middle income groups, governmental support is essential. Under circumstances where financial support is insufficient other resource creating or cost reducing measures should be examined.

ii) It has been observed that small-scale cooperatives composed of members displaying identical social and economic levels are more satisfactory than nonhomogeneous housing cooperatives.

iii)No general recipe could be proposed concerning managerial and bidding strategies except the fact that effective control and supervision should absolutely be provided regardless of the selected bidding system.

iv)Appropriate construction technology should be selected by considering the scale of the project. Industrialized construction methods should be compatible with the saving capacity of share-holders to avoid disputes and delays.

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UNIVERSAL DESIGN: HOUSING ACCESSIBLE TO ALL

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Standards and good professional practice were traditionally directed to the design of housing for the majority of persons. These standards were achieved by focusing on the requirements of the so-called average person, generally a male adult. Though some variation was possible, the resulting design standards posed difficulties for many groups of people. These groups could include children and women because of their size, older persons because of their diminished strength and endurance and disabled persons because of their impairments.

The limiting nature of the design was recognized but changes were slow in coming. Barrier-free design was considered special, separate from mainstream design ideas for housing. The financial and professional communities felt that there were additional costs and efforts involved in building housing that could be used by people that did not meet the "norm". Pressure exerted by the lobby for disabled persons to be integrated in society resulted in the construction of "special housing". Such special housing was custom designed for people with disabilities. Many were collective dwellings for groups of disabled persons. There were professionals who specialized in the design of such buildings. Due to the exclusion of such housing from the housing market, such housing was expensive. Standards for barrier-free design were developed but they were separate from the building codes and design guidelines for housing in general.

In addition to the lobbying efforts of those intent on integrating disabled persons into society, now the increasing need for accessible housing is being driven by demographic and economic reasons.

First, the demand for housing is changing because there are major shifts in the composition of the population in the industrialized countries of the world. The median age of the population is rising and the numbers of elderly persons is growing. Many elderly persons have one or more disabilities, associated with age though their seriousness varies considerably. In industrialized countries, large proportions of households own their housing and they are unwilling to move out of their homes when they age. Furthermore, they prefer to continue living in familiar neighbourhoods where they have established social networks which support them while they age. This phenomenon, known as aging-in-place, leads to the demand for housing that is accessible through out the life cycle.

Second, housing construction in the industrialized countries peaked in the seventies and construction levels are declining. Most countries have sufficient housing stock and any additions are focused on improving the quality of the stock, on replacing demolitions and on adding a limited number of units to accommodate new household formation. The need for flexibility of the housing stock has become more important to facilitate mobility within the housing stock. It is not possible to add sufficient numbers of specially designed units for particular groups of people at the required rates distributed in all communities using available resources. Besides, highly customized housing are not quick movers in the housing market. Therefore, housing design that works through the human life cycle is important for economic reasons as well.

These changes have had several consequences. The need for accessible design for housing and neighbourhoods is now widely accepted. Accessibility standards are being integrated into general codes and guidelines and they are considered good practice rather than special design. The design of environments that allows use by practically all persons is called universal design. Municipalities are working to make their communities as accessible as possible by transforming their pedestrian and transportation networks. Subsidies are available to households that wish to renovate their homes to increase accessibility. Public policy has followed to encourage universal design and to reduce the need for expensive retrofitting. In Canada, human rights legislation provides a legal impetus for the use of universal design. In France and in the United States, housing legislation requires the construction of new housing that is accessible.

For these reasons, universal design is a concept for which the time has come. Universal design implies a move away from design for the average person as well as design for a special group, both of which result in housing which exclude potential residents. Instead, ideally, universal housing is valuable through out its existence to house a variety of persons through the family life cycle without major alterations.

This policy discussion paper examines the issues affecting the implementation of universal design for housing in Canada. It draws on a number of general housing documents and the policy experiences of other countries.

What is the Goal of Universal Design

The ultimate goal of universal design is to achieve universal fit between household needs and dwelling stock. Flexibility of the housing stock will be realized because any household can live in any house, other factors permitting. It is important, however, to take a cold hard look at what can be realistically gained in relation to the effort and resources expended.

The hope is that a household can be accommodated within a home through the usual life-cycle stages of single earner years, early years of marriage, child rearing years, empty next years and widowhood and aging. During this progression, the requirements for space and cost can vary tremendously. However, on human rights grounds alone, it is possible to argue that all dwellings within size and cost ranges should be of universal design to prevent segregation and discrimination within size and cost ranges.

This brings up the true nature of the human rights requirement – that everyone should be able to live as they wish while discharging their duties and obligations to society. Universal design of housing alone will not accomplish this. To succeed, all buildings must meet the requirements of universal design. In fact, it has been said that human settlements must be organized according to universal design criteria.

Some experience from the efforts to improve the accessibility of dwellings is valuable. Thanks to policies aimed at improving residential accessibility, many disabled persons found freedom of mobility to their units and within them. Unfortunately, their mobility did not extend further than their units. They suffered from tremendous isolation and continued to require heavy levels of assistance. Some cities have made great strides in implementing universal design of public thoroughfares. The design of public facilities, such as airports, museums and schools are slowly improving as well. However, many important amenities such as doctors' offices, shopping centres and banks are still designed to exclude use by a number of persons. It is, therefore, important to tie any initiative for universal design of housing, to universal design of the built environment.

Joint inter-ministerial effort is essential if universal design is to be successful public policy. Though the federal government may take a leadership role, other levels of government and other sectors must be involved as well.

What is the Scope of Universal Design for Housing

Municipal governments that have embraced the concept of universal design found, that contrary to expectations, most of the units that met their criteria for universal design were located in apartment buildings and that they were few. The situation in Canada is probably no different.

Most consumer advocates of universal design recommend starting with new housing units. In Canada, an estimated 150 000 to 200 000 units will be built annually between 1991-2001 (CMHC, National Housing Outlook, 1990). The manufactured housing industry is responsible for about 10 000 units a year. Roughly 6% of the housing built in Canada has public involvement. In 1990, for instance, social housing units (non-profit, rent supplement, urban native and rural native housing) accounted for about 15 000 units.

The major proportion of the housing stock, however, already exists. The majority of the households that would benefit from universal design would tend to live in existing stock. For example, 64% of seniors own their homes and a large number of them would prefer to age in place.

Figure 1
Housing Stock in Canada, 1986

Number of Dwelling Units, 000s	8992
Single detached	57.3%
Apartments	31.8%
Other	10.9%
Owners	62.0%
Owners Aged 65 and Over	64.0%

Source: Statistics Canada

The renovation market has been growing rapidly. At present nearly half of all expenditures relating to residential construction is expended for renovation.

From a policy perspective, the priority should be placed on existing housing as well as new construction for three reasons: the greater numbers of units, the level of renovation activity and the immediate benefit to those who need universal design the most at present.

There are other concerns as well. In 1991, over 40% of the housing was aged 30 years or more in the housing stock. This proportion was expected to rise to 50% by 2001. Much of the social housing stock of 600 000 units was built 20 to 30 years ago. In 1985, about 12% of households deemed that their housing required major repair. Some measures must be taken to ensure that the investment of effort will result in outcomes that are durable rather than short term.

Design Requirements

What are the design requirements for an universally designed house? The design requirements must not only support independent functioning of residents but also their well being, safety and security. The risk of home accidents is high among certain population groups. In addition to physical aspects, social and psychological factors must be considered as well.

Does the information exist? A great deal of information is available. However, the discussion rages about how universally designed a house ought to be. Thus, for example, an ideal universally designed house would have more than one means of entry – for example, stairs and a ramp. Most advocates recognize that this is would be overkill.

The degree to which a home meets the ideal criterion of universal accessibility has been an issue for policy debate. There is one school of thought which argues that if space and potential is structurally built in, ramps or other requirements can be added later. A second school of thought argues that the goal of universal design is defeated because such a dwelling is not really flexible. It would exclude clientele that would need to make adjustments and incur costs before moving in. There are serious policy implications associated with both strategies which will be discussed later.

Some countries have taken some first steps regarding minimum design requirements that lead to universal design. These include such requirements as elevators for all multi-floor buildings (France), amenities such as garbage disposal on each floor (Denmark), door widths large enough for wheelchairs (800 mm), a bedroom and full bathroom on the ground floor (Sweden) and minimum bedroom size. Another strategy identifies designs that are not permitted or require special permits with the onus on the person applying for the permit. For example, a requirement may disallow the use of sunken room so raised platforms. It is recognized that such requirements are an imperfect but practical approach to universal design.

There are some design issues that have not been fully resolved. The design of the bathroom and its fittings do not fully meet the requirements of universal design. Emergency egress is a major issue. Some advocate "zones of refuge" instead of special egress solutions where persons unable to descend the traditional exit stairs can wait until rescued. The inequity of life chances under conditions of risk is a serious concern.

Tradition and customer acceptance come into play when considering design. In countries where two storey homes will all bedrooms on the second floor are traditional, there could be considerable client resistance to a requirement that there be a bedroom and a full bathroom on the main floor. With the aging of the population, however, good sense might prevail.

The application of design requirement to retrofitting and renovation is a major problem. Older stock may not have the potential to meet universal design requirements with reasonable effort. Many countries are engaged in writing renovation codes, spelling out acceptable compromises when building codes cannot be met by renovation of existing structures. Such compromises tend to jeopardize universal design.

The design of communities and neighbourhoods to universal design standards has not been studied. Thus far, the concentration has been on buildings, mostly residential buildings. More work may be required on other types of buildings. Some research has been done on transportation networks (infrastructure, public buildings and modes of transportation between buildings and places) but a great deal more has to be done. If residents are unable to function in the larger designed environment, the investment in universal design for housing is devalued and the legal goal of providing residents equal opportunity to contribute to society is lost.

The move to universal design is major shift from the notion of design for a specific need or a specialized solution which has traditionally prevailed. This requires a change in the design culture. The current premium placed on custom-design must work within the larger framework of universal design.

Despite the obvious solution to aging stock, large scale demolition and mass reconstruction is not feasible or affordable. The design challenge must be met within current constraints for sustainable development and environment-friendly growth of human settlements.

Technological Support

Recent technological advances enhance the possibilities of universal design. These range from simple inventions such as motion activated lights to complex ones such as the smart house that have become possible because of the micro-chip. Some of the technology is widely available at relatively low cost while others are still pricey.

Technological support can be provided to achieve universal design by serving different functions. Technology can:

- Automate repetitive or continuous functions. Example: changing the thermostat settings for the desired day and night temperatures; humidity control, turn lights on and off; filtering out dust or pollen.
- Perform heavy tasks requiring great energy or special motions. Example: garage door openers; power assisted lifting or opening of doors; garbage removal, self-cleaning appliances and fixtures.
- Compensate for or optimize abilities. Examples: directing light where activity is taking place, adjusting intensity of light according to need, customize time intervals for automated processes such as elevator doors, security codes, etc.
- Monitor and control for well being, safety and security. Examples: monitor blood pressure, power only well-functioning appliances, turn off appliances that are not attended, sense calls for help or a fallen person on the floor, sense intrusions or break-ins.
- Assist communication. Voice communication with concierge, police or care giver located at varying distances from the dwelling; schedule and provide timely reminders.

Most of these technological supports are not found in standard housing but they tend to be associated with houses in the luxury priced range or in special purpose housing. They incline, therefore, to be considered optional rather than making a vital contribution to universal design.

A careful selection of technological supports at reasonable cost can be promoted to be standard design so that universality is attained. As new technology becomes available and as prices drop, additions could be made to the list.

Cost Implications

Is universal design more expensive than standard design? There are those that argue that universal design does not have to cost much more than present standards of design. There are others who ask if we can afford in the long run to <u>not</u> have universal design.

Some features that are essential to universal design cost no more or minimally more. For example, doors that are 800 mm do not cost more than the more commonly used door widths. In countries where housing standards are high, there is little reason to believe that space requirements would pose an undue burden on new house construction. For example, in North America, the modal number of rooms in new houses is 7 or more and the master bedroom tends to be more than 3000 mm by 3500 mm. Certainly, a dwelling selling at or above average price can easily be of universal design, however, houses at the low end of market price may be a little more expensive, putting them out of reach of a small proportion of households who might otherwise be able to purchase housing.

The cost implications of upgrading dwellings that are being renovated to universal design standards can be significant, particularly if structural changes are required.

The rate of replacement of sub-standard dwellings with new housing of universal design will also affect cost. Some countries hope that over time, with rising housing space and quality standards, the goal of a large flexible stock of universally designed housing will be achieved without undue effort or expense. Others are pressured by the need to accommodate a growing population of aging households who would benefit from universally designed housing now and are therefore unable to rely on the natural replacement approach.

The use of technology will add to the cost of universal design. It is important to select items of technology that are critical to universal design. Only these could be eligible for use in housing benefiting from public funds while other technology may be used on a voluntary basis.

The cost issue is not easily resolved. It is possible that with public education, any additional costs due to universal design would be willingly absorbed by a consumer knowing that costs in the earning years are easier to bear than renovation costs during the retirement years.

Potential Policy Mechanisms

Assuming there is both public support and political will to implement universal design, what are the policy mechanisms available to the federal government in general, and to CMHC, the federal housing agency, in particular? To start with, one must be cognizant of the fact that housing is a shared responsibility between the federal government and the provincial government in Canada. Unilateral action by the federal government is difficult and unwise. On the other hand, the benefits to provincial governments of a flexible housing stock is as great as it is to the federal government, so potentially agreement is possible. The provincial priorities, however, may be very different. Also such a joint venture requires bi-lateral negotiations with each province.

The first policy mechanism suggested by advocates tends to be standards and regulations. Standards and regulations are among the most intrusive of the policy mechanisms that are available to governments. To be effective, requirements must be enforced and maybe even penalties imposed. For such a mechanism to be effective, there must be great public support and political will. Contrary to popular belief, there are considerable monetary (particularly for enforcement) and political (in terms of good will) costs associated with this strategy.

In Canada, there are tremendous problems associated with the use of standards and regulations. Let us examine some of the reasons.

The most venerable of standards is the National Building Code. These are developed by carefully composed committees (representatives of the building industry, professionals and consumers or their advocates) under the auspices of the National Research Council. The primary purpose of building codes are for the promotion of health and safety, the two reasons for which intrusive action by the state is widely tolerated. They cover all types of buildings, not just housing, however, they do not include amenities or infrastructure such as roads or parks. The provinces adopt these codes or modify them for use within their boundaries. The application of the code is the responsibility of the municipalities. Enforcement is by municipal building inspectors and harsh measures are rarely taken for non-compliance. On the other hand, because there is widespread support for health and safety as goals, there is widespread conformance.

Goals other than health and safety, such as efficiency, equity or convenience, have not had the same public or political support in the past. National building code committees are reluctant to breech traditional boundaries to take on such goals as universal design as they have not officially been given such a mandate. Provincial governments who adopt the code, do not always support the imposition of additional goals and may choose to eliminate or water down these requirements. Municipal governments find it difficult to enforce requirements when non-compliance is not harmful to occupants or residents. There is considerable resistance from the building industry which is more concerned with the impact of standards on immediate sales than on the quality of the contributions to the housing stock. This resistance is expressed in the standard development process, in lobbying of the political powers and in the level of compliance. The federal government, particularly CMHC, does not have good control of the standards process so that the codes are an effective policy mechanism for the implementation of universal design of housing.

It is difficult to write standards that deal with universal design. The choice of "performance standards" (i.e. that a space or design must allow the performance of certain functions) over the traditional "prescriptive standards" (i.e. that a space or design meet or exceed a stated minimum requirement) is preferred. Many countries use both, using prescriptive standards an an example that meets the performance one. In Canada, there is little experience with the use of performance standards. Performance standards are difficult to enforce as they depend on judgement. They also require considerable public and professional education which is why they are not more popularly used.

There is also a trend in industrialized countries to move away from standards in general, which were seen as far more important when health and safety standards were negligible. In such countries, much of the construction exceeds the minimum standards of the code.

Central government regulations have been used successfully for policy goals such as efficiency or equity. In this case, all housing that use public funds emanating from the central government are required to meet certain requirements. This method is very effective in countries such as Sweden where practically no houses are built without some public funds and where the plans for construction must meet requirements to be eligible for loans. In Canada, almost all construction (with the exception of social housing) is built with private financing. Mandatory mortgage insurance gives much weaker leverage. Furthermore, such insurance need not be public. If this method is used, then roughly 6 to 8% of the annual new stock devoted to social housing will be built to universal standards of the roughly 150 000 to 200 000 units that are built each year.

Financial incentives offer some possibilities. The value of these must be carefully set for them to be effective and the administrative costs must be meticulously considered for the potential impact of the policy. These financial incentives may be "direct" (i.e. the payment of a sum of money for compliance) or "indirect" (i.e. the provision of a benefit that has monetary value to the receiver). Generally, in the first case, governments expend money from annual budgets and in the second, governments forgo revenue so that they do appear in budgets. These incentives may be provided to the producer, the administrator or to the consumer. For example, the federal government can offer as a direct incentive a sum of money for each dwelling that is built to universal standards by a developer or to a consumer purchasing such a dwelling. It can also offer a sum of money annually to municipalities that can show that they have increased the universally designed units (say by 1%) through payments to the provinces. These alternatives, of course, are a new expenditure for the government and their use might require legislative amendments. Neither of these conditions are insurmountable but they are unlikely in times of restraint and less government intervention. The federal government might also offer an indirect incentive, such as say a 1/4% reduction in the mortgage insurance payment for all dwellings that are universally designed. Another possible but highly unlikely alternative would be a slight reduction (such as 1%) of the GST.

The other side of the coin is to impose some financial penalty for not building to universal design standards. These must also be cautiously set so that they are not unduly harsh. So, for example, one might levy an extra 1/4% cost for mortgage insurance for dwellings that are not to universal design.

Most of these suggestions have dealt with new construction. The greater part of the housing stock already exists and therefore, policy mechanisms to achieve universal design must also examine possibilities offered during demolition and renovation. Because of the aging stock, the rate of demolition could rise. Housing that has no potential for renovation to universal design must be demolished before others that may be upgraded to universal design. This will have to be implemented by municipalities and the incentive grant may be one way to achieve this. However, demolition must be used conservatively, due to considerations of environmental sustainability. Because of the level of renovation activity in most industrial countries, renovation codes are being applied. The problems associated with the use of these renovation codes were discussed earlier under design considerations and the second on the use of the building code.

CMHC has some leverage through the RRAP program, which provided assistance to some 26 500 units in 1990. These units, occupied by low income families can be upgraded to universal standards to be eligible for assistance. This will assist those least able to pay the costs of upgrading while leaving the rest to private sector effort. In addition, some financial incentives or penalties may be offered to those renovating their homes as shown before. For example, RRSPs could be withdrawn without penalty for renovation, on condition that the housing be upgraded to universal standards. One of the major policy problems is the fact that many elderly households live in older housing of lower standards but their need for units of universal design is immediate. Since they rely on retirement income, the costs of universal design may be burdensome. Some type of subsidy based initiative may be necessary. For example, an interest free loan may be offered to elderly households upgrading their dwellings, repayable by the estate, where the subsidy is equal to the interest waived. This initiative could rely on a rotating fund, but would require "patient money" as loans could be locked in for periods of time.

Most countries use less intrusive methods in support of universal design. The key among these is information and public education. Consumer demand is a vital tool for increasing the number of universal units in the stock. For examples, publications listing "Important questions to ask when buying a home" could include the question, "Does the home meet universal standards so that you can live throughout your life there without major renovation expenses?" Design professionals and the building industry also need to be educated. Awards are a potent and visible method of education. An annual award for the best universally designed house for multiple production is a possibility showing both government and public interest in the cause.

The final strategy is to enhance other actors and to achieve the goal through them. Such enabling strategies are time consuming and require commitment from many parties. These strategies will be further discussed under the section on partnerships.

All of the policy strategies discussed above are possible in Canada but they have various levels of risk, cost and effectiveness associated with them for the government. All of the strategies are slow and it will take an extremely long time before true flexibility of the 9 million or so units in the housing stock is attained. The rate of conversion to universal design may be slowed further if the effort is directed to making units potentially convertible rather than upgrading them to standards of universal design standards in the first instance. The cost and effort may be increased as effort must be expended in two stages before the unit is universally designed. Most of the strategies described above work with the current rhythm of housing construction, replacement and renovation. Any strategy that aims at faster implementation of universal design will require additional effort and cost.

Who Pays?

A key question is who should pay the cost of universal design. Is personal benefit sufficiently high that each household should bear the price? Is the public benefit high enough that at least part of the cost should be charged to the public purse? Which ministries should be involved? Which levels of government should be committed to this cause?

There are notions of equity and distributive justice involved in all public policy. Costs and benefits should be shared in a just way. One sector of society should neither lose or gain unfairly. In the case of a durable good such as housing, the costs and benefits are shared not only by the present citizens but by future generations as well.

It can be successfully argued that the costs should be primarily private because the benefits are predominantly personal. In that case, the contribution of universal design to the value of the investment in housing must be stressed and indeed, borne out by the market. Some steering by the public sector is possible. Immediate costs to the household can be assisted by long term loans or financial assistance such as those discussed earlier.

The public sector incurs higher costs by the lack of universal design. There is unnecessary movement because, for example, the elderly population is unable to age in place. Therefore, interventions that pay part of the costs for flexibility of the housing stock maybe justified. However, the flexibility of the housing stock has the potential for reducing exposure to other public costs in the domains of income security, health and social services. The Japanese, for example, have found that is not possible to deliver adequate home care in rooms smaller than 6 tatami mats (approximately 10 m^2) while rooms maybe far smaller while meeting existing standards. Consequently, residents are moved to more expensive specially designed facilities. In Canada, one may question whether it would be possible to deliver adequate home care in a secondary bedroom sized 8 ft. by 10 ft. When elderly people move to institutions, the public costs are not incurred by the housing sector but by other sectors. Therefore, there are grounds to expect public expenditures to be jointly met by health, social services and housing ministries as well as by the ministry of finance if policy initiatives are indirect.

The three levels of government have been assigned varying jurisdictional and tax revenue responsibilities. But all three levels of government benefit to some extent from a housing stock of universal design. So each level of government can be invited to contribute in money or in effort but their participation will depend to a large extent on internal politics. Provincial governments can, for example, require that prior to home care being delivered, the dwelling should be upgraded to universal standards with some public assistance. Municipal governments can add value to municipal assessments if the home is of universal design, thereby enhancing its market value. They may also reduce property taxation by a small premium if the dwelling is of universal design.

It is clear that CMHC cannot act alone to transform the housing stock to a standard of universal design nor can it bear all the public costs involved.

Partnerships

For an initiative of this magnitude, partnerships between the federal government and sectors of society are essential. The federal government must be able to play a facilitating role to assist the activities of the partnership. This can be accomplished by the dissemination of information and other types of support. Key partnerships to be forged are those with other levels of government, those with business and industry, those with professionals and those with consumers.

If other levels of government are to act individually or to act in concert with federal initiatives on behalf of universal design, it is important that strong partnerships are built. Present bi-lateral arrangements offer some possibilities. Tri-partite discussions may also be viable for critical housing markets. Initiatives may complement, add to or top up federal programs.

Partnerships with business and industry is essential to ensure that the costs and benefits to this sector are made explicit. The support of financial institutions, real estate companies and developers will be valuable in achieving the objective of universal design. The key issues of impact on cost and cost recovery potential must be addressed so that adverse effects on the market can be prevented.

Professionals of various kinds are involved in the design, construction, inspection, renovation, valuation and sale of housing. All of these groups must be informed about the societal and long term value of universal design and they must be able to practice their professions in a way that supports the implementation of universal design.

Finally, consumer demand is a key dimension that can be fostered through partnerships with consumers and their organizations. The value of universal design must be sold to consumers by stressing both personal and societal gains. Investment in life-cycle housing must be widely understood if there is to be growing public support. The dangers of high expenditures during retirement for renovation to universal standards must be made clear. The level of public financial and other support must also be evident.

Conclusion

This paper provides a point of departure for an open exploratory discussion on the viability of a housing stock of universal design. While no definitive solutions are proposed, many ideas are suggested and their potential for success discussed. It is also recommended that some action be taken now towards achieving the goal of an universally designed housing stock even if it may not be the most effective one. As the old Asian proverb says, the best time to plant a fruit bearing tree was ten years ago. The second best time is now.

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SESSION 4B
HOUSING ACCESSIBLE TO ALL: A PRESSING NEED

Questions and Discussion

Question
Norman Stats
CEGEP de Vieux Montreal

My question is for Mr. Erdogan. You spoke about integrating certain project management capacities in the construction of your houses, for instance, that these cooperatives were getting together and buying their material and then distributing it to the contractors. Was there any variety, did they also consider schemes where possibly they were paid a percentage of the work, in other words, what we would call a material construction management approach? Were there a variety of approaches that were tried or did this just happen to be one that became very popular and was used throughout the city, this one idea to just buy materials?

Mr. Erdogan

Generally 25% is the contractor's profit in Turkey. It is assumed that 15% is gained for material handling and 10% is gained from workmanship. The construction by this type of contract underlines prevention of contractor's profit from material handling. In this kind of contract, the owner or the two cooperatives supplies materials and gives them to the contractor and he is responsible for the workmanship. The cost of his labour is calculated on the basis of unit prices; there is a unit price analysis and this is calculated with that. Since the materials are procured by the owner, or cooperatives in big projects, they produce their own ready-mixed concrete, procuring reinforcement material from the factory by themselves, so this brings certain advantages and economy to the project for low and medium income families.

SESSION 4C
Building Regulations: A Necessary Evil
La réglementation du bâtiment: un mal nécessaire

Page

Impact of Regulations on Building Products in the United States

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The regulatory chain for building product recognition in the United States at the local level is a complicated one. Higher levels of government such as the Federal and State also enact laws and regulations that can affect building products. Federal requirements are generally enforced by the Federal government itself. State governments may at times enforce certain federal requirements but only by specific agreement between the two. A classic example of this is federal regulations imposed on manufacturers of building insulation in residential construction. Specific test procedures and methods of reporting are imposed to avoid confusion by the consumer. State and local government levels are not involved with this enforcement. However, manufacturers are obligated to comply or be subject to disciplinary action by the federal government.

State laws affecting building products are enforced by the state or delegated in whole or in part to local governments by agreement. Example of this would be minimum state housing laws which are enforced by local government on the basis that the local laws are equivalent. Home rule is a very important right that is guarded closely at the local level. The ultimate authority on whether a building product is permitted in a specific building lies with the local government. It passes and enforces building laws regulating buildings and products therein, except where this right is assumed by the state government, normally because of lack of funding or by default. Local building laws either adopt or closely parallel model building codes published by three private nonprofit agencies in the United States. The Uniform Building Code published by the International Conference of Building Officials has its influence in the western United States. The National Building Code published by Building Officials and Code Administrators International, Inc. has its strength in the northeastern United States. The Standard Building Code published by the Southern Building Code Congress International, Inc. has its strength in the southeast section of the United States. In an effort to achieve uniformity of building regulations in the United States, the three model code groups work under an umbrella organization identified as the Council of American Building Officials, whose purpose is to provide this country with coordinated building regulations that are technically sound and responsive to the needs of government.

The building official represents the local government in enforcing its building laws. Other agencies such as fire departments are also involved in enforcing certain fire prevention laws affecting building products. In evaluating building products under the laws of the local government, the building official considers acceptance under one or all of the following procedures:

1. Review of data and conclusions formulated on the basis of evaluation by the building official and his staff.

2. Product certifications or listings issued by agencies approved by the building official, which in most instances are the testing agencies. They will hereafter be identified as listing agencies.

3. Technical reports issued by model code agencies.

Most local building departments neither have the time nor staff to evaluate unique building products for life safety, property preservation, durability and other qualities required by local laws. Under these circumstances, the building official often depends on his practical experience as well as technical data to reach a decision. Certifications or listings issued by listing agencies provide product information that is supported by technical documentation. Products are recognized as satisfying requirements set by the listing agency that are either based on national or the agency's standards. Accepting this type of evidence is the prerogative of the building official in determining compliance with the code. Examples would be fire doors, fire windows, smoke detectors and fire-resistive assemblies. However, compliance with a listing or series of listings does not assure compliance with the building code. Characteristics relating to durability of the product to retain qualities required by the code are not always addressed in these product certifications. Single-ply roofing membrane listings might note recognition as a Class A or Class B roofing system but the listing does not address durability. Wind resistance and installation procedures to provide weather protection require supplementary information which may not be covered in a listing. Another example would be a roofing system with foam plastic insulation on metal decking where the roofing classification of Class A or B would be only one of two critical fire considerations. The second involves investigating this type of insulated roofing system for potential spread of fire on the under side of the deck.

Technical (evaluation) reports issued by model code agencies provide information for the building official to assist in determining whether a product complies with the local building code. The reports are extensions of product listings which declare compliance with technical standards adopted by the listing agency. Evaluation reports are distributed to building departments and subscribers within the building industry and specify the conditions under which a product complies with the building code. Use of these reports is the decision of the building official since they are not approvals. The building official makes the final determination as to whether the product satisfies the laws of a local government.

ICBO Evaluation Service, Inc. (ICBO ES) represents the International Conference of Building Officials in offering its building official members technical information on building products under the Uniform Building Code. The manufacturer has the right to seek approval of the building official directly. However, he is faced with the same task in each jurisdiction where the product is used. An ICBO ES evaluation report indicates that the manufacturer has voluntarily sought and successfully gained recognition of his product under the Uniform Building Code. The published report is distributed to 2400 building jurisdictions representing local governments in the United States. The reports are also distributed to architects, engineers, specification writers, contractors, etc., who subscribe to the service.

The evaluation process and review of technical data by ICBO ES follow three distinctively separate procedures. The first concerns with product recognition under provisions of the Uniform Building Code (UBC) without the necessity of considering other requirements. The classic example would be fire-resistive assemblies. The ASTM E 119 test standard is the basis of UBC Standard No. 43-1. The same is true for basic products such as wallboard, hardboard, wood sheathing panels and roofing materials where nationally recognized test standards are adopted as UBC Standards.

The second procedure concerns standards developed by technical organizations but not a part of the Uniform Building Code. Recognition of these type of standards are predicated on the organization's membership representation, hearing procedures and voting procedures as they relate to impartial and qualified input.

The third procedure concerns the ICBO ES Evaluation Committee. The committee conducts public hearings on acceptance criteria prepared by the ICBO ES staff. Input during public hearings from testing agencies, manufacturers and consultants, is considered by staff in developing the criteria. They set forth conditions of testing, evaluation and product acceptance. They are published and distributed to building departments and subscribers to inform interested parties of the conditions of acceptance for a unique products. Product specific acceptance criteria are issued on products not addressed in the Uniform Building Code until a need is apparent to establish a generic (general) acceptance criteria. The generic criteria provides procedures and conditions of acceptance under which all similar products are required to comply. This assures uniformity and fairness through the Evaluation Committee process. Approved acceptance criteria are re-evaluated as needed to assure that requirements are current and compatible with the UBC.

Recognition of building products not addressed in building codes present unique problems to the manufacturer and building official. The latter is the sole individual who can approve products for installation in buildings. He may utilize listings, certifications and technical reports to assist him in making his decisions. They are not in themselves an approvals but merely tools to assist the building official.

Measurement of Toxic Potency for Fire Hazard Analysis

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This study is the principal product of a research program to provide a technically sound methodology for obtaining and using smoke toxicity data for hazard analysis. It establishes:

(a) an improved bench-scale toxic potency[1] measurement, one which represents the important combustion conditions of real fires; and

(b) a design and analysis framework which will allow the toxic potency data to be used in a rational, consistent, appropriate, and adequate way.

This establishment of proper bench-scale test conditions, validation of the output against real-scale fire measurements, and development of a consistent framework for fire hazard[2] analysis is unique and represents a successful, usable implementation of the state of the art.

A method for including toxicity in fire hazard assessment should focus on post-flashover fires. The U.S. fire statistics show that 69% of all fire deaths are associated with post-flashover fires, with the preponderance of deaths due to smoke inhalation and occurring outside the room of fire origin. These fires are characterized by:

- primarily radiant heating, with heat fluxes from about 20 to 150 $kW{\cdot}m^{-2}$ throughout the room;
- many items simultaneously on fire; and
- vitiated combustion air for some, but not all, burning items.

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[1] *Toxic potency*: toxicity of the smoke from a specimen of material or product, taken on a per-unit-specimen-mass basis. At present, for fire research, the dominant biological end point adopted is death; and the measured quantity is the LC_{50}, which is the concentration ($g{\cdot}m^{-3}$) of smoke which is lethal to 50% of the exposed specified test animals in a specified time period. The LC_{50} notation must include the exposure time, generally 30 minutes (along with a 14-day post-exposure observation period). **Toxic potency is not an inherent property of a material.**

[2] *Fire hazard:* the seriousness of the exposure conditions which threaten the physical well-being of the occupant. The hazard may come from various sources, for example, smoke inhalation, direct flame burn, injuries due to trauma (*e.g.*, ceiling collapse), high temperatures, or inability to escape due to lack of visibility or the presence of acid gases which affect the eyes.

By contrast, deaths from pre-flashover fires generally occur within the room of fire origin. Both computer modeling and full-scale simulation of these fires show that these deaths are far more likely to be due to heat and burns than smoke toxicity.

The importance of toxic fire hazard[3] (relative to heat, burns, generalized trauma from falling debris or leaping from a window, etc.) in the overall threat to life safety in fires varies both with the type of fire and the time and location of the people relative to the fire. There is thus an inherent error in making materials selection decisions based solely on a single characterization (e.g., toxic potency) of the smoke or even a simple index containing toxic potency and other fire variables.

It is now possible to perform computations of fire hazard leading to assessments of the degree of threat to life safety. These range from:

- simple, closed-form equations ("hand calculations") generally not requiring a computer for solving, to
- computer simulations of a fire where a large number of differential equations are being solved simultaneously.

Either mode of calculation requires valid toxic potency (LC_{50}) input data.

This study recommends that this data be obtained using a radiant apparatus. This device is the first to be validated against data from real-scale fires. It is a descendant of the cup furnace and the Weyerhaeuser radiant apparatus, and is an advanced version of the apparatus developed by the Southwest Research Institute for the National Institute of Building Sciences.

In this radiant apparatus, materials, products, composites, and assemblies are exposed to 50 $kW{\cdot}m^{-2}$ radiant heat under likely end-use conditions. The sample surface area may be as large as 7.6 cm (3") x 12.7 cm (5"), with a maximum thickness of 5.1 cm (2"). Six rats are exposed to the smoke collected in an approximately 200 L rectangular box located above the furnace. Changes in the concentration of smoke are achieved by variation of the surface area of the sample.

The number of animal tests is minimized by estimating the toxic potency of the smoke based on established toxicological interactions of the smoke components. Thus, a small fraction of the chamber atmosphere is removed for chemical analysis of CO, CO_2, O_2, HCN, HCl, HBr, and NO_x. An N-Gas Model had been previously developed to enable the use of these data to estimate LC_{50} values, based on the calculation of a Fractional effective Exposure Dose (FED) of mixtures of these gases. The FED value is approximately 1 at the LC_{50}.

The determination of the approximate LC_{50} is a 2- or 3-step process:

1. **Determine an estimated LC_{50} (30 minute exposure plus 14 day post-exposure observation period) using the N-Gas Model.** This entails two experiments, neither involving animals. The specimen size for the first is obtained using

[3] Toxic fire hazard: a sub-set of 'fire hazard,' where the threat is inhalation of toxic combustion products.

existing data from similar products. The consumed sample mass and the concentrations of gases in the N-Gas Model are measured, and an FED is calculated. Based on this result, a similar second experiment is performed for a specimen that should produce an FED of about 1. The LC_{50} is then estimated by dividing the volatilized sample mass by the apparatus volume.

2. **Check the estimated LC_{50} (30 minute exposure plus 14 day post-exposure observation period) using animals.** Again two experiments are needed: one where the specimen surface area (and mass) is chosen to produce an FED of about 0.7, and one to produce an FED of about 1.3. In each, 6 rats are exposed to the smoke for 30 minutes, and the mass loss and standard gas concentrations are measured. The measurements are to assure that the sample decomposition indeed provided the desired FED. If the LC_{50} estimate is accurate, the exposure at FED = 0.7 should result in 0 or 1 animal death and the exposure at FED = 1.3 should result in 5 or 6 animal deaths. If the animal deaths are as predicted, then the chemical data from the 4 experiments are used to calculate an approximate LC_{50}, and no further measurement is needed. The calculation includes a correction for the generation of less-than-postflashover amounts of CO in bench-scale devices. Post-flashover fires produce CO yields for higher than any bench-scale device (or pre-flashover fires).

3. **If such results are not seen, then determine a more precise value for the LC_{50}.** For a proper statistical determination, 3 experiments are needed in which some, but not all, of the rats die. The selection of sample sizes is guided by the prior 4 tests. After determining the LC_{50}, it should be reported to 1 significant figure.

The LC_{50} of CO_2-potentiated CO is about 5 $g{\cdot}m^{-3}$, and one-fifth of the smoke in post-flashover fires is CO. Therefore, the LC_{50} of post-flashover smoke (based only in CO_2 and CO) is about 25 $g{\cdot}m^{-3}$. The previous work on validation of this bench-scale apparatus showed that the results could be used to predict real-scale toxic potency to about a factor of 3.[4] Therefore, post-flashover smokes with LC_{50} values greater than 8 $g{\cdot}m^{-3}$ are indistinguishable from each other.

A measured LC_{50} value greater than 8 $g{\cdot}m^{-3}$ should be recorded only as 'greater than 8 $g{\cdot}m^{-3}$.' A hazard analysis would then use this value for the toxic potency of the smoke. A measured LC_{50} value less than 8 $g{\cdot}m^{-3}$ would be recorded to one significant figure. These products could well be grouped, reflecting the factor-of-3 accuracy of the bench-scale test. A hazard analysis would then use values of 8 $g{\cdot}m^{-3}$, 3 $g{\cdot}m^{-3}$, 1 $g{\cdot}m^{-3}$, 0.3 $g{\cdot}m^{-3}$, etc.

Most common building and furnishing materials have LC_{50} values substantially higher than 8 $g{\cdot}m^{-3}$ prior to the CO correction. Thus, the toxicity of the smoke will most often be determined by the fire ventilation, rather than the specific products burning.

Further simplification of step 2 is possible. One could perform a single animal test at an FED

[4]A prior risk analysis had demonstrated that his level of uncertainty would not affect the prediction of loss from the most common fire loss scenario: furniture fires in residences.

that corresponds to an LC_{50} of 8 $g{\cdot}m^{-3}$. An observation of no deaths would confirm the suggestion. If any animals were to die, then step 3 would be performed.

When the fire community has sufficient experience with LC_{50} measurements using this approach, some groupings of products could be exempted from further determinations **by inspection** and placed in the "LC_{50} value greater than 8 $g{\cdot}m^{-3}$" category. Some possible examples are:

- wood and other cellulosics, since all species would be expected to show similar LC_{50} values;
- synthetic materials containing only C, H, and O;
- polymer/additive mixtures that have been shown to follow the N-Gas Equation (i.e., produce no additional toxicants) and have LC_{50} values greater than 8 $g{\cdot}m^{-3}$;
- products that are only used in small quantities (for this case a procedure is presented in this report for determining the fractional contributions of concurrently-burning combustibles to the total toxic potency of the smoke); and
- products that would not be expected to become fuel for a flashed-over fire, such as those items only installed behind a sufficiently-protective barrier.

Based on an overview of reported toxic potency values, this process could result in an extremely small fraction of commercial products needing to be measured. Note that this statement applies to post-flashover scenarios only.

There will be some cases where it is important to have toxic potency data useful for analysis of pre-flashover fires. For these, the combustion conditions in the radiant apparatus are directly applicable. One would determine the LC_{50} as above, but not correct it for post-flashover CO. The irradiance of 50 $kW{\cdot}m^{-2}$ for a pre-flashover test is somewhat high, but should have little effect on the LC_{50}. Lower fluxes can be accommodated if necessary.

The computations in a hazard analysis must account for the fact that the oxygen concentation in post-flashover smoke is significantly depleted, the amount of depletion depending on the entrainment (outside the fire room) of fresh air into the smoke. This effect could not be simulated in a bench-scale apparatus. By contrast, the pre-flashover fire, such shortage of oxygen is small.

This study consolidates a number of fire toxicity investigations conducted by NIST over the last several years. Portions of the work have been funded by The Society of the Plastics Industry, Inc., by BFGoodrich, and by The Industry Coalition. There were significant technical contributions from Dr. Arthur. F. Grand of the Southwest Research Institute; the Smoke Toxicity Working Group of the National Institute of Building Sciences, chaired by Mr. Henry Roux; and Dr. Jack E. Snell, Ms. Magdalena Navarro, Mr. William H. Twilley, Mr. Emil Braun, and Mr. Ronald McCombs of NIST.

PROGRESSIVE CERTIFICATION AND ACCREDITATION PROCESS IN THE PROVINCE OF ALBERTA

Mr. Chris Tye
Director of Building Standards, Province of Alberta, Canada

Alberta is a province with a little over 3 million people. Most of the population is located in large to medium sized urban areas. We have a vast rural area with a sparse population. We have had a provincially legislated building code throughout the province since 1974. This was at the insistence of industry and designers and other groups, who felt that a provincial code was necessary and it took the place of all the municipally adopted codes that existed prior to that.

In the 1970's we had, in Alberta, a strong economic resource in oil and gas, exploration and export. Subsequently, the provincial government was able to provide extensive services to the population of Alberta as a whole. We then went through the downturn of the 80's and 90's and government found that it was not able to live up to the expectations it placed upon itself in previous years.

This required that we, as a government, take a look at the way we delivered our services and come up with what we think, at least for Canada, is some new and innovative approaches. What we have recently put in place is what we term the Safety Codes Act. The Safety Codes Act has a number of goals. Number one is to make codes and standards more responsive to the needs of industry and the public. The second goal is to improve the current level of safety in all buildings, and all building construction and maintenance related activities. Obviously, when there is a downturn, quite often the building official is the one who may be on the front line in terms of loosing his job. The third is to introduce training, leading to the certification of all inspectors throughout the province.

I will take a brief look at each of these goals individually and give you some idea as to what our response has been to put them in place, to make codes and standards more responsive to the needs of industry and public. The first thing we did was to take all of the existing legislation, covering construction and building maintenance related activities and put it together under one piece of legislation. So we have taken building, fire protection, electrical, plumbing and gas, elevators, and boilers and pressure vessels and they now will function and exist under a single piece of legislation.

We have also given the control for codes and standards and other activities, from our domain, us being the provincial government, and we have put it in the domain of an industry nominated council. The total council will comprise approximately 100 individuals, all representative of the various disciplines that are under the first point.

This council will be responsible for adopting codes, hearing appeals of inspectors' orders and the certification procedures that inspectors will have to go through. The 100 member council will sit in various industry specific sub-councils, in order to perform their duties.

The second goal is to improve the current level of safety in all building construction and maintenance related activities. The way we are going to achieve this is by increasing the number of partners involved in the delivery of the safety related services, i.e., those involved in plan review inspections. We will do this by accrediting a number of groups. We will accredit municipalities; municipalities are traditionally the deliverers of these services; municipalities also include the provincial government. We will also be accrediting private corporations. Private corporations will be bound by geographic area, such as a university. A university can become accredited to enforce code regulation within its own limits.

The third player in this will be private agencies. This is a brand new concept in that we will be accrediting private agencies to deliver inspection and other regulatory services for all of the disciplines I have previously mentioned.

The way we, as a government, will be doing that and ensuring that the appropriate delivery takes place by the accredited bodies, will be through traditional quality management and audit procedures. Everyone who buys into the system, will buy in by way of a quality management plan and then we as a provincial government will audit their operations, probably on an annual basis.

The third goal was to provide training leading to the certification of inspectors. We do this by two means: establish minimum formal education criteria for those wishing to work as inspectors in each of the disciplines, i.e., an electrical inspector must have a journeyman's electrical certificate, an electrician certificate, and then with the assistance of technical institutions and colleges, they are developing specific code-related training courses which, when added to the formal education, will permit inspectors to become certified.

To complete the loop and make this thing work, we will require all accredited bodies, government and private sector, to employ certified individuals to work as inspectors as part of the accreditation process.

Final point on the results. The results are that government puts industry in control of the code adoption and monitoring process. We, as a provincial government, will no longer hold the reins. We will be required, because of our legislative needs, to pass the codes, but they will establish the codes. The responsibilities of government will be limited to passing the codes and auditing the delivery system. With this we believe the monitoring of construction and related activity increases, and will lead to a safer built environment.

The fire safety design of sandwich panels used in buildings

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Introduction

Sandwich panels are being increasingly used as external wall and roof claddings for buildings because they are lightweight, energy efficient, and can be easily handled and rapidly erected. They are used in many types of buildings ranging from large factories and warehouses to domestic dwellings, their high thermal insulation making them especially suited to extreme climates.

The panels often employ cores of rigid foamed plastic because of low thermal conductivity, high moisture resistance, and low cost. Foamed plastics however, are often regarded as a fire hazard, often unfairly. The number of different combinations of materials used in facings, core and, where appropriate, adhesive is large, making it difficult to give general guidance on the fire behaviour of panels in a paper of this length. Such guidance is given elsewhere[1,2].

Building regulations often control the life risk by reference to standard fire tests which aim to measure ease of ignition, rate of heat release, flame spread or a combination of these, and, in some cases, smoke production and toxicity.

The primary objective is to ensure that occupants inside or nearby a building are not exposed to a life threat if fire occurs. Life threats can arise by rapid spread of flame and hot gases, smoke obscuration and irritancy, and toxicity.

Standard fire tests

Tests which assess the rate of fire growth in building materials and composites from ignition to flashover form a family called the "reaction- to-fire" tests which include tests for ignitability, combustibility, flammability, rate of heat release, smoke production and toxicity.

From flashover, when all the surfaces and contents of a room are involved in fire and combustion gas temperatures reach around 500°C and above, the object is to limit the spread of fire beyond the room of origin and prevent collapse of the structure: here the ability of walls and floors to remain stable, prevent the passage of flame and hot gases through holes, and prevent unexposed surfaces from reaching temperatures which would ignite combustible materials in contact with them, are measured in the ISO 834 standard fire resistance test.

In the United Kingdom the above mentioned tests are specified in various parts of British Standard 476 and a brief description is given elsewhere[3].

Ad hoc fire tests

Standard tests are limited in the information which they can reveal about the important fire characteristics or hazards of a material or composite, and non-standard tests have been developed for this purpose. The room corner-wall test is relevant to sandwich panels incorporating combustible materials[4,5]. The test apparatus can be visualised as a small room with two adjoining walls absent. The fire is usually simulated by a timber crib or an item of furniture placed in the corner close to the specimen walls. Measurements taken include time taken for ignition of the specimen panels, rate of heat release, extent of failure of the facing, rate of fire spread over panels, radiation intensity, temperature of combustion gases and their chemical composition, and rate of smoke production.

The corner-wall test can identify composites which permit rapid fire spread but which appear acceptable when tested in the small scale standard test apparatus. This difference in behaviour can, for example be clearly shown with rigid polyurethane foam faced with aluminium foil, and is caused by the high rate of decomposition of the polyurethane foam following early failure of the foil facing at levels of incident heat flux far higher than those achieved in the standard tests.

The level of incident heat flux is an important factor in assessing the benefit of flame retardants, as it has been shown that a retardant which effectively quenches a flame after removal of a small ignition source may have no effect when a larger sources is involved; indeed some flame retardants may increase the fire hazard by producing more smoke of a dense and irritant nature than a non-flame retarded product.

Large-scale fire tests, sponsored by an industrial consortium, have been undertaken by the Fire Research Station, using a corner-wall test rig, Figure 1, lined on two adjacent masonry walls with a variety of cellular plastics insulants (XPS, EPS, PUR, PIR and phenolic foams), mostly 25 mm thick and faced with 9.5 or 12.5 mm plasterboard. The fire source was a 57 kg wood crib designed to give the heat output of a burning armchair of modern plastics foam- filled type and capable of overcoming the protecting plasterboard facings, Figure 2. The test was conceived because the standard surface flammability tests (BS 476 Parts 6 and 7) were not severe enough locally to represent the above scenario, whereas the standard fire resistance test does not allow measurements to be made of the relevant properties and cannot simulate the localised thermal shock associated with the initial high rate of burning of a piece of modern furniture. The results showed that in no case was a significant additional contribution made to life hazard in excess of that introduced by the ignition source (ie the crib). Small-scale tests, to check the possibility of hidden ignition of the insulants behind plasterboard due to electrical faults, showed that there was only slight damage and little risk of decomposition products entering the room even with a simulated heavily loaded short circuit.

The variety of corner-wall tests now available will be supplemented and perhaps replaced by the ISO Room fire test which comprises a room nominally 3.6 m long x 2.4 m wide x 2.4 m high with a door opening in one of the short walls from which the combustion products are collected. The standard for this test is in draft[6] at the time of writing this paper (August 1991).

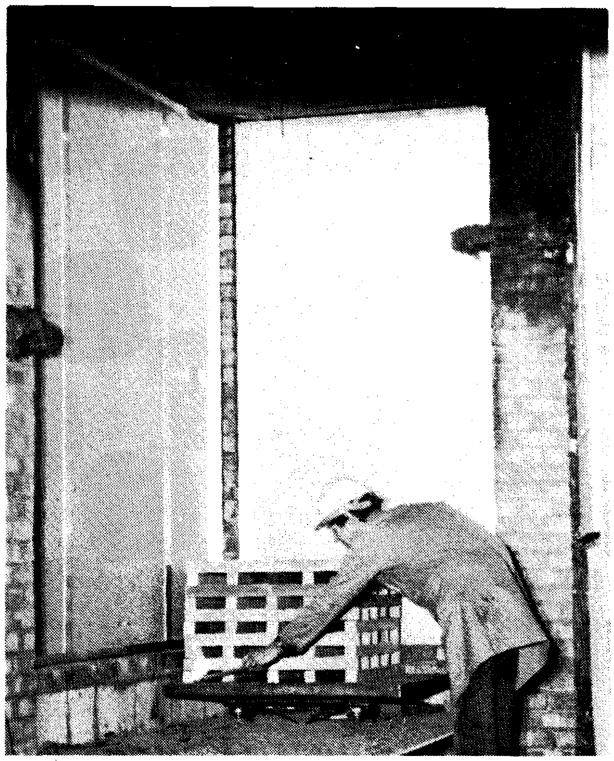

Figure 1 Corner-wall test rig showing panels and crib before test

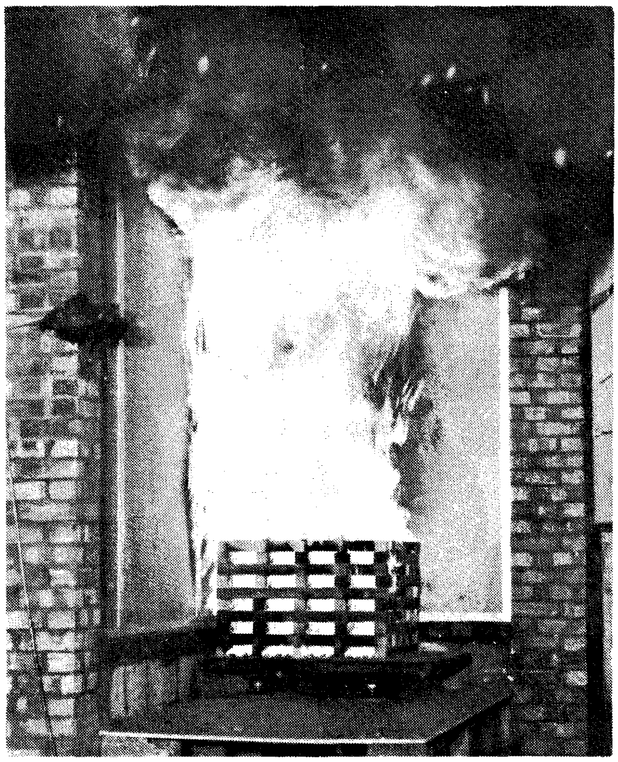

Figure 2 Corner-wall fire test in progress

Proliferation of fire tests

It has been mentioned that standard fire tests fall into two groups: reaction to fire, and fire resistance. In 1988 the author made a survey of fire tests for structural sandwich panels in some EEC and EFTA countries as part of work within CIB Working Group 56 (lightweight structures). The questionnaire asked for information on national Building Regulations and associated fire tests, and the responses showed that there was a wide range of standard test methods reflecting different fire scenarios. This wide variation in fire tests represents a technical barrier to trade between the different countries and underlines the need for harmonization which is especially important for smaller companies which cannot afford the high cost of testing in each country.

European common market developments

The Construction Products Directive (CPD) which came into force in the 12 member states in June 1991 is expected to have a major impact on the design, testing and installation of all products used in buildings and civil engineering works. Products in this context include materials, components (eg windows and roof lights), elements (eg walls and roofs), installations (eg automatic sprinkler installations) and prefabricated systems. The CPD requires that construction works (eg buildings) satisfy several Essential Requirements. One of these is Safety in case of fire. The CPD does not attempt to harmonize safety levels (Building Regulation requirements), but will harmonize fire tests and calculation methods for assessing performance in fire. It will accomplish this by mandating CEN (the European standards making body) to produce harmonized test standards and technical approvals.

A series of documents called Interpretative Documents have been prepared to provide links between the essential requirements (functional statements) in the CPD and mandates to CEN. The European Commission has, via the work of an expert group, identified that more than 37 reaction-to-fire tests exist in Europe and has made recommendations for work leading to a harmonized family of reaction-to-fire tests which could apply for many years - the so-called Robust Solution. It is not possible to say what these tests will be until a careful programme of research, development and testing work has been undertaken to establish the most appropriate fire tests and classification methods.

Fire safety considerations

* Consult, at an early stage, the building and fire authorities, and the insurer, to establish the desired fire performance.

* Try to use wall panels with an effectively fixed fire-protecting inner facing such as plasterboard or other fire protecting board which does not fail early in fire. This is more important where cores are combustible and capable of producing toxic and irritant combustion products, Figure 3.

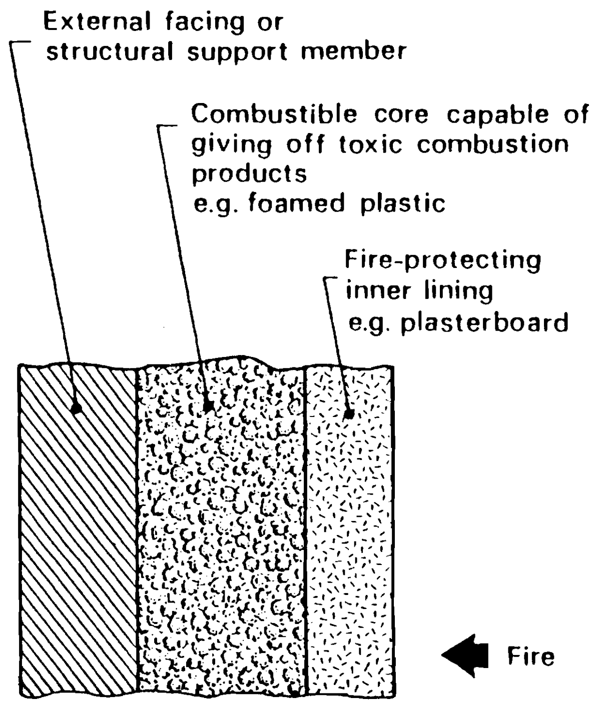

Figure 3 'Use wall panels with an effectively fixed fire-protecting inner facing such as plasterboard which does not decompose, disintegrate or shatter in fire....'

* The use of poorly protected flammable plastic cores is less objectionable if: escape routes and exits are good and easily seen, few people occupy the building, the building has a large smoke reservoir or a system of smoke vents, and a fire detection and alarm system is installed so that the occupants can vacate the building before the atmosphere becomes untenable[7].

* Before insisting that the combustible core or, if appropriate, inner facing is treated with a flame retardant, check with the manufacturer to

determine the range of fire size and levels of incident radiation for which the retardant works. A retardant which effectively quenches a flame after removal of a small ignition source may have no effect when a larger source is involved; indeed some flame retardants may increase the fire hazard by producing more smoke of a dense and irritant nature than the non flame-retardant product.

* Avoid using timber facings where it is important to minimise surface flammability. Small areas of timber, which do not form part of an escape route lining, may not require the use of flame retardants to achieve this.

* Minimise the combustible content of all materials in the panel. In particular minimise the use of materials (eg pvc) which give off HCl when involved in fire which can damage building services, cause corrosion to concrete and damage finishes in the rest of the building.

* Minimise the use of materials which can melt and form flaming droplets to cause new outbreaks of fire. This is especially important in roofing applications.

* Avoid panel seals which are easily penetrated by fire or give off toxic fumes.

* Fire stop junctions between sandwich panels and fire separating walls or floors so that fire cannot spread beyond the fire separating element via the combustible core of the panel, Figure 4. Intermediate fire stops around the perimeter of each panel, and within large panels, are also highly desirable. This reduces the life hazard and property loss.

* Avoid extrapolation of stability data gained from standard fire resistance test results when designing the stability of tall wall panels supported at the lower edge since thermal bowing may produce eccentric loading which leads to instability of the panel. Suspend tall panels from the upper edge making due allowance for vertical expansion.

* Consider the forces caused by unsympathetic thermal movement acting on panels in the fire condition. Unsympathetic thermal bowing can occur at external and re-entrant corners leading to rupture of the panel or, more likely, panel joints, allowing fire to pass through.

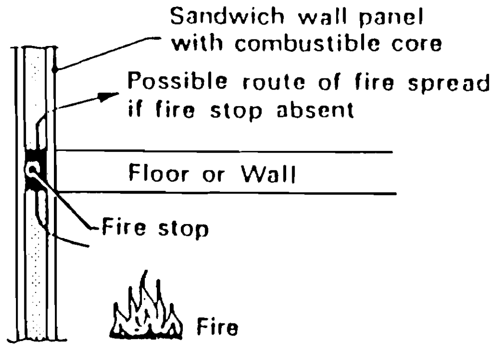

Figure 4 'Junctions between sandwich panels and fire separating walls or floors should always be fire-stopped....'

* Consider safety of firemen and people near the building. For example, avoid external wall or roof panel designs which, in fire, allow the outer facing to become detached and act as a missile hazard, and allow unexpected high levels of thermal radiation to people and property nearby.

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THE IMPORTANCE OF THE COORDINATION OF SCIENTIFIC RESEARCH AND INTERNATIONAL, EUROPEAN AND NATIONAL STANDARDIZATION - ILLUSTRATED USING EXAMPLES

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1. Basic Principles

To carry out work in all technical areas - this also applies to building - we need to have technical rules as written record of the state of experience.

It depends on the addressee at what time a technical rule is written down. As an example, I should like to mention the findings and research which are written down by scientists; that record is considered to be the state of science.

A great many intermediate steps characterize the process which finally generates technical rules which are acknowledged as the state of the art by all those who participate in building. Thus building standards at national, European and international level represent the secured "know-how" for safe and reliable building among building experts - be they from building industry, building material industry, administration, science or material testing.

A broad acceptance of a technical rule is reached by involving all interested parties in its elaboration. This is safeguarded at national level, e.g., in Germany at DIN, but also at European level, e.g., at CEN (European Committee for Standardization) and at international level at ISO (International Organization for Standardization).

While standardization aims at implementing the basic principles such as rationalization, quality assurance, safety, environmental protection and communication, this extensive field of requirements can, of course, not be met by every technical rule set up by a scientific institute. With a view to its principles and objectives this institution is actually rather concentrating on one or several of the items mentioned above, such as, for example, on the field of material testing where RILEM provides a forum for international exchange of experience in building.

2. Relation Between Technical Rules and Public Regulations

The experience of the last decades has shown that it is not suitable to specify technical details in public regulations.

Public regulations should only contain general safety targets and principles and for technical details refer to the rules laid down by the relevant private standardization organizations.

Thus legislature at any time need not elaborate new laws or adopt them to the current state of the art.

This principle of division of labour, which has been applied in building by numerous states has proved in practice. In Germany, for example, the Building Regulations of the Lander specify the general requirements for building, stating, for example, that a building must have a certain stability. As a rule, these regulations are given concrete form by DIN standards which in particular state how to design and execute a building made of masonry or reinforced concrete so as to ensure stability.

Not only at national level had that principle of division of labour been applied, but also at international level. The EC-Construction Products Directive dated December 1989 only contains the so-called "essential requirements", such as stability, heat retention, hygiene and environmental protection, yet is also refers to the so-called "technical specifications" which the building products must comply with. These are harmonized European standards or European Technical Approvals.

Thus the EC-Directive has been kept free of technical details. This principle of work sharing was laid down in the so-called "New Approach" in 1985, after it had turned out that specifying technical details in European Directives was no appropriate approach to rapid harmonization.

3. Activities of Scientific Institutes (Outside Standardization) and Their Importance for Standardization

As far as scientific institutes at national, European and international levels are concerned, a distinction has to be made between institutions which exclusively serve to exchange experience, e.g., among scientists in technical fields, or those which also write down technical rules in order to give a record of the actual state of experience as state of science or state of the art.

There is a number of institutions which cover both of the tasks and which moreover assume public and political functions such as the VDI - Association of German Engineers in Germany.

Today the decreasing availability of resources in particular calls for a closer cooperation of all interested parties with regard to both, personnel and funds. It also requires an efficient exploitation of existing findings. It does not make any sense to "reinvent the wheel" at every instance. Therefore, it is highly important to implement technical rules which had already been documented and proven in practice in national, European and international standardization.

This also applies to the cooperation between different levels, i.e., between national and European bodies, between national and international bodies and even between European and international standardization organizations, such as CEN and ISO. This principle of cooperation, in particular, had been laid down by CEN and ISO in the "Vienna Agreement" of July 1991 which provides for the exploitation of all capacities and a continual exchange of information.

Pursuant to these agreements which also extend to building, a topic is addressed by one institution only, either by CEN or by ISO. Only in case of closely defined exceptions, a deviation from this principle is possible.

The use of international or European rules which have been stipulated on a broad basis is of particular importance for scientific institutes. The working results they generate, such as in building those of:

- CEB "Euro-International Committee for Concrete";
- IASBE "International Association for Bridge and Structural Engineering";

and

- RILEM "International Union for Testing and Research Laboratories for Materials and Structures".

just comply with the condition that standardization requires written rules which - whenever suitable - should also be used at European and international standardization level. This does not mean to give up the individual activities of scientific institutes, but to make important contributions to the work at a even larger scale.

The need for such a collaboration was satisfied in the past by establishing so-called "liaisons" which created a link between ISO or CEN and its Technical Committees and the scientific institutes.

This must not be restricted to the exchange of documents alone, but should possibly extend to a collaboration of experts. This is the only way to carry out efficient work. It does not make any sense if a representative, in his capacity as national delegate, had to deal with the same subject several times, at the level of an international scientific institution, at European and finally at international standardization level. Quite on the contrary, it must be a long-term goal to carry out a work at one level only, once it had reached a certain degree of maturity. However, before a topic is addressed at standardization level, the state of experience has to be examined.

In this context, scientific institutions, such as CIB in particular, offer the opportunity to carry out appropriate work prior to standardization and to verify and test their results in order to finally submit them at standardization level at CEN and ISO to the other parties as soon as a secured level has been reached.

As an example, I should like to mention the activities in the field of tolerance and modular coordination in building construction (in CIB) or the test methods in the field of concrete (in RILEM).

In order to achieve a high efficiency, it is important that the parties participating in building and interested in standardization reach a common agreement on the level at which a topic that requires standardization is being addressed. Procedures that hold true for CEN members at European level, i.e., to examine as to whether a topic is being dealt with at national level at all (be it a revision of an existing standard or the adoption of a new topic at national level), or whether the activities are taken up at European level, should hold true for all scientific institutions working at European or international level. Only if the working programmes are coordinated at a large scale at an early stage, can the targets mentioned above be complied with.

And it is certainly true that for supporting the worldwide trade of products and services in building, the priority issue must be to elaborate internationally secured specifications, i.e., ISO - standards.

The legal approval of building innovations in Australia - An accreditation system for the Global Village?

by Hugh Knox
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The world is a single community. . .
WILLIAM E. SCHLECHT

. . . the human family now exists under conditions of a global village.
MARSHALL MCLUHAN

Lord Ronald. . . rode madly off in all directions.
STEPHEN LEACOCK

1 Definitions, sigla and acronyms used in Australia

accreditation the legal approval of a product or system.

appraisal a technical evaluation of a system or product as to its compliance with the *intentions* of regulations, and its fitness for purpose.

AUBRCC (pronounced "Orbrook") the Australian Uniform Building Regulations Co-ordinating Council; an association of building control bodies; it has liaison with industry and some other bodies including *CSIRO*.

BCA the Building Code of Australia, prepared by *AUBRCC,* adopted with individual variations by all the states; the politicians have decreed the removal of the variations.

BCU the Building Code of Utopia, described fully in another contribution.

credence some means of assuring the building official that the *intention* has been met.

CSIRO the Commonwealth Scientific and Industrial Research Organization; parallel to NRCC and NIST.

intention what the building or part is supposed to do or be, written explicitly in your code as a mandatory clause and supported as much as possible by *credences*.

NBTC the National Building Technology Centre, taken over by *CSIRO* in July 1988; initiated extensive research into the *BCA*.

2 THE OBJECTIVES OF AUBRCC

AUBRCC was set up in 1980 in Australia (a federation of sovereign states) to take over the development of the model code on which most of the regulations in each state and territory had been based. The objectives of *AUBRCC* for building control included national uniformity, a performance base, simple wording and support by a national *accreditation* scheme. At first there was no uniformity - we all rode madly off in all directions - but we are now closer than ever to this objective.

3 WHY HAVE A PERFORMANCE-BASED CODE?

Regulations in Australia have traditionally been prescriptive, like the recipes in a cookbook. You had to use specified materials and put them together in a specified way in accordance with specified dimensions. The only instruments that the building official needed to validate compliance were his eye-sight and a two-metre tape.

Prescriptive requirements are very useful for conventional construction; they provide a ready solution, readily validated, for most building problems. They are wrong only if the regulations say that the prescriptive way is the only way.

Why? Because if you were an entrepreneurial manufacturer, designer or builder who wanted to introduce some new material or method of construction that was not mentioned in the regulations, the exclusive prescriptions stopped you.

4 INNOVATIONS - THE TRADITIONAL APPROACH

Before there was an *accreditation* system, you had to have your product or system *appraised* by a technical expert and then you had to submit it to the local municipal council as being just as good as the usual material or system. In order to do this, the *intentions* of the relevant regulation had to be understood because it was most unusual in traditional regulations for the *intentions* to be explicit.

If you wanted to promote your innovation in another municipality you had to repeat the process with that local council. If you wanted to promote your innovation throughout Australia you hàd to repeat the process more than 800 times by approaching all local councils.

5 THE APPRAISER'S PROBLEM

The basis of *accreditation* is a technical *appraisal* (or evaluation). But how does the appraiser know what the *intentions* are? He could deduce the *intentions* implied in the prescriptive requirements, or he could ask the building official. But why not write the *intentions* into the regulations as mandatory clauses? This eliminates guesswork and promotes uniformity in assessing the performance of an innovation. It introduces many other interacting benefits as well.

An *intention* should be supported by *credences*. A *credence* could be a prescriptive requirement, a standard, a test and a criterion for compliance, or any combination of these. If the *credences* are inapplicable or if there is no *credence*, the innovation could be *accredited*. So *accreditation* is another kind of *credence*.

With regulations in this form, *accreditation* becomes an essential part of the regulation system; since the *intentions* will be included as mandatory clauses in your code, an innovation can be said to comply with a specific clause. Otherwise, *accreditation* has to be based awkwardly on *intentions* that are not only unstated but are usually unknown.

6 YOUR OWN CREDENCE?

What if an *intention* is supported by *credences* but you want to adopt some way other than the specified *credence* because you feel it is more appropriate? An example is an imported system, designed in accordance with a foreign standard which could meet the *intention* just as well. Since the foreign standard might not be mentioned in the *BCA*, the system and the standard would need *accreditation* if it is to be accepted within Australia.

7 A NATIONAL SYSTEM

In the old system, you had to take your innovation to every local council in Australia if you wanted to have it accepted nationally. Two states have attempted to resolve this problem within their own jurisdictions by instituting state *accreditation* systems but if you use national *accreditation*, you only have to do it once. *Accreditation* is based on the *intentions* of the *BCA* and the *BCA* will be accepted nationally by adoption in every state and territory during 1991.

These are the 4 essentials of the Australian national *accreditation* scheme:

- A national, uniform building code.
- The code based on a comprehensive and coherent system of *intentions*.
- A technical *appraisal* of the innovation for its compliance with the relevant *intentions* and its suitability for its intended purpose.
- A coordinator who arranges approval by all the legally competent member bodies of *AUBRCC*.

8 THE MECHANISMS

Accreditation is based on a technical *appraisal*. So this is the first step. It can be done by *CSIRO* or by the Australian Building Systems Appraisal Council (ABSAC), a body set up in 1978 just for this purpose. However any expert body can do an *appraisal*.

An *appraisal* is a thorough technical evaluation of a product and its application in a building, so we advise the applicant on how to assemble all relevant technical data needed for sound judgement. The applicant will almost certainly have detailed technical discussions with the *appraisal* body and there is nearly always the need for additional data as the *appraisal* develops. So the applicant helps himself greatly if he has all relevant data, assembled in a logical and coherent form, and provides experienced technical personnel, either his own staff or a consultant, to handle the negotiations.

The next step is to send the *appraisal* report to *CSIRO*; the applicant might have to be prepared for further technical negotiations with *CSIRO's accreditation* officer.

CSIRO is the independent technical assessor and channel to the accrediting authority, *AUBRCC,* and this ensures uniformity in assessment of the *appraisal* irrespective of who does it. So *CSIRO* assesses the report and draws attention to any additional data that might be needed. *CSIRO* then prepares an *accreditation* report recommending the issue of a certificate of national *accreditation.* If *CSIRO* does not recommend approval, the *accreditation* officer will go back to the applicant, perhaps with suggestions as to how the product or system could be further developed.

The certificate of national *accreditation* refers to the description of the product or system and to the conditions that apply to its use. These are given in the *accreditation* report that goes with the certificate. So if an *accredited* product or system is incorporated in a building, the building official will insist that the designer and builder must comply with the terms of the *accreditation* report. The report must therefore be definitive, precise and clear, with no ambiguity; it has to be prepared thoroughly just as if it is a regulation itself.

All parties have to keep the application confidential until the certificate is issued in case the application is unsuccessful.

9 A WORLD CODE

There is regular talk of reciprocity of *accreditation* between countries but since *accreditation* has to be tied to a building code, the only practicable way to achieve reciprocity is a world building code. The only form likely to be accepted is the 2-level system similar to that proposed by *CSIRO.*

A properly structured *BCA*, based on a system of *intentions,* is an ideal basis for a world code. The demand for such a code will increase in response to increasing pressure to facilitate the international movement not only of physical goods, but of services, skills, information and capital that must go with international trade.

Moves to this end are already well advanced in the European community which is moving towards complete economic integration by 1992 when it hopes to have removed all internal barriers to trade and related services. It will then become the world's biggest trading bloc.

Already, the Economic Commission for Europe (a United Nations agency) has prepared a model code in the 2-level form similar to that proposed by *CSIRO.* (*CSIRO* and ECE were working quite independently of each other.)

10 CONCLUSION

Never loose sight of the complete picture. *Accreditation* is only one part of a comprehensive system of regulation that controls or influences every person in the building industry, even those who never read regulations.

An effective *accreditation* system is a consequence of a properly structured building code. A proper structure has enormous benefits for everyone using or effected by the regulations, benefits that can come about as the result of radical changes in the attitudes of regulators and a demand from code users for clarity, simplicity and good organization in the documents that the law says they must follow.

These conclusions emerged from some extensive research into the *BCA* that *NBTC* initiated in 1987. See the separate contribution from *CSIRO.*

A mandatory document developed along these lines will then be a positive aid for the designer instead of being a convoluted maze. Such a code can still maintain the objectives of regulation while at the same time cutting design and approval costs, encouraging the development of sensible technical requirements, encouraging innovation and flexibility (that is, by *accreditation*), creating favourable conditions for international trade and other international activities, and leading to a better built environment.

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THE NEW ZEALAND BUILDING CODE - AN INDUSTRY DRIVEN INITIATIVE

John H. Hunt
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In New Zealand, which only has a population of 3 million, which is small when I hear the size of some of the cities where some of the members come from. Back in 1980, industry approached government and said there were too many regulations, so on the basis of this industry initiative, the government decided it would have a look at the whole question of building regulations, the need for them and what in fact needed to be regulated and from that, over the 10 years that have since gone, New Zealand is now introducing a whole series of building control reforms, a Uniform Building Code, which will apply right through the country and eliminate the by-law making powers of the municipalities or territorial authorities and this new performance-based building code comes into operation on the first of July of this year.

It was the industry that wanted controls to be reduced and on that basis, industry has had a very large input into what should be regulated. One of the areas that is not regulated to any degree at this stage, are those matters relating to the environment, except for the control or efficient use of energy.

One of the other aspects that has been introduced with the reforms is the question of accreditation of building products and building systems and this is being introduced to assist manufacturers, mainly on a marketing basis. Any product that is accredited by the new authority, which is a small body being set up by the government to administer the code, any such accreditation will have to be accepted by the territorial authorities, who will be administering the code. It is a voluntary basis and if manufacturers choose to go down that track, then it is up to them, the choice is theirs.

Similarly, New Zealand is introducing what is being called building safe fires, from the private sector, and these again will be approved by the authority and they are all set up in competition to the territorial authorities. In a similar way, that has been introduced into the United Kingdom, but in England insurance matters has reduced or held back the number of people that have taken up that route.

In developing the performance-based code, New Zealand had a look at all the codes that were in operation over the last 10 years and has based its work on the Scandinavian and then very much on the English and Welsh codes, which were introduced in 1985, South Africa, a similar period and Australia, since that time. The more I listen to what has come out of this conference, I realize that there are a tremendous number of people who are all going down the same track. There tend to be variations on a theme and I don't think that it matters too much the extent to which you get your system in place. The important thing is to get a system in place. I believe going down the performance track is the only way to go and that is the way you break down the trade barriers, by having a uniformity of objectives.

As far as the work done by the building industry commission, originally, and now the building industry authority, the more time and care that is put into defining the objectives of your building code, so it makes the rest of the work and coming up with the actual performance criteria and the whole way the code comes together, it makes that aspect of it very much easier. Once you have your objectives spelled out, then the rest of it is relatively easy.

SESSION 4C
BUILDING REGULATIONS: A NECESSARY EVIL

Questions and Discussion

Question
John Fernlord
Cost Consultant

There is obviously a trend towards standardization in codes; there is also a counter phenomenon, inasmuch as each jurisdiction is responsible for code writing or code enforcing, think they have the right answers and even if they say adopt a national or a model code. Can someone give an opinion whether we will ever see some degree of standardization in codes, either on country-by-country or continent-by-continent basis?

George Hadjisophocleous

In Canada, there is one National Building Code, but it gets changed when it is adopted in each province or the city of Vancouver. My understanding is that there are a number of provinces now which are adopting it without making any changes. The Deputy Ministers have written a Memorandum of Understanding that, as much as possible, they will try not to make any changes in the National Building Code. Having said that, provinces like Alberta, which has a very large mobile construction force, construction camps and whatnot, does need to bring in some of the regulations, additional regulations from that point of view. But you are right, we should limit ourselves to just making additions and not making changes.

The pressures are building up on code writing authorities to make a uniform code and I think that public pressure will eventually lead to a truly national code.

John Nosse

I would like to speak from the U.S. perspective. We have three model building codes in our country, as many of you are aware. We are working very closely. I personally feel that, as far as technical requirements, I don't feel that there are major conflicts between the model building codes, because they all stem from national requirements and specifications that are entered in our country.

Certainly the manner in which these regulations are interpreted and users subjected to perhaps some of the conflicts or concerns expressed by many of you out here, and I think that from that standpoint the dissemination of information, which is one of the services that my organization offers, is very critical to that, in that there is that need, that we as an organization to be open to information that comes from people like all of you. We need your assistance on that and if we are to do away with this adjective called evil, we need the assistance of the entire building profession. We want that information. If we get that information, I can assure you that we will take that information and work towards having the uniformity that is coming in this world.

At the other end, it is our responsibility to disseminate this information to the users of our codes, who adopt them as building laws, in hopes that we can get the uniformity that we all want.

Hugh Knox

In Australia, if someone had said Australia will have uniform building regulations, you would have been laughed at and ridiculed and the reason for that ridicule is that Australia, being a federation of states, has its own little bureaucracies, each and every state, and the people running these bureaucracies are not going to give up their power.

In point of fact, there has been a progressive movement for the last 20 or 30 years, where the bureaucracies have, in fact, decided to give and take and they have decided to give up their own little empires and cooperate with each other in having uniform regulations throughout Australia.

We still have a long way to go, we have got a building code of Australia which is about 20 mm thick. Each state has added its own variations to that building code and as a result, the variations are also about 20 mm thick, but you can see them, they are standing out in the open and the politicians in Australia are most embarrassed by these variations and they have ordered the bureaucrats to get rid of them.

The point I am trying to make is that the reason why there was no uniformity at first, and the reason why there is no complete uniformity now, is because of the attitudes of people. Those attitudes have changed radically in the last 20 or 30 years and in fact, they have changed radically over the last 2 or 3 years. Once we can get those changes of attitude, we will have a world building code; it's as simple as that.

Bertrand Delchambre

If you include the codes of practice under the concept of building codes, I am happy to tell you that an Italian court in a liability case in construction has used a French code of practice to decide a case of liability. There you have a beautiful example of international contamination between building codes.

Speaker

About 5 years ago, I had a draft contract from the European Commission, to work in a small group of about half a dozen fire experts in Europe, a man from France and some others, to make a survey of fire regulations in Europe, initially in the main member states, and then go beyond that to cover all 12 member states and the new approach came along which Mr. Rilling mentioned in his talk, and this was swept aside and it was said that for the moment you shall only harmonize standards. Let us get the standards right and then perhaps, and I now give a personal impression because the Commission are very clear on this, they do not anticipate harmonizing regulations, but my view is that once this work on harmonizing of test standards comes about and is complete, then one will almost inevitably move into the area of harmonized regulations.

The reason is that, at the end of this standards testing harmonization, you will have harmonized standards, but you will still have for the same product in the same use in a building in two different countries, two different requirements. That, I maintain, can represent a barrier to trade and I think the whole picture will emerge perhaps in about 10 years, when we really begin to get to grips with harmonized regulations and then in Europe, bearing in mind that we have a lot of interest in some countries. That will be a very powerful situation and I think it will encourage lots of other countries to do the same.

Question

We talk a lot about standards and accreditation systems and regulations, but I have not heard about insurance. What is the relationship between standards, accreditation, regulations and insurance systems?

Mr. Knox
Sweden

The French insurance system, which is, of course, the most well thought out and the most consequential in the world, says the liability insurer is entitled to drop the producer or the constructor who does not follow good practice. If the insurer can prove that the damage to the building resulted from a deviation from either the code or good practice, he does not have to pay. There is a very strong link, but I think it is uniquely French.

Raj Sharma

This new Safety Codes Act in the province of Alberta, again does the same thing, leaves most of the responsibility on the architects and engineers for specifying products and if they are specifying products which are not certified or not approved in the various codes, then I would assume that they would be held liable because there are no code cases yet to prove that.

John Nosse

As far as the U.S. is concerned, the government really, as I understand the system in our country, insurance industry certainly is involved to a degree in the sense that, depending on their ratings, and there are various ways at one time or another. Each governmental jurisdiction was rated overall as to their fire department, the response systems, regulations concerning fire, things of that nature, and they were given a rating on which the insurance companies base their insurance rates, based on the rating of that particular area. It is my understanding that that type of a rating system does not carry quite the weight that it has in the past, but what has happened, simply said, is that the courts really make the determination of responsibility in our country, as many of you know, and as to what happens in the court, only the evidence that is presented and the jury ruling on the merits of a case, make the determination of who is at fault and who pays.

Hugh Knox

The reforms in New Zealand through the Building Act which has been passed by government, clarifies to quite a large degree who is responsible for their various actions. Each of the players, producers, including the territorial authorities, the municipalities administering the building regulations on a day-to-day basis, all have to have their own insurance. As far as the building certifiers are concerned, that's the private enterprise people, who are either as individuals or corporations who are going to be approved by the building industry authority, they themselves have to have special insurance, a ten year full covered insurance, because that is the period for liability for defects and at this stage the private insurance companies that insure the registered architects and registered engineers, through the Association of Consulting Engineers in New Zealand, these insurance companies believe that they can provide this full coverage insurance, which will allow these private enterprise people to get off the ground. Once that happens, I believe there will be a change in the availability of full coverage insurance in the area of checking of building controls.

SESSION 4D
Responsibility and Risk Management
La responsabilité et la gestion du risque

CONSTRUCTION PROCUREMENT STRATEGIES

Professor David Jaggar
The Liverpool Polytechnic, United Kingdom

I will give you a little background about the working commission. It actually started in 1989, when we first met in Liverpool, in England, and we then went to Yugoslavia for the second meeting and the third meeting we had in Los Palmas last year. We had about 40 delegates at each of these three sessions and I will show you what we are actually about to embark on.

What we have now managed to do is to secure some funding to use for research assistance and to actually try to gather the information that I want to refer to on this particular overhead that you see in front of you. The meetings that we actually had were mainly collections of papers of people talking about the way that procurement should actually be going, and we did, in fact, develop a series of terms of reference and I really just want to refer to the next stage of the work, which is to actually go out and actually do something. What we actually want to try to do is look at the way that procurement operates in a number of different countries and try to find out the context within which those particular procurement strategies might be working. From that we then, hopefully, will be able to provide some information, some results, which those interested in procuring construction in different parts of the world can actually move into that country and actually match the kind of procurement strategy with the context of that particular country. I suspect at the moment, a lot of contracting organizations, design organizations, are actually going out into the world and imposing their particular views, which may or may not be the right approach.

Dr. Lavers has alluded a little to that, the changes in Singapore and in Hong Kong; clearly these are not happening on an international basis. I worked in the Middle East, in New Guinea, and it seems to me that the kind of procurement strategies being imposed in those countries are not necessarily in the best interest of those countries.

The first thing that we are trying to do with the research and, as I said, we have now got the funding for two individuals to participate and develop these ideas, is to look at the contextual background to the particular countries in terms of legal, economic, political and social factors and I want to look at three different kinds of countries: obviously those developed, like Canada, United Kingdom, Western Europe; developing, such as the Middle East, and underdeveloped, such as in New Guinea, which I referred to. We want to look at the way that the country actually operates. A very large task to actually undertake, but if we can get some kind of feel for how those particular countries operate in terms of that context, then it may help us to develop the procurement strategies that should be used.

The second point we want to look at is, what are the formal and informal relationships between the participants in the construction process? What kind of formal links are established in terms of how procurement is carried out, where do the design individuals fit in, where do the contractors fit in, what kind of informal links also exist? We then want to look at what are the procurement methods operating within a particular construction industry in the countries falling within the categories? So we want to try to find out how they actually procure construction, with the various actors involved, against the context of that particular country.

We then want to look and see the underfall, and see what is the usage of the various types of procurement. What range do we actually get in the United Kingdom, for example, we have a very wide array of different procurement strategies, and so we want to try to find out, is there a consensus, is there a wide range of systems actually being used?

We then want to find, which is a fifth point, which I think is perhaps the most important, is there any correlation between the context now identified and the procurement method? As I said, I worked in New Guinea on three separate occasions and also in the Middle East, and it struck me, although I was not there a long period of time, that often the context of that particular country was not in harmony with the kind of procurement strategy that was actually being used. So that is really what we want to try to find out, is there a correlation? If there isn't a correlation, then maybe the results of our work should give some indication of the strategy that should be used, in terms of procurement.

A very arrogant assumption. I am not trying to suggest that we are going to lay down any guidelines or rules, but hopefully the results of our work may give people some information, some guidance on what to expect in a given country's environment and what kind of procurement might be worth pursuing.

The sixth point, how can a framework be developed to identify the most appropriate procurement method for a given set of circumstances, with particular relevance to an emerging country?

I think that is the background to our study. We are now embarking on that study. As I have said, we have got funding of around about £30,000. We hope that will provide at least one year of leg work of two individuals to try and gather this information. A lot of it is already there in literature, some of it we might have to go out into the field, and we are hoping that CIB will help us with that collection process, the actual assembly of the data and the identification of the relevant people to see, advice for in the various countries. So that is where we are at the moment. We have got some support from the World Bank, moral support in terms of their suggesting that what we are doing is very useful and could be very helpful to the construction industry, and my co-coordinator, who is, in fact, a lawyer from the Bar Nathonson in London, a large international legal company, and again, they are going to help with the secretarial, the actual distribution and collection of information as and when we get it. So that is where we are at, we are hoping to embark very shortly.

The next meeting of the commission will be in London in November of this year, following on from W87 and we hope that will be a reporting meeting, simply to advise how far we might have gone with that particular idea that I have tried to express to you today.

CONTRACTOR'S CLAIM AVOIDANCE

Dr. George F. Jergeas
Revay & Associates Limited, Calgary, Alberta, Canada

Introduction

In recent years, the number of construction claims have been increasing and have become a time consuming and costly element in construction projects. Today's highly competitive tendering environment highlights their importance.

Claims may arise on a construction project for the following reasons:

- inadequate bid information;
- inferior quality of drawings and/or specifications, giving rise to ambiguities in contract requirements;
- work different than that provided in the drawings and/or specifications;
- changes and extra work;
- change in anticipated method of construction;
- stop and go operations because of lack of coordination and lack of design information or material;
- work in congested area;
- faulty and/or late owner-supplied material and equipment; and
- acceleration to regain schedule by increasing labour force or material, i.e. add more men, working overtime or extra shifts.

Although no guarantees can be given that claims will be entirely avoided, there are certain fundamental means of reducing:
a) the number of claims encountered;
b) their effect; and
c) the time required to achieve resolution.
These essential steps are the focus of the paper.

The following guidelines will also facilitate early recognition of potential cost/time overruns and ensure preservation of contractual remedies.

Record Keeping

The first essential step is record-keeping procedures which monitor cost, time, scope and quality. Such a record system should contain the following:

- daily progress records;
- cost/labour reports;
- project correspondence;
- minutes of job sit meetings or other meetings;
- photographs and video films (dated);
- memoranda to the file;
- progress payments;
- delivery reports of permanent material;
- inspection reports;
- diaries;
- daily time records;
- daily force reports;
- daily production logs;
- expediting reports;
- exception reports;
- job schedules;
- change orders;
- daily equipment reports;
- drawings and specifications;
- shop drawings;
- transmittals;
- reports (soils, etc.);
- drawing logs; and
- accident reports.

Knowledge of the Contract

To understand contractual rights, obligations and liabilities, it is necessary to read the whole contract and appreciate that the words <u>will</u> be interpreted as written.

Special attention should be given to contract sections titled "Special" and/or "Supplementary Conditions". Articles in the general conditions dealing with the following matters should be particularly considered:[1]

- changes/extras;
- disputes;
- authority/roles/definitions;
- soil/site conditions;
- delay;
- payment; and
- notice provisions.

Contractor's Rights

The following is necessary to preserve contractual remedies:

- ensure site personnel know and satisfy all notice provisions;

- request appropriate extension of time;

- qualify change order to cover time extension and/or impact costs. Contractors should not waive claim rights by negotiating and signing off on change orders which only pay the direct costs. In such cases, contractors should consider indicating that the change only covers the direct costs incurred in performing the work;

- make clear who pays for acceleration; and

- wait for authorization before proceeding with changes and extra work.

Proactive Action

Contractors should consider the following:[2]

- respond as quickly as possible to every complaint, question or allegation;

- analyze job progress in detail prior to any job site progress meetings which are held. Such meetings should be used as a forum for discussing and notifying potential or current delays, extra work, etc.

- open cost codes when encountering disputed extra work;

- record in detail all delays and manhours lost, conflicts, discrepancies, etc.;

- obtain written confirmation of all oral instructions. If owner will not confirm in writing, contractor should write a confirmation letter to the owner;

- maintain a log of all drawings, submittals, change orders and proposals, pertinent correspondence and other like data for ease of reference and also to indicate changes; and

- review daily reports in detail and revise their format as necessary to better reflect potential claim areas such as extra work performed, delays, etc.

Planning and Scheduling

Planning is the spine of the whole project, and must be based on clearly defined objectives. With proper planning, adequate resources are available at the right moment, adequate time is allowed for each activity, and all activities start at the appropriate times.

Planning for contractors should include:

- forecasts of resource requirements of people, materials and equipment, and analyses for their most efficient use;

- forecasts of financial requirements; and

- provision of "milestones" against which progress can be measured.

Planning techniques range from simple bar charts to computerized network analysis. All the techniques are based on certain important principles:

- the plan should provide information in a readily understood form, however complex the situation it describes;

- the plan should be realistic;

- the plan should be flexible; and

- the plan should serve as a basis for progress monitoring and control.

Conclusion

There is no guarantee that claims will be entirely avoided. Avoiding disputes requires:

- understanding of the causes of claim;

- understanding of the contractual terms; and

- early non-adversarial communication.

The guidelines presented in this paper will assist contractors to reduce liability. Contractors' knowledge and implementation of these guidelines would benefit all participants in the construction process (including owners) since baseless claims can be counterproductive and very expensive.[4]

Using a proper project construction management is more cost effective than seeking advice of a construction claim consultant after the dispute has become entrenched.

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EXPERIENCE QUEBECOISE EN MATIERE DE PROTECTION FINANCIERE DES CONSOMMATEURS ACQUEREURS DE MAISONS NEUVES

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Pour l'instant le seul mécanisme de protection financière dont peuvent se prévaloir les consommateurs sont les plans de garantie offerts par des associations d'entrepreneurs (A.P.C.H.Q. et A.C.Q.). En effet, le cautionnement exigé par la R.E.C.Q. est d'un montant très minime de 5 000 $ et ne peut être utilisé qu'en cas de fraude.

Les plans sont offerts par deux associations d'entrepreneurs dont les membres oeuvrent dans le secteur résidentiel. Elles ont mis en marché depuis 1976, ces plans de guarantie qui sont au fond des cautionnements offerts par ces associations à leurs membres. Au terme de ces cautionnements, les associations s'engagent à réparer les bâtiments résidentiels couverts. Ces plans comportent aussi une garantie des acomptes et une garantie de parachèvement des travaux. Ces plans de garantie ont pris leur essor en 1982 avec le programme Corvée Habitation qui les rendait obligatoires.

<u>Problèmes sérieux quant à la protection financière offerte par les plans de garantie privés.</u>

Au cours des deux dernières années, à travers les plaintes des consommateurs, il a été possible d'identifier des problèmes sérieux quant à la protection financière offerte par ces plans:

- *Problèmes liés à la recherche de la garantie;* ainsi, malgré l'information qui leur est donnée à cet effet, nombre de consommateurs ne peuvent bénéficier de la protection offerte par les plans de garantie parce que leur vendeur ne s'est pas conformé aux exigences de ces plans (i.e.: non paiement de la prime ou vente par un promoteur plutôt que par le constructeur bénéficiaire de la caution, etc.).

- *Problèmes liés à la couverture de la garantie;* la notion de défauts cachés et de défauts majeurs couverts par les plans sont des notions floues et l'évaluation de ces défauts apparaît partiale; nombre de consommateurs voient les problèmes d'infiltration d'eau, de toiture qui coule, de fissures dans les fondations assimilés à des défauts cachés et leur plainte rejetée parce que portée plus d'un an après la réception des travaux, donc hors délai. A cet égard, il importe de noter que la couverture offerte par les plans ne couvre pas complètement la responsabilité légale de l'entrepreneur.

- *Problèmes liés au mécanisme de mise en oeuvre des plans;* par exemple, les délais d'intervention sont souvent très longs, et ce, particulièrement dans les cas où l'entrepreneur en défaut est encore en opération. Dans ce cas, les plans jouent dans les faits, un rôle d'arbitrage de responsabilité pour le moins fort délicat et source de frustrations importantes pour les consommateurs: correspondance interminable, longs délais d'intervention, etc. Ils sont par ailleurs réticents à accepter à titre de caution une responsabilité que l'entrepreneur refuse.

- *Problèmes liés au fait qu'il n'existe aucun contrôle gouvernemental* quant à la solvabilité de ces plans qui pourtant visent à assurer aux consommateurs une protection financière.

<u>Solutions envisagées pour assurer une protection financière adéquate</u>

- Bonification de ces plans offerts par des associations d'entrepreneurs sur une base volontaire.

- Négociations entreprises entre la R.E.C.Q., l'O.P.C. et les plans de garantie de l'A.P.C.H.Q. et l'A.C.Q.

- Intervention de l'Etat pour assurer une protection financière minimale.

- Réglementation des plans de garantie offerts quant au contenu, à la qualité de la personne qui offre ces plans, etc.

- Plan de garantie étatique, fonds d'indemnisation, cautionnement, etc.

GESTION DES RISQUES

Laurent Arsenault
Directeur de l'exploitation, "International Specialized Risk Management", Firme d'experts en sinistres, Canada

Pour vous situer rapidement, et je dois être très bref, ISRM est une entreprise spécialisée dans la gestion des risques. Les mandats nous sont confiés par le principal assureur sur le marché canadien, ainsi que par des ingénieurs et des architectes dans le cadre de leurs responsabilités professionnelles.

Le facteur clé à mon avis, du succès relatif de notre entreprise au Canada, vient du fait que les assurés de cette compagnie, sont tenus d'aviser leur assureur le plus tôt possible d'une possibilité de réclamation. Ce qui signifie qu'au stade où la réclamation possible nous est signalée, nous avons plusieurs possibilités d'interventions en vue de minimiser l'éventualité, ou plus concrètement, le coût rattaché à la solution des problèmes. Maître Gauthier a decrit la résolution des conflits et les différents modes de résolution des conflits. J'estime que nous nous orientons vers une collaboration plus grande et ce, pour une raison relativement simple: la hausse exhorbitante des coûts de tout le processus juridique ainsi que les délais inadmissible qu'il engendre. L'expérience au Canada jusqu'à maintenant a connus le succès du moins dans le sens où il n'y a pas eu de faillites d'assureurs en responsabilités professionnelles. Notre industrie mise fortement sur la prise en charge des problèmes le plus tôt possible, permettant ainsi de réduire énormément les délais. C'est la lenteur à corriger les difficultés qui donne parfois naissance au litige.

La pertinence d'intervenir est réelle, si on considère que dans plusieurs cas on peut se préoccuper malheureusement trop des considérations juridiques éventuelles en prévision d'un procès, et insuffisamment du problème réel concret qui donnerait naissance à un procès. La majorité des problèmes provient des plus petits projets qui, en fait, représentent notre pain quotidien, et il est remarquable qu'on accorde peu d'importance à règler le problème. Nous accordons souvent plus d'importance à nous protéger contre les risques futurs et à se préparée pour la bagarre en documentant tout, ou comme on dit en anglais: "laying a paper trail", Si on intervient tôt, avec les experts qui conviennent, nous ne laissons finalement à l'appareil juridique que le soin de définir et clarifier les questions nébuleuses, ce qui devient beaucoup plus avantageux d'un point de vue économique.

C'est dans le court temps qui m'est alloué, l'essentiel de mon message: l'importance d'une intervention prompte et du choix d'un expert. Il faut avoir des experts en choix d'experts possiblement pour faire un processus efficace et rapide et cette expérience là au Canada, nous l'avons vécue depuis une dizaine d'années avec le succès qu'on a et ça me fera plaisir de répondre à plus de questions puis de comparer peut-être certains cas concrets avec vous si vous désirez.

INSTITUT D'ARBITRAGE DU QUEBEC

Denis Gauthier
Avocat Droit commercial et corporatif
Président, Conseil d'administration de l'Institut d'arbitrage du Québec, Canada

Comme j'ai beaucoup de choses à vous dire, mais peu de temps, je me permettrai de référer à mes notes écrites afin de m'assurer de vous livrer l'essentiel de mon message.

Par la suite je pourrai m'adresser plus librement à vous puisque je répondrai à vos questions en espérant que vous en aurez et aussi que nous aurons le temps nécessaire.

Je tiens d'abord à remercier maître Dagenais de m'avoir invité à participer à cet atelier portant sur la responsabilité et la gestion des risques. Je suis avocat pratiquant le droit commercial et des sociétés, et je suis aussi Président du conseil d'administration de l'Institut d'arbitrage du Québec. Ne soyez pas inquiet, je ne parlerai pas d'interminables procédures judiciaires pour régler les litiges dans le domaine de la construction. Je veux plutôt que nous échangions nos idées et nos points de vue sur les solutions de rechange au règlement des conflits, comme moyen pouvant être utilisé pour régler de façon rapide, efficace et la moins coûteuse possible, les divers problèmes survenant dans le domaine de la construction.

Je veux simplement énoncer quelques idées qui alimenteront par la suite, du moins je l'espère, nos discussions. Je m'éloigne déjà de mon texte pour une seule minute pour vous dire que le seul but de mon très court entretien ce matin est d'attirer votre attention sur un phénomène sociologique relativement nouveau dans le contexte de la province de Québec. Ce phénomène est le suivant: le milieu des affaires comme le milieu de la construction qui cherchent de plus en plus résolument à régler les problèmes par d'autres méthodes que les méthodes habituelles que nous connaissons, c'est-à-dire les procédures qui se déroulent devant les Cours de droits communs. Je peux vous dire que nous assistons présentement, sans exagérer à ce que je pourrais appeler une véritable révolution quant à la façon de penser dans le milieu juridique. L'université nous a montré à régler les problèmes dans ce qu'on appelle l'adversité, alors que le règlement des problèmes par d'autres méthodes, telles que l'arbitrage et la médiation consistent plutôt à ce qu'on commence à appeler une justice douce. Il s'agit d'une toute autre approche qui présentement n'est pas très facile et acceptée de tous. Par contre, il s'agit d'un phénomène avec lequel il faut aujourd'hui composer et présentement, je peux vous dire que le barreau du Québec se penche sur ce nouveau phénomène et s'apprête à prendre les dispositions voulues pour que les services «d'ordre juridque», puissent être rendus aux parties qui en ont besoin suivant ce que j'appelle une nouvelle façon de penser, du moins dans le contexte juridique canadien.

Quand nous utilisons l'expression, «solution de rechange au règlement des conflits», connu du côté américain par l'abréviation «ADR», qui veut dire «alternative dispute resolution», nous nous référons aux diverses façons de régler les problèmes autrement que par les procédures habituelles devant nos Cours de justice. Nous pensons surtout à l'arbitrage, à la médiation et à la conciliation, même s'il existe un grand nombre d'autres modes de résolution des litiges. Je souligne immédiatement que la principale différence entre l'arbitrage et la médiation ou la conciliation est la suivante: dans les cas d'arbitrage, un tiers tranche la question, dans les cas de médiation-conciliation, les parties conservent le contrôle total de la situation, c'est-à-dire qu'une tierce personne joue le rôle de «facilitateur». Ce sont les parties elles-mêmes qui prennent les décisions finales, quant au règlement du problème. Quelques mots sur l'arbitrage. Dans la province de Québec, la notion d'arbitrage a énormément évolué depuis quelques années. A l'automne 1985, un important congrès international sur l'arbitrage s'est tenu à Québec, auquel congrès ont participé des juristes d'un peu partout à travers le monde. A la suite de ce congrès, les gouvernements fédéral et provinciaux ont modifié la législation.

Pour la première fois par exemple, une définition de la convention d'arbitrage a été insérée dans notre code civil. Les dispositions de notre code de procédures civiles, s'appliquent autant à l'arbitrage national, qu'à l'arbitrage international. Plus important peut-être que la législation, si je peux m'exprimer ainsi, notre pensée sociologique a beaucoup changé. De façon plus particulière, le sommet de la justice qui a eu lieu à Québec, en février dernier, semble avoir créé un nouveau dynamisme en faveur des solutions de rechange au règlement des conflits. La Chambre de commerce de Montréal a même adopté tout récemment, une déclaration de principes en ce sens.

Comme vous le savez sans doute, il existe d'autres sortes d'arbitrage: l'arbitrage ad hoc et l'arbitrage institutionnel. L'arbitrage ad hoc se déroule entre les parties et le ou les arbitres, sans aucun autre intervenant. L'arbitrage institutionnel, se déroule sous l'égide d'une institution spécialisée dans la domaine, comme par exemple, l'Institut d'arbitrage du Québec. A mon point de vue, l'arbitrage comporte beaucoup plus d'avantages que d'inconvénients.

Les avantages les plus reconus sont les suivants: le choix par les parties de personnes expertes dans le domaine soumis à l'arbitrage. Il y a comme vous savez, beaucoup de moins de formalisme que dans le cas des procédures régulières et une souplesse beaucoup plus grande. Il y a aussi l'aspect de la confidentialité.

En plus, l'arbitrage ne se déroule comme vous savez, qu'en présence des parties et de leur procureur. Il y a aussi toute la question de la rapidité avec laquelle un arbitrage peut se dérouler par rapport aux procédures ordinaires. L'arbitrage peut aussi être avantageux du point de vue des coûts, qui dans un grand nombre de cas sont moindres et, même dans les situations où les coûts sont égaux, je pense que les parties en sorte gagnantes, ne serait-ce que par la rapiditié avec laquelle on peut arriver à une solution ou à une sentence arbitrale.

Quant aux inconvénients, il faut mentionner qu'il n'y a pas d'appels en garantie possible à l'intérieur d'un même arbitrage. Il y a aussi le fait que l'arbitrage est sans appel, aspect perçu comme un inconvénient par certaines personnes et comme un avantage par d'autres, parce qu'on se dit qu'une fois que la sentence est rendue, on sait exactement à quoi s'en tenir et il n'est plus nécessaire de se présenter à des paliers supérieurs de justice. Enfin, c'est une question d'opinion. D'autre part, les arbitres doivent créer eux-mêmes leur crédibilié et leur autorité morale. Comme vous le savez, l'arbitre ou les arbitres sont choisis par les parties, et il ne s'agit ordinairement pas de personnes qui portent ce que j'appelle "l'auréole d'un titre officiel". L'arbitre doit donc s'imposer par ses connaissances et par son ascendant moral auprès des parties.

Quant à la médiation et la conciliation, rappelons encore une fois que contrairement à l'arbitrage, le problème n'est pas tranché par une tierce partie. Ce sont les parties elles-mêmes, qui décident de l'issue. Le médiateur ou le conciliateur est un facilitateur, c'est-à-dire une tierce personne dont l'objectif est d'essayer de rapprocher les parties entre elles. Une distinction de sémantique doit être ici apportée. Le médiateur à l'origine s'engage, c'est-à-dire qu'il fait des recommendations aux parties, tandis que dans le cas de la conciliation, le conciliateur ne fait que transmettre d'une partie à l'autre, le pour et le contre de l'argumentation. De toute façon, je ne crois pas opportun de nous attarder maintenant sur ces questions de sémantique.

Il y a également d'autres solutions de rechange au règlement des conflits. On dit qu'il y en a trente-huit. Je ne ferai qu'en mentionner que quelques autres, tels que le "mini-trial" et la formule "rent a Judge" qui vient des Etats-Unis. Je trouve important de souligner l'existence d'une autre solution de rechange qui semble se répandre de plus en plus aux Etats-Unis dans le domaine de la construction, le «Dispute Review Board».

Il s'agit d'un comité, ordinairement formé de trois personnes, (selon l'entente entre les parties), qui est constitué au début d'une mise en chantier et dont la fonction est de régler les problèmes rapidement, au fur et à mesure qu'ils surviennent. Pour répondre à une question que Maître Dagenais m'avait posée: «Par exemple,si une poutre tombe, qu'est-ce qu'on fait?» Il ajoutait: «Comme vous le savez, beaucoup plus que moi, il y a toutes sortes de questions qui peuvent se poser. Qui est responsable? Qui doit la réparer? De quelle façon etc, etc.» S'il n'y a pas d'ententes entre les parties à ce moment, le «Dispute Review Board», siège dans le plus bref délai et règle le problème tout de suite.

Je crois que la rapidité d'exécution tout comme la rapidité de la communication, sont aujourd'hui un phénomène mondial. Quelles solutions trouver pour appliquer ces normes de rapidité et d'efficacité à la gestion juridique des risques? Telle est notre sujet de discussion aujourd'hui.

La MONDIALISATION DE LA CONSTRUCTION À LA LUMIÈRE DE L'EXPÉRIENCE DU GROUPE DE TRAVAIL CIB W87, *RESPONSABILITÉ ET ASSURANCE POST-RÉCEPTION*

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Une mondialisation véritable des travaux de construction et de l'industrie des matériaux est-elle possible tant que les responsabilités post-réception des constructeurs seront si différentes d'un pays à l'autre? Pour répondre à cette question il est utile de comparer la structure des "systèmes" en vigueur dans différents pays.

Le mot "système"

Le régime de responsabilité post-réception est la somme des garanties dont jouit le maître de l'ouvrage, pendant une certain période après la réception de l'ouvrage, en ce qui concerne les désordres qui peuvent l'affecter et qui sont dûs à une faute commise par ses constructeurs.

Les termes soulignés sont explicités plus loin.

Aux régimes de responsabilité s'ajoutent les couvertures financières de ces garanties "post-réception." Dans la pratique cette couverture est fournie par l'assurance, bien qu'il faille souvent mettre à part la responsabilité des entrepreneurs qui ne s'assurent que dans peu de pays. Plusieurs questions se posent alors: la couverture de l'assurance correspond-elle exactement à la garantie, en envergure et en temps? Qui peut et qui doit s'assurer? Les réponses, évidemment importantes, diffèrent selon les pays; ici elles ne sont qu'esquissées.

Le régime de responsabilité, plus la manière de couvrir la garantie, constituent un "système."

Les systèmes peuvent être nationaux, ···

Tous les systèmes analysés par le Groupe de travail CIB W87 s'avèrent être nationaux, dans le sens qu'il n'y a pas deux pays qui appliquent des systèmes identiques. Il est intéressant de noter que, par exemple, les Communautés Européennes s'abstiennent, au moins pour le moment, de viser la mise sur pied d'un système communautaire, tellement les systèmes, même au sein des seuls pays de la CE, divergent; qui plus est, ils semblent se développer indépendamment les uns des autres.

··· ou régionaux, ···

Dans plusieurs pays — Canada, Etats Unis d'Amérique, Royaume Uni — les systèmes suivent des circonscriptions administratives.

··· sectoriels, ···

C'est une règle presque générale que plus d'un système est appliqué à l'intérieur de chaque territoire. Le système à appliquer dépend alors le plus souvent du secteur de construction visé, c'est-à-dire de la destination de l'ouvrage. C'est surtout — mais pas uniquement — la distinction résidentiel/non-résidentiel qui joue.

··· et peuvent même varier avec le statut du maître d'ouvrage ou avec le financement de l'ouvrage.

Dans certains pays, le système à appliquer dépend du statut du maître d'ouvrage. Au Portugal, par exemple, le maître d'ouvrage public applique un système différent de celui du secteur privé, et dans d'autres pays aussi la responsabilité post-construction selon le droit civil est distincte de celle du droit administratif. Egalement, la provenance du financement peut déterminer lequel parmi les systèmes du pays s'appliquera; tel est, par exemple, le cas au Danemark et en Suède.

C'est donc d'une multitude de systèmes que le Groupe de travail a pu tirer des leçons. Les différences bien fondamentales entre les pays ressortent d'une manière éclatante d'une comparaison des mots clefs.

Les termes utilisés

Maître d'ouvrage et propriétaire(s) successif(s)
Le maître d'ouvrage est la personne, physique ou morale, pour qui l'ouvrage est construit.

Dans certains systèmes, chaque propriétaire successeur du maître de l'ouvrage jouit automatiquement des mêmes garanties que lui — la garantie suit l'ouvrage — ; dans d'autres, ces droits peuvent être transférés mais ne le sont pas d'office; et dans certains encore, un propriétaire autre que le maître de l'ouvrage peut faire jouer les garanties uniquement d'une manière quasi-délictuelle ("in tort" en anglais) — la garantie suit alors le maître d'ouvrage.

L'ouvrage
Les ouvrages dont il est question sont les bâtiments. Pour évident que puisse paraître le sens de ce mot, aucun pays n'en a pu donner une définition exhaustive et limitative, bien que dans des pays, tels le Danemark et la France, où la loi a instauré une obligation d'assurance qui s'applique uniquement aux "travaux de bâtiment", il importe de définir le terme, ce qui ne se fait pas nécessairement de la même manière partout.

Les délais
Le début de la période pendant laquelle le maître de l'ouvrage ou, le cas échéant, un successeur peut faire appel aux garanties est presque toujours le moment de la réception. Le système français fait exception en ce qui concerne l'isolation phonique dans le résidentiel, où le début coïncide non avec la réception mais avec l'occupation effective de l'ouvrage. Autre exception, le Royaume Uni: décrire les règles qui définissent, en Angleterre et en Ecosse, le début et la fin les délais ne peut se faire dans un bref exposé.

Dans de nombreux pays, il y a deux réceptions successives, l'une "provisoire" et l'autre "définitive." Par exemple en Belgique, le début peut se définir ou bien par l'une ou bien par l'autre. Mais dans la plupart des systèmes, c'est bien la dernière réception qui est déterminante.

La fin de la période de garantie se situe un certain temps après la réception pertinente.

Au Royaume Uni, la garantie contractuelle est souvent de six mois, mais elle est suivie d'une période, au début variable, pendant laquelle le propriétaire, et certaines autres personnes, peuvent, dans de certains cas de désordres, réclamer une compensation des constructeurs. Ailleurs, la garantie — contractuelle, légale ou les deux — peut durer un an (Portugal), deux ans (Suède), ou dix ans (Italie); en France, la garantie est biennale pour les éléments "dissociables" et décennale pour d'autres, tandis qu'au Québec, où la période est de trente ans, le régime de la garantie change en cours de route.

Les désordres
Egalement, eu égard à la définition du fait duquel le constructeur est responsable, aucun système ne ressemble à l'autre. Dans l'un, il y a "désordre" si le bâtiment, pour une raison ou une autre, ne peut être considéré comme "propre à sa destination", tandis que dans un autre il faut qu'il y ait pratiquement "ruine" pour qu'il y ait "désordre." Entre ces deux extrêmes, le droit et la jurisprudence varient. Des mauvaises odeurs émanant du sous-sol, par exemple, rendent-elles un immeuble d'habitation impropre à sa destination? Oui pour les uns, non pour d'autres. En plus, le concept "propre à la destination", important dans tous les systèmes, change, à l'intérieur d'un même système, avec le temps. La tendance semble être un élargissement de la protection du maître d'ouvrage, une protection qui, pour justifiée qu'elle puisse paraître, se paie nécessairement.

La faute
Ici encore, on trouve des systèmes bien différents. Dans certains cas, dès qu'un désordre est constaté, le constructeur en est responsable "de plein droit": il est présumé avoir commis une "faute" même si personne ne peut identifier ladite faute; le constructeur est alors soumis à une "obligation de résultat." Dans d'autres systèmes, le constructeur est soumis à une obligation dite "de moyens", c'est-à-dire qu'il peut valablement faire valoir qu'il a agi selon sa compétence — qui doit quand même être "raisonnable" — et selon les règles de l'art, telles qu'elles étaient au moment de l'exécution de son travail; selon cette doctrine ce n'est alors la "faute de personne" si le résultat souhaité n'a pas été obtenu, c'est-à-dire que le maître de l'ouvrage subit la perte.

La différence est, bien entendu, fondamentale.

Les constructeurs
Qui est "constructeur", c'est-à-dire responsable vis-à-vis du maître d'ouvrage? Les réponses sont loin d'être uniformes.

Partout, sauf à Singapoure qui constitue un cas particulier, l'entrepreneur est bien un constructeur, et donc responsable vis-à-vis du maître de l'ouvrage en cas de désordre. Les réponses se nuancent pourtant quand on s'interroge sur les sous-entrepreneurs. Au Royaume Uni, par exemple, un maître d'ouvrage a pu réclamer réparation d'un sous-entrepreneur sans passer par le "donneur d'ordres" (l'entreprise contractante), et ceci serait possible, bien qu'en pratique exceptionnel, en d'autres pays aussi. Le même principe s'applique aux sous-traitants conseils.

Architectes et bureaux d'études — les maîtres d'oeuvre ou, en Allemagne, les "auteurs de projet" — sont presque partout considérés comme constructeurs, mais pas en Italie, au Portugal et à Singapoure.

Les contrôleurs techniques sont — sauf par exemple en Italie — des constructeurs; mais au Portugal et en France, bien que l'entrepreneur soit soumis à une "obligation de résultat" (voir ci-dessus), le contrôleur n'est soumis qu'à une obligation "de moyens". Au Royaume Uni et en Scandinavie, le bureau municipal de contrôle est soumis à une responsabilité quasi-délictuelle, mais au Royaume Uni, sa responsabilité est limitée proportionnellement à la valeur des travaux, ce qui n'est pas le cas dans d'autres systèmes.

Normalement, les fournisseurs, sans contrat avec le maître d'ouvrage, ne sont pas responsables vis-à-vis de lui, sauf éventuellement "in tort." La seule exception connue est la France: là, certains fournisseurs, plus ou moins bien définis, sont responsables solidairement avec l'entrepreneur qui a mis en oeuvre leur produit.

Enfin, à Singapoure, le système prévoit obligatoirement la nomination d'une "personne qualifiée" envers qui le maître de l'ouvrage peut se tourner en cas de désordre.

Discussion: La mondialisation de la construction et les "systèmes"

Une grande variété existe donc dans les obligations et, partant, dans les polices d'assurance offertes et parfois imposées aux constructeurs, et, le cas échéant, aux maîtres d'ouvrage. Cette abondance de variantes excluent-elles effectivement une mondialisation des études, des travaux, du contrôle et des fournitures de la construction? Tel acteur, qu'il désire agir comme fournisseur, constructeur ou maître d'ouvrage en dehors de son pays, et qui, de par son éducation et ses expériences, n'est au fait que des systèmes de son propre pays, n'aura-t-il pas de grandes difficultés à adopter un comportement professionnel optimal ailleurs? Ne sera-t-il pas, pour ainsi dire d'office, défavorisé par rapport à ses confrères de l'autre pays? Et pourra-t-on alors honnêtement parler de concurrence internationale équitable?

Il semble pourtant que les très grands cabinets d'architectes et d'ingénieurs-conseils ainsi que les très grosses entreprises de travaux n'éprouvent pas trop de difficultés à travailler dans des pays autres que le leur. Ou bien ils doivent se procurer l'expertise étrangère nécessaire, ou bien ils ouvrent une filiale dans l'autre pays laquelle contractera directement; dans les deux cas, ils encourent des frais généraux supplémentaires par rapport aux cabinets et entreprises nationaux. Et les moins grandes entreprises et les bureaux et cabinets de taille moyenne, y arrivent-ils? De même, pour les fabricants de matériaux désireux de se "mondialiser", l'expérience semble montrer que les différences fondamentales dans les systèmes créent des obstacles réels à leur mondialisation, et, ici encore, surtout pour les petites et moyennes entreprises. Il y aurait donc bel et bien distorsion de la concurrence à tous les niveaux.

Le domaine pharmaceutique est peut-être "exemplaire" à cet égard. En effet, il arrive que l'on passe aux essais grandeur nature dans un pays où les dommages et intérêts sont modestes avant de lancer le produit dans les pays plus exigeants en matière de responsabilité, en misant sur le fait que les essais valent bien les dommages à payer en cas d'accident. Peut-on s'attendre à un comportement semblable dans le domaine des procédés et des matériaux de construction? Selon un juge à la cour des Communautés européennes, cet aspect de la mondialisation de la construction mériterait réflexion.

Que faire?

Pendant ses premières années d'existence, le Groupe de travail W87 s'est limité à comparer les systèmes nationaux. Il est maintenant prêt à mettre en relief les difficultés. C'est sans doute faire la partie ingrate du travail, car proposer des systèmes flambant neufs serait bien plus glorieux. Mais il n'est écrit nulle part que la recherche doive toujours être glorieuse.

Legal Responsibility in Construction: A Distinctive Far East Approach

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Introduction

Singapore, Malaysia and Hong Kong share a common law background with other Commonwealth countries, such as Britain, Canada, Australia and New Zealand. There is close legal identity in terms of the structure of the courts, the legal profession and the legal tradition. The closeness extends to substance to a large extent, with British and other Commonwealth precedents cited in Singapore, Malaysia and Hong Kong and to some extent subject to continuing reception there. Statutes too, especially in the commercial sphere, may become applicable through adoption. Singapore and Hong Kong continue to have civil appeals heard by the Judicial Committee of the Privy Council, as did Malaysia until 1985. In procurement systems too there are recognisable similarities with standard form building contracts in all three countries showing their initial derivation from the JCT family of forms. However, in the area of definition of roles and duties in the construction process there has been divergence from the soi-disant 'developed' systems. Singapore, in particular, now has a statutory model, containing echoes of Malaysia and Hong Kong, which is different from that in any other construction system. Its hall-mark is tight statutory definition of the principal protagonists and of the parts which they have to play. While the principal purpose of the legislation is not to regulate civil liability by providing remedies, it is submitted that there are consequences for the responsibility and risk exposure of the personnel concerned.

The purpose of this paper is to explain the Singapore approach, with some reference to comparable features with Malaysia and Hong Kong.

The background

The impetus for producing the present Singapore system was the Hotel New World disaster of March 1986 in which great loss of life was caused by the major collapse of a six-storey hotel/commercial complex in the Indian quarter.

The Commission of Inquiry which reported on the disaster was examining a system which was regarded as one of the strictest in the region and which in theory seemed to contain adequate safeguards against poor quality design and construction. The principal figure in the process was the 'qualified person', required by the Building Control Act 1973 to be a registered architect or professional engineer. The professions in Singapore are statutory professions with mandatory qualification and registration. This 'qualified person', appointed for every project, had to submit signed plans, specifications and calculations to the Development and Building Control Division (DBCD) of the Public Works Department (PWD) and then signed certification to the effect that he/she had "supervised the erection of the building" so that it was "in accordance with the relevant regulations plans and conditions under which such plans and amendments... were approved".

The Commission of Inquiry discovered that the formal approval by the DBCD and the qualified person's signature and certificate of supervision were often merely nominal. The building in question had suffered from serious under-design, miscalculations in loading and non-compliance with both the approved design and the Building Control (Construction) Regulations. A number of abuses were revealed. Virtually all of the design work had been carried out by unqualified personnel and signed by a qualified person. No supervision had occurred and the certificates of supervision had also been signed. The DBCD's approvals had appeared to be based on little more than ascertaining that the signatures were those of a qualified person. Under Singapore law no civil liability could accrue to the DBCD (or any other government body) in respect of approvals. The qualified persons in question were dead and the developer, who also undertook the construction, was killed in the collapse.

Reform of design and supervision responsibility

Following the Commission's report, a Building Control Working Committee studied the systems in Hong Kong, Japan, Britain and West Germany. The outcome was undoubtedly a contribution to what became law in May 1989, the Building Control Act 1989.

1) **The role of the DBCD and the accredited checker**

Singapore's legislature, in considering the role of the DBCD, resolutely set its face against imposing further liability upon the Building Authority and its officers. This is by no means unique. Hong Kong's Building Ordinance contains a provision to the effect that the Building Authority is immune from suit arising from the exercise of its statutory powers. This is also consistent with the decision of the High Court of Australia in Sutherland Shire Council v Heyman (1985) 60 A.L.R. 1 and more recently with the House of Lords decision in the UK in Murphy v Brentwood District Council (1990) 3 WLR 414, although those decisions do not amount to total immunity from suit as the Singapore and Hong Kong statutory provisions do. Despite this firm rejection of potential civil liability, it appears that in the period after the Act the DBCD has sought to recruit further professionally qualified staff in an effort to make its function more than nominal.

Nevertheless, Singapore has not assumed that the DBCD can realistically monitor either the adequacy of submitted plans or the question as to whether proper supervision has been given. The Commission of Inquiry had noted that "the heart of the problem is that supervision is not enforced at all". Even though DBCD inspectors take a somewhat more proactive role than previously, it is not the intention that this level of control would be sufficient, instead, a new level of monitoring has been introduced, namely the accredited checker.

Section 6 of the Building Control Act 1989 introduced a form of 'privatised' building control in some respects similar to the 'approved person' concept of Section 17 of the UK's Building Act 1984. However, the level of scrutiny envisaged by the Singapore legislature is beyond building authority officer level. Singapore's Building

Control (Accredited Checkers) Regulations 1989 set the required qualifications of the accredited checker at a high level, namely 10 years post-registration practical experience of the design or construction of buildings in Singapore. They are also required to be distinguished in their profession by virtue of their ability, standing or special knowledge/experience. This is a significant departure from the typical building authority standards in Britain. Sir Douglas Frank Q.C. sitting as a judge in Stewart v East Cambridgeshire District Council (1979) 252 E.G. 1105 said that he should "bear in mind that a building inspector has limited qualifications; ordinarily he is not a civil engineer, architect or chartered surveyor and cannot be expected to the vested with the expertise of those professions". The same might have been said of the limitations of building inspectors in Singapore where immunity from liability may not have helped to achieve the highest standards or at least the greatest vigilance. The accredited checker concept bears a closer relationship perhaps to Germany's Prufingenieure, and its is noteworthy that the Working Committee visited the Federal Republic during its study tour. The 'qualified person' is subject in his/her design work to the scrutiny of a highly qualified member of the engineering profession whose task is to augment the limited scrutiny of the building authority.

2) The site supervisor and augmentation of supervision

The qualified person had previously been required by the Building Control (Administration) Regulations 1979 to sign certificates of supervision, but the Commission of Inquiry's investigations suggested that such signatures were often issued on the basis of little actual knowledge of compliance of the work with the Building Control (Construction) Regulations or indeed with the approved design. "Qualified persons" i.e. architects and engineers normally exclude "constant supervision" from their duties in their standard form Conditions of Engagement, but the legislature now regards it as essential, referring to it as "immediate supervision". For projects exceeding $10,000,000 (approx Can $7,000,000) a full time qualified resident engineer must be employed to supervise the structural element of a building. For smaller projects 'concreting, piling, pre-stressing, tightening of high-friction grip bolts and other critical structural works' must be carried out under the immediate supervision of either a clerk of works or the 'qualified person'. The DBCD has indicated that it will make efforts to ascertain whether this more exacting level of supervision is being observed, by instituting random checks. Certainly the tighter definition of supervision means that the 'qualified person' has little scope for denial of responsibility if defects occur due to lack of conformity with the Regulations. The concept that certain critical structural works should receive a degree of qualified supervision, notwithstanding the designer's rejection of 'constant supervision' is not entirely new. The Ontario Court of Appeal in Dabous v Zuliani (1976) 68 D.L.R. 3d 414 would not accept that telling a contractor what was to be done and assuming that it had been was a sufficient discharge of the designer's duty to the client. Where such a fundamental element as a chimney was concerned, the Court was of the opinion that an opportunity for inspection should have been reserved but that, failing that, the contractor's work should have been examined, even if this meant that the concealing gyprock had to be stripped back. However, it is believed that Singapore is the first system which requires immediate supervision where the practice was only of irregular supervision.

3) **The builder**

The client is now required to appoint a builder by Singapore's Building Control Act 1989. Hong Kong's Building Ordinance also contains a party identified as a 'registered contractor'. The intention seems to be to place an additional and strict responsibility upon the contractor, namely to ensure that the building works are carried out in accordance with the Building Control Regulations 1989 and with the approved design and any conditions imposed upon it. Further, the builder appointed must notify the DBCD of any contravention of the Building Control Act or Regulations. The extent to which this may affect the builder's obligations and to which it is consistent with his traditional role is considered further below.

4) **The periodic structural inspection**

After the Hotel New World disaster, owners of buildings erected by those who constructed that building were required to have structural inspections. Under the Building Control Act 1989, this measure has been turned into a full-scale statutory system of mandatory periodic inspection. Non-residential buildings may be required to be inspected every 5 years and residential and 'special' buildings (at least 90% residential by floor space) may be required to be inspected every 10 years, although all kinds of houses are excluded. There is no perceived problem with low-rise buildings.

The inspection must be carried out at the owner's expense by a registered professional engineer from the civil or structural discipline. The inspecting engineer's precise duties are set out in the Building Control (Inspection of Buildings) Regulations 1989, including a visual inspection of condition and a report on the condition, loading, any additions or alterations and recommendations for any further inspection or testing needed. The report must be sent to the DBCD to appraise the need for further action. Responsibility for ensuring that the inspection is made and the report submitted is shared by the owner and the professional engineer. It should be noted that the inspecting engineer cannot be any of the personnel associated with design, construction or supervision of the project. The qualified person, accredited checker and site supervisor are all ruled out for these purposes.

Civil responsibility and post-construction liability

As has been stated, the purpose of the 1989 legislation in Singapore, or for that matter of the respective systems in Malaysia and Hong Kong, is not to create mechanisms for the recovery of civil damages. Nevertheless, it is submitted that there are major liability implications for the new building control regime.

a) **The qualified person**

The qualified person has a closely defined role in Singapore law. This must have an impact upon the contractual obligations of the qualified person with the client. The qualified person as designer is not only under a duty to comply with the Building Control Regulations but to report any disconformity with them to the

Building Authority. This obligation must form part of the contractual obligations of the designer to the client. It must form part of the tortious obligations of the designer to third parties, although Singapore, Malaysia and Hong Kong are all subject to reception of common law and can be expected to follow the Murphy v Brentwood District Council (1990) 3 WLR 414) limitations on recoverability of economic loss in tort. The qualified person as supervisor is also in a very weak position to argue that the contractual duty to the client is to do something less than the fulfilment of the qualified person role. In the UK and other jurisdictions designers, especially architects, seek to argue that the express terms of a standard farm contract exclude any responsibility for supervision of construction at all. This argument is not restricted to partial services only, but extends to the situation where the architect is in a management role as the client's 'lead consultant'. It is not intended in this paper to enter that debate, but in Singapore the Conditions of Engagement of the Singapore Institute of Architects (SIA) carry a similar purported restriction in the role of supervision. If the architect in question is a qualified person carrying out the immediate supervision role required, it is difficult to reconcile that role with such a contractual limitation. To put it at its crudest, can the architect/engineer undertake to act as the 'qualified person', an appointment which the owner must make, but deny in his contract that he will be, or will be responsible for, carrying out that role? Is the architect/engineer supervising as a qualified person or not? It is true that the appointment of a clerk of works or resident engineer may reduce by a percentage the degree of liability which the architect/engineer is obliged to bear and the effect of these appointments is considered below, but there are projects in which they do not have to be employed. In any event, the U.K. cases such as Kensington and Chelsea and Westminster Area Health Authority v Adams Holden and Partners (1984) 331 BLR 57) see such an appointment as a reduction of supervision liability not its replacement (in that case 20% to the clerk of works, 80% to the architect).

It is one of the conclusions of this paper that an architect or engineer is liable to the client in contract both for design and supervision, which is inadequate to fulfil his role as qualified person if so appointed. That liability may be extended in tort to third parties (subject to the modern law on recoverability); that tort may be negligence or, even more attractive to a plaintiff, the tort of breach of statutory duty, which would not require proof of culpability or fault on the part of the defendant, merely a breach leading to loss or damage.

b) **The accredited checker**

The accredited checker is employed by the client to check the qualified person's design for compliance with the Building Control Regulations. The accredited checker certifies that the detailed structural plans checked "do not show any inadequacy in the key structural elements of the building." The certificate is provided to the DBCD but is clearly relied upon by the client. If the accredited checker missed such an inadequacy through negligence, he could be liable to the client (and again through tort to a third party). But there is a difference from the position of the qualified person who fails to supervise as he should. The Building Control Act refers to the accredited checker certifying "to the best of his knowledge and belief". There must be a defence here of 'reasonable care and skill'.

Accredited checkers will in that sense find it easier in some circumstances to mount a defence than the qualified person. However, if they are negligent, they will be liable. Their liability will not be removed by the fact that the qualified person produced and signed the plans, any more than the qualified person's will be removed by the presence of the accredited checker. It is worth noting that accredited checkers should presumably be judged by the standard of the ordinary competent accredited checker rather than the ordinary competent engineer.

It is a conclusion of this paper that accredited checkers may be liable to clients in contract and third parties in tort for negligence in their checking of the structural plans and calculations.

c) **The site supervisor**

This level of appointment, now mandatory for large projects to ensure the adequacy of key structural works, does not replace the responsibility of the qualified person for supervision. Rather it is meant to enable the qualified person's certificate of supervision to be based upon knowledge rather than belief or hope. The site supervisor is employed by the client and may be liable for breach of contract and/or tort for the neglect of his/her duties. But the existence of that fact does not negate the primary responsibility of the qualified person who signs the certificate of supervision. If the qualified person relied upon the site supervisor there may be a reduction in the extent of his liability, and it is conceivable that he will have acted with reasonable care and skill, so as to be able to resist liability altogether. But the point to make here is that the presence of a site supervisor does not negate the duty and possibility of recovery as between client and qualified person.

d) **The builder**

Clearly the builder owes a contractual duty to the client and potentially a tortious duty to third parties.

The possible effect upon civil liability of the statutory imposition of the role consists in the obligation of the builder to notify the Building Authority of contraventions of the Building Control Act or Regulations. The burden of proof is placed upon the builder to show the defence that he did not know nor reasonably could have discovered the contravention or non-compliance. If the builder could not discharge that burden, i.e. proving that a contravention in the design (for example) was beyond his knowledge, the effect would be to say that he knew or should have known of a problem in completing the building. There are remarks in the Canadian case of Brunswick Construction v Nowlan (1974) 49 D.L.R. 3d 112) and the English case of Equitable Debenture Asset Corporation v William Moss Group (1984) 2 Constr L.R. 1.) to the effect that a builder may owe a duty to a client to advise upon an obvious lack of buildability of a design. See, however, the Scottish case of University of Glasgow v William Whitfield and John Laing Construction (1988) 42 B.L.R. 66) which makes it clear that there is no general duty upon a contractor to check the design. In the Singapore system the accredited checker, not the builder, has this task.

Nevertheless, a clear sequence of events can be identified which highlights a potential source of liability to contractors. The Building Authority need only find a contravention of the statute in the design to prosecute the builder for failure to inform them of the contravention. (Action could also be taken against the qualified person and the accredited checker and interestingly perhaps against the site supervisor/clerk of works if the deficiency was very obvious). The burden of proof is upon the builder to show that it was not reasonable to expect him to detect the failure. If he cannot succeed in doing so, the implication is that it was reasonable to expect him to detect the failure, which would be an enormous advantage to a plaintiff client or third party in bringing a civil action against him and having only to succeed on a balance of probabilities.

e) **The inspecting structural engineer**

The engineer who inspects a building is engaged under a contract by the building owner, who may well not be the original client. Any action which this owner may have had against any of the personnel who constructed the building may in effect have disappeared, due to lack of privity of contract, limitation, restricted recoverability in tort, absence of collateral warranty or mere disappearance/insolvency of the parties. The owner will certainly read the report, although the Act and the Building Control (Inspection of Building) Regulations 1989 only require that they should be sent to the DBCD. If the owner relies upon the report and suffers loss, including economic loss, it would seem to be recoverable in contract if the inspection was negligent, in breach of the implied term of reasonable care and skill. The inspecting engineer would be expected to interpret and recommend in his report as well as observing and describing. The duty must be similar to that of the structural inspection described in the English case of Daisley v B.S Hall (1973) 225 E.G. 1553). "to see the things that the average skilled professional in that field would see, draw from what he sees the conclusions that the average skilled professional would draw and take the action that the average skilled professional would take. "A failure to produce a useful report would be an actionable breach of contract with the client. An action in tort by an injured third party might also lie against the inspecting engineer, including an action for economic loss (see Smith v Eric S. Bush (1989) 2 WLR 790).

Insurance

Because the legislation was not intended to provide civil remedies it does not include requirements for insurance. The above comments on civil liability are of course subject to the defendants having resources to meet the claim. There is no mandatory system of insurance in Singapore of, for example, the French type. Many professionals, both architects and engineers, practice without cover, or with a low level. However, there are indications of awareness of the need to improve this situation. The Association of Consulting Engineers of Singapore has been active in securing the arrangement of a professional indemnity scheme for its members. Furthermore, there are signs of legislative concern. The recent Architects Act 1991 was passed primarily to permit architectural practice by a corporation (see also the

Professional Engineers Act 1991) following the unreported case of BEP Akitek v Pontiac Land (1991) in which it was held that a corporation could not recover professional fees because it could not be a registered architect. Section 24 of the new Act requires that every corporation licensed to practice "shall be insured against liability for any breach of professional duty arising in the conduct of its business of supplying architectural services in Singapore as a direct result of any act, error or omission committed by the corporation or its directors, managers, secretaries or employees".

Conclusion

The Singapore system, and to a lesser extent the Malaysian and Hong Kong systems which have comparable features, seeks to achieve better quality building by a strict system of building control with an emphasis on the individual responsibility of identified personnel, whose duties are closely defined. Its effect, while secondary to its purpose, is to influence considerably the risk exposure of the professionals who work under it. The effectiveness of recovery of civil damages under such a system will to some extent depend upon further progress being made in establishing a comprehensive insurance coverage, particularly professional indemnity insurance.

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LES MARCHES PUBLICS

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Je vous remercie Monsieur le Président d'avoir choisi le représentant d'un petit pays comme la Belgique pour vous entretenir d'une question aussi vaste. Les marchés publics.

Il est vrai que notre pays a une longue tradition de réglementation des marchés publics et que celle-ci a servi de modèle aux institutions européennes. Elle a servi de modèle pour la mise au point des spécifications générales des marchés financés par les institutions européennes et plus particulièrement, au fond européen de développement, pour tous les marchés financés par les communautés européennes dans le tiers monde, notament en Afrique. C'est la réglementation belge qui est à la base des spécifications européennes dans ce domaine et c'est aussi la réglementation belge qui a servi de modèle aux nouvelles directives européennes en matière de procédures d'attribution des marchés publics européens.

Je ne sais pas si les fonctionnaires européens se sont servis de la réglementation belge parce qu'ils l'a trouvaient bonne ou parce qu'ils se trouvaient à Bruxelles ou s'il était tout simplement plus facile pour eux de l'utiliser. Je vais tout de même tenter de vous convaincre en quelques minutes que la réglementation européenne fonctionne bien et sous certains aspects peut toujours servir de modèle à d'autres pays ou d'autres institutions. Cela étant dit, tout en étant honoré d'avoir été choisi pour traiter de ce sujet, je me suis posé la question suivante: n'y a-t-il pas un piège, un guet-apens à me demander d'aborder la question des marchés publics dans le cadre de notre débat de ce matin sur la responsabilité et la gestion des risques? Lorsqu'on analyse le contenu des obligations des parties dans un marché de construction, dès qu'on aborde les aspects techniques et concrets de l'exécution des contrats, on se rencontre des similitudes entre les marchés publics et les marchés privés. Or, il existe une distinction fondamentale entre les marchés privés et les machés publics. Les marchés privés sont conçus pour satisfaire des intérêts privés, tandis que les marchés publics sont conçus pour satisfaire des besoins d'intérêt général, d'intérêt public. A tout le moins nous pouvons l'espérer.

Et c'est pourquoi il existe toute une réglementation spécifique des marchés publics, qui touche particulièrement l'attribution ou la passation des contrats. Je n'aborderai pas cette question ce matin, mais plutôt certaines règles de base qui se retrouvent dans la réglementation belge et qui ont eues pour effets de diminuer le nombre de litiges, de prévenir les désordres, ou à tout le moins d'en diminuer le nombre, tout en asssurant la bonne tenue dans le temps des ouvrages mis en oeuvre.

Un des soucis majeurs des clients publics est de bien sélectionner l'entrepreneur qui se chargera des travaux de mise en oeuvre. C'est tout le problème de la sélection qualitative de l'entreprise, de la vérification des aptitudes à réaliser les travaux publics et à cet égard, nous avons mis sur pied en Belgique un système de listes officielles d'entrepreneurs.

C'est-à-dire que tout entrepreneur pour solliciter des marchés publics, doit au prélable avoir été agréé, c'est-à-dire avoir été sélectionné et avoir reçu un certificat d'aptitudes pour la mise en oeuvre de travaux publics. Or, ce système de listes officielles d'entrepreneurs n'existe pas seulement en Belgique, mais aussi dans de nombreux pays pour ne citer que ceux du sud de l'Europe, soit l'Italie, l'Espagne, le Portugal et la Grèce.

D'autres pays ont des systèmes de listes que je qualifierais d'officieuses, comme en France. Enfin, il y a encore d'autres pays qui ont des systèmes moins élaborés, où plusieurs administrations établissent leurs propres listes d'entrepreneurs, surtout dans les pays au nord de l'Europe. Nous possédons donc, en Belgique, un système qui repose sur des critères objectifs et les entrepreneurs qui en font la demande sont classés par catégories financières. Ces entrepreneurs ont accès à des marchés en fonction de leurs capacités financières, économiques et techniques. Il existe en Belgique une Commission qui relève du gouvernement, laquelle est présidée par un haut magistrat et est composée de fonctionnaires et de représentants d'organisations professionnelles d'entrepreneurs qui donnent un avis sur la capacité de l'entrepreneur à accéder au marché en fonction de critères objectifs. Cet avis est transmis au ministre qui décide d'accorder un certificat d'agréation ou de le refuser à l'entrepreneur.

Ce système n'est absolument pas statique mais bien plus évolutif. Au plus tard tous les cinq ans, l'agréation de l'entrepreneur est re-vérifié par la Commission d'agréation qui vérifie s'il possède toujours les capacités en personnel, les capacités financières au niveau du chiffre d'affaires, pour se charger de travaux publics. En outre, s'il apparaît que des clients publics entre temps ont été mécontents de cet entrepreneur, dans le cadre de l'exécution de l'un ou l'autre marché, ces clients publics le font savoir à la commission spécialisée, la Commission d'agréation. La Commission d'agréation est alors en mesure de suspendre l'agréation de l'entrerpreneur ou même de le radier de la liste. Ce système a permis d'assainir les marchés publics. Les administrations des services publics peuvent compter sur des entrepreneurs sérieux qui possèdent les garanties suffisantes pour mener à terme l'ouvrage. Ce système fonctionne tellement bien en Belgique parce que je sais que dans d'autres pays, par exemple en Italie, le système ne fonctionne pas très bien, au niveau des marchés publics, qu'il a aussi été appliqué à l'entreprise privée. Les clients du secteur privé pour les projets importants, exigent de l'entrepreneur qu'il soit agréé pour les marchés publics.

Ce système de listes officielles d'entrepreneurs est admis par les institutions européennes dans la mesure bien entendu où il n'engendre pas une discrimination de nationalité entre les différents pays faisant partie de la Commission européenne. Autres particularités du système belge pour les marchés publics d'une certaine importance, les clients publics exigent de l'entrepreneur qu'il souscrive à une assurance spéciale, appelée assurance-contrôle. Pourquoi ce terme d'assurance-contrôle? Parce que les compagnies d'assurances n'acceptent de couvrir les responsabilités des entrepreneurs pendant l'exécution des travaux et pendant une période de dix ans après l'achèvement des travaux, que si les projets et leur éxécution ont été soumis à la surveillance d'un organisme spécialisé dans le contrôle technique. Les compagnies d'assurances peuvent alors s'engager en toute connaissance de cause dans le couverture des responsabilités des entrepreneurs.

Cette mission de contrôle technique porte aussi bien sur la conception que sur l'exécution des travaux. Les ingénieurs de cet organisme spécialisé procèdent à un contrôle des études, des plans, à l'examen des options techniques qui sont à la base du projet, les résultats des essais sur le terrain, des systèmes constructifs de fondation, des plans d´exécution, du choix des matériaux etc. et ensuite de la mise en oeuvre par des visites régulières effectuées par les représentants de cet organisme spécialisé.

Ce contrôle est exercé dans un esprit de collaboration entre les parties. Les entrepreneurs comme les architectes conservent toutes leurs initiatives et toutes leurs prérogatives et ce contrôle est mené bien entendu dans un souci de concilier les exigences de sécurité normale et les desirs légitimes d'économie du maître de l'oeuvre et de l'entrepreneur.

Cette mission de contrôle par l'organisme spécialisé de contrôle technique, ne comprend donc jamais l'établissement de projets, ni la direction des travaux. Le contrôleur technique a donc un rôle de prévention et de normalisation des risques pour le compte de la compagnie d'assurances pour laquelle il agit à titre de le conseil technique. En Belgique, le contrôleur technique est donc lié à la compagnie d'assurances, il n'est pas lié contractuellement au client ou à l'entrepreneur, ce qui est le cas dans le système français, sauf erreur de ma part. Bien entendu, si les recommandations techniques du bureau de contrôle ne sont pas suivies par l'entrepreneur, la compagnie d'assurances peut suspendre sa couverture, ou ne plus couvrir la responsabilité de l'entrepreneur. C'est la raison pour laquelle, dans la pratique, les conseil donnés par le bureau de contrôle qui assure le contrôle technique sont suivis par les entrepreneurs. Il s'agit bien entendu d'un bureau de contrôle qui bénéficie d'une compétence technique exceptionnelle, reconnue par tous les participants à l'acte de construire et ce système d'assurances-contrôle a permis, en Belgique, de réaliser une diminution appréciable des sinistres post-construction. Ce système fonctionne tellement bien qu'ici encore, il a été adopté pour les contrats privés d'une certaine importance.

Par conséquent, les problèmes de responsabilités post-réception d'une certaine gravité se posent en Belgique surtout dans le cadre de projets privés d'importance moindre. Par exemple, les constructions unifamiliales, les constructions d'habitations ou de petits immeubles à appartements pour lesquels l'entrepreneur n'est pas tenu d'avoir reçu l'agrément où l'on impose pas non plus de système d'assurances-contrôle.

En conclusion sur le système de responsabilités post-réception en Europe, je tiens à indiquer que beaucoup d'efforts sont actuellement déployés au niveau des autorités européennes en vue d'harmoniser le droit de la construction en Europe, dans les principaux domaines comme la responsabilité, la réception, les garanties financières et les assurances. Monsieur Claude Maturin qui devait être ici aujourd'hui, a préparé un rapport en qualité de consultant pour les communautés européennes qui a été analysé par la Commission européenne et soumis également à différents groupes d'experts techniques. Il appartient actuellement aux autorités européennes d'établir un projet de directives dans ces différents domaines, mais c'est très difficile. Vraisemblablement les divers pays européens conserveront leurs systèmes nationaux, mais ces systèmes devront s'harmoniser au minimum dans les domaines que j'ai cités. En mettant l'accent sur certains points comme notamment la prévention des désordres par un système de contrôle technique où un système de contrôle émanant des autorités locales, ou encore par le système de qualification des entreprises et les systèmes que vous connaissez sous le nom de l'assurance-qualité de contrôle interne des entreprises.

Mais je le répète, nous attendons toujours les propositions des communautés européennes à cet égard et il m'apparaît prématuré d'en parler d'avantage tant que le texte des propositions n'est pas connu.

L'EXPERIENCE PRATIQUE DE SNC-LAVALIN

Claude Boudreault
SNC-Lavalin Inc., Canada

J'apprécie l'occasioné qui m'est donnée de vous entretenir ce matin de notre expérience pratique du traitement de la responsabilité et de la gestion des risques à l'international pour une compagnie comme SNC Lavallin. Avant d'entrer dans le vif du sujet, il m'apparaît approprié de vous donner quelques éléments d'informations qui vous permettront de mieux apprécier l'ampleur et la complexité des problèmes auxquels nous avons à faire face chaque jour dans l'exécution de nos contrats.

En premier lieu, et sans vouloir verser dans la publicité, SNC Lavallin est le regroupement récent de deux des plus grandes firmes d'ingénieurs-conseils au Canada, dont 35% des revenus d'ingénierie proviennent maintenant de contrats internationaux. Notre entreprise forte de 5500 employés est active dans les quatre coins du monde, dans quelque soixante-cinq pays, notamment la Turquie, la Tunisie, Le Népal, le Niger, la Chine, la Thaïlande, le Vénézuela, le Chili, la Russie, l'Australie, l'Egypte, la Lybie, le Kenya, et j'en passe.

Alors que le génie conseil demeure l'activité de base, nous avons mis en point une compétence unique en gestion de projets et en gestion de construction et nous nous interessons de plus en plus aux grands projets de contruction dits: «clé en main». En plus d'être présents dans ces divers pays pour l'exécution de nos contrats, nous menons aussi continuellement des entreprises commerciales en Belgique, en France, en Angleterre, à Haitii et en Tunisie. Ces entreprises nous permettent d'accéder plus directement aux diverses banques de financement international afin de mieux établir les montages financiers dans le cadre de nos différents projets. Chez SNCLavallin, la responsabilité et la gestion des risques sont deux notions prises très aux sérieux et qui demandent une attention constante.

C'est dans cet esprit que le service de gestion des risques que je dirige et qui compte cinq employés à plein temps, a été constitué comme partie intégrante des services juridiques. Comme le temps qui m'est accordé est relativement restreint, je me contenterai de donner un aperçu général de la situation et de présenter notre approche de la gestion des risques et, plus particulièrement nous verrons par quels moyens nous parvenons à gérer les risques et quand nous le pouvons, à les transférer.

Même si mes propos traitent généralement de l'exécution des projets internationaux, nous adoptons une démarche très similaire sur la scène locale, j'oserais même dire que nous appliquons les mêmes principes de façon encore plus stricte au Canada, car c'est un marché que nous connaissons et que nous maîtrisons beaucoup mieux.

Au fil des années, nous avons constaté que la clé du succès d'une entreprise pays étranger est directemet reliée à sa capacité d'adaptation aux méthodes de travail et aux conditions «politiques» locales. Ceci signifie qu'il faut acquérir une connaissance des coutumes des pays hôtes. Nous acquérons cette connaissance du milieu ordinairement par l'entremise de notre vaste réseau d'agents locaux, tous recrutés dans les pays où nous désirons faire des affaires.

Notre deuxième source d'informations, nous la trouvons dans les nombreux articles qui paraissent dans la presse internationale ou dans des revues spécialisées. Egalement, notre gouvernement par l'entremise du ministère des Affaires extérieures, représente à l'occasion une vaste source d'informations.

Dans mon cas personnel je n'hésite jamais à communiquer avec nos courtiers d'assurances et avec les grands assureurs et ré-assureurs internationaux, qui tous mis en oeuvre des banques de données considérables sur les conditions locales dans chacun de ces pays, mais aussi la plupart disposent de sources d'informations importantes sur ce que nous appelons généralement la gestion des risques.

Comment traitons nous directement de la responsabilité? Notre premier outil de gestion demeure la négociation contractuelle qui mène éventuellement à la signature du contrat. Notre politique générale établit clairement que tout contrat doit obligatoirement être revu par nos services juridiques et dans le cas de contrat importants, un de nos avocats sera même assigné à l'équipe de négociations.

Le service de gestion des risques intervient dans la négociation de façon ponctuelle et est tenu informé de l'évolution du dossier. Nous intervenons surtout dans la rédaction des clauses d'indemnités, de responsabilités et dans l'élaboration des programmes d'assurances. A l'international, il arrive très souvent que le donneur d'ouvrages soumette avec sa demande d'offre de services, un contrat type auquel il voudrait nous faire adhérer. Nous prenons systématiquement exception à toutes les clauses jugées offensantes, injustes ou unilatérales. Nous demeurons convaincus que le succès d'un contrat réside largement dans des stipulations contractuelles équilibrées qui respectent les droits des deux parties, et nous prenons les moyens pour y parvenir.

L'expérience passée a également clairement démontré qu'à quelques exceptions près, il y a toujours moyen de trouver un terrain d'entente avec le donneur d'ouvrages et d'arriver à des dispositions contractuelles acceptables. Ceci signifie malgré tout que nous devons respecter certaines exigences minimales qui sont entre autres de ne jamais accepter aucune responsabilités pour des dommages consécutifs ou indirects tels que des pertes de revenus, de production, d'achalandage et autres. Pour ce qui est des dommages directs, pouvant découler de notre responsabilité, ils doivent dans toutes circonstances être limités dans le temps et quantativement. Limités dans le temps en ce que notre responsabilité prend fin avec la période de garantie contractuelle ou jusqu'à l'acceptation finale du projet. Limités quantativement en ce qu'elle se limite à une partie de nos honoraires ou à un montant forfaitaire, ou encore aux produits des polices d'assurances.

De plus, toute entente internationale doit être assujetttie à un processus de règlement des différends par voie d'arbitrage, habituellement dans un pays neutre. L'Europe demeure notre forum favori et toute résolution est assujettie à la réglementation de la Chambre de commerce internationale.

Maintenant que nous avons vu l'aspect contractuel de la gestion des risques, voyons maintenant la partie plus pratique. Lorsqu'il s'agit de la réalisation des projets internationaux, nous avons déterminé au fil des années que les plus grandes difficultés émanent habituellement d'une très mauvaise connaissance du client ou du pays hôte. Pour assurer le succès du projet, nous devons être particulièrement vigilant dans l'établissement de nos prix. Nous nous rendons souvent compte, malheureusement après coup, que la pire erreur aura été d'établir les prix sur les critères de construction d'Amérique du Nord qui s'appliquent difficilement dans la plupart des pays étrangers.

D'autres complications viennent ensuite envenimer davantage la situation, à savoir les lenteurs administratives, les hésitations du processus décisionnel, l'absentéisme chronique dans certaines sphères de compétence, les méthodes d'exécution totalement différentes de celles que nous connaissons, le manque de compétence de la main-d'oeuvre et dans certaines régions, des coutumes religieuses qu'il nous faut respecter.

Il en résulte inévitablement des retards non imprévus et le non respect des échéanciers. Des difficultés avec la réalisation des projets, résultant de l'exécution du travail basée sur une conception et des plans trop complexes, le tout engendrant quelques fois des vices de construction ou des travaux non conformes qui peuvent mettre en péril tout l'aspect «procédé» du projet. Toutes ces situations peuvent entraîner des pénalités sévères et même des coûts supplémentaires imprévus pour des travaux de modification et de réparation.

Comme nous rencontrons ces risques commerciaux à tous les niveaux et dans tous les projets internationaux, si on veut éviter les écueils, il est essentiel que l'entrepreneur soit familier avec les méthodes locales de mise en oeuvre des travaux. Une façon appropriée d'y parvenir, est de créer des co-entreprises avec des entrepreneurs locaux, ce qui facilite aussi grandement le transfert technologique. Dans certains cas nous avons former nous-mêmes ici au Canada, la main-d'oeuvre locale nécessaire à la bonne marche du projet, facilitant d'autant plus le transfert technologique et le respect des conditions locales. Nous demandons à nos directeurs de projets d'être vigilants et de définir le plus tôt possible les problèmes qu'ils pourraient devoir régler. Ceci nous permet d'intervenir rapidement, avec des traitements chocs pour limiter les dégâts. Ce traitement choc peut même aller jusqu'au remplacement du directeur du projet s'il est jugé que les méthodes de travail qu'il préconise sont inadéquates ou inadaptées à un milieu donné.

Comme nous ne pouvons éviter toutes les situations à risques, nous avons au moins des programmes d'assurances internationaux spéciaux qui nous permettent de transférer aux assureurs certains des risques d'accidents que nous jugeons trop coûteux à absorber nous-mêmes.

Pour faciliter le transfert des risques aux assureurs nous nous sommes donnés un véhicule privilégié qui est notre compagnie d'assurance captive établit aux Bermudes. C'est par l'entremise de cette compagnie que nous avons accès directement à tous les grands marchés de ré-assurance internationaux. En plus de nous donner cet accès, cette compagnie nous permet également de garder à l'interne, un certain niveau de risques moyennant contribution financière du projet. C'est ce qu'on appelle l'auto-assurance. Elle nous permet également d'utiliser le poids moral de la rétention d'une partie du risque, pour inciter nos employés à un haut degré de vigilance dans l'exécution de leurs tâches. La formule s'est avérée très profitable à ce jour, car nous n'avons eu que très peu de réclamations.

Le dernier aspect du risque que je voudrais aborder est le risque politique que l'exportateur doit assumer et sur lequel il a très peu de contrôle dans le pays hôte. Ces risques se caractérisent habituellement par leur nature économique. Ils se traduisent généralement par la confiscation ou la nationalisation des biens de l'exportateur par le pays hôte, par le non paiement des sommes dûs, ou le non respect du contrat pour des raisons d'ordre politique, ou encore, par l'annulation pure et simple de permis d'import-export soit par notre propre gouvernement, ou par le gouvernement du pays hôte. Comme ces risques sont généralement hors du contrôle de l'entrepreneur ou de l'exportateur, il existe très peu de façons de les contourner contractuellement .

La seule façon de minimiser les pertes possibles demeurent la souscription à des programmes d'assurances de risques politiques. Nous le faisons soit par des programmes globaux, ou en souscrivent des polices spéciales adaptées aux besoins des projets particuliers. Les sources de disponibilités de ces couvertures sont gouvernementales, comme par exemple la S.E.E. au Canada, la C.O.F.A.S en France, E.P.I.C. aux Etats-Unis et E.G.D. en Angleterre.

La deuxième source est le marché commercial généralement représenté par Lloyds, Paris et certains assureurs américans tel E.I.G. Les risques auxquels s'adressent cette protection sont d'ordre purement économiques et dépassent largement le cadre de cette présentation. J'ai seulement voulu le souligner au passage comme étant un élément important de la gestion des risques employée dans son sens le plus large. Voilà donc très rapidement et très superficiellement la façon avec laquelle nous traitons de la responsabilité et de la gestion des risques. Nous préconisons une approche active et directe aux incidents en tentant de les prévoir et de les prévenir plutôt qu'une approche passive que se limite à corriger des situations déjà détériorées. A ce jour, l'expérience a été profitable.

THE BUILDING CODE OF AUSTRALIA - A PERFORMANCE CODE FOR THE GLOBAL VILLAGE?

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INTRODUCTION

Australia is a large continent with diverse weather conditions, long distances between centres of population and responsibility for government divided between the federation, the states and local councils. Despite this enormous diversity, by mid 1992 each state in Australia will be using one national code for technical requirements for building regulation. This code, the Building Code of Australia (BCA) has taken the Australian Uniform Building Regulations Co-ordinating Council (AUBRCC) some ten years to produce. In its present form, it contains some variations for each state. Every effort is being made to reduce these variations and AUBRCC hopes to see their demise within three years.

Uniformity has many advantages, but it will not be fully achieved until the regulations have become so clear that each requirement is open to one and only one interpretation. Such uniformity could be considered restricting, but regulations based on building performance introduce new flexibilities to the regulatory system.

PERFORMANCE REGULATION

Traditionally, building regulation has been expressed in terms of a detailed description of how each building element or system should be constructed. Rather than asking the builder to ensure that, for example, people could escape from a building if there was a fire, the regulators told the builder how thick he should make his walls, how long he should make his exit travel distances and so on. This system worked well with a limited range of building materials and design methods. In the days following the great fire of London, there was no need to consider the possible use of structural bamboo in central London, or the construction of the Taj Mahal on the banks of the Thames. Times have changed, and today we have available a wide range of building materials and methods of design. Old descriptive regulations have become restrictive, and often hinder the introduction of new technology and more economic methods of construction.

Instead of restricting the materials and method of construction of a building to those with which we are familiar, it is time we considered the intentions of the regulations and just what it is the regulators are trying to achieve. If these intentions are clearly stated, we can regulate the performance of our built environment and at the same time allow for the use of modern methods and materials.

This does not mean that there is no place for descriptive regulation. The old descriptions, which have provided us with safe building for decades, can still be used by those who wish. But in performance regulation they become just one of a choice of ways of fulfilling the regulatory intention.

A STRUCTURE FOR PERFORMANCE REGULATION

A suitable structure for performance regulation in Australia is shown below:

A C T
Buildings shall comply with the BCA.
(Range of building regulation may be defined here.)

INTENTIONS
(fall within defined range and say what the regulators wish to achieve.)
ACCEPTABLE LEVEL OF ACHIEVEMENT
These form part of the intentions
(eg acceptable degrees of resistance to failure - damage, collapse, leakage, sound penetration)

CREDENCES
Means of fulfilling intention. (These may be tests and criteria, design methods and criteria, prescriptions or "accredited" solutions.)

Enabling acts establish the range of the system, determining whether such matters as life safety and energy efficiency should be included in the regulations. There are only two levels (or perhaps two and a half) for the technical regulations themselves.

First, the intentions of the regulators for the building system or component must be clearly stated. For example, these intentions would state that a building should resist all loads to which it will be subjected, or that in the event of a fire people should be able to escape without risk of injury.

Intentions say exactly what the regulators are trying to achieve. They may cover a wide range of technical requirements, or they may be quite specific. As part of the intention, an acceptable level of achievement may be given. Eventually, in the case of fire, this may be a quantified risk to life. For structural stability it may be a quantified risk of structural failure. The level of achieving the intention is a part of the intention. Every building must fulfil the intention to the level stated.

I call the second level of technical requirement "credences". These are ways of showing the regulators that the intentions have been fulfilled. If stated credences are followed, the regulators guarantee to accept the solution.

The credence can take many forms. However, there are four approaches with which you may be familiar:

(a) Tests and Criteria

The regulators may agree that the results of certain tests give an indication of the real performance of a building or element. Examples include fire resistance levels, smoke densities, exit travel times and sound levels. The regulators specify the details of the method of test and then choose parameters which they feel represent an acceptable level of certainty that their intention is being met. These parameters are often called "performance criteria".

(b) Design and Criteria

A building or element may be designed in accordance with a design code. In this case the regulators will have accepted the method of design and may specify certain criteria, such as loads and load factors which the design must accommodate. For example, design in accordance with the steel structures code to resist the loads given in the loading code will satisfy the intention that buildings resist forces to which they are likely to be subjected.

(c) Descriptions

In addition the regulators may provide a detailed description of acceptable construction. The description is like a recipe. It gives instructions and if you follow them to the letter the regulators are prepared to say that their intentions are fulfilled.

(d) Imaginative and Accredited Solutions

The code user may have his own way of showing compliance. It may be worth his while to have his product tested, appraised and accredited for compliance with the intention along paths not detailed in the regulations. He should be free to choose his own way of convincing the inspector that his solution meets the intentions of the regulators.

THE DERIVATION OF PERFORMANCE REGULATIONS

Existing descriptive regulation can form the basis of performance regulations. In order to change from descriptive regulation, the current descriptions must first be analysed to deduce the regulatory intentions. In some cases the intention may be quite obvious, but in others there may be hidden intentions. For example, a brick or concrete wall that is needed to resist the spread of fire may also provide sound insulation between two dwellings. If the wall extends through the roof cavity between the dwellings, it may prevent access through the roof space from one dwelling to the next. The intention of providing such security probably falls outside the range of the regulations.

The intentions that have been derived from existing provisions must then be analysed for technical compatibility and to ensure they fall within the terms of reference or range of the regulations. They must then be refined to provide sets of intentions that are consistent and free from extraneous issues.

When the intentions have been finalised, the existing descriptions can be reformulated in the form of credences or ways of complying with the intentions. It is interesting to study an existing description, in the light of clearly stated intentions. In the present descriptive BCA, we have many stringent blanket requirements followed by concessions for certain buildings. If we look at these requirements from a performance viewpoint, we realise that "concessions" is a misnomer. We are really trying to achieve a uniform level of safety, and in order to do this we provide suitable protection for each class of building. To achieve the same level of safety in buildings of high and low occupancy, different construction will be needed.

For ease of use each credence should be expressed in terms of

(a) objective;

(b) description of the class and element of building to which the technical requirement applies, or any special circumstances under which the technical requirement applies; and

(c) technical requirement.

Once we have sorted out the old technical requirements in the form of credences which fulfil our new intentions, we can in some cases ascertain the level to which the intention is fulfilled. Where there is more than one credence for an intention, the levels to which the credences fulfil the intention can be compared. Any intention for which there is no credence can be identified. These activities will doubtless precipitate the need for research and development and code development should be accompanied by an ongoing program of research. It will be some years before all the gaps in the performance hierarchy will be filled.

ADVANTAGES OF PERFORMANCE REGULATION

Performance regulation offers advantages to the code user and the code writer.

1. It encourages the code writer to adopt a methodical and logical approach to regulation. This leads to clarity and good organisation within the regulations.

2. A variety of solutions to the regulatory problem (that of fulfilling the regulators' intentions as economically as possible) can be provided, and the level to which each of these solutions fulfils the intention can be compared. An acceptable level of fulfilling the intention can be derived from past descriptive regulation. The solutions can then be fine-tuned to achieve a uniform level of fulfilment.

3. The likelihood of commercial pressures influencing the regulations is reduced, as the regulators focus on fulfilment of intentions rather than a description of materials which may favour one manufacturer.

4. An accreditation scheme depends on the statement of clear regulatory intentions. Products are then accredited to fulfil these intentions. If the code is descriptive and the intentions are not stated, the accreditation officer must first derive an implied intention from the description. This leaves room for error and inconsistency.

5. Clearly stated intentions ensure that only necessary requirements are included in the regulations. There is no place for over-restrictive regulation.

6. Regulatory intentions are the same throughout the world. Acceptable levels of fulfilment may vary from country to country and time to time (for example, some countries may accept a higher risk to life than others). Acceptable means of complying with the intention to the level stated will vary from place to place and time to time. Local building practice, availability of materials and local weather conditions will influence these solutions. However, if the solution clearly states the conditions under which it is acceptable, and the regulations clearly state the intention and level to which this must be fulfilled in the country concerned, an acceptable solution for one country can be assessed against the level of fulfilment required in another country. Test results, for example, can then be used to assess a product's acceptance in another country. This helps remove barriers to the international movement of building materials and technology.

PERFORMANCE REGULATION AND THE COMPUTER

There is no doubt that, in years to come, building regulations will be computer-based. CSIRO has developed a knowledge-based computer system to check that building designs comply with relevant clauses of the BCA. It has taken many patient hours of programming, checking and consulting with the code writers to ensure that the interpretation given in the software (called the BCAider) is correct. The logic required for developing such software has highlighted deficiencies, inconsistencies and inaccuracies in the current regulations.

The BCAider has been developed to accommodate performance regulation. In sections where the BCA is expressed in terms of performance, the user is first asked if he complies with the solution given in the BCA (in some cases this may be compliance with an Australian standard). Should he have chosen to provide his own solution, he is then asked if he complies with the regulatory intention.

The software accommodates state variations to the BCA. It provides the user with commentary on interpretation of clauses and on-line help with use of the software itself. BCAider's release on a commercial basis was designed to coincide with the adoption of the BCA in various states of Australia.

There has been wide-spread interest in the BCAider, which runs on a PC in a Windows environment. The software consists of a "shell" and a knowledge-base (the BCA). By swapping the knowledge-base, the shell could be applied to any regulatory, legal or diagnostic area. Other countries are already expressing interest in purchasing the shell which could easily be adapted to suit their regulations. We believe BCAider is the first commercially successful knowledge-based system for building codes.

THE BUILDING CODE OF UTOPIA

In Utopia, that country of ideal perfection, there is no fear in the hearts of engineers and architects as they check their designs against the building regulations. They know that regulations exist to provide a safe built environment for all Utopians, and all sectors of the Utopian building industry work together for the safety of the people. In Utopia, the builder does not quake in her boots when she sees her building inspector approaching. She puts on the kettle, happy in the knowledge that she has done all she has to do and done it right.

The Utopian researchers are busy developing new products. Utofoam is not yet fully developed, but early tests indicate compliance with the BCU. It will soon be commercially available and accredited for use throughout Utopia, but in the meanwhile Woopifluff from distant Outer Woopwoop insulates the Utopians against the blazing summer sun. Trade flourishes, and harbours and airports are busy importing and exporting building products.

Beneath the sun lie the varied and interesting homes of the Utopians. Utopia, that happy land where there is time to relax, turn on the computer and teach the little ones how to build a play house that complies with the BCU.

CONCLUSION

We live in exciting times. The world is indeed becoming a global village where national survival depends on international trade. Our building regulations must allow the use of imported products and we must be free to export. If we are to seek economy and innovation in the building industry, our regulations must accommodate change.

Performance regulation is a natural progression from descriptive regulation. It allows the old solutions to exist side by side with more complex solutions based on risk analysis and modern methods of assessment. Australia is taking steps to introduce uniform performance regulation. Perhaps the Building Code of Australia will become the basis for the Building Code of the World. Utopia may not be so far away!

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SESSION 4D
RESPONSIBILITY AND RISK MANAGEMENT

Questions and Discussion

Question
Mr. Paul Siega
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The Singapore case looks interesting, but still leaves a few questions begging. One of the basic questions is this: that the regulations as defined in the 1989 Act place more responsibility on the engineer, rather than the architect. In other words, the question of esthetics, whether the thing is badly designed in terms of comfort, does not seem to be considered, but it is only assumed that the problem arises when the building collapses. When it doesn't collapse, of course, there is nothing wrong with it.

At whose cost are the inspectors and the site supervisors appointed, who is responsible for the deficiencies in the building regulations, because it is presumed here that the building regulations are top notch, and therefore any deficiencies that arise are as a result of negligence on the part of the design team and not probably within the building regulation itself. How current are the regulations, and are they performance or material based? What are the limits of liability to the builder in terms of time frame? In our context in Kenya, I won't do anything with a contractor after the fixed liability period. What about issues that are the manufacturer's fault? It is assumed that the contractor has chosen a particular building material, which therefore must be necessarily of top quality. What about if there was a latent defect within the building material itself?

Finally, a comment. While prescriptive regulations could matter very much in a developing country, but more importantly, in my opinion, is the professional integrity. This has to do with the transparency and the accountability of the particular professionals. If these professionals have been used to signing things without actually inspecting them, until there is a re-orientation of their mentality, whatever laws are laid down will not help us very much. Therefore, professional integrity, which arises out of the training from within our institutions, which arises out of our own feeling responsible to the client and the consumer, are to me most paramount in this respect.

Dr. Lavers

I sympathize with his last point, that the professional integrity and professional standards are crucial, of course. I would just add this one comment to that, which is that in difficult economic times, if the possibility of abuse is there, then the temptation may be very great for practitioners who are hard pressed. So in ideal circumstances we would expect professional integrity always to achieve the highest standards, but in difficult economic circumstances, when the practice may be faced with perhaps going out of business, then the temptation arises for this kind of abuse if it is possible, so the purpose of these checks is to try to make sure that abuse is not possible.

The inspections, at whose cost are they carried out? Quite simply, the client's cost, throughout. The client has to pay for the accredited checker, and the client has to pay for the site supervisor, the client or the owner has to pay for the structural inspection.

Who is responsible for deficiencies? Under the Singapore system, certainly the contractor bears a very heavy responsibility under the standard form contract and so, when it comes to the actual cost of carrying out repair work, it will usually be first to the contractor that the owner will look. My points about professional responsibility are really, where the contractor has gone into liquidation, because it is comparatively much easier to sue the contractor in Singapore than in comparable jurisdictions.

Limits of liability was another question raised by the speaker. Here the position is clearly different between his own system and that of Singapore. There is the concept of the defect liability period in contract, which I think you said is six months in your system. It used to be six months in Singapore and Malaysia too, but that is now usually increased to one year under the standard form contract. But that is not the end, the one year defect liability period is not the end, that is merely a limited contractual arrangement between the parties. The limitation period for bringing an action may extend to six years from the breach of contract. The limitation act in Singapore and in Hong Kong follows the U.K. model of six years from the date of breach of contract and the breach of contract is usually taken to be the handover of the building.

I think it is fair to say that the building regulations are not simply materials based or performance based, so I cannot give an easy answer to that question.

The final question, what about latent defects? The contractor may still be liable for those after the defect liability period has run out. If there is fraudulent concealment, if there is deliberate concealment, then the six year limitation does not apply and liability may continue to run until it is discovered.

THEME 5
INFORMATION AND COMPUTERS
KEYNOTE ADDRESS

William J. Mitchell
G. Ware and Edfyth M. Travelstead
Professor of Architecture, Harvard School of Design, U.S.A.

Thank you. I am going to speak to you about some recent work in the application of computer technology in the design process. I am not going to give a technical presentation. What I thought I would do is illustrate very quickly what is happening by showing you a sequence of slides which give a visual impression of some of the things that are starting to happen and that I think are particularly significant at this point. I have a lot of slides to show you and relatively little time so I would like to go immediately into the slides.

There is a mirror in front of me so I can see the slides over my shoulder and we are going to see this amazing piece of technology work and it allows me to see what we are doing.

To introduce this topic let me quickly sketch a rather simplistic model of what's involved in any kind of application of computer technology in architectural design. We can say that there are essentially four basic activities. There are many others but just four activities that are involved here.

Our first activity is maintaining some sort of model of the building or the urban environment or the landscape context that is being modelled. There is an activity of constructing and maintaining and manipulating some sort of digital presentation which becomes the repository of the decisions that a designer makes and it becomes the repository of the data about a project that supports all of the other kinds of things that one might want to do.

Secondly, given the existence of some type of model of a built artifact, a building or whatever, you can use that model to support processes of visualization. These may be very simple processes producing some very quick and simple views in order to understand the basic geometry of the building or it might go all the way to sophisticated animations, virtual reality simulation and so on, but one of the things that has developed a great deal over the last five to ten years has been this aspect, the visualization aspect of computer aided design.

Thirdly, there is the activity of using the digital representation to support some kind of processors of reasoning that are involved in the design process automating various of those reasoning processes. And here we see a spectrum of sophistication, a spectrum of complexity in the sorts of reasoning procedures that are applied. At the simple end of the spectrum, things that many of you are familiar with, software that performs some simple geometric and arithmetic computation, takes off areas and volumes, and so on and basic tedious time-consuming operations that designers have always performed. This is the simplest kind of reasoning. Slightly more sophisticated kinds of reasoning to be applied to a digital model of a building requires more sophisticated software and more sophisticated integration with the representation. The integration of engineering analysis, structural, thermal, all of the sorts of things that many of you here are certainly very familiar with indeed. And something that is getting a lot of research attention at the moment, although I think not a lot of practical consequence out in the field yet, is the application of techniques of critical reasoning, automated procedures for performing derivation of the kinds of critical comments that a good human design critic might perhaps derive. When some experienced architects stand around in front of drawings of a scheme, argue about it and discuss it, criticize it, develop lines of reasoning about why it may or may not be a good scheme. Some very sophisticated discursive reasoning is going on there and we are seeing now a significant amount of research in the field of automation of that sort of critical discursive reasoning as a research issue but not, I would suggest yet, as very practical technology. Anyway there is the issue of reasoning.

And then finally, given a digital representation of a work of architecture, we can produce the documentation that we need to guide a construction process. Now this is changing typically. This is being thought of in rather traditional terms as an issue of producing traditional drafted documents and printed specification documents and so on. That still is a very important thing but I will show you some examples where the end product, the kind of documentation that is produced by a computer aided design process, is something very different, direct transfer of digital information to guide a fabrication or a construction process without the intermediary of traditional documents.

Anyway this is the conceptual framework I would like you to keep in mind and I am going to focus mostly on the issue of modelling. There are all sorts of things we can do with various types of modelling techniques and I am going to characterize what we can do with different modelling techniques by showing you quite a lot of examples. I will quickly move forward and introduce one more piece of theory here that I would like you to keep in mind. Here is a very simple schema I have laid out behind me to characterize fundamentally the different approaches that one can make to the digital representation of a work of architecture or indeed any three dimensional artifact. This is rather simple but it is a useful framework for looking at. Across the top axle of this diagram we make a distinction between two dimensional representations and three dimensional representations. In traditional practice, that is the distinction, if you like, between two dimensional drawings and three dimensional models in computer aided design. It is the distinction between representation of object geometry, two dimensional x-y coordinate system or representation in a three dimensional x-y-z coordinate system. So that is one distinction.

Secondly, we can draw a distinction in the kinds of geometric primitives that we use as the building blocks to construct a representation. We can construct a representation point by point by either dividing a two dimensional plane up into a regular grid or dividing three dimensional volume up into regular three dimensional grid and then we simply construct a representation associating numbers with points in that grid to specify different colours, materials and so on. This is the idea in two dimensions of a bit mapped image and in three dimensions of a voxel representation, a type of thing that is very important in medical image processing these days. This is the idea of a point by point representation.

Next we can go from 0 dimensional points to 1 dimensional lines as primatives and construct a representation as a collection of lines in space or a collection of lines on a two dimensional surface. This gives us the familiar idea of a computer drafting system or a wire framed modelling system.

Next we can go up the hierarchy of dimensionality once again and we can construct images or representations surface by surface. We can take two dimensional surface elements as our basic building blocks and we can either organize those on a plane surface to produce a map or a plan or we can organize them in three dimensional space to organize something that is rather analogous to a cardboard or a chipboard working model and finally we can take three dimensional solids as our building blocks and assemble a representation volume by volume. This gives us the idea of a solid model. Or else we can put all of these sorts of things together within an integrated framework and we can have something that is known technically as a non-manifold modeller that enables us to work with all of these different sorts of entities within a coherent mathematical framework.

What I am going to do now quickly is start up in the top corner of this representation with simple bit mapped images, the simplest kind of representation and move down to solid models and talk about some of the current uses in the design process.

Firstly, the idea of a bit mapped image is that it is made up pixel by pixel. This is not a sketch from a computer graphics textbook, this is, in fact, a sketch by Paul Klee, the Swiss painter, illustrating, in fact, many decades ago, the fundamental idea of a bit mapped image. Here we see an actual bit mapped image generated by placing a shell on the platinum reflected scanner and simply scanning the shell to produce, as you can see, an exquisite high resolution detailed image. Now what can you do with this very simple sort of representation? Well, the sort of software that we have associated with that type of representation essentially enables us to design by a process of transformation and combination and collaging of image fragments. So here is a simple student design exercise taking an image of a strawberry and doing some colour transformations and making some rather bizarre looking strawberries and then collaging all of those pieces together to make a collage.

Now in the exploration of design possibilities, how can this kind of operation be a useful operation? Here is an example, this is Harvard Yard, very beautiful space but a space that has a problem. Many of the trees in Harvard Yard have dutch elm disease and there is a problem working out a landscape design strategy to make the transition between removal of these old trees and replacement by some new trees. It becomes very important to think about the visual qualities of this space as this transformation takes place. So some of my students recently worked on a project where they took photographs of Harvard Yard, scanned them and then used image processing techniques to remove the trees from Harvard Yard and show very clearly the qualities of the space that would result if one took the extreme procedure of simply cutting all the trees down at once and replacing them all at once. A very simple kind of representation but it supports a very useful kind of exploration in the design process. Here we see another corner of Harvard Yard and then here we see the trees removed once again. A very simple sort of representation but a very useful intervention into the design process made possible by that type of representation.

Here we see another type of application of the simple imagery, that many of you may recognize, of a building bay under a palazzo in Venezia and it is an incomplete building. It is only built up to three bays as you see here. It was meant initially to either have five or seven bays. A student in one of our architectural history classes at Harvard recently used image processing to complete the building simply by simple operations of manipulations of a bit mapped image. Here we see once again from a different viewpoint and then the building artificially completed. So simple image transformation and a combination of operations but a very useful way of exploring and showing architectural possibilities or in this case what might have been.

The construction of representations now out of plane surfaces. In two dimensions this is very much like a process of collaging and this is from a recent project using two dimensional surface polygon modeller. This is an architectural figure ground drawing produced by representing building footprints as plain polygons and then producing this simple kind of figure ground display from that. Here we see an initial stage which happens to be a representation of a university campus. This is in progress of a master planning project and then at a later stage produced from the same model collection of polygons showing transformations of building footprints at a later stage in the development of the project.

Here is something a bit more elaborate. The association of data with plane polygons in this type of representation, we end up with a geographic information system. Here is a geographic information system representation of the City of Venezia once again. Here building footprints or city blocks represented as plain polygons and historical data in this case associated with the different footprints and then a query and retrieval system enabling us to get very effectively into the information that is structured in that fashion.

In three dimensions, organizing plane polygons in three dimensions gives us, as many of you are familiar with, this kind of model. Here is a three dimensional model used to produce a simple shaded image constructed from plane polygons. Extending the technique of surface modelling takes us into the domain of curved surface modelling and let me show you a couple of projects in curved surface modelling that we have done recently that I find particularly suggestive for the potential of curved surface modelling in architecture.

Firstly, some architectural reconstruction work. This you may recognize if you know your architectural history as a reconstruction of one of the famous buildings in Hadrian's Villa at Tivoli; it is a maritime theater. Curved surface modelling here has been used to reconstruct the exterior physical form of the way that would have been and then here the same modelling technique as used to model the interior spaces show us the interior spatial organization.

Here is another project in architectural historical reconstruction that one of my students recently carried out. This drawing that you see here is a computer rendition of a design for a motif that was discovered on a medieval scroll in Topkapi Palace in Istanbul by an architectural historian recently and we were interested in seeing what this design would have translated into when it was realized in three dimensions. This is essentially reflected in ceiling plan. This is the information with which we began the definition of the design. Here we see the student who worked on the reconstruction has defined a vocabulary of three dimensional elements that can be disposed within that framework and here we see those fragments, those elements are assembled, put together to correspond to the plan and here we see the final three dimensional form of the reconstruction. This is something that would be possible certainly using traditional drawing techniques but it was very much faster and very much more effectively done by using a fairly sophisticated curved surface modelling system.

Now I am going to show you one more example from a very different domain of the application of curved surface modelling in architecture. This is a recent project by the Los Angeles architect, Frank Garry. It is for a building in Barcelona. It is under construction now. This, as you can see, is in the form of an extremely large fish. It is a ten storey high fish. Now one can argue whether building a ten storey high fish is a very good idea, but this project raised some very interesting questions about how one can model complex architectural form and fabricate complex architectural forms. In this case, my laboratory did the curved surface modelling. Here you see one of the images from the curved surface model that mathematically defined the surface of this building. This is a mesh representation. Here is a shaded surface representation so you can see what this thing is like. And here now from a different viewpoint, underneath. The interesting thing about this project was not only the modelling and the geometry done by computer but the physical modelling was directly produced from the digital model. A technique of stereo lithography was used to automatically produce a three dimensional physical model from this digital model and then the information from the digital model was used directly to control computer controlled metal cutting machinery to fabricate the panels out of which this was constructed. The issue with this thing was that all of the panels are different, there are no repeating parts in this thing. So the advantage of that type of automated processing, the integration there of design and construction was very great.

I am going to say a couple of things very quickly now about solid modelling and show you an example of that and then I am going to conclude with a couple of examples of recent visualization work. With solid modelling, as I said, you work with three dimensional building blocks and you can sculpt these three dimensional building blocks into more complex forms by performing union intersection and subtraction operations as we see here with some examples of cubes being put together, union intersection and subtraction. Very rapidly you can build up complex forms from simple forms using this simple technique. Here we see a couple of cubes put together and unioned. If you continue that process, this is the development of a cube into a very complex polyhedron. It can be very rapidly defined, as you see here. These volumetric sculpting operations are very powerful and provide a very useful way of thinking about the exploration of design of architectural form.

Let me show you again an example of historical reconstruction using these solid modelling sculpting operations. Here, once again we are working on a project in Venezia by Palladio and students begin taking an undifferentiated block. We start to sculpt the exterior form by performing subtraction operations. It is like carving the form away. Here the interior spaces are modelled as solid volumes. Then the interior spaces are subtracted from the exterior volume to define the basic form of the building and then sections can be cut automatically by simply slicing the solid volumetric model, like a piece of salami, if you like. Just cutting up the solid model, literally slicing it, so you can arbitrarily take a section anywhere that you would want.

There is a quick tour through the current widely used techniques of modelling. I just have a couple more minutes left so what I would like to do is show you a couple of examples of sophisticated visualization developed from these three dimensional models. Let me show you one that may surprise you a little bit. It is done by one of my former students. This is a drawing that architects will recognize. It has the qualities of a sketch that architects like very much. The sense of the human hand, the sensitivity with which the pen touches the paper, the fluid quality of the line and so on. This in fact is a computer generated drawing from a three dimensional model produced by the immensely sophisticated technique of putting a wobbly pen in the plotter and it can be made freer and more sketchlike by making the pen looser and looser and it is remarkably convincing that it is a rather foolish thing to do. Anyway this is one type of image we can produce on a standard plotter drawing. Simple shaded images, something with which you are all familiar. A lot of the development in computer graphics in the last five years or so is focused on issues of texture mapping and this is now starting to become very useful to designers so here are qualities of different grains of wood, for example, being simulated using a reasonably sophisticated textured mapping system.

Here are different qualities of materiality being simulated, again using texture mapping in combination with the technique of ray tracing and I am going to show you a couple of examples. This is not by my students in this case but illustrative of a technique that is becoming very important, indeed, in the visual simulation of interior lighting conditions. The use of radiaucity calculations which are essentially finite element techniques with computing the way that energy bounces around in an interior space. If these techniques are properly calibrated, they can yield very precise simulations indeed of internal lighting conditions, so here is a living room simulation and here rather precise simulation of the lighting conditions in the interior of a recently designed auditorium in California.

I will conclude by showing you a combination of some of these techniques in a couple of interesting architectural reconstruction projects. This project I show here, the starting point, is a drawing by Palladio for a scheme that was never built for one of his villas, the Villa Pazarni. Historians among you may know that the scheme that was built for the Villa Pazarni differs from the scheme that Palladio originally designed. We were very interested in seeing precisely what the original scheme would have been like if it had, in fact, been built to the original scheme. So students worked with a solid modeller. You see some progress work here in modelling that scheme in three dimensions, step by step, built up a detailed solid model as you see here, shaded that model to ground level perspective views and then combined these ground level perspective views with photographs of the villa as it exists. So here we see a combination in the centre of computer synthesized imagery and at the edges, the existing fabric of the building, the photograph. So here we see in fact what the Villa Pazarni looks like today and if I just go back for a moment, here is the computer reconstruction. You can see that this achieves a level almost of photo realism.

One more famous Palladio project, a similar kind of thing, many of you may know that the dome on the Villa Retunda which was built after Palladio's death, is different from Palladio's original design. Here we see the Villa Retunda as it exists today, here we see Palladio's original drawing. You see that the dome is much higher and much more ecclesiastical in form. Here is a solid model developed from Palladio's original drawing and image generated from that solid model and here we see a reconstruction of what the Villa Retunda would have been like if it had been built to Palladio's original design. In this image we see most of the image is a scanned photograph that has been combined with a texture map ray traced image from that reconstructed three dimensional model showing the original design.

This is a very quick tour through some of the techniques of geometric modelling and techniques of visualization applied to these geometric models. What I would like to suggest to you very quickly in conclusion is that this technology has been around now for many years. It has been around since the 1960's but we are reaching a point where it is not only technologically mature but we are starting to see absorption into the mainstream of architectural practice at a rapidly increasing rate and most importantly we are starting to see a kind of cultural absorption development of craft traditions and the engagement of design at a very high quality with this medium for the exploration of design ideas and I expect over the next decade we are going to see the emergence of computer based techniques in architectural design not only as technical aids but as a foundation for carrying the exploration of architectural form into domains to which it has never been carried before.

THEME 5
INFORMATION AND COMPUTERS
KEYNOTE ADDRESS

Barry Pendergast
Principal, The Pendergast Group, Canada

I am going to make it quite easy for you today, I am going to have totally slides, it will almost be bilingual in how I am going to show you. I am kind of a contrast to yesterday's lunchtime speaker, because I tend to be very nuts and bolts in my use of computers. I am in private practice and you will see some of the commitment we have to computerization.

Everything you see is being done using computer technology, a lot of it, maybe some of the slides are a little bit scratchy, but they are taken straight off my screen. I tend to use the technology for everything that we do, including this little composition, scanning images from the brochure and other images that I had.

I just want to go through three main topics. One is a little background to our practice, the kinds of things we do, then I want to deal with what I see as some of the obstacles to computerization, the reason it hasn't happened in the way that I though it might happen. I guess we have all had dreams about how these things would happen and there seem to be incredible obstacles at times. I want to get into some of the more hopeful sides that I see in the industry and that is from public, private, right through the computer suppliers and finally a few glimpses into the future.

This takes me back to my first computer in the early 80's and I was so proud of this, my little Apple II and I had a CAD program that was virtually unusable, but I actually designed a little 3D program that I have since developed and we now sell copies of that around the world and I developed it on this little computer. I kind of joked that I got into computers, I had menopause about the same time, but I bought a sports car, it all happened in the same year; I think the computers had the biggest impact on me.

Just to tell you that my sports car is about twelve years old now and I put more effort into my computers than I do that and my wife did this to me because of my obsession with computers, and particularly the MacIntosh, which I have got to admit, right up front, I am one of the terrible people that sing the praises of the MacIntosh computers and my wife, she claims to be the first computer widow in the world and she is taking registrations for that new group that she is setting up to deal with people like myself that have become obsessed.

A lot of what we have been working towards is kind of interaction between the design team members, and we certainly, in terms of the way that we work in our office, we work very closely with clients in front of computer screens; we try and get them involved in the project from the very early stages. We are starting to get that happening on the construction sites, not to the level that I would like yet. It's kind of interesting because a lot of people look at our firm and say that we are highly computerized and we are, in a sense, because we have eleven computers for seven staff. Everybody uses a computer, everything we do has to be done with a computer. I don't allow any manual techniques other than maybe doing minor things on old projects on old standard drawings.

I really feel that we are only that far along in the process of computerization, so it is kind of an interesting thing the forward progress has a lot of challenges and a lot of excitement for me, but we are, by normal terms, relatively computerized in what we do.

Then, of course, instead of CAD, I guess we call it MAD, because we use the MacIntosh; it's MacIntosh Aided Design. For lots of reasons, I found that, to some extent, I wanted computers that had a high degree of creativity potential with them, and I am not saying it's the only one, but in terms of an office like ours, we have had a great deal of success with using a system like this. I think as time goes on, we will probably be moving into other equipment, particularly when we get into rendering, but that interface has really helped us do a lot of novel and different kinds of things and I think some of it is because of the way that we have used object oriented graphics, this ability to use, in this case, my drawing board, which allows me to do a lot of very flexible things. It's something that somehow the other CAD platforms have not allowed until fairly recently and very few of them allow it now. This ability to go to my drawing board and use it just like I used to use a standard drawing board, almost using water colour techniques, using anything I want to, if I want to do a scale drawing I can do it, and that's what the drawing board in the computer has got to be if it's going to be something that we can all use.

This is my computer, it is the best computer in the office because I believe the boss should have the best computer. I don't want to be facetious about that, I really believe that if the top management and the owners of firms do not understand the computer technology then you are almost lost, and I see it happening in so many firms. The important thing for success in introducing computerization is to have the top people understanding and using the technology and here I have, you can see, I have my normal computer screen on the right hand side with a CIB logo that is being scanned in and I am showing on the left hand screen, that is the screen I use for interacting with the video stuff. I can mix computer and video technology in one place and it is with these tools I can mesh all of the things I need to do as an architect.

I don't know what took me to get into this, this is a little sheet from a recent proposal, but I decided to tell people, clients, that we do things differently and from time to time we do use the 3D graphics in some of what we do, but it's often a struggle to tell clients how you use computer technology and how it might be an advantage. Another aspect, and I will get onto it later on, is the way in which we are now using colour output in our office, using some very affordable technology, that has made a major difference to how we produce our work.

Our office, this is the main drawing office, it's got the one lonely drawing board, that we just use for assembling laser prints together and other bits of information. Four of the seven staff are in fact graduate architects, two are registered architects, the other two are in the process of getting registered, so we are tending to use fairly well qualified people. We do not have designers or CAD operators and I really believe that again is a secret of how we have managed to make computers profitable. The person who does the design, just as in the days before computers, actually plugs the information into the computer and we really believe that to be very important to how we operate. Everybody in our office does their own drawing, their own word processing. We are connected by an electronic network, both inside the office and out. We are connected to a one gigabite file server for storage and backup, so a fairly well networked office, so we do not have separate typists, we don't have separate people to do admin. tasks, we all do our own admin. tasks and generally we do a fairly good job on backup of our information back into the central file server.

Some of the projects we have been working on, just to give you a little bit of an idea, a lot of our projects, we are a small office, a lot of what we do is small- to medium-scale jobs and we have been doing a round of community centres in the last little while. So these are just some examples. We do use 3D graphics on everything that we do, we have made that a condition of our practice, although we still use 2D CAD for most of the technical drawings and the initial drawings. We do use 3D in everything that we do, we have forced ourselves to use that as a way of interacting with our clients and really for us to know what we are doing.

We do have a lot of satisfied clients, that we work for and, again, this is one of the community centres, part of an animation that we did, one of the frames from that, just showing some of the early design ideas for that.

We just recently got involved in some school work, some school renovations and we seem to have a run of those projects coming up and the school board tells us that in respect to the size of the project that they have worked on with other architects, they have never had an architect come in with 3D representations like this. We took a video of some of this to show in the very early design sessions. In some of the sessions, we have mixed scanned images of people to add a little bit more realism to try to make people more comfortable with the computer graphics that we have produced. What we really believe in is bringing people into that design process as quickly as possible, again the line drawing of that same project, just really kind of examining the function, we almost use it for some of the functional programming, that definition of the brief before we really get into the design.

Some of the work we have done in airport design, we have been involved in a number of renovations in Calgary, we actually did a little bit of work at Dorval and we have found that the computer, this is an area where computer graphics and computer animation has really helped us do some interesting things. This is, in fact Dorval. I took the intergraph file that was given to me and I exploded it and added depth to it, so that was the layout, just some very early sketches. They were all done in the computer environment and based in this case on wire frames that were generated and then I just did it as if I was using a fountain pen over the top to fill in the information, but really using it as a working sketch. This is a similar area at the Calgary Airport, the earlier rendition of it, in this case, using a full rate raise program that gives me shadows, reflections and so on. I really see this as a working image to help the client group, and in this case we were dealing with nine airlines, they all had to use this facility and plug their electronic modules in and out and you can imagine dealing with Transport Canada, Federal Public Works, and nine airlines can be a really tough challenge to work with. Of course, in this particular case, the airlines looked at this and said it looked like Air Canada colours, we won't allow it to do that, but I was able one morning to put 32 colour schemes on the desk, which I just photographed off the screen. I thought, this is going to be a very tough thing, to choose a colour scheme that is going to satisfy every airline. If it was blue, it would be too Canadian and so on.

Again, we used little working models of the modules, to really test with the user group how we might design them, because we are actually increasing the input or the throughput by something like a 60% increase in passengers by turning all of our bays sideways, so we had to really test whether this could be effective or not and we did it by making these models that we could use with colour and so on.

Some work at Edmonton International Airport, the same kind of area, this is a U.S. pre-clearance area where we can go through customs and immigration. We use documents to really examine where the essential parts of that space go and we are now trying to do this in every facet of our design work, where we examine the little modules of the design ahead of time with the user group, a kind of a visual programming.

We are even getting into things in Calgary, with the baggage handling system. We wanted to look at that, and I find this area of 3 dimensional graphics quite intriguing, the idea of putting in the systems, in this case, baggage handling. I guess what it did tell me is that it is amazing that our baggage ever ends up with us on the same plane going to the same destination and we try to do something about that in some of the replanning. Another kind of graphic trying to trace those movements, because baggage handling can really affect the planning of the building and this was just putting it in wire frame with different colours for the incoming and outgoing, again, almost a manual sketch.

We have started a move in the last little while, trying to take an interest in getting involved in the design of hospitals by using the same kind of techniques. We really believe that using computer graphics to explain a design, test a design, test the way that it functions, never mind the wonderful architectural features, but how does it function? So the sketches around the outside are actually part of a room module we designed and the other shot shows how we poured in an autocad file from a local hospital, an old area there in the hospital and we just showed how we can very quickly turn that 2D rendition into a 3D image that can be used in renovation; again you just kind of graphic the ideas. This is a project at the University of Calgary we did in conjunction with Apple to test some of the equipment in the early days. One of the things we have been fortunate with is a number of people in the industry, like Apple and Autotest and Alias have helped us with early versions of software to try our ideas, new ways of doing the technology and without that we might have had problems introducing it into our practice.

Some of the basic urban design modelling that we have done, another a parkade that we are working on now, and trying to fit it into a community setting, is a fairly big project and the images are realistic images that can certainly cause some concern when you show them to community groups.

A project that I was just finishing as I left on Wednesday, is a model that we are doing, a computer model of part of the downtown on the right hand side, in Calgary, and then a new housing project on the top left hand corner of that plan. It is a model that is about 8 000 m by 6 000 m that we are checking to see whether our scheme blocks the view from existing dwellings and it's quite a controversial scheme so we are using it now to test viewpoints from existing homes and because of previous legal problems, we cannot get into the homes to verify our views, so we are now doing this totally in the computer environment. We can roam around the existing homes and see what impact our scheme has and we have had a number of design sessions with our client, where we are moving units up and down to test how our scheme works.

Another project that we have just been working on, showing another piece of the technology that we use, I wanted to produce an elevation of a building, so what I put into my electronic drawing board is a scan of the existing building and I have offset it slightly, so you can see what happened, but I am able to trace off that scan. We use scanning a lot to input existing data, because I only have to take one scan of the image and just purely duplicate it. A lot of that work, where we mesh different kinds of techniques on our drawing board to achieve results. Then we found, because we had pretty tough times in Calgary, because of the oil industry going up and down, we have tended also to get into the marketing aspects. we have done logo design, brochure design, even now are beginning to do work in the oil and gas industry, where we use the 3D modelling techniques to work in more plant type structures, but we are finding it pretty effective and in some ways easier than the work that we do architecturally.

What we have found, to stay in business and make the computer technology pay, we have to diversify, we have to find new markets and that is going to apply to everybody in the construction industry. Also breaking into facility management, because a lot of what we do has got the basics for facility management, all the drawings, all the information is in CAD, so why don't we break into that? We are slowly getting into that area.

This is the latest version of the piece of software that I wrote 10 or 11 years ago and we now have sold copies to most of the major countries in the world. It is very low level 3D but it does allow you to get into that area. We act as a consultant in firms that are looking into putting CAD and computerization into their offices and here we have been talking to Canada Safeway, a fairly big food retailer and we have shown them how we can take their standard existing autocad drawings, but in our drawing board, we can actually add 3 dimensional graphics at the same time. So we can do a lot more with the drawings than has happened in the past. Just assemble the whole thing together as a presentation drawing for their marketing people and their retail people, so that is more that just a cold 2D drawing, which most clients, to be honest, don't even understand. It is something that has certainly been a problem, I think, and even here, where I used it when the one time that the Calgary Flames beat the Montreal team and it only happened once and I have never been able to use this graphic again.

What are some of the problems that have delayed progress in computerization? I think one of the things, I kind of try to produce this graphic to explain to people, is CAD pulling you down when it should be lifting you up. So many of the people I have lectured to in the past few years, will tell me these agonizing stories of introducing CAD into their office and yet I can sympathize with them, because I have been through some of that and it is a major problem, because CAD should help, it should be a major plus in your organization. It so often is a limitation and many firms are now reevaluating whether CAD really was a significant improvement over their manual techniques and that is pretty sad if we have got to that stage.

This one is, is your CAD too much geometry and too little design? It may be a little unfair to do this but this is from a micro station version for the Mac and here I have got geometry pieces that were fine if I was designing a plane, or some mechanical part, but for an architect, the thing is overloaded with too much power. If I wanted to go into a simple drawing, it's really quite tough to do it so this is one of the major problems, finding a CAD system that is comfortable for you, something that if you are an architect you can use it. If you are a contractor doing 'as built' drawings, you have got to choose something that's compatible to the way you work. That is the starting point.

One of the problems, I think we have had is trying to computerize an industry which is not working that well now. This is a lovely cartoon of the realities of the world of construction. We see the top left hand corner, here is the project as the artist drew it, here is as the architect planned it, here is as the engineer designed it, here is as the estimator bid it, the very minimal sand castle, here is as the contractors built it and the right hand bottom one is what the customer really wanted and I think most of us in the industry really, you know, most projects still run that way. It's a very fragmented industry, very poor communication and the only hope that I see, there are two things: one is, I think, we have to use computerization and two, we have to restructure the industry. We can't have the architect playing some super human being role, sitting on this huge platform, trying to orchestrate building design and delivery. The contractors have got to become much closer to the process and we have got to become much more integrators to the industry to do it. There is enough research being done on that to suggest that we have to do that, we can't just go and computerize the existing process, it isn't going to work.

On another sheet, the problems of being an architect in this world, or trying to deliver projects that people truly find enjoyable to live in, use and so on, and there are so many problems within our own industry at the present time. Within government circles, the Auditor General in Canada warned of outdated government computers, and I've got to say that generally, my gut feeling about government is, and I can only relate it to government in Canada, that provincially, civic and federally, is that computerization really has not taken hold in government. I see lots of isolated encouraging signs, but the government has the chance to make major changes to the way that we all work, but frankly, everything I see gives me the impression that it is not doing that. It would probably be similar, I suspect, from any of the countries that you come from, that the government, which should take the lead role, is somehow very confused on how it delivers and that I, as a private architect, fully computerized, I have to make a profit. I have to buy my equipment out of the profits. I can make it work. It should be possible when you are spending a lot of money in the government level, to also make it work, but I have seen so many errors made and many many millions of dollars mis-spent and all I can do is pray for those few people who seem to be doing some excellent work and hopefully try and give them some encouragement to carry-on with that.

I am kind of amused that one of the drawbacks from the industry, Bill Gates, who just came out with the Windows, which, I feel kind of makes the technology go back six or seven years, because he has really made all technology look as though it's new technology and all he did was confirm what Xerox and Apple did, probably seven or eight years ago.

This document that came to me about CAD, if life was fair, your CAD system would be truly easy to use, if life was good, your CAD system would free your creativity, if life was great, your CAD system would help you grow your business. All these wonderful statements from a CAD consultant who, generally, most CAD consultants, but in my experience, all they want to do is lock you into something where you need them forever and that is certainly not what you need in the industry.

Then we get interfaces like this, which I have got to memorize so that I can do some simple drawing, this is from micro station. This one, which is from my computer, and I assume this was multi-tasking, this is where the machine broke down one day, this is also a transparent interface, where everything is visible at the same time, so even my computer breaks down at times and it's kind of a little bit confusing.

This whole dilemma of which machine should I buy, and I think, my advice to most people is to leap in with any system to start with, because I think until you have had your first system, you really don't know what you are going to need. People say, should I wait until next year, when Apple or IBM bring out the new machine and I generally said no, leap in, start now because your first computer, you can always use it for something else sometime in the future. Get in now, start the process as part of a learning exercise.

Probably the way that offices are laid out with these very mechanical layouts in the use of CAD, it also reminds me of a situation, in this case, I believe it's micro stations training centre, and I remember a few years back asking one of the leading guys in micro stations, one of the Bentley brothers, they had just built a new plant and I said, of course you did use micro station in the design of your new plant. He said no, the local architect, the one that knows micro station, is deadly dull as an architect and the one that is a good designer, it would take too long to train him. It really tells you something about the commitment of the industry.

This is part of a system in Canada, Apple gave all of the universities, the schools of architecture, Mac labs and this is the one at Calgary. To some extent I am pretty critical, my only real experience is in Calgary, is the lack of training in, not only architectural design in computers, but probably in this whole ideal of the integration of the construction industry and we see very little use. This centre, which has something like eight or nine MacIntosh computers, very highly powered, is mainly used for word processing. So we do have a bit of a dilemma in our training institutions in terms of bringing in technology that we are all using outside.

I have been teaching there for a year and this is some work that I did with a student recently and he had only been using computers, probably in graphics for a month at the most, and yet, by some care, we were able to evolve some kind of interesting results using some of the modelling software. We need more effort in the training in our institutions if we are going to get an industry that is going to change.

What are some of the positives after being negative about so many things? One of them is output technology. We have resisted plotters like the plague, we have always tried to do things in small format. After all, if the drawing is drawn accurately, why do I have to have this huge drawing? I now know there are reasons why, but we have resisted it, we will piece laser prints together to do that, so the Canon technology with the bubble jet is now producing very high quality output. Disk storage, which used to be a major problem, now we have got almost unlimited storage.

Programs like autocad, which I know is just arrived as I left, and I wanted dearly to get into the new version of autocad to run on the Mac, which I think introduces a lot of the newer technology in a program, that for me, got pretty old fashioned in its approach. Even the big guys, the most popular CAD system in the world, is starting to make some major changes.

Programs like Sketch, which is a Canadian program, very high quality graphics from Alias, one of the top computer graphic companies in the world, programs that deal with quick time and I will try and deal with that afterwards. This is one of Alias' programs which deals with four way tracing, this is really in the upper platforms of graphics and in their lower end, Up Front, which does some really nice modelling in the micro computer end.

Things like communication, this is some test work that we did last year and we are starting to progress. I was actually, from my computer, running a computer in the Frank Lloyd Wright Foundation in Phoenix. I was actually running that computer and it was in full colour, this is only a black and white rendition. They are showing this ability now to work on computers around the world and to be able to work fully interactively at the moment. I was trying to move 24-bit colour images between the two stations, so that is full photographic quality imaging and I was able to use that computer as if it was in my own office.

Projects like, project Pegasus, which Russel Thomas has been involved in, and helping to spearhead, this is a whole management system for managing files and data, something we badly needed, and a firm in Calgary, Chronologic, has been working with NRC to develop a system that will allow us to manage our data, because any of you that are involved in computer work, you know that trying to manage the data is a major problem. This is a system that will allow you to fully track and put tags on every bit of data that you produce on a job.

Other things in Alberta, we have probably been fortunate in having a lot of work in the construction industry. Here is a proposal for a bid system, to make everything fully electronic in the construction industry in Alberta. The Calgary Construction Association has also done the same thing, they have an electronic bidding system now. We have run a couple of very good conferences with the help of government in the west, that have dealt with the whole of the construction industry and its impact by computerization and the government is supportive. It is very strongly into that.

Things like the electric architect, which the Royal Architectural Institute of Canada has been putting out, and that has been a major influence. Anthony Pierson has really helped a great deal with that and again, in Canada, despite the criticisms, we are doing a lot of good things and we are getting the information out.

This whole idea of CAD for life, once we put drawings into a computer, it has to travel through the system, it must not be something we stop once we get to the hand or the stage. Another idea is on build, before you build, basically this is a little job at the Calgary Airport, where we actually completely built the thing within the computer system, because it was a complex little job.

A number have talked about the fully electronic project, the way in which we could all be connected by satellites and so on. We certainly have all the technology to do that, we need some lead, we need government to give the lead in doing projects which are fully electronic, tapeless and so on. The technology is here to do it, let's do it, let's test it and stop talking about it.

An update on some of our new ideas on the electronic approach, where we are using a very icon-based scheduling system, but I don't have time to go into that now. So what are some of the future aspects? For those of you that are aware that in the Apple environment, quick time, which is the ability to bring video imaging into a computer screen and I think if we see things happening like this, the ability to mix video and computer imaging together, we are already using it in our office. It is limited, because of the hardware, to fairly small images.

But I can now do a Hollywood style, editing a video and my computer animation, and produce a very professional looking document. The imaging is small; that is the only limitation at the present time.

Concepts like this which, this is a concept for the Mac in few years time, which fully does everything, it is a printer, it is a video machine, it is a computer, and in fact Apple has just announced Newton, which is a new computer that you can actually write into and you will be able to use it as a fax machine, it will understand the writing and so on. There are some pretty novel things happening in the computer industry.

Virtual reality, this in fact, is one of my student's, we were experimenting with virtual reality there, and we hope to continue to do that. I am not so sure that I want all of my clients to wear helmets like this, but it is certainly a novel way to look at a project and fully experience it, at least visually.

Again, we do a lot of this, I didn't subject this group to this, but I was very delighted a few months back, to have a whole audience with 3D glasses on and I did the terrible thing of taking a photograph of them.

SESSION 5A
Computers, a Tool for Integration?
L'ordinateur, un outil d'intégration?

An Integrated Design-Construction Information Coding System (IDCICS) Based on Keyless Data Acquisition Technologies

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The handling of the basic information required to produce the built-environment has relied heavily upon traditional data processing and telecommunications technologies for the movement of information among clients, designers, and constructors. A measure of adaptation of the state-of-the-art advances in information and computer technologies has occurred or is ongoing in several design-construction areas:

1. Utilization of computers in drawing generation (CADD);

2. Employment of Geographic Information System (GIS) mapping technology in urban planning;

3. Applications of CD-ROM technology for specification preparation;

4. Software applications for engineering computation (CADD), estimating, and project planning/management;

Despite the widespread use of these technologies by construction professionals, the main business of the production of the built environment is conducted in much the same fashion as it has been since the invention of the telephone. With the exception of GIS usage, the application of the computer technologies listed above has largely mimicked the traditional processes and methodologies of conducting the business of construction, albeit at much higher speeds. As a consequence there have been numerous difficulties over the past decade in taking full advantage of the potential speed, accuracy, reliability, and power offered by the pervasive microcomputer and its telecommunication counterparts. This has been particularly evident in many design offices where the advent of CADD produced no increase in productivity or profits because the computer simply replaced the drawing pencil without a parallel change in the thought process and procedures used to organize and execute design.

Rapid advances in information handling spurred by industries as diverse as manufacturing, retail business, medical data systems, and aerospace sciences provide the potential for a radical departure from the traditional ways of handling information within the design and construction industry. The underlying purpose for making a great leap forward in the methodology for handling design and construction data is to reverse the falling productivity of the industry. As previously noted this change in technology must be accompanied by a change in thinking and procedures to make it effective.

A specific example of a potential avenue to just such a radical departure in the information handling of design and construction data is offered by the "keyless" data entry systems which are so pervasive in retail businesses and supermarkets. Rapid, accurate tracking of sales and stock levels is achieved through the use of bar codes on the packaging which uniquely identify packages and contents. Additional information about the manufacturer and the cost of the product is rapidly accessed by communicating with a database. The use of a "keyless" data entry system is attractive because it provides huge advantages in speed and accuracy over the traditional key-based systems which rely on the human interface to provide a string of reliable information as the basis for manipulating the database. Many classic situations which occur in the various phases of creating the built-environment could proceed much more rapidly and reliably using similar keyless data systems. Keyless data systems are not limited to bar code systems and include other keyless systems such as the touch screen, the trackball/mouse and optical scanners.

Presented in the following paragraphs is a conceptual description of a revolutionary new means of handling a large amount of important design and construction information which takes full advantage of keyless data systems. This system is called the Integrated Design-Construct Information Coding System (IDCICS). IDCICS is centered around the concept of maximizing the handling of information by means of keyless data systems.

The flow of information which begins at the design architect level is replete with manufactured products: doors, windows, and finishes are common examples. Much of the labor of producing the contract documents and the cost estimates which back the contract documents is expended in the endless pursuit of product information, prices, and other pertinent data. The ultimate decisions of the designers are incorporated into specifications which are then utilized in the bid process by the group of contracting firms which have decided and are qualified to pursue the project. A second flow of queries, largely for pricing information is generated by the constructors to assist them in bid preparation. This process is followed by at least one more circuit of information flow as the winning constructor obtains final pricing information prior to purchasing the requisite items. It is clear that the same information is handled repeatedly at these various stages. Errors can be introduced through the incorrect writing or reading of the specifications by the parties involved. The net result of this entire process is a system of handling information which is very slow, awkward, and error-prone.

The antithesis of the traditional system is one based on a bar-coded system of information handling. Assume first that each manufactured product utilized in construction has a bar code containing its CSI division and other information detailing its model, type, and "or equal" manufacturer where appropriate. As the designers are creating the specifications, the product information would be loaded into the specifications by "wanding" the information from catalogs using a bar code reader, extracting it from CD-ROM's, and by using other magnetic or written sources of information. The specifications would ultimately contain the product bar codes for use during the bidding process.

At any point in the design process the architect or engineer would be able to transfer the bar code information to a computer based telecommunications system which would automatically query the manufacturers of the bar coded product. In turn, the manufacturers' terminal side would automatically respond with the pricing data required by the designers. A similar scenario would occur at the bidding stage where the competing constructors would wand the bar codes into the telecommunications computer which would then automatically query the manufacturers of the required products and materials. Again the manufacturers' terminals would automatically respond with the required information. This process would be followed at least one more time as the winning contractor queries industry for finalized pricing.

The generation of cost estimates could be greatly enhanced by using this same bar code system for the entry of information about products which has either been retrieved from references or from the information obtained from product queries.

The advantages of keyless data systems are extensive. In the case of bar codes, for example, current technology allows the encoding of up to 43 characters in a single code line. The speed of moving information using the bar code is extremely fast, with codes being able to be entered at a rate of at least one per second with little or no fatigue. This must be contrasted with the entry of information via keyboard which entails a comparatively slow, error-prone method of handling information.

Clearly, for an IDCICS system to function requires the participation and cooperation of the various members of the design-construction community consisting of designers and constructors or construction professionals, and the material manufacturers. Within the various CSI divisions manufacturers having common interests would have to decide on subsets of encoding systems for their products which are tied in to a common template for the overall IDCICS system. To gain acceptance bar codes would have to begin appearing in advertising and in national product references such as Sweets. The means of taking advantage of the bar codes would have to be developed in the form of hardware and software which allows several operations:

1. Wanding of bar codes out of references

2. Searching CD-ROMs for compatible product manufacturers

3. Transmitting queries to manufacturers

4. Receiving and storing manufacturers' responses

5. Incorporating bar codes into specification text

The technology for accomplishing each of these tasks exists in the form of bar code wands and their microcomputer interfaces, computer fax cards and modems, CD-ROM mass storage devices, mouse/trackball systems and optical scanners. Implementation would be fairly straightforward with the main effort being spent on the generation of the requisite software to allow IDCICS to function.

Industry should find this a very cost-effective method of conducting marketing and sales efforts. The combination of keyless data entry, modem, and product literature containing bar codes would provide manufacturers with a ready means of customer contact and service as well as numerous other options for exploiting the technology described here.

LA POST-ÉVALUATION DES BATIMENTS A L'AIDE DE L'APPROCHE DE SYSTEME EXPERT

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1- <u>*Introduction*</u>

La post-évaluation des bâtiments et espaces administratifs fait l'objet de nombreux articles portant surtout sur des aspects particuliers du bâtiment (économie d'énergie, sécurité, qualité de vie, etc), mais relativement peu sur une évaluation globale. Seuls des essais de nature conceptuelle [Boyce - 1982] [Adum - 1991] proposent une liste plus exhaustive de facteurs à considérer, toutefois ils n'indiquent pas comment les intégrer, d'autres ne s'intéressent qu'à un seul type d'espace tel l'espace bureau [Vischer - 1989].
L'effort de planification et de contrôle qui s'effectue à l'aide d'encadrements concernant les bâtiments et espaces administratifs [Hydro-Québec, 1989] dicte pourtant une approche de post-évaluation plus globale afin de s'assurer du respect des politiques, directives et méthodes de l'entreprise. C'est dans cette optique qu'a été mis en oeuvre cette étude qui cherche à développer une approche de post-évaluation plus intégrée. Plus particulièrement l'approche informatisée à l'aide des outils de développement de système expert a permi de suivre les quatre orientations principales concernant les bâtiments et espaces administratifs tel qu'énoncé dans les encadrements comprenant la rentabilité financière, la qualité de vie, la sobriété et l'intégration fonctionnelle.

2- <u>*La post-évaluation des espaces*</u>

Il faut distinguer l'évaluation en cours de spécifications et la post-évaluation comme telle. Alors que la première a un caractère préventif ou correctif, la dernière est plus de nature pro-active visant des objectifs de planification et contrôle à moyen et à long terme. Outre cette précision il faut aussi s'attarder sur le terme d'*espace* qui fait l'objet de cette post-évaluation. Il est en effet apparu que la notion d'espace revêt des connotations diverses, dépendantes de la formation de l'évaluateur et surtout de sa spécialisation en tant qu'architecte, ingénieur, financier, etc (Moulin et ass. 1991).

Nous avons distingué les quatre groupes de caractéristiques suivants: les caractéristiques topologiques, l'appréciation générale de l'espace, les caractéristiques de gestion globale, les caractéristiques techniques:

- Les caractéristiques topologiques: *Un espace est lié fonctionnellement à des espaces adjacents (principes architecturaux).*
- L'appréciation générale de l'espace: *Un espace présente une esthétique globale qui impressionne les humains qui sont en contact avec l'espace.*
- Les caractéristiques de gestion globale: *Un espace est associé à des données de gestion qui sont en général des données financières typiques de l'espace, ou des données agrégées issues des opérations liées à l'exploitation de l'espace.*
- Les caractéristiques techniques: *Un espace est construit de constituants physiques.*

En tenant compte de ces modèles on a identifié un ensemble d'indicateurs associé à chacune des orientations que l'évaluateur veut suivre en conformité avec les encadrements d'entreprise.

ESPACE BUREAU

	INDICATEURS
RENTABILITE FINANCIERE	*écarts budgétaires et coûts / m2* /année* {énergie, (location), entretien et réparation (équipements, aménagements), services} *coût.location / employé* *superficie.locative / superficie.brute* *superficie.aménagée / superficie.locative* *qualité.gestion.exploitant* *gestion.des.garanties* *degré.satisfaction.vis-à-vis.sous-contractants* *degré.satisfaction.activités.bureau*
QUALITE DE VIE	*normes santé, sécurité, superficies etc.* {équipements, services, aménagements, constituants.physiques} *fiabilité.services* *qualité.services* *ergonomie* *problèmes.santé* *degré.satisfaction.usagers / problèmes* {équipements, services, aménagements, constituants.physiques} *plaintes.usagers*
SOBRIETE	*coût.décoration.intérieure / m2** *atmosphère.générale* *degré.satisfaction.usagers / esthétique* *visibilité.oeuvres.d.art*
INTEGRATION FONCTIONNELLE ET HARMONIEUSE DANS LE MILIEU	*harmonie.matériaux* *harmonie.couleurs* *qualité.utilisation.espaces*

Tableau d'Évaluation pour l'espace bureau

3- *Une grille d'évaluation des orientations*

Les résultats d'une évaluation par orientation et par espace sont assemblés sous forme d'une grille d'évaluation. Ils se présentent sous forme de matrice qui fait ressortir les valeurs marginales pour les indicateurs globaux recherchés. Plus spécifiquement l'évaluation relative à chaque orientation pour l'ensemble des espaces peut être identifié directement par la colonne concernée de la matrice; par ailleurs les évaluations de chaque espace pour l'ensemble des orientations est la valeur marginale d'une ligne. Enfin l'évaluation globale peut être identifiée dans la valeur combinée des valeurs marginales tel qu'indiqué à la figure 1.

----------------------------------ORIENTATIONS----------------------------------

Type d'Espace	Rentabilité	Qualité de vie	Sobriété	Intégr. fonct.	Evaluation
du bâtiment	Valeur %	Valeur %	Valeur %	Valeur %	
Espace 1					évaluation de l'espace 1
Espace 2					évaluation de l'espace 2
Evaluation	Valeur %	Valeur %	Valeur %	Valeur %	évaluation globale

Figure 1 - Rapport d'évaluation sous forme de matrice

Le processsus d'évaluation global exige donc l'évaluation de la valeur de chaque cellule de la matrice (ex.: qualité de vie, espace bureau) et la combinaison des diverses valeurs avec leurs poids respectifs. La représentation informatisée à partir de la grille fut réalisée à l'aide de l'approche des systèmes experts. L'aspect de processus nécessite un raisonnement en chaînage avant. Autrement dit, le fait constitué par le résultat détermine l'étape d'évaluation qui suit.
Quant aux expertises particulières, elles s'effectuent par chaînage arrière, l'hypothèse à évaluer soit la rentabilité financière, la qualité de vie, la sobriété et l'intégration fonctionnelle constituant le but. La relation entre le but hypothétique et les facteurs sous-jacents est représentée par des règles. Chaque expertise est encapsulée, le tout constituant un véritable système multi-expert (figure 2).

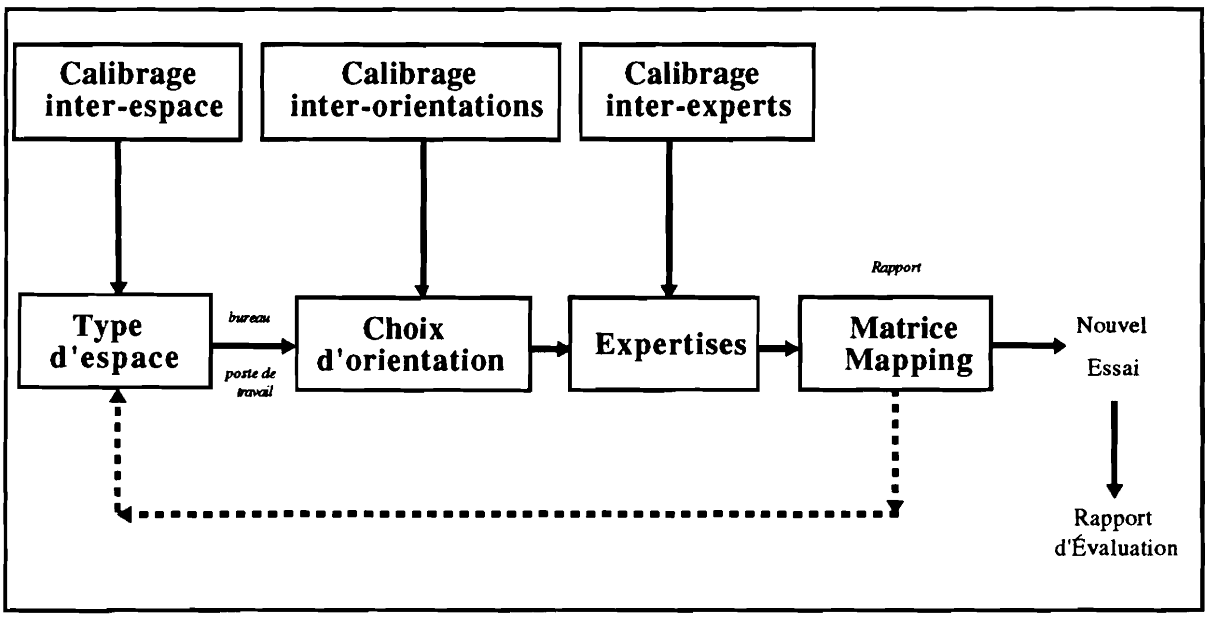

Figure 2. Les fonctionnalités du système multi-expert

L'appréciation des poids relatifs entre les espaces et entre les orientations, ainsi que l'importance des avis des experts impliqués ont été identifiés par un exercice de modélisation hiérarchique multi-critère (M.H.M.) proposé par SAATY (Saaty 1981).
A titre d'illustration, l'arborescence suivante fut utilisée pour calibrer les poids relatifs inter-experts, inter-orientations et inter-espaces (figure 3):

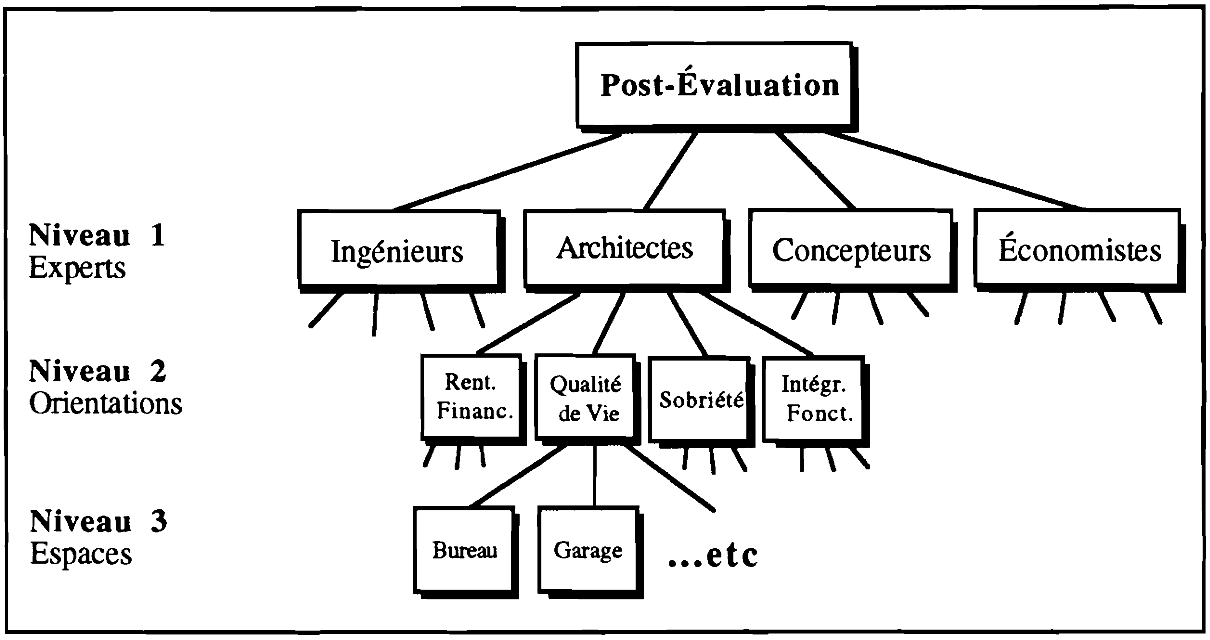

Figure 3. Arborescence permettant le calibrage.

La méthode de SAATY, tout en "découvrant" à partir de comparaisons deux à deux les poids relatifs quantifiés, teste la cohérence logique des appréciations fournies par les experts.
Les modules experts ont été développés à l'aide de l'outil ARGUMENT[1] un outil de développement à base de règles en chaînage arrière qui offrait la facilité de mise en oeuvre de la représentation de la connaissance et d'exécution rapide. La calibration fut implantée à l'aide de l'outil DESCRIPTOR[2] qui applique d'une façon systématique l'approche de décision d'évaluation multi-critères par la méthode de SAATY [Saaty - 1981]. L'intégration de l'ensemble avec la conception d'interface usagers et la production de rapports a été réalisé à l'aide de DECIDEX[1] une véritable boîte à outils pour développer des systèmes multi-experts. Lors d'une session l'usager sera guidé entièrement par le système qui intègre en transparence les diverses technologies employées. Suivant le processus de la figure 2 le système posera des questions de *navigation* pour solutionner un type d'espace donné et offrira un choix pour la calibration et lancera un expert pertinent lorsque requis.
Les options de cartographie ou *mapping* peuvent être exécutées sur demande permettant de positionner d'une façon graphique les diverses opinions des spécialistes pour des indicateurs données (figure 4)

[1]. Marque déposée de STRATEMS.
[2]. Marque déposée de INTELMARK

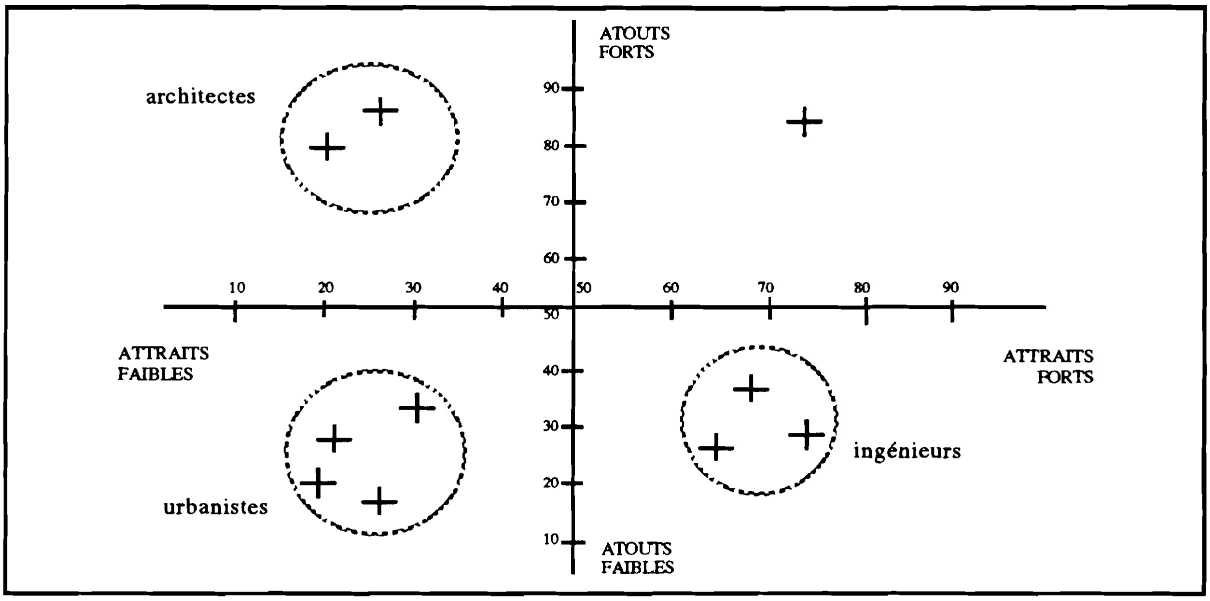

Figure 4 - Cartographie des options d'experts

Cette option facilitera donc la communication requise pour résoudre les conflits reliés à des expertises variées. Cette dernière préoccupation fut également utilisée dans le modèle hiérarchique de calibration.

4- Conclusions

Le développement d'un système expert de post-évaluation globale est un exercice difficile qui, sur la base de l'expérience décrite se présente comme un véritable processus de recherche et développement. Les hypothèses sont testées continuellement lors de l'exercice d'ingénierie de la connaissance, l'expérimentation avec le système lui-même servant de prototype.
Le système développé jusqu'à présent bénéficie d'un accueil favorable de la part des experts du service, et de sa direction; et est encouragé par un *champion interne.* Beaucoup d'éléments d'une stratégie d'implantation sont donc réunis pour assurer le succès du projet. Toutefois le défi à relever est celui de disséminer le système auprès des utilisateurs finaux se trouvant dans les régions. Outre une validation interne et des ajustements conséquents c'est le problème prioritaire à résoudre pour la suite du développement.

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SESSION 5A
COMPUTERS, A TOOL FOR INTEGRATION?

Questions and Discussion

Question

I am from the University of Florida. I am just curious, how much does a bar code reader cost, because I heard that they were fairly expensive, and does Sweet's catalogue look at this process as an advantage in terms of what they are doing, or do they look at it as competition?

Mr. Kibert

The bar code reader is, including the bar code reader and an interface card and some software cost, in the order of a few hundred dollars and, again, there is a lot of different prices, but the elementary ones are relatively cheap on the order of computer technologies nowadays.

Sweet's catalogue, we are just basically starting to talk to them about it, but that is a big concern, because they may in fact see this as a big competition, but we are trying to point out to them some of the advantages of them doing this, that this in fact is the cutting edge. That is why we are trying to get them involved early, so that they will understand and also participate in the process, plus they are already starting to produce their catalogue on CD ROM's and we want to try to demonstrate to them that they already have a leg up starting into this technology and therefore it would be to their advantage to participate.

For those of you that don't know, Sweet's catalogue is perhaps the most commonly used catalogue in the States. They are an enormous supplier of information. They are part of the McGraw Hill Corporation, who are a publisher. Nonetheless, they are somebody that we are trying to work with and we are starting to talk to them about this process to try to get them involved.

Question
Nash Harper
City of Montreal

Exchanging the information between the manufacturer is usually OK, but for pricing wise, how do they manage not to, especially when you are pricing a job on a bid.

Mr. Kibert

One of the problems is going to be, in a system like this, is going to be how to keep manufacturers from accessing other manufacturers' or competition's data. This is going to be a function of, I believe, access codes and having access. So anybody who wants to be on a system like this, will obviously have to pay some sort of fee, hopefully not too onerous, to maintain the system, because there is going to be the need to have access codes and communication amongst the users and to maintain the system itself. We don't think that is going to be very expensive.

I see it functioning as access codes and only folks with authorized codes can get in. Obviously, manufacturers will not be authorized to access other manufacturers' systems. We see a great deal of problem working with manufacturers, at least in America. There are a lot of different ways of pricing, for example, if an architect comes in and asks for a price, they will get one price, whereas if a contractor comes in and asks for a price, they will get another price. Again, the ID coming into the system will tell the manufacturer who that is and the price will come back however the manufacturer designs that. So really they are not going to change the way they are doing business. It's a function of setting up the communications interfaces and the gateway so that it's understood who is trying to access and break into the system (hopefully not a lot of young kids from Los Angeles).

Question

That means that the pricing can change between the different levels, and they are finishing the bid, that can be different also?

Mr. Kibert

That is exactly what happens in the construction process, that is not any different. The only time that you lock in a price, is when you place a purchase order.

For those of you from Europe that use unit price type specifications, especially in Germany, where there is basically a long list of products with the quantities, this system would be ideal for that, because basically the quantities and the product could be each bar coded and the information would be very easy to handle in that situation. In fact, that is the ideal way of using a system like this.

Question

I am wondering about the fact that the IBM and the Mac, at least in Canada, I realize that the government uses one system or many, and then the industry, because of the different needs that they have, they use all the different systems. If you are going to have an ability to integrate these things, you are going to have to be able to transfer the information from one to the other – perhaps be able to translate them or decide on one way.

It's great if we can have this integrated system, it sounds wonderful and you realize immediately that there is so many complications that are going to have to be solved. It's going to take a lot of time, you go into the companies, find the small problems and try to give them the information so that they can immediately start implementing what's available now.

Speaker

There are a couple of ways that you can go with this problem. The first is in terms of how can you deal with many platforms with many different ways of doing some of this information? There are a number of attempts at standardization currently taking place around the world. In terms of the system that my colleague described, in Europe, there is a reasonably sophisticated level of use of EDI, Electronic Data Interchange, which is a protocol and a standard for exchanging information between clients and bidders in terms of both their requirements, and basically it's a standard that says who the person requesting the information is, what the information is that they require, and this can even go down to the level of electronic funds transfer, so that you can exchange a bid information, you get back the information from the supplier saying, I will operate at this, you can order it and then you can pay for it using the electronic funds transfer.

Those protocols have been established and they are in place in Europe and being used fairly extensively. Probably in the earlier stages, about five years ago, the English were leading that situation, now it is more widespread in Europe, and probably the English are slightly behind, but at least Europe has it fairly well established.

In North America, that system has not yet really come into place, it is rather more a free-for-all between the suppliers. It partly depends on a very good client/supplier association, in other words, if you are a client, you can basically require that your suppliers adopt a system because it can speed up your process of getting the bids in. In a sense, you have to know what it is you want, but then you can send that out to all the possible suppliers on your normal supply list and get their bids back in and you can select appropriately.

That depends upon the adoption of standards and basically those are at the lowest common denominator. For those of you who know basic computing techniques, that's using ASCI level communications. It doesn't matter which platform you are working from in terms of hardware or software, it's a low common denominator, with a structure in the messages that you are exchanging.

At the slightly higher level, my colleague mentioned the W78 working group, of the CIB. They are presently working at developing the basis of a standard for database structures. They are really called product models, which is an attempt to identify what components exist within the construction process. But by establishing the basis of a standard in terms of the model of the process, it allows us now to use that model to develop databases, which we can begin to exchange between the different participants in the process, so that we all have a common understanding of what we expect to find in each of those slots in the database.

In a sense, we have been talking about CAD drawings, about information and about standards; those are really all components in that construction database and all we are doing is looking at it from different perspectives. The designer looks at the information in the database and expects to see a graphical representation of it, the accountant in the company looks at the same database and expects to see a summary figure at the bottom.

It's all accessing the same database, but from different perspectives and those are based upon the placing in position of standards and in a sense I think that's one of the activities that CIB can attempt to do, it can place into the situation the kinds of starting position, so that we can achieve the kind of integration that we are talking about. Without a level of commonality across those databases, we are not going to get very far.

Question

I am wondering, once you have established a common database where you find reliable, up-to-date information on prices of materials for construction and once that database is generally accessible to everybody, so everybody shares the same information, what do you foresee happens to a market in construction services in terms of competition? What do they compete on?

Mr. Kibert

First of all, there is not one database; each manufacturer would maintain its own database, only because in our initial investigation of the size of this database and the number of elements, if it were to be handled by a service that established one database and one location, it would just be a massive ordeal to try to keep the data current. Another thought was perhaps to allow the manufacturers access to that database and update their own information.

The second level, we are pretty well convinced that the manufacturers are going to do a much better job at maintaining their own database and so each of their databases would be there locally on this network, which could be accessed the way manufacturers do the same thing today.

There really is no difference in the way these people are going to do business. They are still going to be competing upon price and quality of their products. They are not going to have access to each others information, so in that regard, I don't see that there would be a difference in terms of levels of competition.

The same situation exists nowadays. Contractors will get the price and I am sure there are going to be other mechanisms in place, such as phone calls after the fact, to try to beat the price down; that is a normal situation, I don't think we are ever going to change that. When it comes down to the final level of competition, where it gets down and dirty, they are going to pick up the phone and call whoever they have to, to get the price knocked down. It may be a matter, they have gotten a price but will call the manufacturer of a certain air handler which is a major price component of a building and say look, I have bought these things from you for the last 20 years, I expect a better deal than I am getting on this, over this computer system and they will get their verification that way.

Question
Eugene Marota
Government Official, Engineer

I was intrigued by his example of how changes could take place during the construction process, where the architect and the engineer or the contractor and the architect could agree on changes in the construction phase and I can see that has been the case in the past as well. Never did he mention the fact that somewhere along the way there has got to be a government official, who is asked to look at the change and see if, in fact, it is still in accordance with the proposed building design as reviewed and approved by that government official.

I was wondering if in the integration process, is deliberately forgetting that step, as is normally the case, or is it trying to improve upon it by making sure that this is not done while the computerized integration process is completed.

Mr. Thomas

One government official asked somebody else a delicate question. I think there are a couple of answers to your question. We are talking in a perfect world, as though a particular process was going to be achieved within the next year or so. I think one has to look at two issues; there is the pragmatic approach which is, what can we do now to solve people's immediate problems and what kind of research should we be doing to forestall problems occurring down the road and to look forward to solving some of those problems?

In terms of your solutions, with regards to checking the verification of the changes that you are going to do, I think that in a number of years' time, some of the research that we have seen here this week, some that took place in the W78 workshop indicated that there are a number of centres around the world who are currently looking at automated verification systems.

Basically, those are systems which take the existing standards and codes, model those standards and codes as constraints upon the design structures and then during the design and during the checking of those designs, it would automatically identify violations. In that sense, what you have got is a policeman sitting at your desk all the time, telling you, yes, you are violating constraints and you shouldn't do it.

There are other approaches to solving the you can do it and we heard about those in the session on risk assessment, when they pointed out that in Singapore, for example they are turning the onus and responsibility onto particular individuals, to check that process. In some of the provinces here in Canada, they are beginning to talk about giving the responsibility to the actual constructor. He becomes legally responsible for checking that his designs continue to meet the original intent of the codes as he constructs the building, i.e., self certification.

There may be an increasing trend in that direction, because we are electing more and more to the stage of saying, somebody has to be responsible for this building and that individual has to be well identified. I think we may begin to bring in legal mechanisms for achieving the sort of concerns you had, as a government official. I am sure you will be able to do something about it.

Question
Dave Renshaw
Public Works Canada

I would like to explore this just a little further, with respect to the problem we have in the life cycle of any facility in its planning, design, construction, operation, maintenance and final disposal; that industry is terribly fragmented as we know. Because of that fragmentation and the legal liabilities and concerns, there is not very much that is there in terms of incentives to encourage people to innovate, to use new technology.

As we know, the designer produces a defensive design, the owner wants something that's cost effective, the contractor follows the plans and designs carefully, looks for extras, where there are mistakes. Do you see the system that you are talking about, improving this situation, such that the communications and cooperation between the different players will allow for greater innovation, greater risk taking? I would be particularly interested in hearing the experience of our Finish friends in this regard.

Markku Salmi

I really believe in the information techniques, and open information systems are the only way to increase integration among the construction field and among one single building project. As I mentioned, we have already experienced this, it has already worked for three weeks.

Pekka Leppanen

There are requirements for maintenance, there are requirements for flexibility, requirements for actual performance and use performance and with these we have already made tests, actual projects, we have asked for bids with this kind of paper only and it's the manufacturer's, contractor's job to design and sell and give a guarantee for a product and here you can use all your innovative power you ever had. This is the strategy of Finnish Technical Development Centre, to push manufacturers and contractors to take the responsibility. With these tables, these are in plain Finnish, the user can use them, engineers can read them, architects can read them, manufacturers and maintenance people can read these, so it is very easy to verify. This is a quality control tool for the whole project. It is easy to say, is this the performance that was promised, that was required and this is a very simple looking system, but it is really working. We have one whole building, all contacts are made with these papers or even less information. Here is a lot of requirements.

Question

Can I throw your own question back to you, because I think one of the things is quite clear is that it is a question of who has the biggest vested interest in achieving your objective and I think that is clearly the owner of the construction process, the person who wants the building built. Until that individual is prepared to specify that there is continuity through that process that you have just described, we are not really going to see the individual players taking advantage of it, because it's the owner who makes the gains in the process. He doesn't have to have the 'as built' drawn from the actual construction drawings, because it's the same information being updated that moves through the system and they are the people who are going to win; the construction process can off lay those costs right back to the owner. So until the owner is in the position to specify that he wants it done in this particular way, where integration is the theme through the whole process, I don't think the other individual players, it's not in their interest at the present time to do it.

Question
Norman Spatz
CEGEP de Montreal

I also feel, just in reaction to what you were saying, that we now have a construction process, at least in North America, that is, if anything, combative; everybody is trying to cover themselves to avoid a law suit. This is, again, not a question, this is a comment. If we are going to have the kind of integration that we are talking about, are we going to have some sort of structure or evolution that is going to permit us all to work as a team, with possibly a team responsibility, as opposed to everyone sort of retreating into their corners, saying I am really working as part of a team but I don't want to be the one that is blamed for this. I think that we have to somehow change the structure of vested interests within the process, before we are really ready to integrate because, as you were saying, there is absolutely no incentive for a lot of people to integrate because in many ways they are putting themselves in a position where they cannot control their own liability.

Speaker

I will respond to the question that was thrown back, and I think it's a fair answer. I quite agree, the owner has to be the one who initiates and as Public Works Canada, as owners, we try. We also see ourselves in a position of being quite concerned about risk taking and what we would suggest is that risk taking, as Norman so aptly put it, has to be shared and I think there is a great part here for manufacturers in particular, people who want to put their products into play, to share in the risk taking involved. I believe that extends itself to the architects and engineers. There must be a team effort, there must be a cooperative effort such that risk is spread around enough that everybody feels comfortable.

Mr. Kibert

I wanted to mention a few factors that are involved in that. One is that a lot of the quality and problems that are developed have to do with the payment of fees. The owner, when they are paying designers to do a project, try to pay the minimal fee possible, and consequently many times they get what they pay for and therefore the effort as far as sorting through various options, as far as trying to find absolutely the best systems, are kind of short circuited by the amount of time available being constrained by design fees, so that is one problem area.

The second one is the hard bid process, where you actually have extremely competitive bidding, creates an atmosphere of trying to lean on getting extras and creating an adversary relationship in order to earn additional money. There is some room there to change that process to some extent, to base the actual construction, using people who have a reputation for quality, instead of simply making it an actual hard bidding process, to change that process itself. The studies I have seen performed in the U.S. have shown that doing the jobs that way will save, oftentimes much more money than the hard bid process, because of the litigation that goes on, all the extras that are claimed and so on. I think there is a need to examine some of the processes of the way people obtain their construction, obtain their designs, in order to perhaps emphasize more quality rather than simply the lowest possible price of doing things. Because in the end you pay, is the bottom line.

Comment
Mr. Pendergast

I guess I was probably hoping to see more of a discussion about a revolution, perhaps in the way we do things. I think a number of us feel that it is timely to do that. It's kind of interesting when you think of General Motors, when it designs a new car, puts a billion dollars into research and still screws up in the final product. And there we go bravely, I listened to my fellow architects and myself, we are saying we can do miracles, we can do it on cost and quality. I think what we do need is a complete change in how we put buildings together. Somehow we have got to come up with a tendering system that lets contractors come into that early stage. We have got to have competition but when I start building things in the computer, I would like it to be based on realism. I watched so many of my fellow professionals who run through their life in a dream world and the final building often represents that. I think we have got to do a lot more than what we have discussed this morning, even though I am intrigued by the thought that we are making progress, but we have got to do a lot more.

SESSION 5B
Computers as a Design Tool
L'ordinateur comme un outil d'aide à la conception

A Knowledge-Based System Concieved To Be An Architet's Partner In Creative Design

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1. The representation of building objects

In recent years, professionals engaged the building process have resorted increasingly to dedicated architectural design software, such as drafting and management systems, data bases, calculation and evaluation programs.
However, at the same time, it has become increasingly necessary to integrate these tools into a single system that will help the designer through the various design phases.
To meet this need, a research project is being conducted at the CABD LAB of the Department of Building and Environmental Control Technologies to create a dedicated architectural design system based on Knowledge Engineering techniques.
The proposed system will serve as an interface between the designer and the conventional software, and can perform the following tasks:

- interacting with the designer in a simple and natural manner using a high level language;
- checking the consistency of the data input and ensuring that they match a given system of constraints;

The design process needs to continually check the consistency of the design choices against a given set of goals to be attained: this check is generally performed by matching abstract representations of design goals against those of the Real Building Objects (R.B.O.) being sought resulting from complex intellectual actions closely related to the designer's own culture and environment. this paper defines a possible formalization of such representations for the goals and the r.b.o. that are usually considered in the architectural design process by our culture in our environment.
the representation of the design goals is performed by expressing their objective aspects (requirements) and by defining their allowable values (performance specifications). The resulting system of requirements defines the set of allowable building objects (B.O.) consisting of the set of characteristics (attributes and relations which are considered relevant to represent the particular kind of R.B.O. with respect to the consistency check against the designer goals. The values related to these characteristics define the performances of the R.B.O., while their set establishes its behaviour.
It is not possible to completely define a B.O. deductively in advance, since it is inferred from the considered goals and is itself a result of the design process. All that can be established in advance in that set of characteristics assumed to represent any R.B.O. are hierarchical, topological, geometrical and functional relations between the parts of the object - at any level of aggregation, components, space units, building units, the whole building - which we define as representation structures.
In other words, the representation structures, by superposition and interaction, form the abstract representation that matches the design goals.

2. The structure of the knowledge base

The KAAD system's knowledge base has been created by implementing the representation structures through a set of prototypes, slots and calculating procedures. The system of prototypes is a basic component of a frame-based knowledge representation system because it guides the inferential process of the system through the slot filling process, which we shall examine shortly.
The fundamental prototypes that will be used stem from the previous definition of the representation structure.
Below is a brief description of the most important prototypes used in the KAAD system.

2.1. The building unit prototype

This represents the highest level of aggregation of the building objects. A B.U. is a structured set of space units. The form which represents the B.U. prototype comprises a single slot: IMP (Immediate Predecessor) and the indication of the type of values which it can have. As a result of the definition of the hierarchical structures, these values are yet more B.U. or Space Units. Using the B.U. prototype, it is possible to insert more instances of specific B.U., filling in the frames of the further slots which are required.

2.2. The space unit prototype

A S.U. is a class of equivalent environments used for the same group of activities, requiring the same environmental characteristics and the same equipment.
The S.U. prototype comprises a set of slots which represent the fundamental features, such as the elements which comprise it. the elements b whose definition it contributes, the topological relations between it and the other S.U., and its geometric forms.
The main slots in a S.U. are:
- the IMP: as with the B.U., the IMP contains the type of hierarchically subordinate building objects which contribute to the definition of a S.U., namely the functional elements;
- the **IMS** (Immediate Successor): this contains the building objects on the immediately higher hierarchical level, to whose definition the S.U. may contribute, namely, the B.U..
- **ADJ** (Adjacent): this establishes an adjacent relationship between a S.U. and those contained in the slots. Its content may have consequences on one or more S.U.
- **COM** (communication): this establishes the existence of a path between S.U.
- **SHAPE:** this defines the geometric form of the S.V., and its content may only be an object of the SHAPE type. SHAPE is another prototype of the system which establishes the way in which the S.U. is represented in terms of the type of geometric model used.

2.3. The functional subsystem prototype

A functional subsystem (F.S.) is a class of equivalences of complex physical elements, used for the same functions to delimit space, to assure an appropriate level of safety and environment comfort. The prototype that the F.S. represents is structurally similar to the one which represents an S.U. The IMS and IMP slots contain the names of the S.U. which the F.S. helps to define. and the F.S. and/or functional elements which comprise it, respectively. The ADJ slot indicates the names of the F.S. to which it is deemed to be adjacent. The SHAPE slot, as with the S.U., will contain a SHAPE object.

2.4. The functional element prototype

A functional element is a class of equivalences of physical elements with a specific value in the definition of the F.E. and their functional operations.
The F.E. prototype is wholly similar to the functional subsystem prototype. The IMP and IMS slots can only contain constructive elements and functional elements, respectively. The ADJ slot will contain elements of a more complex type, also prototypes, which describe the variations of their mutual positions in the space of the constructive element in terms of the functional elements that they contribute to define. The SHAPE slot contains a SHAPE type object.

2.5. Constraints

In the KAAD system's knowledge base, two types of constraints can be defined: natural constraints (N.C.) and design constraints (D.C.).
The natural constraints determine the limits on the variation of certain features of the building objects in order to guarantee the internal consistency of the knowledge base.
The second type of constraints stem from the need to comply with the demands of the designer. The N.C. are represented in the knowledge base by defining appropriate facets for the characteristics to which they refer. In this way, they are propagated to the instances as they are created and hence there is an ongoing consistency check on the input data.
The D.C. are represented by appropriate frames whose prototype REQ (requirement) is the slot domain which defines the object(s) which constitute(s) the domain of application of the requirement. The requirement's instances are completed one after the other with the specification of the slot(s) to be constrained and of the accepted variation limits.
The variation domains of the constrained features. whatever the type of constraint involved, are defined using the facets listed below:
- **Range:** this contains two values which define a continuous variation interval;
- **Set**: this identifies a set of discrete values which the slot may token on ;
- **Classes:** this comprises pairs of elements which identify intervals of variation. in terms of which the value attributed to one feature

can be classified;

- **Max, Min:** these identify acceptance thresholds;
- **Value:** this is the facet which contains the value supplied by the instance in respect of a feature, and which must be matched against those defined by the preceding facets.

3. The operation on the Kaad system

The KAAD system operates on the basis of a general deductive process which can exploit the hierarchical relationship established by the frame formalism between the instances and the knowledge base prototypes .
This process. called inheritance, has been created by means of a calculation procedure which uses two slots called ISA and AKO (is a) and (a kind of). The ISA slot establishes a hierarchical relation between a prototype and the instances which depend on it. The AKO slot relates the instance in question to the class to which the prototype it is linked to belongs.
Whenever a new instance is defined in the knowledge base. the system uses the inheritance procedure to trace back the hierarchy of information defined by ISA and AKO, thereby removing the structure of the instance to be created from the prototypes it finds.
The system then tries to get the operator to define the values for the slots in question, in default of which it triggers off another inherit procedure to search for the default values or procedures able to calculate the desired values. Since all the information is memorized in the knowledge base by appropriate prototypes, the inheritance procedure is used in the system to manage interaction with the user, to interface with the conventional software tools, to check the consistency of the input, and match them against the constraints defined by the system.

4. Conclusion

The proposed system has been conceived for cooperating with the designer in defining project objectives and solutions, as also to evaluate their mutual consistence. But what significance attaches to the word "cooperation" in this context? Given that the creative project is an extremely complex activity, deeply rooted in human subjectivity, and that it concerns the designer's culture, as well as his intelligence and experience, is it really useful for a computational system to tackle this problem in a totally automatic manner? Probably not.
An expert system treating a complex design problem would certainly be no different from any other designer, even automatic, and all the same would be very much like the designer himself. Hence, rather than strive to develop a system capable of an autonomous creative project, it would appear more prudent to define a context, in which the creative project is made possible, and in which its results may be obtained in the best form available. The KAAD system described intends to be such a context.
But there is more. The potential results of successfully integrating an energy expertise in the design process and of making the corresponding performances a main project criterion are unprecedented in the field of the energetic design of buildings. Making it possible to design with particular regard to the real needs of the end-user, such an advanced "intelligent" system can effectively be the vehicle to make all this possible.
It has therefore been shown that the formal representation of the frames adopted is able to use the instruments of programming orientated towards the objects that enable the building system to be supplied with the specific "knowledge" of the necessary sphere of application.

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APPLICATION OF 'HYPERCARD' FOR THE DESIGN OF SPRINKLER INSTALLATION

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The use of computers in Building Services Engineering design is mainly applied to problems that are well structured and problems precisely described by mathematical formulas and models.

Some of these programs may also be interfaced with computer-aided drafting (CAD) programs to facilitate automated drawing procedures.

However, there are cases in Building Services Engineering design work where the problem is not well structured and cannot be represented by simple mathematical modelling techniques:
- in public housing estates;
- sprinkler installation;
- lift and escalator installation;
- electrical installation.

These designs are governed by the "Rules for Automatic Sprinkler Installation" (or LPC Rules - Loss Prevention Council), "Regulations for Electrical Installations" (or IEE Regulations), and other Codes of Practice.

However, using conventional written design guides may lead to ambiguity of design intent and more frequently, confusion over the original design methodology.

A computer-aided design tool is necessary to facilitate conceptual or preliminary design that can represent the knowledge base derived from the various rules.

Therefore, the poster paper submitted describes the development of a hypertext model for the design of sprinkler installation that is based on a set of well defined rules structured in a non-linear search sequence. It is argued that such a non-linear flow of information is best handled in the hypertext environment.

The Macintosh HyperCard has been chosen to demonstrate the effectiveness of the procedures. HyperCard is an authoring/ programming tool. It is an information organizer. It can handle ideas and information in non-linear manner.

The sprinkler installation design procedure is split into six different processes:

- classification of occupancies;
- selection of installation type;
- sprinkler spacing and arrangement;
- pipe sizing and sprinkler array design;
- type of water supply; and
- storage requirement of water supply.

Clicking different boxes will lead to respective design process. Although the design procedure is in the form of a flow chart, the design engineer is allowed to jump between different processes by clicking buttons.

The HyperCard model provides three functions for the designer:

- choose design options;
- provide data manipulation; and
- provide graphical display to explain spatial and geometrical relationship.

Data manipulation - automated sizing of range pipe.

To provide graphical display.

Provide facilities to bypass some of the information depending on the designer's interest.

If YES, more information;
if NO, go direct to design data.

Conclusion

Current development indicates that it is feasible to represent LPC rules as a hypertext document.

The design engineer is able to obtain data efficiently and to determine the design constraints that need to be considered at the preliminary design stage.

It is possible to construct non-linear pattern for flow of information. It is suitable for semi-structured problems. However, development time is large. It is too restricted to be a fully "intelligent" interface. A truly "naive" user may need more information before a solution can be determined. A partially experienced user may generate solution more quickly.

Architectural Computer-Aided Design Systems: An Example

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1. INTRODUCTION

1.1 Aim of the Paper

In 1987 started a Design Research Workshop project at the IMS Building Research Institute in Belgrade with the aim is to study the effects of the introduction of CAAD methodology on the possible qualitative improvement of architectural design in the Institute's proprietary Building System "IMS". The system consists of a precast prestressed concrete skeleton structure that incorporates various sub-systems, and has been applied extensively in housing and public building in Yugoslavia and many other countries (Banic et al 1986).

The paper describes some of the project results - the design tools to be used as aids in the conceptual design stage of IMS family houses. The tools have been developed to a prototype level, with limited, but adequate testing of their functions. The present versions are applicable on IBM personal computers.

Generally speaking, all well-defined and well-structured aspects of architectural design, mainly dealing with the technical aspects and/or graphical presentations, have been successfully modelled and merged with the computer application and applied particularly in the detailed design phases. This is not so with the ill-structured problems that dominate the fluid situations in the conceptual phase. Many decisions here depend on the subjective judgements of the designer. Knowledge-based systems have been applied in the selected domains to aid decisions based on experience and difficult to model by algorithmic methods. However, the "increasing of quality of design process" is an open-ended question. The semantic aspects of design have not been sufficiently treated in CAAD research projects so far.

2. "OBJECT-ORIENTED DESIGN METHODOLOGY"

2.1 Design Objects

Let us define design process as "modelling" of design problems, ideas, proposals, physical objects, contexts. In this paper, we shall use the term "object" to refer to various "models" of the real architectural object that is going to be built, an IMS house. Model type depends on its role in the design process. For example, an abstract model can be comprised of the expected design requirements of a house, while a geometric model shall contain the description of a physical structure with the required characteristics. Use of object models may differ from one to another user of design information, but can be "standardized" and used by many users in similar situations (Tolman et al 1990, Penttila et al 1990).

"Object model problems". Definition of an object model depends on what the model is going to be used for, where (in what phase of design process), how (what tools shall be applied), by whom, etc. If the designer is not sure what model to use, there exists an "object model problem".

2.2 Design Process

We shall now claim that design is "modelling of the desired change of a design object". This definition is based on the writings by J. C. Jones (Jones 1970), and G. H. von Wright's "logic of change" (von Wright 1967). Description of change

includes the descriptions of: a) the initial state of the object (when the change started), b) the goal state of the object (when the change was completed), and c) the interims states leading from a) to b). Design process functions in such a way that the design methods are applied to perform various tasks, e.g.:
i) to define what is required (in the initial state),
ii) to propose and represent an idea of a kind of physical object that corresponds to such requirements (in the end state), and
iii) to evaluate object's attributes in order to assure the designer that the design tasks are achieved (in the interim states).

"Design-method problems". If the designer is not sure what method to use, or there are more methods available leading to the similar results, there exists a "design method problem".

2.3 Design Methodology

Design methodology is a body of knowledge that can help our understanding why certain design methods are used for achievement of certain tasks in various design situations, or, explains various approaches to solving "object model problems" and "design methods problems". Design methodology in the new, systematic sense (Jones et al 1962) is contrasted to the "traditional" one, claiming that the design process can be externalized, and rational design decision-making applied throughout. The dilemma of the general applicability of such approach is not quite settled yet. Examples of methodological problems are the treatment of mixed objective and subjective assessments of both requirements and achievements, and absence of the "dependable" methods for transformation of the requirements expressed in words into the description of "novel" physical objects.

How designers work. A rational methodologist may follow the described linear design sequence of definition of change, and apply various algorithmic procedures for "composition" (and decomposition) of objects using rational decision procedures. A traditional designer may start in the middle of the process, go from the end to the beginning of the process and back, changing ideas and design methods as he/she sees fit, and even ending with a proposal that radically differs from the given requirements but supported by the "subjective judgements". The favorite design method is the "trial-and-error" technique which depends on designer's intuition and experience. While the rational design techniques are apt for computer modelling, the traditional design process is not. "Knowledge-based design systems" contain the designer's "heuristic" experience, and can, to some extent, simulate designer's behavior in certain situations (Gero 1985, Coyne et all 1988).

2.4 Proposed Approaches

Approach to methods-problems. If a CAADesign program is to be of use to a demanding type of an expert designer, it should contain a "requisite variety" of methods which shall at least tally or be greater of the variety of problems (Ashby 1961 207). This requirement comes natural to a traditional designer. Naturally, the methods should be able to cope with problems arising during the design process.

Approach to object-model problem. As design methods are applied to objects, there must also exist a requisite variety of object model representations adequate to the design problem at hand.

Fusion of object and method. Each object model (data structure) is implicitly associated with a set of design methods, techniques and tools that have participated in its formation. As a proper match between the object and the method is desirable, the latter can change the former to a different state. It is a common-sense design economy to use the "fused methods and objects" in design process. A similar idea appears in "object-oriented programming" approach (Goldberg et al 1983). As more objects may be compatible with the same methods, the same methods can create different objects. We are facing now a problem of choice of design method. The requisite variety of fused objects and methods must be provided by the program.

We leave the selection of the methods to an expert designer, to apply them in a way appropriate to his/her objectives, intuition, and the applied design logic defining the nature of the task to be performed. In our experience, many a seasoned expert applies only a few of the favourite methods applied at the "critical" points in design process on the conceptual level, being able to judge the appropriateness of each applied evaluation criterion and devise a plan for further object transformation upon such partial results. This leads to the eventual creation of an "expert's expert design system".

A cyclic structure of design process. Instead of the following the "linear" design procedures following the description of change, we propose instead the cyclic, "whirling" design process structure, where one can start at any point (beginning, end or at an interim state), and go between the states in accordance to the designer's plan (Hickling 1980). This means that the designer may propose the final solution first, than go back to the beginning to see whether the solution is acceptable, and than go through the interim stages back and forth between the initial and end stage until an acceptable/satisficing/optimized solution is produced. Many variations on this theme is possible. However this approach may seem hectic, in the authors experience, it reflects the way many a traditional designer works quite effectively.

The described concept enables:
a) designer's implicit selection of the method that suits the problem at hand and not vice-versa,
b) application of a method or their sequential mix as many times as necessary at any phase of the process,
c) object's transformation or replacement providing the new one responds to the available methods, and
d) inclusion of new methods and objects.

At present we stay with the interactive application of the program and shall continue seeking the justifiability of its automation in future.

How to deal with object semantics? We place this problem to the "subjective" area of design, and would like to enable designer's/user's participation during the process in assessing what kind of semantic meaning an object ought to have, or what kind of meaning is achieved. To this purpose we propose the use of a neural-net based tool, with a "semantic differential" diagram as an input/output device (Osgud et al 1957). This diagram is simple to understand and enables easy description of approximate meanings, but escapes the theoretical formalization. We see no reason to exclude the investigation of usability of such non-formal methods in systematically organized design contexts (Petrovic 1991a, 1991b).

3. METHODS IN USE: AN EXAMPLE

3.1 Examples of GIMS Methods and tools

Plans synthesizers: ARCH. The prototype program is based on the exhaustive search using depth-first branch-and-bound algorithm for layout synthesis. The problem and the solution are represented by the same data-structure (state-space) which contains the description of all elements. The properties can be defined by the user or by the program defaults. The second data structure contains the binary relations between pairs of elements, and is implemented as an associative memory matrix. The third data structure is the knowledge-base, still to be implemented. In each step of the search, the program adds one element to the layout, and evaluate its links with other elements, both located or unlocated. If the relationship of the element with its context is proven to be satisfactory, the next element is proceeded, else, the next position of element in the layout is tested. When all properties are (nearly) defined, the arrangement is taken to represent the solution (Svetel 1990). Room shapes are rectangular without any special dimensional constraints.

Plans synthesizers: GIMS-EXPERT. This is a "consultant" to a designer of individual family houses to be built in the "G(generative)IMS building system, in this instance featuring the modular structural skeleton grid of 4,20 x 4,20 m. Following the user's preference of the shape of the house, type and number of functional spaces and the location data, the program generates a set of feasible design alternatives using the elements from the GIMS Catalogues and rules on their combinations, both contained in the Data/Knowledge Base. The catalogues include the "functional elements" such as living rooms, entrance, stairs-WC-or-bathroom units, bedrooms with corridor etc., all designed to fit the structural module. The ground-floor and first- floor plans are generated separately, and then fit together. The sub-program Roof Planner, a production system by itself, produces all possible roof alternatives for all selected design alternatives.

It should be pointed out that although the functional uses are indicated in plans, the internal partitions and elaboration of facades are missing as their elaboration is treated in a separate project in progress. However, the information obtained on this (conceptual) level is in fact sufficient for further project programming phases: builder can start planning the production and infra-structure as the bill of quantities of the load-bearing structure is known, together with the main inputs and outlets for energy, water and waste. Finalization of the projects of individual houses can be completed with user participation.

The sketches are subsequently evaluated and sorted out according to the heuristics rules on the relation between indoor spaces and outdoor specifics: micro-climate conditions, vistas etc. Each alternative is supported by the explanation of the expert's (changeable) evaluation method of design decisions taken. For each alternative, ground-floor and first-floor plans, isometric or perspective surface-model views of the house with all possible roof solutions are presented on the screen and offered to be drawn on the plotter (Petrovic et al 1987).

Evaluators: OYSTER. A prototype rule-production shell, allowing forward and backward chaining, and inclusion of new information in form of "What if" command, allowing a change of suppositions in course of the process and creation of alternatives. Tested on an number of "small" expert system applications, such as a simple "Aseismic design consultant for architects". At present, it is used for the additional assessment of attributes of GIMS objects, and for providing proofs of the object's attributes confirmation to the building regulations (Miric et al 1990).

Graphic tools: Little 3-D Modeller. Program for interactive surface modelling of 3-d objects. Version 1.0 allows the basic operations with the primitives (translation, rotation, reflection). Although the program allows the general application, at present it is used as a graphic tool associated with GIMS objects (Svetel Ibid)

Hybrid tools. These unorthodox design tools based on the parallel distributed processing paradigm for knowledge processing known as a "neural net", (Rumelhart et al 1986a) have been suggested as " tools for exploring associative reasoning in design" (Coyne 1989). They are significantly different from the AI methods, such as rules and knowledge-bases. Instead of having a separate knowledge-base which is interpreted by some control program, a connectionist system consists of a framework of large number of simple processing elements (nodes), and is both, the container of learned knowledge, and the processor of that knowledge.

These systems:
a) do not require the formal theory of design method what makes them applicable for non-algorithmic design procedures,
b) can "learn" from examples, thus making compensation for absence of theory, and
c) can generalize the learned knowledge on the basis of learned examples and draw "conclusions" about the new instances, providing they belong to the same class of objects.

PDP-AAM: Parallel Distributed Processing - Analogical Architectural Modeller. The program uses the back-propagation algorithm (Rumelhart et al 1986b, Knight 1989). The semantic differential technique is used as an input/output device. The tool enables the subjective assessment of object's form in two main ways: a) learning from examples and producing a semantic differential for an unknown GIMS building form, and b) learning from examples and producing a GIMS building form for the given semantic differential. The typical queries are: "What GIMS building is such that is associated with the given semantic differential?" and "What is the semantic differential of this GIMS building?" in view of the user's subjective preferences learned by the program. Despite the fact that the buildings or semantic differentials may be new to the program, the neural net shall produce the answers. The "Little 3-d Modeller" is attached to the neural net, enabling the instant visualization of design proposals (Svetel,1991).

3.2 Methods at Work

Designing GIMS houses.
GIMS-EXPERT, as an automatic design system produces an answer that is one of the possible states of a two-storey object that belongs to the field constrained in 3 x 3 structural module of 4.2 m. The output is treated by the Little Modeller producing 3-d representation of the chosen object.

ARCH also produces GIMS houses, but in various modular structural spans. The plans are made in interactive mode. The rest of the produced design information is identical with that of GIMS-EXPERT.

Semantic evaluation. The semantic evaluation of GIMS houses is made with the help by PDP-AAM. The obtained house is "evaluated" by the program containing someone's preferences; be it the designer himself, the investor, the user, or anyone else. The interpretation of the semantic differential is made by OYSTER. For example: an output from the semantic differential, "house is original = low" is taken as a fact. Rule no. 15 states that IF house is original = low, THEN, house character = traditional. In forward chain, starting from the facts, we would conclude that the house is traditional. In backward chain, we can find the values of the goals not obtained in forward chaining because the corresponding facts were missing. Starting with a goal statement: "house environment relationship", if the program finds the fact missing it will ask for the value. If the value is as required (traditional), the program shall conclude that "house relationship" is good. "What IF" command allows experimenting with different (existing) values.

The application of the methods can also be in the opposite direction. We can start with the required house character, which will define the semantic differential. This shall further propose the 3-d volume and the plans. We can use any existing method, apply it individually, or combine it with any other method in any direction.

All described methods act on the object, instantiating the object data structure and using the knowledge base. It is the intention to keep both data and knowledge within the object model. An interface is used to connect the object and the method, and in fact provides the "fusion" of both.

4. CONCLUSIONS

The results of the first phase of the project produced a discrete design process, based on a set of independently applicable design tools related to the critical design decisions. As for now, the idea "works" but further elaboration is needed to enrich the possibilities, eliminate the deficiencies, and find more possible uses. The present applicability of the project results is primarily in the field of experimental research and education.

The possibility of the subjective assessment of designed objects and easy introduction of new information indicates some new paths for further research in CAADesign methodology.

6. ACKNOWLEDGEMENTS

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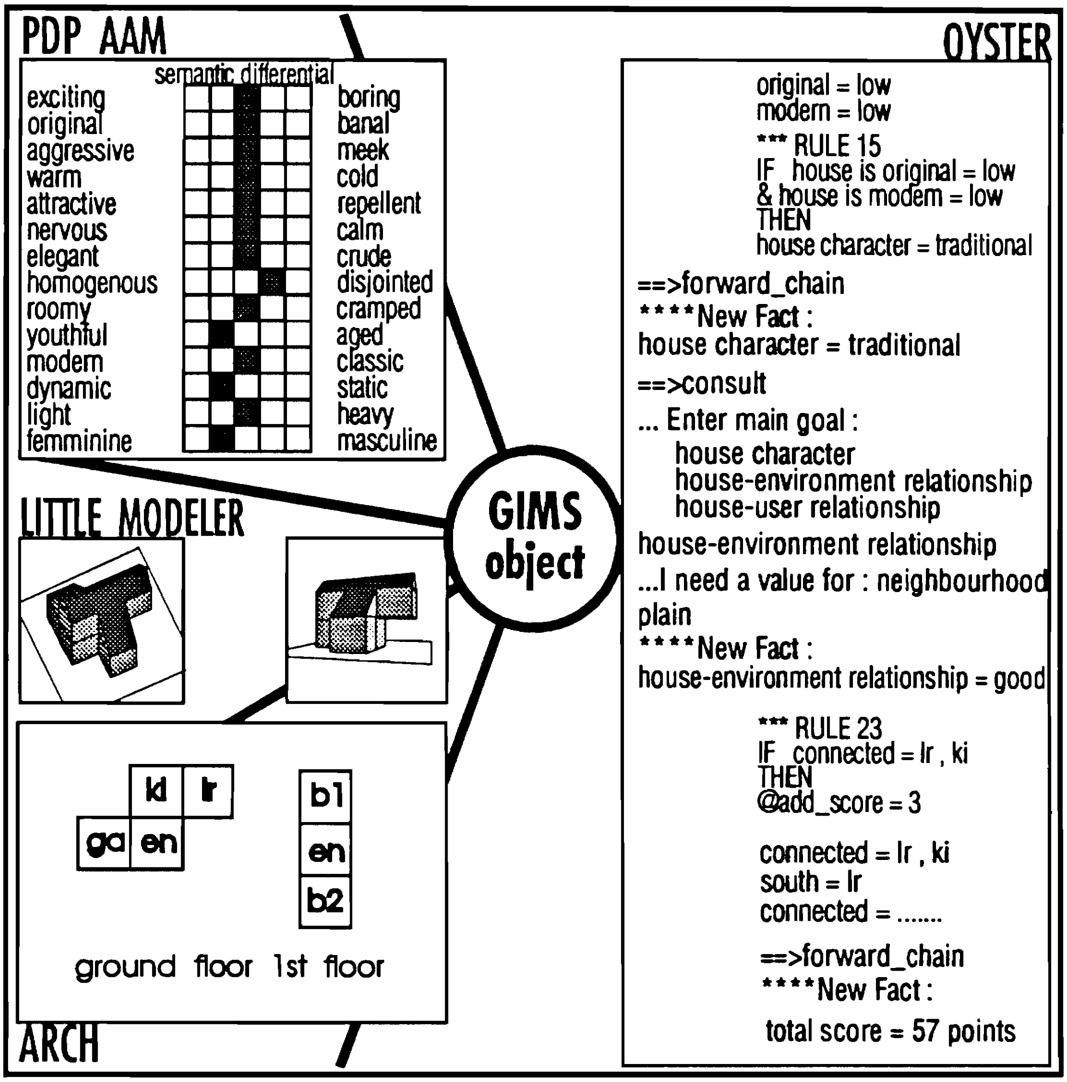
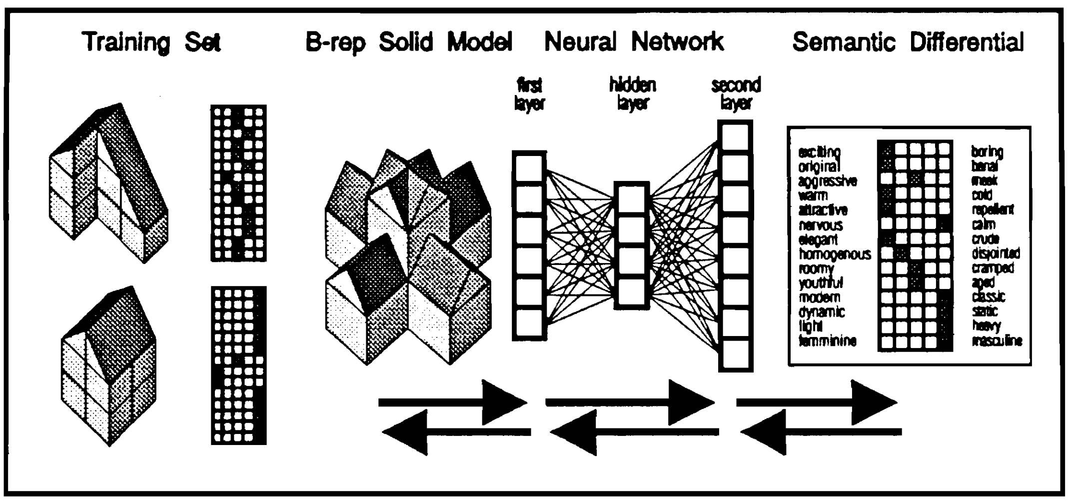
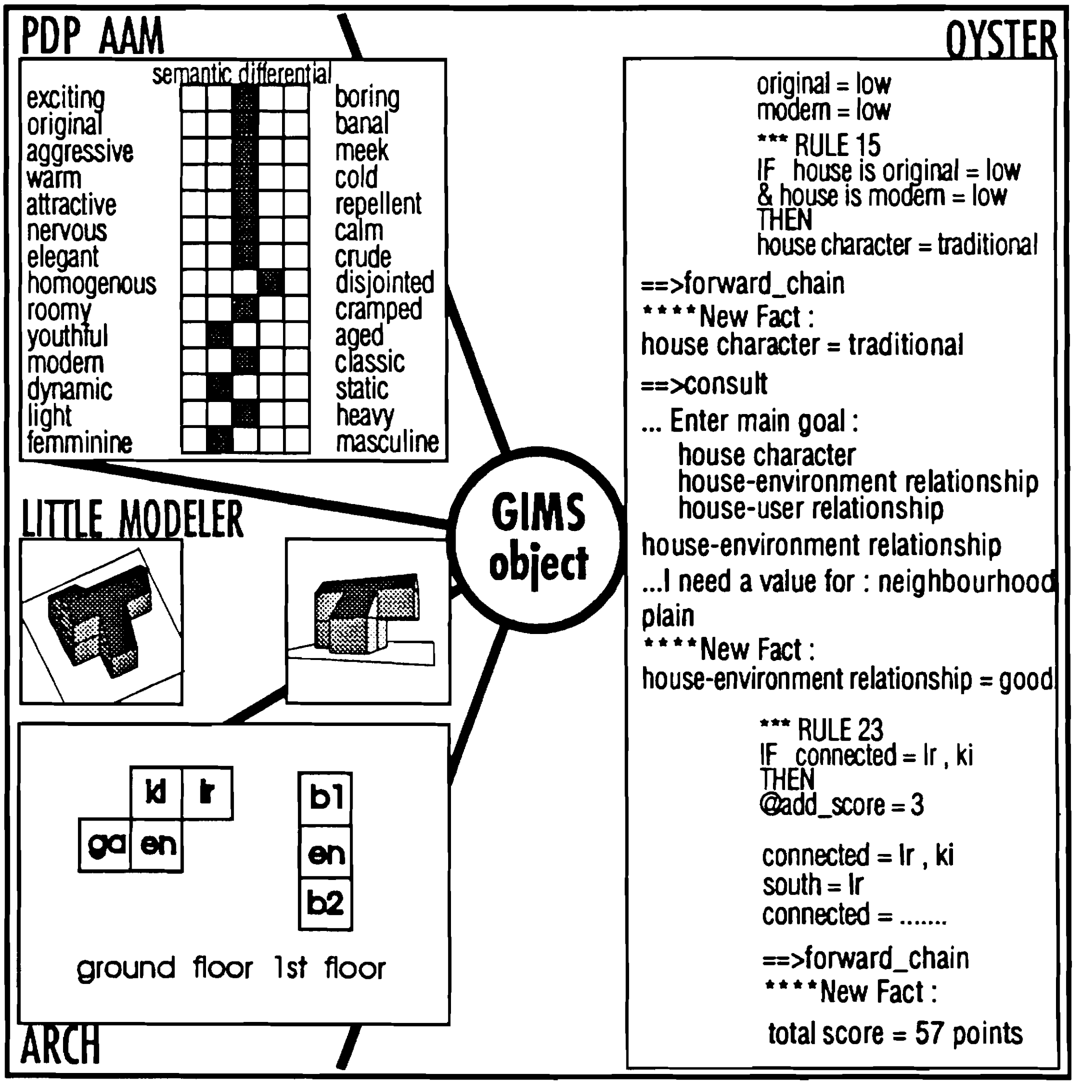


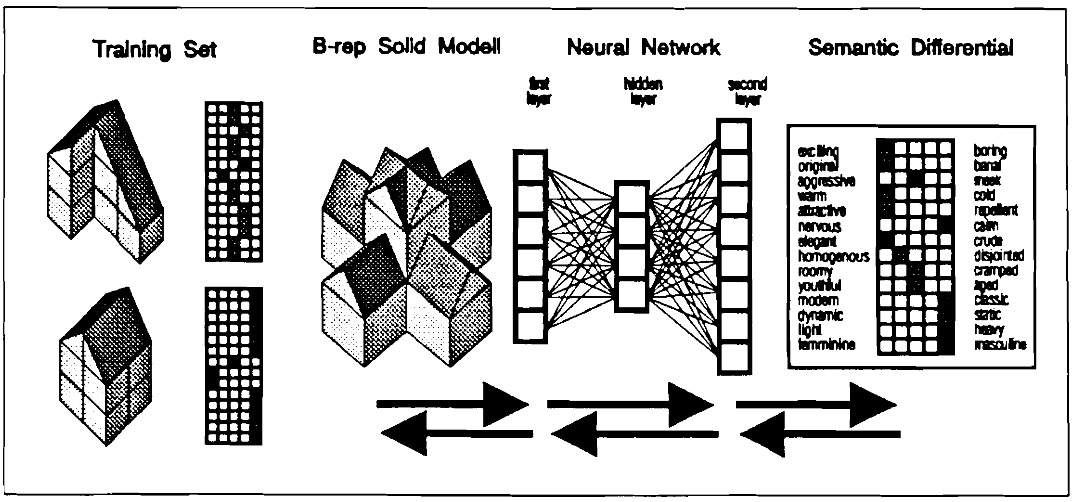
Application of ARCH, OYSTER and PDP=AAM Programs



Functioning of PDP-AAM Program



Application of ARCH, OYSTER and PDP=AAM Programs



Functioning of PDP-AAM Program

Architectural Computer-Aided Design Systems: An Example

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SUMMARY

The paper describes the initial results of a project which aim is to study the possible qualitative improvement of architectural design of family houses to be built in the Institute's proprietary Building System"IMS" using a set of "IMS-CAAD" prototype tools applicable in the sketch design phase.

Firstly, examples of tools are explained. "Plans synthesizers" include: a) ARCH, the prototype program based on the exhaustive search using depth-first branch-and-bound algorithm for layout synthesis, and b) GIMS-EXPERT, a "consultant" to a designer that automatically generates a set of feasible design alternatives using the elements from the GIMS Catalogues and rules on their combinations. The sketches are subsequently evaluated and sorted out according to the heuristics rules. Each alternative is presented by ground-floor and first-floor plans and 3-d models of the house with all possible roof solutions. "Evaluators" include OYSTER, a prototype rule-production shell, allowing forward and backward chaining, and experimenting with new information in form of "What if" command, thus allowing a change of suppositions in course of the process and creation of alternatives.

PDP-AAM (Parallel Distributed Processing - Analogical Architectural Modeller) is a program based on a neural net and the back-propagation algorithm, using the semantic differential technique as an input/output device. The tool enables the subjective assessment of object's form in two ways: a) learning from examples and producing a semantic differential for an unknown GIMS building form, and b) learning from examples and producing a GIMS building form for the given semantic differential.

There exist many possible combinations of GIMS design procedures and methods. For example, GIMS-EXPERT, produces an answer that is one of the possible states of a two-storey object in the given field and complies to the given constraints. ARCH also produces GIMS houses in an interactive mode, but in various modular structural spans. Semantic evaluation of the proposal is made using the PDP-AAM allowing designer to check what would the investor think of the house providing the program has learned the investor's preferences. OYSTER is used only for the "translation" of the semantic evaluation of GIMS objects to conclude what the overall house character is, and explain the basis for the assessment. We can also start with the required house character, which will define the semantic differential. This shall further propose the 3-d volume and the plans. Finally we can start with any existing method, apply it individually, or combine it with any other method in any direction.

The results of the first phase of the project produced a discrete design process, based on a set of independently applicable design tools related to the critical design decisions. The present applicability of the project results is primarily in the field of research and education. The possibility of the subjective assessment of designed objects and easy introduction of new information open some new possibilities for further research in design methodology.

Building Envelope Sealant Selection: An Expert System Approach

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Introduction

The selection of an appropriate sealant for a given building envelope application is a time consuming process, and does not always result in a satisfactory choice as indicated by numerous premature sealant failures in new buildings. An expert system was developed, using specialized expert system development software, as a rudimentary tool for simplifying the selection of a suitable sealant for a given application. In its present form, it is a user friendly system which prompts the user to input design conditions and criteria, and through a process of elimination classifies the information and presents the user with a list of suitable sealants.

Significance

This expert system would be a great benefit to sealant specifiers (i.e. architects & engineers) as appropriate sealant selection is a complex matter due to the multitude of performance criteria which must be considered simultaneously. In addition, sealants must fulfill their performance requirements in the weakest location within the enclosure system, namely joints. For this reason they tend to be prone to failure if not properly matched to the surrounding conditions and materials.

Description of Expert System

The expert system Sealant Selection Assistant was developed to assist in the selection of one or more of the following nine sealants, for the purpose of sealing joints in the exterior wall of building enclosures:

Butyl, skinning
Butyl, non-skinning
Hypalon
Acrylic
Polysulphide, 2-part
Polysulphide, 1-part
Polyurethane, 2-part
Polyurethane, 1-part
Silicone

The relative performance of any of the nine sealants within the system is assigned a rating (performance factor-PF) for each category of criteria (see case study for list of criteria) ranging from 0 to 1. This rating is related to the degree to which the sealant performs for a given criteria (e.g. low performance, PF = 0.1; high performance, PF = 0.9-1). In the selection process, all sealants are initially assessed a value of 100 and there after, this value is reduced in relation to the sealants capacity to meet specific performance criteria. In otherwords, initial values are multiplied by the various factors, and once the system passes through all the required criteria, the cumulative total of all the ratings for each sealant is calculated by the system and presented to the user. This is essentially a process of elimination, as sealants which do not achieve the user's required level of performance are either eliminated or are assigned a relatively low performance factor.

In performance criteria not deemed critical, the user is given the option of deciding whether the category is to be considered, thus giving a certain amount of control over the outcome of the consultation.

Aspects related to relative costs are kept separate such that a selection can be made based solely on performance characteristics, or based on a combination of both performance characteristics as well as the relative cost of the sealant.

Programming Assumptions

Certain assumptions and simplifications were made to limit the amount of data required to be inputted by the user: These were:

1. The environmental conditions around the building under consideration are assumed to be uniform across the entire surface of the building envelope.

2. Cladding differential movement due to moisture absorption or drying is disregarded.

3. Minimum joint widths are suggested according to panel sizes, following the general rule that the larger the cladding panel the wider the joint should be.

4. The required ultraviolet (UV) resistance of the sealant depends only on its required service life. Thus the required UV resistance is assigned, within the program, to service life expectancy according to the following scheme:

Life expectancy	UV resistance
0-5 years	Fair
5-15 years	Good
> 15 years	Excellent

5. The coefficient of thermal expansion for four typical cladding materials (masonry, concrete, aluminum & copper) is given specific values by the system.

6. The colour of either aluminum or copper is as stated.

7. Certain performance factors are more critical to overall sealant performance and service life than others. In this respect, less critical performance factors were assigned higher ratings (i.e. 0.8-1) & more critical factors were assigned the entire range of ratings (i.e. 0.1-1).

Program Limitations

Although this expert system is quite comprehensive in terms of the performance criteria and design aspects it covers, there are a few limitations to the system:

1. The system is limited to making recommendations with respect to the nine specified sealants only. These sealants are however, generally representative of the types of sealants which are currently used in the construction industry.

2. Recommendations are made for an appropriate sealant choice in a given environment on the basis of the rating system. The performance factors for each sealant are specific to the present program and can not, as yet, be altered.

3. The system does not accommodate for joint widths other than the minimum ones recommended by the system (13mm for cladding panels < 3000 mm, 16 mm for larger panels). The only accommodation that the system does make is that it recalculates the minimum joint width to limit the maximum joint movement to 25% of the joint width.

4. The system does not allow for changing of just one or a few input values without re-starting the entire consultation.

Interactive program
A manual is provided with the sealant selection assistant program which provides a brief outline of the procedure involved with using the system. The program interacts with the user through a series of queries from which a selection may be made of either a set of alternatives or a true/false answer. Explanations of the questions the system asks the user are also provided, including the purpose for the question when necessary.

Case Study
The system was used to assess the choice of an 1-part polysulphide sealant which was specified for an eleven storey hotel located in Sydney, Nova Scotia, on a site that is prone to significant amounts of wind-driven rain. The sealant had failed after two years of exposure due to loss of adhesion to the substrate. for this case study, the following queries were made of a user having to assess the choice of that particular sealant.

Performance Criteria	Inputted or Assigned Values
Life expectancy	> 20 years
Exterior service temperature limits	- 18 deg. C (taken from the NBC)
Cladding material	+ 27 deg. C (taken from the NBC)
Surface colour	white
Heat capacity	(concrete considered high)
Joint movement	moderate
Coefficient of thermal expansion	(concrete = 0.000012)
Resilience	moderate
Extension/compression cycling	moderate
Colour range	not considered important
Surface dirt pickup	low
Puncture and tear resistance	of no consideration
Surface preparation	thorough
Surface primer	of no consideration
Tack-free time	1 day

Based on this input, the following sealants were rated and their associated percentages indicate the level of recommendation, with 100 being the maximum recommended level. Case I results relate to the requirement that a moderately resilient sealant be selected whereas Case II, to the choice of a highly resilient sealant.

	Not Considering Cost		Considering Cost	
	Case I	Case II	Case I	Case II
Butyl, skinning	1	1	0.9	0.6
Butyl, non-skinning	0	0	0.0	0.0
Hypalon	2	2	2.2	1.7
Acrylic	1	1	1.2	0.6
Polysulphide, 2-part	36	20	25.4	14.1
Polysulphide, 1-part	56	42	42.0	31.5
Polyurethane, 2-part	15	15	9.2	9.2
Polyurethane, 1-part	2	2	1.4	1.2
Silicone	49	49	29.2	29.2

The results in Case I confirm the choice of 1-part polysulphide sealant. However if the severity of wind-driven rainstorms in Sidney is considered, then it is apparent that the resilience of the sealant should be high due to the magnitude of the stresses imposed on the sealant during inclement weather. In fact if the requirement for a highly resilient sealant is specified instead of only a moderately resilient product, then the program suggests (Case II) that a silicone sealant is better suited in terms of performance. Resilience is considered a relatively important performance criteria in this program, hence its effect on the resulting sealant ratings is evident. This case study is particularly significant because it demonstrates that this program may be used not only to help select sealants for particular end uses, but also aid in assessing the consequences of particular choices. The program also calculates maximum and minimum surface temperatures, effective panel lengths, suggested joint widths, calculated and maximum joint movement, and as wel, specifies the UV resistance required.

NEW APPROACHES TO COMPUTER-AIDED ARCHITECTURAL DESIGN: THE USE OF ARTIFICIAL INTELLIGENCE TOOLS

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ABSTRACT
After a short introduction on current trends in searching new paradigms of design, the fields of validity of the application of the planner paradigm to architectural design are explored . A system is illustrated, implemented in the Univerity of Ancona, using a planner committed the designing tasks of a designer's assistant. An example follows

0. INTRODUCTION

Design has always been one of the main topics of A.I. both under its theoretic aspect and under the operative one, that is in the construction of CAD tools. Under this second, two ways have been followed. The first one discards any temptation to simulate the behaviour of an human designer; the second one, on the contrary, tries to follow the path a designer is thought to have gone all over.

Of course the practical effectiveness of the latter is tightly connected with the capability of succesfuly interpreting and representing the design process as it develops in the mind of a human designer.

The difficulties met in trying to fulfill this task have been severe and untill now it is not possible to affirm that they have been fully overcome. Many are the reasons. Someones are listed below.

- The knowledge of the design process as it develops in the mind of a designer is, so far , from a cognitive point of view, very incomplete;
- the design process is not unique, as it has been for a long time thought; on the contrary ,it changes non only from field to field, but also from designer to designer
- the connections between qualitative values and multiple meanings of an object on one side and descriptions manageable by a computer on the other are extremely difficult to formalize,
- hence equally difficult is to devise a truth maintenance system capable to detect the moment and the amount to which a connotative value is partially or totally lost as a consequence of a change in the manageable quantitative or logical parameters of the descriptions.

1. CURRENT TRENDS IN DESIGN

The progressive aknowledgement of these difficulties has led to significative adjustements and changes in the proposed interpretative paradigms and to the birth of new ones. The classical paradigm is always *search in a problem state.* The shitfs were from procedural to heuristic process and, through the grown importance of the knowledge base, from domain independent to domain dependent systems. The basic technique remains the search of a path leading from a start state to a goal one through a continuosly evolving problem space in which the set of constraints and the set of goals have to be constantly updated as a consequence of the better knowledge of the problem coming from the contributions of a long term memory through a retrieval system fired by the intermediate states. In this direction the *planner* (Newell and Simon 1963,1972,) seems yet the most apt paradigm

Recently new paradigms have been proposed by J.Gero (Gero 1987,Oxmann and Gero 1988, Gero and Rosenmann 1990) and by Smithers et alii (Smithers and Troxell,1990; Smithers & alii 1990; Logan & alii,1991).

The emphasys of Gero's proposal is on the *Prototype refinement paradigm* It is based on a knowledge base in which previous design experience is condensed in abstract, context independent prototypes comprising functional, behavioural and formal properties. the design procedure is refinement and contextualisation of the prototype. This work of adaption can go so far as to generate new prototypes. Smithers's *exploration paradigm* refuses the a priori decomposition of a design problem in autonomous sub-problems and any possibility of keeping separate the moment of a better knowledge of the structure of the requirement space from the moment of elaborating a non terminal solution. It hipotisizes a contemporary (non linear) evolution of a requirements state and a design state through a continuous reciprocal modification and adaption. Since the emphasys is on the interdependence of the multiple parameters of design to the set of requirements its tool best fit seems to be the blackboard (Nii,H.P.1986), a global space in which many informations can be gathered that are to be manipulated by many separate operators

2. THE PLANNER AS A DESIGN ASSISTANT

In the University of Ancona, Italy, a work is on trying to build a design assistant able to cooperate wih the uman designer in as many moments of the design process as possible. Early work has led to the construction of three reasoners each fulfilling a different task but able, if managed in sequence, to compose an elementary assistant system.(Colajanni and De Grassi 1989) The tasks were: placing objects in a delimited space handling the constraints of the desired relative positions among objects and between objects and the contour of the space;(Ferrari,C.and B.Naticchia,1989); the search, in a knowledge base, of the architectural object best responding to a given set of requirements taking into consideration only some geometric and topological features (Colajanni 1989); an operator capable of small geometric deformations of a wire frame representation under the imposition of new formal constraints((De Grassi,M. and M.Di Manzo 1989)

The work which is actually on is about the possibilities of the planner paradigm in emulating a valid assistant to an human designer.(Colajanni,B et alii 1991). The planning technique is the generation of a path trough a space state connecting a start state to a goal state. If the design process has the characteristics at present generally accepted ,and specially the continuous changes of the definition of the space of requirement *,planning* cannot be a *general paradigm of the total design process.* Moroever it can be a precious tool to which commit the search in the solution state *when it is plausible to assume that it will remain unchanged till the resolution of the partial problem the planner has been entrusted with.* In fact a planner has to" start with a non contradictory initial state of the world,and it is supposed to make[its] way to a non contradictory state of the world via various intermediate world states that will exist after planned actions are executed."(Kartam N.A. and D.E.Wilkins 1990) A precondition is the presumption of consistency in the non terminal states. Now, everyone accepts that the design state is everchanging and, worse, the start state is inconsistent for definition and the design process is just the search of this consistency in satisfying the requirement constraints. Again the solution lies in the choice of requiring from a planner only what it can do, that is fulfilling well identified tasks in well identified segments of the designing process. In fact this is the "professional" status of a design assistant. Then the operative task becomes identifying typical actions frequently present in the design process and covering a segment of it such as to satisfy the precondition of the practial stability of the design state.

In this perspective a planner is being implemented in collaboration with MESARTEAM s.p.a. looking to the structure of SIPE (Wilkins D.E. 1988) and making use of Intellicorp's Kee.

An advantage of the planner with a SIPE-like structureis its ability of working on the " main" transformations leaving the search of consistency to the causal representation of the domain at the "lower" levels allows handling temporary inconsistent design states inasmuch as the incosistency is limited to "lower" levels and then not immediately detected , as they can be corrected later.

It is in this vision that an assistant system is being constructed according to the blackboard paradigm. The structure of the system, called **Mondrian**, is shown in figure 1. **Adepto** is a planner, whose organisation is shown in figure 2. It works on three different abstraction levels: symbolic, qualitative,and metric. It produces plans that, emploing the Knowledge Base, and checked by the Control Section of the blackboard are operated by independent modules. Untill now only two modules have been developed. The first one, called **Aspide**, has the functional strucure shown in fig. 3. It deals with poligonal shapes both instanced and uninstanced, and performs three actions: *place*, *make* and *set*. *Place* puts new objects in well defined configurations; *make* changes or defines configurations on existing objects, and *set* fixes some parameters into values. The second module, called **Norma** compares design layouts with existing regulations,detecting any failure. [1]

3. AN EXAMPLE

An example of the way t he system works is the commitment to it of repairing a failure, detected by Norma, regarding a staircase whose goal was to connect three levels in a house but was unable to do it because of the wrong number of steps and consequent lenght of the flights. The problem submitted to the system, was solved by generating a

[1]More details on the way the system works can be found in the posters of M.Lemma and L.Spalazzi " a planner in Architectural Design" and of A.Giretti and B.Naticchia " Aspide, a Constrain Oriented geometrical modeller, an aid to architectural design"

plan that with the aid of Aspide produced, as a consequence of the necessary dimensions of the staircase, a different layout of the house. The lack of space obliges us to limit ourselves to the presentation of the layout with the wrong staircase and the new layout generated by the system. Other plans were generated changing dimensions of staircase and of the rooms whithin the same layout.

4. CONCLUSIONS

A possible application of a planning system to architectural design has been shown, that can succesfully cope with problems respecting the conditions of validity of use of a planner. The value of planning systems is that they ca produce plans also under poor knowledge conditions. their present limits are that they have to accomplish plans in order to detect failures. Next step will be devoted to surmount that obstacle as well as study applications of frames capable of effevtively orienting planner's choices

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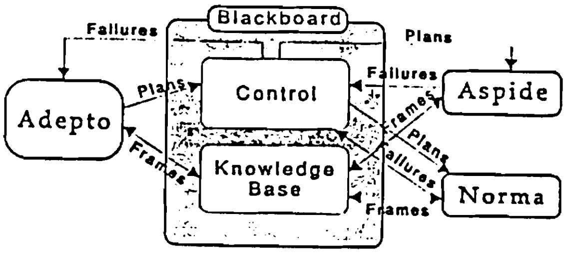


Fig. 1 The Structure of Mondrian System

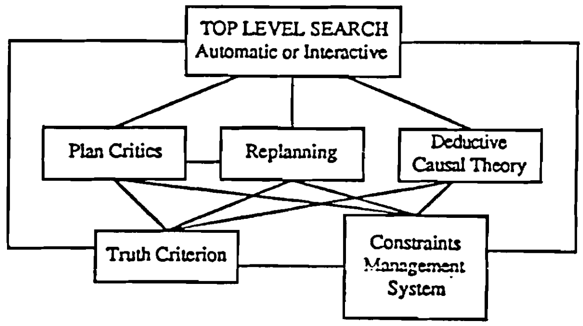


Fig. 2 - The structure of ADEPTO.

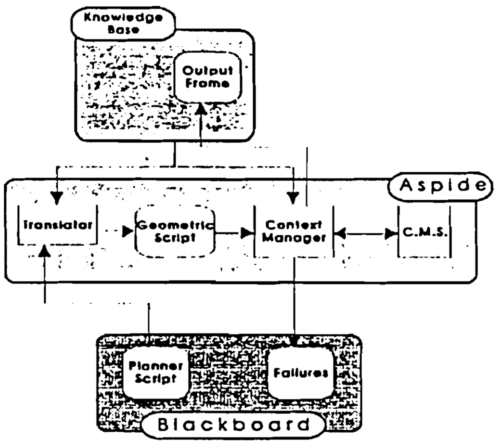
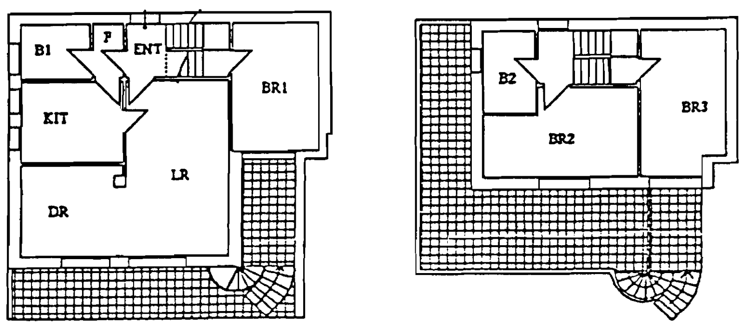


Fig. 3 Aspide Functional Block Decomposition

The case study

Plans and section of a split-level unit of dwelling-building are shown in fig. 4.



a) - First floor.

b) - Second floor.

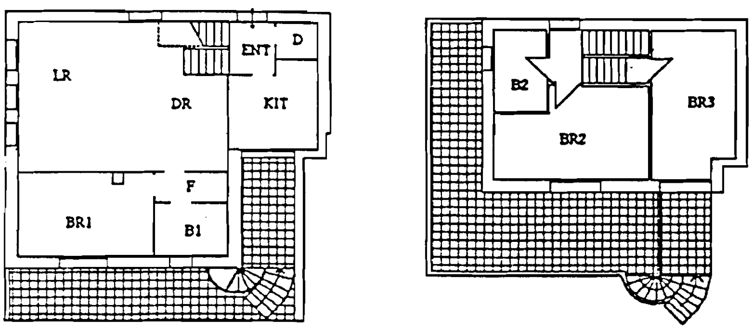


Fig 5 The replace of rooms

Research and Development of Expert Systems for the Construction Industry

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Introduction

The Department of Surveying and the Information Technology Institute have been cooperating for several years to develop expert systems for the construction industry. The emphasis has been on the application of such systems and has involved several substantial grants from the Department of Trade and Industry and the U.K. Science and Engineering Research Council. Two systems are being sold commercially with over 300 users and a software firm specialising in expert systems for construction has been started at the University Business Park as a joint venture between The Royal Institute of Chartered Surveyors and Salford University Business Services Ltd. The key projects in recent years are as follows:

ELSIE and ELI

These two expert systems are for use in the strategic planning of construction projects. Each consists of several modules:

Budget -- How much will the building cost?
Time -- How long will the development take?
Procurement -- What procurement path is appropriate?
Development Appraisal -- What is the profitability of the scheme?

Each program produces approximately thirty pages of advice and supporting evidence and explanation. The package is intended to be used prior to design to provide a framework for future management and design. However, several firms are using the package at sketch design. Some twelve leading quantity surveying practices provided the expertise and knowledge for the systems, and the reaction from users has been very favourable. Indeed, several firms have commented on the improvement over normal estimating techniques at this stage of design, and there have even been cases where the program has found mistakes in the human expert's work.

EMMY

An initial feasibility study identified a need for the long term strategic planning of building maintenance in Housing Associations. However, conventional Maintenance Management programs require too much data input, are too inflexible, do not explain their results, and do not permit their users to explore potential alternatives. The application of Knowledge Based System's technology to this area directly addresses these problems.

EMMY enables a user rapidly to obtain a description of a building or a group of buildings for which a strategic maintenance plan can be prepared. A plan shows a graphical summary and a detailed breakdown and can be prepared for any interval of up to 60 years.

Intelligent Authoring

In this project we are investigating the possibility of expert systems to author construction contracts. A model contract is held in a database, and the user inputs his requirements for the contract in terms of risk, time, payment, and so forth. The program then infers from the requirements what changes should be made to the model contract and so produces a revised contract which takes into account consistency across all legal clauses. The user can then make further modifications manually. At each stage these modifications are tracked and in future will be colour coded for ease of understanding. This project is still in its infancy, and a pilot demonstration is being developed using Hypercard. However, severe limitations have been found with current software, and the team is now developing its own intelligent hypertext system for complex documents.

Methodology for Evolutionary Development of Expert Systems

This project underway at Salford studies the evolutionary development of expert systems within small & medium sized enterprises (SMEs). Such organisations cannot gain access to expert system technology because of its high entry price and because the tools and methodologies now available were developed for and by large organisations. Within this context evolutionary development encompasses the entire life cycle of an expert system from initial conception to implementation (termed Evolutionary Development Part 1 or ED1) and then to the eventual maintenance and updating of the system (Evolutionary Development Part 2 or ED2). The central premise is that the methodology should be "Client-Centred," emphasizing "what " the client can see rather than being "technology-centred," emphasizing "how" the knowledge engineers work.

The project aims to study ED1 by developing an expert system, called REX, (Residential EXpert) for the construction industry. This system will prepare strategic budgets and cashflows for the development of residential building projects. In addition, the project has monitored the development of EMMY, and aims to study ED2 by monitoring the use, maintenance, and upgrading of the ELSIE and ELI systems. The objective of this project, in addition to producing a greater understanding of the area, is to produce a methodology that will enable an SME to manage better an expert system project. The project also aims to produce training manuals and software tools to support the methodology.

Conclusion

The above projects represent an example of expert systems research at Salford. They are part of a research programme designed to enable the construction industry to operate more effectively. Also being developed are integrated databases, intelligent simulation modules, and bidding modules. The success of the commercial packages has enabled the research teams to investigate the manner in which expert systems are embedded into firms and the changes they make to working practices in those firms. This work is continuing under another grant from the Science and Engineering Research Council.

The research intends to develop further expert systems that will test the viability of the technology for solving construction problems. At present there is approximately £1.5 million of research in this area within the Department, and it is hoped this will be maintained and grow.

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TECHNOLOGY TRANSFER OF EXPERT SYSTEMS AT STONE & WEBSTER ENGINEERING CORPORATION: A CASE STUDY

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1. INTRODUCTION

ES technology provides the Architecture-Engineering-Construction (AEC) industry with significant potential for fostering competition. However, the majority of US AEC firms are slow in adopting the technology. A previous study of the process of adoption of ES technology (De La Garza and Mitropoulos 1991) has led to the development of a T^2 beta model, and to the identification of stages, actors and factors affecting the adoption of the technology. The purpose of this paper is to test and validate the T^2 beta model by comparing it with the actual T^2 process as occurred in the case of one US construction firm. The paper first introduces the beta model and describes the methodology used to validate it. Subsequently, the T^2 process as occurred in one US construction company is summarized.

2. T^2 BETA MODEL FOR EXPERT SYSTEMS

The T^2 model has been developed from the models of innovation by Rogers (Rogers 1983), Tatum (Tatum 1987), and Shaffer (Shaffer 1985).

2.1 Stages of T^2 process

The seven major stages of the T^2 process are the following: (1) recognize forces and opportunities for exploring new technologies; (2) identify expert systems technology; (3) commit initial resources; (4) evaluate the technology; (5) decide on the adoption; (6) develop and implement systems; and (7) confirm technology's value.

During the first stage, market and competitive demands or operational problems may create the forces for exploring new technologies. At the second stage, a member of the firm performs the role of the technology gatekeeper and identifies ES technology. Subsequently, in stages three and four, champions commit the human and financial resources required for the business, technological and organizational evaluation of the technology. In the fifth stage, senior management decides on the adoption or rejection of the technology. At the next stage, the development of the systems and their transfer to the end-users takes place. Finally, the benefits derived from the use of the technology are evaluated and its importance is confirmed.

2.2 Flow of the T^2 process

According to the position of the individual who introduces the technology in the organization, one can identify two types of the T^2 process: (1) top-down approach; and (2) bottom-up approach. In the top-down approach, a senior manager initiates the T^2 process by performing the role of the technology gatekeeper. Subsequently, this manager becomes the executive champion of the technology, and initiates and supports the evaluation. In the bottom-up approach, the technology is introduced and championed by a member of the organization who does not belong to the senior management group.

2.3 Factors affecting the T^2 process

The following factors have been identified to primarily affect the success of the T^2 process: (1) senior management's attitude towards technology; (2) organizational environment; (3) position of the gatekeeper; (4) organizational technological capabilities; and (5) state of maturity of ES technology.

2.4 Validation methodology

The validation and refinement of the T^2 beta model includes the following tasks: (1) identification of large AEC firms currently using ES technology; (2) conducting interviews on the adoption process of ES technology in these firms; and (3) developing case studies of the T^2 process in these companies. The paper presents one such case study, specifically, the T^2 process as occurred in Stone & Webster Engineering Corporation.

3. CASE STUDY: EXPERT SYSTEMS IMPLEMENTATION AT STONE & WEBSTER

Founded in 1889, Stone & Webster Engineering Corporation (S&W) is one of the largest US engineering/construction companies, with many millions of dollars in contracts annually. S&W's activities expand all over the world and include engineering and construction of manufacturing, transportation and building projects as well as software development. Additionally, S&W is a leader in the use of the latest available design, construction, maintenance and control technologies.

S&W's top management has always recognized the importance of new technologies in gaining competitive advantage. As a result, S&W has adopted a proactive technology strategy focusing primarily on clients' needs and how technology can be used to satisfy them. Thus, S&W is continuously looking for new technologies and examining how they can support the business objectives.

The identification and adoption of ES technology was a result of this proactive technological strategy. A senior engineering executive made a proposal to the Executive Office to initiate an investigation of ES technology and its potential in assisting the operations of the engineering corporation. With the support of top management, a project was initiated and was provided with a budget to examine ES technology. The novelty of the technology required additional in-house technological capabilities which were acquired with the recruitment of additional staff.

Right from the beginning, S&W saw the ES technology as a tool for maintaining organizational expertise and for improving its competitive position. The first project was an equipment diagnostics expert system for centrifugal pumps. The objective of the pilot project was to examine the usefulness of ES techniques in real world engineering applications. Therefore, mainstream computer hardware was selected as the platform for implementing ES. Despite the state of development of ES technology, which at that time required specialized hardware, the project team successfully developed the first applications.

Until that time, no strategic commitment had been made to ES technology. However, as new PC-based tools became available, the ES group identified the opportunity offered for both development of applications to support the internal operations of the firm and development of applications to satisfy external clients' needs.

As a result of the successful implementation of ES and the simultaneous development of advanced CAD and database technologies, S&W made the decision to establish the Advanced Systems Development Services (ASDS) division which was chartered with two basic roles: 1) develop and market new software products to support internal operations and external clients' engineering operations; 2) provide consulting services to clients.

By entering the software market, the ASDS division grew both in size and in capabilities, and became a leader in the development of Computer-Aided Engineering systems. Clients' awareness of S&W's ES technological capabilities is raised through mainstream marketing techniques and procedures. During the first years of its operations, ASDS was using ES tools only on external projects. Subsequently, ASDS started developing systems which incorporated ES technology for internal use.

Before a decision to develop a system is made, a need of the company or a problem of a department must have been identified. Thus, there are two ways that a project can start: 1) a proposal can be made from division managers who identify a specific need. In this way, the awareness of division managers about new technologies is a critical factor for the technological improvement of the firm; and 2) the ASDS identifies a potential application which could support operations and proposes the development of a system to the division managers.

Potential internal ES applications are screened by senior management who decides which applications are developed and allocates the resources accordingly. For the development of the system, a team is formed with the participation of the experts, the developers and representative end-users. After the system is developed, it is transferred to the end-users who are provided with training and support during the implementation.

Until today, ASDS has developed a significant number of client-financed and in-house funded ES in the areas of construction, structural and mechanical engineering, which support all the areas of the firm's operations.

4. COMPARISON WITH T^2 MODEL

The T^2 process in S&W follows the top-down approach of the T^2 beta model. The seven stages of the T^2 beta model are identified, as shown in Figure 1. The implementation strategy in S&W is similar to the strategic approach.

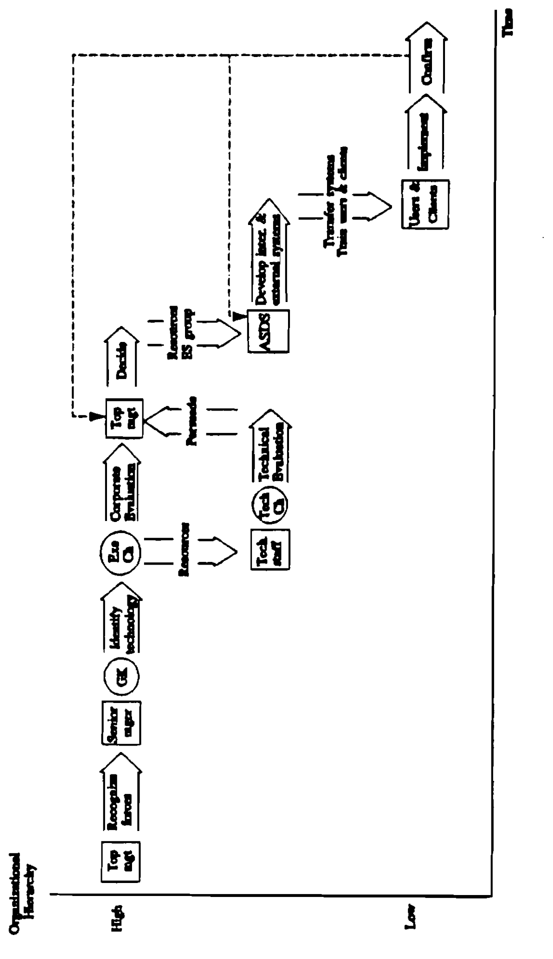

Figure 1. Expert Systems T² Process in Stone & Webster Engineering Corporation.

4.1 Recognize forces for exploring new technologies

Recognition of technology's importance as a competitive weapon by senior management was the primary force which led S&W to explore new technologies. This proactive technology strategy focuses primarily on how new technology can be used to support the business objectives. S&W is continuously looking for new technologies and examining how they can satisfy the clients' needs.

4.2 Identification of ES technology

The role of the technology gatekeeper was performed by the executive manager at the Engineering Corporation who initiated the investigation of ES technology. Although at that time, the technology was in its early stages of commercial development, the gatekeeper's technological capabilities enabled him to identify the technology and foresee its potential.

4.3 Commitment of initial resources

The position of the gatekeeper enabled him to become the executive champion of the technology and persuade senior management to provide the required financial resources. Subsequently, the human resources and technological capabilities required were acquired with the recruitment of additional technical staff who became the technical champion of ES technology in S&W.

4.4 Evaluation of ES technology

The technological evaluation was performed with the development of an equipment diagnostic prototype system in the centrifugal pumps domain. The results of this first application were the following: 1) it verified the potential of the technology and raised top management's enthusiasm; 2) the ES group developed more technological capabilities; and 3) it proved that the available tools were not yet appropriate for engineering applications. However, the development of new PC-based tools uncovered the opportunities ES technology offered.

4.5 Decision on adoption

As a result of the successful evaluation, senior management decided on the adoption of ES technology. Thus, the Advanced Systems Development Services (ASDS) division was established and chartered with two basic roles: 1) develop and market new software products to support internal operations and external clients' engineering operations; 2) provide consulting services to clients.

S&W's senior management identified the opportunity ES technology offered for supporting both clients' needs as well as internal operations. An additional goal was that many of the ASDS's clients would become mainstream S&W clients.

4.6 Systems development and implementation

ASDS develops the systems needed both by the firm and the clients. For the development of an internal system, senior management evaluates the potential applications and subsequently, commits the required human and financial resources.

S&W follows the strategic implementation approach. The ASDS division develops the applications and subsequently the systems are transferred to the clients or the end-users in the firm. Training and support is provided throughout the implementation.

The factors that affect the success of the implementation strategy are the following: 1) the explicit support of new technologies from top management who has recognized ES as of strategic importance for the firm's future; 2) division managers technological awareness; 3) the involvement of end-users in the development of the systems; and 4) the implementation strategy the company selected.

S&W believes that companies embarking on ES technology should follow an evolutionary, as opposed to revolutionary, approach to avoid discontinuance or disenchantment from the failure of the first application.

4.7 Confirmation

The retention of S&W's valuable expertise is considered the most important benefit from the internal use of ES technology. This enables the company to respond to the changing market environment with products and services of lower cost and higher quality.

The creation of a new business line is another major benefit from ES adoption. S&W is today one of the pioneers in software development for engineering systems. Thus, ES technology offered the opportunity for S&W to enter a new market.

4.8 Factors affecting the success of ES implementation in S&W

1) Corporate commitment to technology. Top management has identified the importance of new technology in achieving the business objectives, and has developed a proactive technology strategy based on the customers' needs.
2) Innovative environment. As a result of top management's commitment, the entire organization is looking for new technologies. While ASDS focuses on information technologies applications, there are other groups like the Construction Innovation Committee which is chartered with the objective of finding better ways of executing construction.
3) Position of the technology gatekeeper. ASDS's ability to understand both the clients' needs and the organization's objectives are critical for identifying those technologies which better serve the organization.
4) Technological capabilities. The company's managers have strong technical education, and are kept abreast of new information technologies. Additionally, the individuals in the ASDS group are recruited with a strong engineering background before they work in Computer-Aided Engineering and become Systems Engineering Application specialists.
5) State of maturity of ES technology. The evolution of ES technology enabled its wide implementation in business applications and its integration with other information technologies.
6) Quality of employees. Last but not least, S&W believes that the quality and motivation of the employees is a major factor for the success of the ASDS division and the organization overall.

5. CONCLUSIONS

This case study highlights two new findings: 1) the adoption of ES technology by an engineering/ construction firm for creating a new business line; and 2) the importance of staffing the AI group with individuals with strong background in engineering, which enables the system developers to better understand the end-users' needs.

6. ACKNOWLEDGEMENTS

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SESSION 5B
COMPUTERS AS A DESIGN TOOL

Questions and Discussion

Question
Russell Thomas

The expert systems in shells, did you actually use commercial shells or have you adopted a build-it-yourself system?

Mr. Brandon

In each case, we tended to go for commercial expert system shells but in each case we have also had to add to those shells, so we used for our first expert system LC one called Savoie, but we had to build something like 48 different routines on top of that shell to do the sort of things we wanted. We are now working with a shell called Capper and again we are having to develop new architectures alongside it. The advantage of this shell is that it assists you in trying to address some of the more standard functions that you would need to build yourself if you were developing your own expert system shell.

Varkie Thomas

I received my PhD in 1968 from the University of Strathclyde and since then I have been in the United States working in developing architectural engineering programs and as project engineer in that field. Twenty years ago when I was developing ME programs at Sisca and Hennesey, the theory of transferring technology was to put a gun at your head, tell the users, use it or get the hell out of here.

Twenty years ago it did not work because of hardware limitations and recently I was the director of developing a mechanical electrical program called IBM at Skidmore, Owings and Merrell, the same philosophy applied; the architects and engineers were asked to use the programs or get out, and this time it worked. Jesus de la Garza has come up with a new method of transferring technology, that is, expert systems. I read his paper and I think that is the way to go about it.

Question

Have you done any investigation into different dates of building codes, shall we say 1985 and 1990, to find out if, given the changes that happened to the Building Code, whether you had changes in logic and you had to redo your logic for every change to the National Building Code in Canada?

Mr. Vanier

We have not done any work in that area at all, but it might be a way of using the system to validate changes and there are some people that are doing the risk assessment and change assessment of building code modifications, so that there are probably some rules in the Building Code that could not technically be accessed unless you bypass some of these rules. That is fuel for additional research, but it could be addressed by this sort of a system.

Question

You emphasis the National Building Code of Canada; can this be parted to analyze Oka or Chicago code? To me it seems that we are analyzing the syntax of the English language as well.

Mr. Vanier

From a cursory look at the Uniform Building Code and the Standard Building Code, they tend to have roughly the same structure because they all came from the same source. It would be possible to develop the same sort of classification systems. You might have to go through the same laborious methodical method in order to extract those concepts or you might be able to use the concepts as a starting point.

Varkie Thomas

When I reviewed all the presentations, I was trying to relate everything to what we were doing in practice, in using computers and when we developed the IBM piping system, we tried to master plan all the piping system for the building in one shot, with one foundation generating all the systems, and we generated sixteen types of piping systems except one, sprinklers, because the logic was slightly different.

Even if we had started on sprinklers, we would not have followed the method that Mr. Y.C. Lee is going to present. Could we just try to imitate manual processes, because architects and engineers can immediately relate to that?

Mr. Lee is a building services engineer with the Hong Kong Housing Authority and is a research graduate with the Hong Kong Polytechnic.

Question

What you have described is really a tool for engineers and some of the earlier presentations dealt with sort of an expert systems approach. Do you feel, in general, that a tool kind of approach has many uses independently of whether it's an expert system? You seem to say it really was not much because it was not an expert system. I think, in practice, tools for the designers are as varied and, in some cases better, than trying to use expert systems. Do you have any comments?

Mr. Lee

This system is not an expert system and I am an engineer in the housing department and our model in this approach is based on my personal experience. When I start my sprinkler installation design, I think I need badly tools like these. It would give me very efficient access to other inside information and constraints.

Question

Is the Hong Kong Housing Authority actually using the system to design sprinkler systems? I noticed that you are also doing graphics, you are laying out a piping system graphically. Is your design, your analysis, linked to the graphics model and what platform are you using?

Mr. Lee

This is actually a prototype model and the rules are used by the Hong Kong Housing Authority but the model is still under development; it is not being used yet. Another thing, the graphics is mainly for display purposes; it is not as yet an interactive CAD interface.

Question
François Lebeau
EMR, Canada

I really enjoyed his presentation. I think I can see the value of that kind of tool. When do you see the real market penetration of that system, because you need a CD ROM reader to start with and I don't think a lot of people have it.

Mr. Vanier

The question regarding CD ROMS; I think everybody will have one on their personal workstation in about two or three years, and that is based on the fact that when we had personal computers in our office five years ago, very few people bought hard disks. Nobody would ever conceive buying a computer system today without a hard disk. The same thing happened at home, when you bought your first computer at home, PC, MAC, whatever, you very rarely bought it with a hard disk. You wouldn't buy one now without a hard disk.

You have your small medium, your large medium and you are going to have your extra large medium, lots of places to put lots of things, your encyclopedias, your Oxford Dictionary, so I have a feeling that it will come around in three or four years. The price of CD ROMS are very low, when you look at the amount of data you can access. All you have to do is pay for this compact disk on one job; five hundred dollars can be saved quite easily when you browse through a large database on one project. That's the way you justify it.

There is a cooperative research project that I am dealing with for the classification system and this is all being done within the National Research Council and that is a consortium of research contributors from the Province of Ontario, Labour Canada with the Fire Commissioners Office, the Province of Alberta, the National Research Council, ourselves, as funders and also the Code Development Fund, who are all getting together to make this custom code available and possible.

There is a smaller project which is being done in-house in Alberta, in conjunction with our advanced construction technology lab, which looks at creating what we call a mini-code, which is more of a code for generic buildings. First there is a specific project, like this building, you might talk about a generic code for hotels, a generic code for a single family residence, so there is a cooperation between all of these bodies. We basically are dealing with the same data in the National Building Code, in the model code for Canada, and everybody has their own variation. Russ probably can speak at length about the standard generalized mark-up language and other projects that are taking place within NRC to assist the transfer of electronic data from the National Research Council to other government bodies.

Question
Mr. Monty
Central Building Studies
Concordia University

How much of a demand is there for computer-based design tools, for instance at the preliminary design stage?

Speaker

At the moment, its almost 100% use of computers in the production. In the conceptual stages, I think this is where AI and expert systems are going to come in, in the conceptual stages a lot of experience is involved, because the building has not been formulated yet. It's like an interactive process at the moment, so what we are looking at is trying to accumulate data on classifying data on the basis of geography or in terms of core areas. In fact, analyzing the space alone just for historical information, is the basis for preliminary conceptual design phase. You cannot use the production tools that we have now at the preliminary conceptual stage, it is too inefficient.

Question

In my opinion, the demand is very high. Nearly all our work is being driven towards the conceptual design stage for expert systems because that is where people want the most help in getting started. If you can get a good starting point, you can refine quickly and get to your first solution, so the good thing about expert systems is that they put you in the right ball park. We are getting a lot of requests to build systems for, not only architects, for surveyors, for engineers, a whole range of people to build systems for the very early stages of whatever process we are talking about, in our case usually the development process. That is where the major demand is, because they want to get into the right ball park quickly and then they can use their human skills to adapt and adjust what the machine has come up with in a very, often, crude, coarse way.

Speaker

I believe that the tools for conceptual design are to be placed not in the designer's office, but rather in the client's office, the owner of the project. I think that the move is to empower the owners of the facilities with computing tools that will allow them to communicate their needs and requirements to the designer. If one were to, not to predict the future, but to invent it, one should be able to be in the position to give tools to the owner, as opposed to the designer, so that the owner can communicate his/her dream to the designer, who will then translate that computer model into a more detailed design with the tools of the designer.

To summarize the point, is to say is that those tools belong not in the designer's office but in the client's office, the habitual owners, ones that are doing construction all the time.

Comment

Our situation is a little different. For some strange reason the architects that I deal with and we cooperate with are not in the least interested in the conceptual, to use any computer-aided design tool in the conceptual phase. I would worry about it, if it were not for another phenomenon that happened, namely, it took us a long time to not only get acquainted but to free them from any misconceptions about the work we are doing because, as you might have guessed, lots of suspicion was created when we started to meddle into the conceptual phase, although we were claiming all the claims the expert system builders claimed. We are here to help you, we are here for your own good and so on, but the architects are a suspicious breed and they know that these offers are not really free and it is not as simple as that.

When we started to make alternatives, and rules, the resistance mellowed a little, especially when they themselves started to work on the drafting systems and they relaxed. In our case, it went the opposite way, it started from the detail phase and coming slowly to the conception phase. We can only hope that it continues.

On the other hand, it should really stay like that, it should be spread out throughout the design process.

Comment
Jesus M. de la Garza

I can only say that I myself have a double life. I am a full time professor of the University of Rome and one of the fields I am working with is computer design. I have another full time profession, which is to act as an architect professional. This means that I have 24 hours work a day. In the other field, acting as a professional, I see which is the low level of the user of the systems that are working today. In Italy, everybody has an autocad. I would say it would be better, most of the time, if they didn't use it.

On the other hand, I work also with much more bulky and difficult to use systems, so that we're tended to give me a lot of help and I formerly used them in the University and I tried to use them as tools in the professional work.

Speaker

I did tend to agree with you to some extent, its seems to me that we are going back to the beginning of CAD with original concept of a sketch pad, before we began to formalize that a CAD system dealt with lines and vectors. The early work was a very simple example of a sketch pad. What we now seem to be doing is to demand that those sketches take on a formal nature at the same time and it becomes structures rather than just concepts.

I must agree with Jesus, that I think one of the real problems in areas that are going to evolve in the near future is the need for knowledge and tools to support the original specification. One of the areas that we are going to see development in over the next couple of years, is trying to support the idea of producing quality products, quality buildings. One of the ways of conceptualizing a quality product is to say a quality product is one which meets most closely the original requirements of the owner, the specifier. To be able to measure the quality, we are going to need to get a clear understanding of what those requirements of the owner were at the beginning and then we have something to measure our achievements against.

We all know how bad we are at expressing our own requirements; we need tools to support us in that. I think that you are perfectly right, that is one of the areas we are going to have to start looking for tools in and perhaps we look at the knowledge engineering community to at least begin to guide us in that direction with supporting tools.

At this stage I would like to turn the question back on the audience. Do any of you feel that some of the tools that have been proposed here would help you in your practice or do you feel there are tools that we have not yet described which would provide you with better support than the current technology?

Comment
Anthony Pierce
Royal Architectural Institute of Canada

I think in general, many architects would be glad to see involvement of any and all of these tools, but I am just looking around this room right now and this was a well attended conference this week, with experts from all over the world and it's really a very small number of the total that are interested in these very important topics. It seems to me that there has to be some selling or some education going on because it's going to take many more years than we anticipated if people are not

willing to come and listen to these future trends and understand the tools that are already available and where we need to go.
I had another question or clarification on the classification system that Dana was discussing. I am not clear, was that intended to generate a codification system for building parts and for the building industry in general?

Dana Vanier

Yes, but only as it is delimited by the Building Code. So if the Building Code talks about mezzanines, then there is something about mezzanines. It has to know whether it is the area or the percentage area of a mezzanine or the height of a mezzanine.

Anthony Pierce

Maybe it is not intended as this, but it seems to me that if it would become a universal system that's a very mean beginning because in Europe they have the SFB, the CISFB system. We are somewhat stuck in North America with the 16 division master format system, which ties all coding down to specific trades and the way the labour division works in a construction project and it simply doesn't go far enough. If we are going to codify all of the activities that need to be computerized, that need to be automated, then we are going to have to have some codification system that is much broader, like CISFB.

Dana Vanier

I guess it depends on what the codification system is for. A lot of people know what the origin of the CISFB is and it was for classifying construction documentation and it serves that purpose very well. It is very difficult to apply that to the Building Code because you might be using the same component for different reasons within a building to meet certain Building Code compliance requirements.

There could be some sort of mapping from the classification system over to CISFB.

Anthony Pierce

From a cursory standpoint, it would seem that there are many applications within CAD and computers that could actually use that kind of overall system, where the 16 division system falls short. Perhaps we should ask the people from other parts of the world, how they are using coding systems in their own work.

Gianfranco Carrara

Perhaps before we answer this question we owe to the audience an explanation about the W78 Commission meeting. Actually CIB works through 50-70 commissions and the very commission that treats the computer integrated design held a conference last week here in Montreal and was attended by about 80 people and not to mention other agencies like Acadia, Design Futures and so on, so there are people who are doing this. Although I think you are right.

About coding, I am the last person really to start to tell you about coding, although I must confess that we also transferred Belgrade architectural regulations into using a list in form of questions and answers. It goes about five or six steps deep, but actually didn't involve too much qualification because the regulations as such didn't require anything special. Also there is an interesting question, I would call such a thing more an active book because there is nothing really very special about it, there are no incidences of any sort, it just follows the tree and goes up and down and so on. If you are lucky; in our case, it goes only one way, unfortunately. It works and it gives you all you need and in the end, if you really want to, it can give you a whole printout and it's not so difficult to include the picture.

As far as codification goes, we are an open book. We are following SBF and even have developed our own qualification system, but we ran into another type of trouble which I am not going to involve here, which deals directly with a resistance of the construction firms to accept anything that is different from what they are already using in Rome.

Varkie Thomas

When I was asked to look at all these presentations and papers, I took it up with architects, structural engineers and the whole group of people with strong computer science background who worked on the IBM system. We kind of prioritized according to importance, what is going to have the biggest impact in the future, and we looked at Dana's paper and we decided that this was the future. Whoever comes up with a code analysis program that can not just synthesize the code but also check construction documents for code compliance, is going to make a fortune. I believe something is being done, he is the head of the software development at Prime Computer and Computer Vision, he used to be an AI consultant at MIT, he has developed a code checker that checks the New York State Code, but when he gave that presentation last year I, having worked in the building industry from both sides, thought it had a long way to go before it was really practical.

Dana Vanier

To address that, there was an interesting study done at York University in the United Kingdom, looking at how people use information. It turns out the largest usage of technical documentation was for building codes. People typically went to colleagues first as their prime source, to a so-called expert and then they went to building codes and then they went to manufacturer's data. It is a heavily referenced source document and we just have not been placing enough importance on it because it looks mundane, but I think it's an exciting area that is small enough that we can grow from that small area and that is why I feel that there is some chance with the identification of components in a building code, whereas to model a building is very complex.

When you have teams of something like 10 or 15 PhD, Masters and Assistant and Associate Professors at some universities working on the same problem and they have for the last 15 years and you don't see any clues of answers or you just get a little fragment, you know it's a very complex problem. But it is an important area for the representation.

Varkie Thomas

Yes, I agree and I think in a sense that comes back to Ivan's point that the outcome of the project that Dana was describing was really a dynamic book. What happens is basically you specify the kind of building that you are dealing with. It doesn't give you the answers, what it gives you is the code for that building. You still have to do the interpretation and the reason that you have got 15 or 20 or 30 professors in a university trying to develop a system that will do it automatically is simply because there is a large amount of interpretation necessary for these documents because generally they have ambiguity in them deliberately, to leave an area of interpretation. It is the area of interpretation that gives most of the problems to anybody that is trying to implement a rule based system.

Peter S. Brandon

I think one thing that seems to be uniting the people here today is the drive towards object oriented programming in some way, which seems to be at the root of all these problems. If we could define the objects and their relationships and the messages that they carry and the concepts that they hold, then perhaps we have got a start in driving forward. It seems to me that it's a very good thing for all of us to be working at, if you like, the bottom on specific problems but at the same time, I think we need a high level model which actually begins to put a framework within which these things fit and in which we can bubble up towards it. Otherwise, I think that we are all doing this in an ad hoc way, unstructured way and there is no overall view to which we can contribute or comply. One of the things we are trying to do at the moment, we have actually tried to develop an object oriented database for design procurement and construction management in order to see the different perceptions of people when viewing the data so that you can screen off the information that is not important but pull out what is important. We are all handling the same objects, we call them different things, we use them in different ways, we apply them in different concepts, but in essence they are the same thing. So if we can begin to define at a high level, and I am not trying to get down to the bottom level because I think that is where the 15 professors are, but if we could design the framework at the highest level then I think that we have something with which we can all work.

Comment

I think at this time it's a point to make a plug for our new CIB task group which has just been formed. The CIB has just initiated, in the last week, a task group that is being led by Kent Reid of the National Institute of Building Standards and Technology in the U.S. and the working group is aimed at doing comparisons between representations on an international scale between a source document relating to the construction industry, looking at the different representational approaches that countries are adopting in an attempt to try and come up with some internationally recognizable standard for representation of structures and documents and objects and anybody who would like to take part in that, please contact me and I will put you in contact with Kent Reid, who is coordinating that activity.

Question

I had two reactions, one on the codification or on the informatization of the code, which is that the advantage that I feel in the tools we are acquiring as architects, is the fact that possibly by forcing us to go through the structure of the code, which would be inherent in a software like this, we are forced to discover the structure of the code which, until I began teaching it, I never knew. Because I would only use the sections of the code that applied to me and I would always get screwed up when some sort of inspector of the city would find some other section of the code that I didn't know applied to the thing and I never understood the organization of the code and I think that is one of the advantages of these tools. The same thing with the hypercard on sprinklers, possibly even more dynamically, is that you actually get an idea of the overall structure of how the thing works. As a working architect I feel that is an advantage, because none of these codes ever explained to you how they are organized, they just sort of present it all out for you and you have to wade your way through it, in order to get the information. I see it as a real advantage.

The other reaction I had is, if you are talking about some sort of tool to hang all of these very low level specific researches that you have done, I see the program. Dr. Carrara, it would be interesting to see some sort of coordination between what is being done on this side of the table, which is information specific, sorting these things out and finding a way of attaching all of those givens to the graphic image that you had in your program, where you had some sort of values, because the program was giving you some sort of criteria that you have not satisfied and criteria that you had satisfied, and it would be interesting if there were some way of attaching enough information to those things that the flags on your databases could somehow be integrated into it. I see this in 20 years, but it's an interesting thought.

Jane Blackmore
Australia

I have been involved in a workshop last week on the development of computer tools for regulations and so on. I think we should not overlook the fact that the regulations themselves need some organization in order for these computer tools to be really useful. I don't think we should hide the confusion of the regulations and I think almost everybody's regulations have some confusion within them, behind the computer tools and we shouldn't be using the computer tools to sort out problems that are inherent in the codes themselves. I feel very strongly that a performance basis for the development of regulations, where intentions are clearly stated, after all we have been trying to achieve something with our regulations, which is to achieve a safe built environment and we have given ways of doing that.

Traditionally, we have not actually spelled out what it was we were trying to do, we have told people how they should do that. The move toward performance regulation is requiring us to spell out the actual intentions of the regulations. If the regulations themselves are structured on that basis, we have clearly spelled out intentions, in fact the means of compliance can be much more clearly and positively stated and we get much more logic within the regulations. The last speaker's question can be answered by clearly spelled out intentions within the regulations.

I am a great supporter of computerization of building regulations. We have, in fact, developed interactive computer software for our own regulations in Australia. We have developed (the software) which takes you step by step through the requirements of the regulations and also gives you access to the support documents that you need for matters of interpretations, compendia of approved products and so on, directly within the software and that is commercially available. I don't want to say that it's not a very useful package, but I do feel that the regulations need more work done on them, and hopefully the move towards performance will encourage a clearer way of thinking within the regulations themselves.

Gianfranco Carrara

I appreciate your question. I would say that nowadays I believe in the necessity of having a mapping between the performance of shapes in design and the behaviour of the shapes as an object, that means not only to have a beautiful subject as a shape, but also the meaning that this shape has and what it means physically and the behaviour in comparison with some uses which are looked for.

The system we are proposing, I believe we have done something a little more than proposing it. It is to have not only a geometrical model which is stacked actually in the system itself, it's only part of it and to connect through a very complex symmetric network, shapes - that means just how geometrically the objects you are dealing with are done with the materials that these meetings can be done with, that means that you can start giving your requirements and performance specifications to some sub-sets of categories of objects and then see what kinds of materials we can look for in achieving these types of specifications, or the other way around, starting from materials and go and see if the specifications that you are looking for are achieved.

This means that all the work that those gentlemen are doing can be and should be brought in. As a matter of fact, the system will perform as a brick wall made of a lot of bricks, and bricks already exist. Let's say that what we call evaluators are programs, computational programs, such as structure calculations for concrete, maybe you know super sub or sub 80, that is, large structural programs, they exist and they perform well, they can be brought in the system, the only thing is that you have to make the interface between a sub-set of data and the entry to these programs. So all the things that you can look for in heavy or bulky building codes, must be structured and must have a way of entering or selecting it easily, according to the different points of view that you set earlier, the architect, the client or the contractor or so on, because the system should be used by different points of view along the design process. That is the aim or the goal that we are looking for.

SESSIONS 5C & 5D
Information and Its Communication
L'information et sa communication
Technology Transfer: An Evolving Process
Le transfert de technologies: un processus en évolution

A GIS FOR GEOTECHNICAL DATA MANAGEMENT

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1. Introduction

In the geotechnical engineering practice there is a constant need to review information about past projects in the surroundings of prospective projects. This information helps the project engineer to answer the following questions:

- What is the general type of soil in the general area of the new project?
- What test methods were used in previous projects in this area that can be considered for the new project?
- What types of equipment was previously used in this area?
- Are there any abnormalities in the general area of the project that require special attention during the investigation process of the new project?

Efficient retrieval of such information requires an automated system that can handle, not only descriptive data of projects, but also data that reflect geographic locations of these projects.

Prevailing databases lack the capability of handling spatial data, a desirable capability in today's complex projects. A **Geographic Information System (GIS)** is the technology that meets this demand. A GIS is an integrated system that stores, manipulates and displays spatial as well as non-spatial data. Spatial data are used by a GIS to determine the geographic location of an object in relation to other spatial objects. **Spatial objects** are objects that have physical dimensions as a major attribute. There are three main types of spatial objects, namely: polygons, lines and points. **Polygons** are 2-dimensional objects with a closed path boundary. **A line** is a 1-dimensional object that connects two points. Lines with multiple segments, curves, and lines with specified directions are more complex forms of lines. **Points** are 0-dimensional objects. These objects are abstractions of the real world. For example, a polygon can represent the general area where projects are located, with a line corresponding to a street inside this area, and a point symbolizing a project site (see figure 1). **Non-spatial** data reflect descriptive information about objects such as project name, number of borings in the project and so on (see table 1). The ability to combine spatial and non-spatial data in a GIS offers the user several benefits. For example:

- The project engineer can view a map of the area containing the new project in addition to other projects in its vicinity.
- A GIS offers tools that allow the user to zoom to specific locations and perform visual search on the screen within desired areas.
- Modern GISs offer high level query languages that enable the user to perform complex queries that satisfy specific requirements.

Because of these capabilities, a GIS is very suitable to the needs of geotechnical engineers. Among the geotechnical companies that came to realize this, is a major company that is currently introducing GIS in its nation-wide offices.

This paper discusses the expectations of the company from the automated system and how a GIS comes up to these expectations.

2. Functionality of a GIS:

2.1. Storage of spatial data

As mentioned above, there are three types of spatial objects: points, lines, and polygons. Figure 1 shows part of a map where the projects of a geotechnical company are located. Points are the simplest elements of the spatial objects. On a manual map, a point is located by its XY coordinates. A GIS locates each point in the same manner using its XY coordinates. Figure 1 shows the coordinates of the points in the map between parenthesis. For the representation of lines and polygons, one scheme would be to define such objects solely by the coordinates of its points. In this case, every object is stored as an independent object, i.e. there is no explicit relationship between the locations of different objects. The relationship between spatial objects is referred to as **topology**.

2.2 Storage of Non-Spatial Data

Non-Spatial data are descriptors of spatial objects. Most modern GISs use the relational data structure as the method of data storage. In a **relational data structure** data are stored in the form of tables. Each table represents an entity. An **entity** is a real world object about which there is an interest to record data. *Table A*, for example, represents the entity "Project" and *Table B* may represent the entity "Owner". Each row in the table (called tuple) represents an occurrence of the entity (Proj A, Proj B, and so on), while each column (called field) represents a different attribute of these occurrences (Proj_Name, Owner_Code,..., and so on). Different entities are related together by a field that is common to both entities. Each project, for example, is related to its owner by the common field "Owner_Code". Since each owner has more than one project, this relationship is said to be a one-to-many relationship. Maintaining one-to-many relationships in this way has the advantage of reducing the amount of data. The Owner_Name is stored only once instead of being repeated with the multiple occurrence of the corresponding Owner_Code in the "Project" table.

2.3.Linking Spatial to Non-Spatial data

There are two major methods to relate spatial to non-spatial data. The first method is to store spatial and non-spatial data in the same table. A major disadvantage to this method is that retrieval of either data types will always be associated with working through the other data type which can slow the retrieval process. The second method eliminates this disadvantage by storing each data type separately. A disadvantage in this method, however, is that there are more files to maintain. When spatial data are related to non-spatial data using either method, the representation of the result is referred to as a layer. Another important feature of a GIS, is the thematic maps. A thematic map is a map where user defined attributes are indicated by value. For example, the range of the dollar value of projects might be required to be shown on a map for reporting purposes. The GIS provides the user with tools to define the range of values as well as the symbol used for each range.

3.The Case Study

In this section the GIS application for the Honolulu office of a major geotechnical company is discussed. The office keeps a manual system that contains records about all previous projects. When the office receives a new job, the project engineers need to retrieve information about previous projects that were done in the vicinity of the new project. The records in the manual system, however, are arranged by the job serial number and not by location. To know what projects were previously done in a certain area, the project engineers have to ask senior managers who have been with the office for a long time. Relying on senior managers in this way has serious disadvantages since with the growing business of the office, it becomes impractical for the project engineers to ask senior managers about projects locations. Also if senior managers leave working at the office for any reason, the system will be crippled.

3.1. Expectations from the GIS.

The interview revealed that the management's objective was to change part of the existing manual system (which stores records about all past projects) into an automated GIS that can be used to:

- Store descriptive data (such as owner code, project name, number of borings, and so on) about all past projects.

- View the location of all past projects on a digital city map, displayed on the computer screen and search for past projects in the vicinity of the location of prospective projects.
- Retrieve stored information about past projects in the vicinity of prospective projects. This information is then used to reference the manual system to get more detailed information about the corresponding projects.
- Produce a printed map showing the part of Honolulu where the prospective project is located.

3.2. Definition of Data Entities

The selected descriptive data to be stored in the system included the elements shown in table below. To reduce the storage space the data elements were divided between two entities: "Projects" and "Owner" forming two tables.

After studying the software market with the above considerations in mind, the GIS chosen was MapInfo for Windows. MapInfo is manufactured by Mapping Information Systems Corporation of Troy, New York. MapInfo was chosen because in addition to being cost effective and applicable to PCs (the platform available at the office), it has the features desired for the application.

Data Element	Definition
Owner_Code	Code of Project's Owner
Serial	Serial Number of Job for the Owner
Office	Office responsible for Job
Proj_Name	Name of Job
Address	Job Address
#of_Borings	Total Number of Borings
Max_Depth	Maximum Depth of Borings in the Job
$Value	Dollar Value of Job
Owner_Name	Name of Job owner

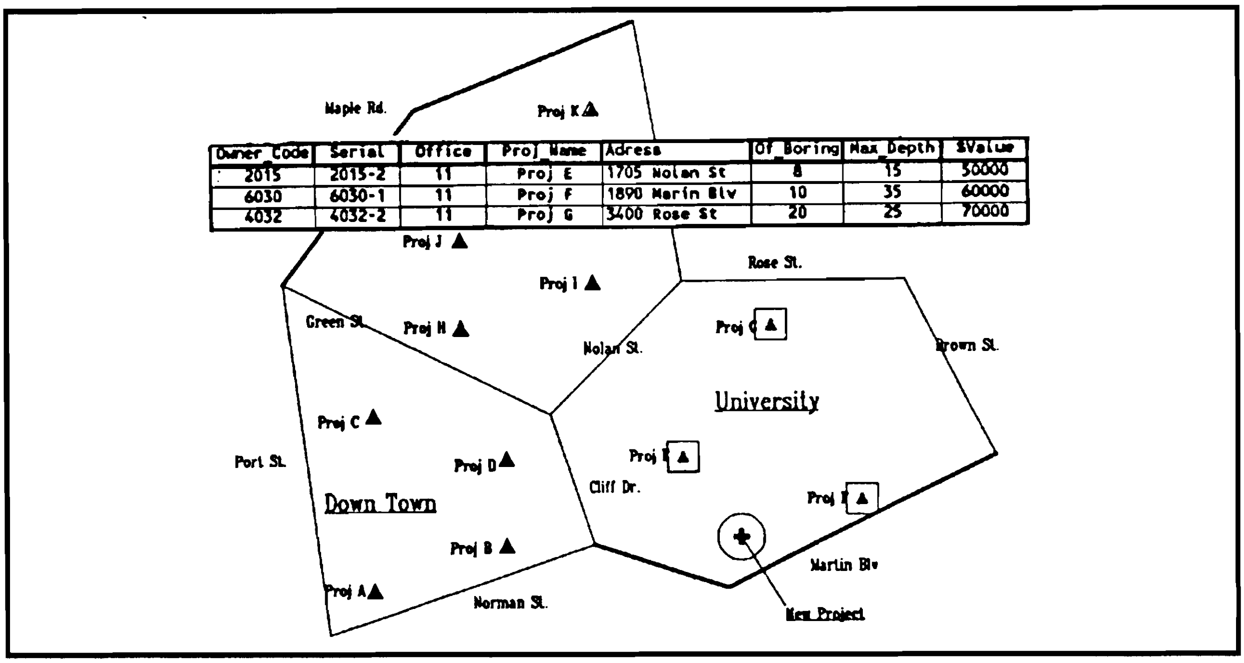
3.3. Data Acquisition and Entry

After deciding upon the software to be used the next step was to acquire and enter the data. The non-spatial data were acquired directly from an ASCII file including records about individual projects. After defining the two tables: "Project" and "Owner", the corresponding data was imported into the program. The spatial data involved two layers: the "Project" layer and the city-street map layer. Digital city-street maps can be produced by digitizing manual maps. Many GIS manufacturers, however, produce digital city-street maps that are available in the market. The spatial data for the "Project" layer were created using the geocoding method discussed before.

4. Summary

Reviewing information about previous projects in the vicinity of new projects is an important input to the planning process in geotechnical engineering. Retrieval of such information requires a system that can handle data that reflect the geographic locations of these projects. This type of data is referred to as spatial data. While traditional databases cannot handle spatial data, a GIS has the advantage of storing, manipulating, and displaying both spatial and non-spatial data.

One of the major geotechnical companies came to realize the advantages of GIS. The company is developing its GIS to replace part of its manual file system. Using the manual system required heavy reliance on the senior managers in the office because the files were not arranged in a manner that reflects the locations of the projects. With GIS the project engineer could view the location of projects on a digital map on the computer screen. The GIS could also be used to retrieve descriptive information about the projects as well as produce customized maps and reports according to the company's format.



Owner_Code	Serial	Office	Proj_Name	Adress	Of_Boring	Max_Depth	$Value
2015	2015-2	11	Proj E	1705 Nolan St	8	15	50000
6030	6030-1	11	Proj F	1890 Marin Blv	10	35	60000
4032	4032-2	11	Proj G	3400 Rose St	20	25	70000

Fig. 1 Map with Projects

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AN ITALIAN INTEGRATED RESEARCH PROGRAM : THE PROGETTO FINALIZZATO EDILIZIA

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1. Introduction

The Progetto Finalizzàto Edilizia (PFEd) is a scientific initiative of the National Research Council, the main Italian Research Body, which was started in 1989, following the approval of the first Executive Program.
The research program will be conducted over a five-year period by providing financial support to specialists and professionals within the building industry. The total funds allocated to the program amount to Lit. 115 billion (roughly 82.15 million U.S. dollars).
One of the fundamental aims of the PFEd is to act as a link between the areas of research and of production so as to trigger operations and processes that will lead to development and innovation in the building industry, while promoting Italian companies on the European market.
The P.F.Ed has made use of a 'Feasibility Study', conducted in 1987, based on the proposition that the building industry is among those sectors most in need of new stimuli to boost both technological and general growth, as well as the establishment of a well-coordinated plan for technological development. Among the factors which have, up to now, most hindered technological growth in this sector is the difficulty of coordinating technological programs with all of the other inter-related issues, ranging from social considerations to economic and political problems, which often result in different segments of the industry working at cross-purposes.
One element of particular importance that stems from this situation is the need to fill the gaps in technological and practical know-how relative to already existing techniques, and to foster the development of new practices in the industry, the ultimate goal being that of enabling Italy's building industry to meet the European market of 1992 on a firm footing.
In an early stage of the Feasibility Study, the criterion had been adopted to consider the building process, which represents a highly complex reality, into two basic phases: design and production-construction.
One the other hand, however, this process unfolds in a procedural context which, in latter years, has pointed to the need to provide elucidation, articulation and simplification. Hence the necessity of identifying a further research problem, the one that relates to the process and procedures, which is considered as being more general in scope as compared with the first two because it permeates the whole process and provides the framework in which the other two themes are to be viewed.
The PFEd, therefore, is divided into three major programs, each covering specific research areas, ranging from procedural context-related problems to the analysis of innovative planning instruments, to the search for technological products and systems capable of meeting quality requirements in the building industry.

2. Subproject 1

In keeping with the guidelines set out in the Feasibility Study, the first Subproject aims at improving the efficiency and the effectiveness of the building process as a whole, by focussing pre-eminently on operators and

relations among operators, through the identification of the various organizational stages and of tools for their implementation. The results of the Subproject as a whole can, therefore, be employed both within the process, thus closing an ideal circle which hinges on an analysis and an awareness of the operations underlying said process, and be transferred to the other Subprojects, both in terms of practical testing and in terms of distinct, successive stage in the building cycle.
Subproject 1 aims at developing topics which relate to the general and particular organization of the building process. The directly involved "phisical" objects eventually turn out to be lesser in number as compared with the procedural and context-related definitions. The context itself, which is difficult to define and to homogenize within the national framework, is bound to change radically as the free European market of 1992 approaches.
One of the results to be pursued, therefore, relates to a set of regulative proposals, preceded by tools offering insight into the various phases of the cycle and followed by automatable, standardized, operational tools, capable of developing the process of industrialization of the sector on the basis of a re-composition of the productive factors.
In this connection, the widening of the market, of the range of typologies considered and of the stages taken into account, has traditionally reduced the number of potential operators, while ensuring, on the other hand, survival in significant industry niches.
In order to prevent rationalization and average technological up-grading from being delegated to the market laws alone, the ultimate object of Subproject 1 is to redefine, in terms of models and easily accessible computerized tools, the entire building process.These models are in turn based on other models which, though smaller in range, offer greater depth and versatility in a continuing mutual dialogue, and are therefore capable of improving the understanding and the efficiency of the individual stages and of the individual procedural issues, in other words, of the factors involved in the building productivity cycle.
If these results are to be achieved, the intermediate objectives shall, first of all, have to be consistent with the final one(s); secondly, sequentiality and correlations should be provided for, also through a reduction in the time accorded to the individual research projects and diversification of the topics and specifications to be addressed.
In order to implement this program, topics and research proposals have been combined in some cases, while in others they have been broken up so as to attain a better definition of the intermediate objectives. A substantial role is also to be played by training, both in terms of creation, through a centralized, planned scholarship-awarding schema envisaging training agreements for the development of new potential operators, with a common language and common skills, so as enable them to play a conditioning, directive role in the industry's market, and in terms of minor business enterprises, in accordance with a model that has already been successfully tested by other Progetti Finalizzati.
The topics addressed by Subproject 1 lend themselves to organized participation on the part of associations, both public and private, which often prove to be also the most interested potential users. However, a share of experimental work concerning the contents and the participants, has been retained; in this connection, an effort has been made to carrefully consider prospective additions and integrations.
Consequently, the Operational Units that have been proposed reflect, to a considerable extent, the instructions and suggestions contained in the CIPE Project-funding resolution; in addition, they also acquire a comparable average size, a certain degres of administrative clarity with respect to the contracting body and composition.
Another of the specific topics dealt with by Subproject 1 relates to the acquisition of standards, data and information, which

provides the essential basis of nearly all of the research projects submitted. However important, this stage has not been included among the items covered by the direct financing of the Project, for it is a task - often an institutional one - which pertains to the proposing organizations, or, more often than not, has already been funded by other agencies. The Project's resources, on the other hand, are directed towards the generalization of know-how and partial results and towards the development of technical tools which are specially designed to spread information and transfer the relevant results.

3. Subproject 2

The second Subproject hinges on innovations concerning design procedures and a set of design contents. The former are to be sought explicitly in the area of information-processing; the latter, on the one hand, relates to the functional, spatial and technological modelling of some classes of buildings, which have hitherto either been analyzed only superficially or represent a recently-emerged problem-area (a case in point is represented by the informatization of buildings - "intelligent buildings" - for which Subproject 2 is to provide methodological and propositional results, as well as experimental results).
As for the actual contents of the designing process, emphasis is laid on the prospective production both of Guides and Data-Banks, and of regulative results, possibly fitting into the EEC regulative framework.
The significance of the expected experimental results implies the establishment of an independent Research Area - including overall testing in accordance with the goals set out in Subproject 3 - characterized by altogether peculiar management and coordination procedures. In general, Subproject 2 aims at:
- raising the cultural standards of the designers, including those operating in the industry, so as to enable them to play a prime role and act as actors capable of fostering the development of the industry also in a supranational perspective.
- up-grading the instrumental assets (in terms of effectiveness and accessibility) with respect both to the management of design-making processes.
The ultimate goal, namely the attainment of know-how and of readily applicable procedures, leads to the definition of the following priorities:
- research aimed at the settlement and rationalization of the existing setting, which call for experimental applicational tests during the implementation of the Progetto:
- research projects specifically aimed at providing results of general interest (for instance, employment by Public Agencies).
One criterion that has been adopted in drafting the Progetto Finalizzato Edilizia is to have different operational Units compete over the most important topics, in the attempt to establish some kind of progressive convergence between the results brought about at each step in the implementation of the Progetto.
A second criterion, which will be more specifically addressed later on, is to promply orientate the results of research work in the direction of an immediate convergence in the main experimental stages of the PFEd as a whole.

4. Subproject 3

The Feasibility Study relating to the third Subproject had, both as a theme and as a goal, an increase in the quality of the technologies and products developed for use in the building industry.
Thus, having established quality as the ultimate goal, the tool for pursuing this goal operationally were identified in innovation (viewed as a process aimed at promoting revision and new solutions, through the introduction of the new systems and criteria) and in organization (intended as a process designed to enhance the functionality and efficiency of operations, regardless of their ordering and structuring).

Research activities in this context must be viewed in a perspective that will eventually affect, even though on a long-term basis, the development of the domestic market, via the development of scenarios, reference and tools designed to direct and increase the technical-scientific capabilities of the industry vis-à-vis the new, foreseeable changes in the foreign markets.
The trend implicitly engenders the first analysis criteria, which were duly taken into account in investigating the proposals put forward by national Scientific Community; these criteria can be summarized in the following general remarks:
- Focusing on the expected results, giving priority to studies relating to:
  - the actual introduction of innovation
  - the implementation of experimental work concerning new technologies
  - increase in the operational effectiveness of "key" facilities
  - critical analysis and appraisal of instrumental set-ups
  - identification of the contents and means required for the implementation of the training schemes
- Focus on the strategic and instrumental results, with a view to the establishment of the Single European Market; in this Subproject, these results are interpreted synergically as compared with the procedural results afforded by Subproject 1, with special emphasis being laid on the manufacturers and the certification, testing, standardization and technical training organizations.
The specific approach underlying this Subproject in its investigations of the research proposals was to favor those which effectively met the following requirements:
- Gaining insight and analyzing critically, through the study of "what can be done" rather than the study of what "has already been done"
- foresting technological innovation and experimenting with well-defined topics that can be pursued in accordance with the PFEd's schedule and available resources.
- Enhancing the operational potential of "key"-facilities within the process, by focusing on action such as the optimization and coordination of the existing facilities rather than on the establishment of new ones.
- Prividing technical and professional training in order to actually enhance the capability of transferring technological know-how and research data and, most importantly, the access to technological innovation entailing significant advantages for the industry.

5. Experimental Area

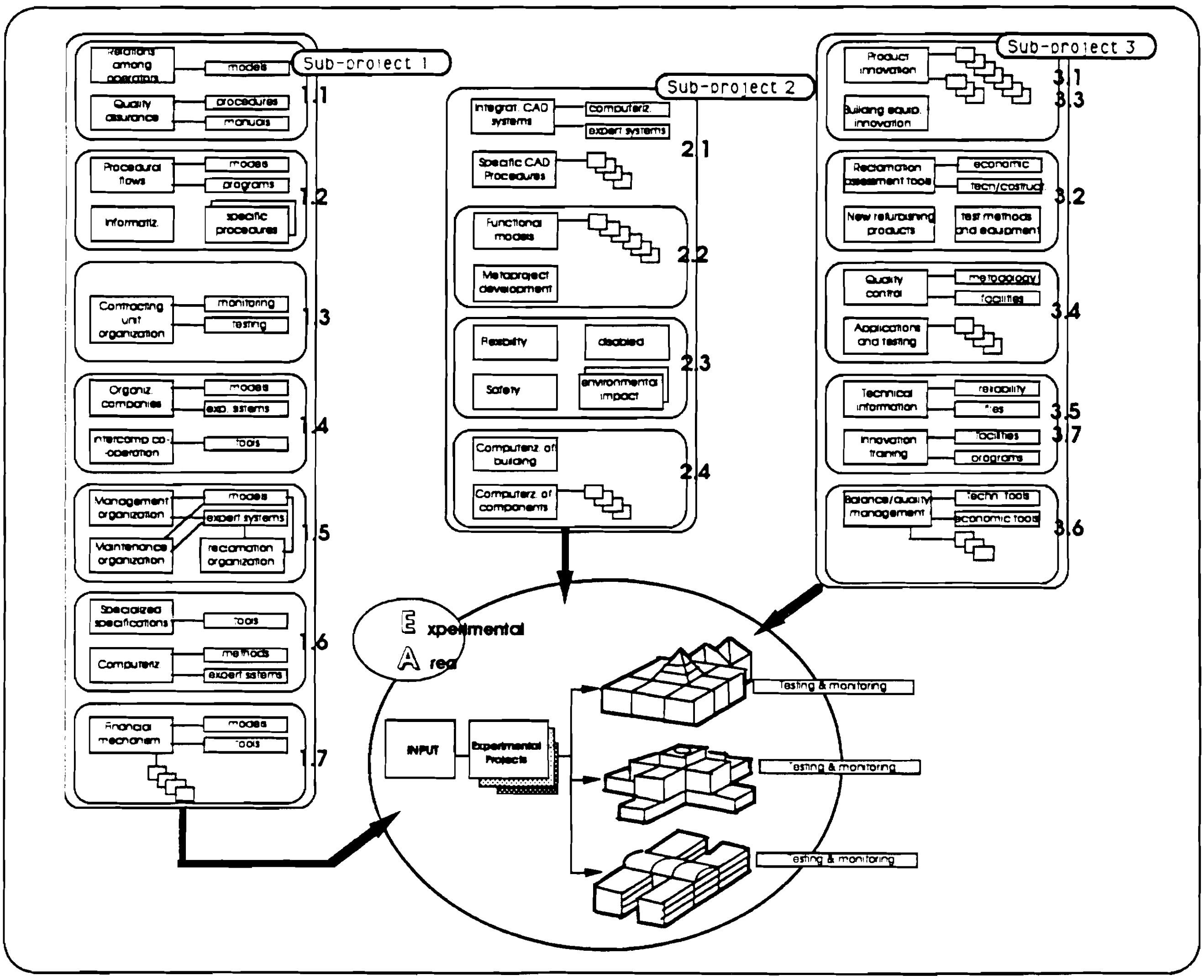
In the Feasibility Study, Subproject 2 "Project Innovation" and 3 "Quality and Technological Innovation", were to lead to the actual development of experimental buildings, with the object of testing the design procedures and monitoring the technological and functional inter-relations as well as the functional and performance values also in an economic perspective. The buildings to be constructed include an Institute for Biomedical Research, a Scientific Documentation Center and an Institute for Research in Building.
The crucially important role played by experimental developments in the framework of the Progetto Finalizzato Edilizia, and the ensuing pre-eminence of the organizational and management related aspects associated with these experimental developments, have necessarily led to the establishment of an "Inter-Subprojects" Research Area, which is to be coordinated and controlled so as to transform it - as far as possible - into a suitable locus for experimenting and monitoring the results supplied by the Progetto Finalizzato Edilizia as a whole.

6. State of the Art

1991 marks the third year of financing in the Progetto's three-year activity program, which was undertaken in 1989, and this offers the opportunity to make use of the results afforded by the research activities carried out so far and to direct the researcher's efforts toward the

pre-eminent objectives. In particular, the Project Committee and the Managing Board have endeavored to lay the foundations for the organization of work over the final two-year period, during which greater attention shall be paid to the disclosure and propagation of the results, is to be viewed in this context.
Thus, seven transversal thematic areas have been identified, all of which relate to a number of research projects under way:
1. Quality - Identification and organization of the experiments conducted both within the Progetto Finalizzato Edilizia and in other contexts, in order to optimize the real data-acquisition potential and thereby develop an effective quality management system in the various stages of the building process at the national level. Analysis and proposals for participation in international and, more specifically, European projects.
2. Training - Development of a PFEd training scheme through a servey of the activities under way, also at the international level, the processing and testing of "training packages" envisaging involvement on the part of scholarship-holders, the scientific managers of the Operational Units involved in the specific topic and the Member of the Project Committee. In addition, methodological aspects relating to the transfer of the acquired data to the various levels of professional competence will be developed in accordance with the specific features of the industry.
3. Information - Identification of possible and necessary synergies for transferring the research hypotheses and contents concerning technical information at various levels of complexity, interest and goal-orientation to the marketing stage. Development of joint initiatives aimed at promoting discussion and involvement. Implementation of proposals relating to the management of experimental work conducted on the results of research work.
4. Project-related handbooks - The basic goal here is to integrate a significant portion of the results afforded by Subproject 2 with a set of other topics addressed by Subproject 3 and Subproject 1. By focussing on metaprojects, the latter may indeed provide a point of reference for all problem-areas relating to the informatization of the PFEd, for studies on safety criteria, environmental impact, flexibility, computerized equipment, and, in the last instance, provide a basis for summarizing operator organization models, programming and financing procedures, specifications, maintenance policies, etc.
5. Reclamation - Provide coordination and interpretation of the different expected result levels so as to enhance their mutual complementarity as well as their correspondence with the results of research work in the area of reclamation joint initiatives aimed at promoting discussion and involvement. Development of proposals for the management of the necessary testing of research data.
6. Monitoring instruments - The object is to homogenize, within an overall frame of reference, the individual results of research work aimed at contributing to innovation or to the modification of equipment and procedures for effectively monitoring the characteristics and performance standards of building materials, components and systems both in reality and through laboratory simulations. This is expected to result in a contribution more readily transferrable to practice - a point of major importance as the 1993 deadline approaches.
7. Cooperation agreements - Consolidation and increase in the interactions with field research activities carried out abroad.
Development of joint initiatives, first of all relating to the exchange of information, meetings, conferences, as well as direct meetings between different research groups. Involvement of the central staff of similar centers for formalized initiatives. Contribution towards the internationalization of the industry.
Among the results of the first year of activity, major opportunities for scientific discussion were provided by the International Symposium on Composite Materials, organized by the

"Quality and Technological Innovation" Subproject, in Milan, in May 1990, and by the Conference on professional training in building, organized by the "Process and Procedures" Subproject, in Bologna, on the occasion of the SAIE '90.
As far as the second year of activity is concerned, it is cosidered a year of consolidation of the activities carried out in the first year, except for a few additions in those areas where gaps were found to exist.
Moreover, several and seminars and meetings are currently taking place in order to gain better insight into the objectives of the different thematic areas and into the actually pursuable results, to single out the guiding Operation Units and the most active research groups, while also outlining some scientifically pre-eminent or particularly interesting thematic areas, that is, research areas which are most likely to supply interesting contributions in terms of industy innovation.
The second National Conference of the Progetto Fianlizzato Edilizia, which took place in Venice in December 1990, marked an important stage in the assessment of the activities carried out by Operational Units involved in the PFEd itself.
The event provided the opportunity to present the results of research work currently in progress and information concerning a number



1. - General Comprehension Key to PFEd

of initiatives to be undertaken.
On that occasion, reference was made to a bilateral cooperation plan between the Progetto Finalizzato Edilizia and the Plan Construction et Architecture through a french research program called Eurorex, which envisages the financing of research and experimental work in building with bilateral research agreements signed with European partners whose programs and goals provide interesting opportunities for interaction. In Venice, furthermore, the relevant memorandum of agreement was signed and the working groups reviewed topics of common interest, developed programs and exchanged the first partial results of their respective research activities.

CONSTRUCTION TECHNOLOGY TRANSFER: ISSUES AND OPTIONS

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Present situation

This paper summarises key findings in an aspect of a research study on construction technology development undertaken for a United Nations agency. Its main theme is that the study of the transfer of construction technology, which is often undertaken in isolation, can benefit from the work on technology transfer in general. The inadequacy of the level of construction technology development in the developing countries is evident in: the massive unmet construction needs; failure to use the countries' natural human and material resource endowments; and reliance on foreign sources for a large part of construction needs (materials, professional consultancy and contracting). This leads to high foreign exchange costs which contributes to high cost of construction with implications for affordability to the poor and pressure on national budgets. It also hinders the expansion of the construction industry, and hence the construction industry, and so on. The transfer of construction technologies from the industrialised to the developing countries has been of topical interest for decades. The increasing globalisation of construction further highlights the issue.

The low level of technology development is not unique to construction. By any indicator -- number of persons engaged in research and development (R&D), level of aggregate R&D expenditure, volume of exports of manufactured items, share of high-technology services, number of international patents owned and so on -- studies show that there are great disparities between the industrialised countries and the developing nations (UNIDO, 1980). The technological systems in most developing countries are characterised by *dualism*. A small modern enclave (normally associated with technological progress which conscious attempts are being made to improve) exists within (and operates independently of) a traditional, rural setting (containing know-how accumulated over centuries, which has been undervalued and underdeveloped) (UNIDO, 1980). This dualism is, in itself, perhaps, inevitable and not necessarily bad, as sectors of the economy (and different geographical areas) of any nation would develop at dissimilar rates, probably following different patterns. However, the lack of linkage between the "modern" sector and the "traditional" one, and neglect of the latter are undesirable. Generally, the developing countries are technologically dependent on the industrialised ones; they import the elements of technical knowledge and the capacity to use it. This dependence hinders efforts by the former to develop suitable technologies (Stewart, 1977).

The technological weakness of the developing countries is attributable to (Choi, 1983; UNIDO, 1980; UNCTAD, 1990): (a) low level of accumulation of technology; (b) limited capacity to import technologies -- owing to a weak foreign-exchange earning capacity and inability to attract foreign investment; (c) tendency to adopt import-intensive models of industrialisation making industry unable to stimulate the development of local technologies; (d) failure to consider science and technology as integral parts of national development plans, and to adopt, implement and monitor relevant policies; (e) insufficient investment in science and technology owing to economic limitations and a relatively undeveloped private sector; (f) inability to select and manage suitable technologies owing to shortage of technology personnel -- due to inadequate educational and training facilities, insufficient attention to the orientation of educational traditions and curricula to technology; (g) insufficient institutional infrastructure -- non-existent, inadequate or poorly co-ordinated government agencies for promoting and/or supporting private sector initiatives, weak or non-existent R&D institutions, poor linkages between them and industry, and inadequate dissemination and application of their results; (h) inadequate physical infrastructure and information necessary for investments in technology; (i) social structures and culture not supportive of technology (for example, absence of "social carriers" or "champions" of technology development); and (j) lack of mechanisms to facilitate the transfer of technologies.

Nature and sources

Technology may be transferred (in many different formal and informal, direct and indirect ways) from one part of an organisation to another, between enterprises in the same sector of the economy, between enterprises in different sectors, from a research centre to industry, and from one country to another. This paper concentrates on that at the nation-to-nation level. In its most common usage, *technology transfer* refers to the formal and direct forms whereby an agreement is signed between a buyer and a seller. Governments everywhere (and especially in the developing countries) have sought to control, guide and encourage technology transfer through various means: (a) training components are made mandatory in joint-venture agreements between a foreign and local partner(s), in the terms of engagement of foreign companies for construction projects or in agreements for direct investment by a manufacturing enterprise; (b) guidelines for licensing agreements are formulated and administered which prohibit the transfer of certain technologies, outline prices or pricing mechanisms, or suggest terms of contract; and (c) support is provided for technical information and extension services to facilitate the diffusion of technologies.

Technology transfer among firms in the industrialised countries is generally a two-way commercial process which has taken place for a long time, and was used to close the "technological gap" between the United States and Europe in the sixties. Another successful example of technology transfer is that from the industrialised to the newly-industrialising countries. These successes have led critics of the process to blame it for the loss of economic pre-eminence by the United States, and to the competition being offered by the newly-industrialising economies to the industrialised countries in many areas. They have also inspired some writers consider technology transfer to be a short-cut to development for the emergent countries: it could stimulate exports, enable the country to substitute for imports, or generally improve the country's economic efficiency (Emmanual, 1982). While underlining the importance of technology transfer, other writers have stressed the need for the technologies transferred to be appropriate. Despite these high hopes, technology transfer to the developing countries has been generally unsuccessful. Therefore, it has become a politically-sensitive aspect of the dialogue between the industrialised and developing countries. The latter call for the transfer of more appropriate technology under more favourable terms, and set up mechanisms to ensure these (Oldham, 1987). Technology transfer is characterised by differences in economic, financial and technological bargaining power between buyers and sellers; restrictions on technologies by sellers; attempts by governments in the buying countries to monitor and control such transfers; and suspicion and dissatisfaction among buyers, which among other things, led to the formulation of several handbooks and an international code of conduct.

Construction technology transfer arrangements cover different forms of technologies, ranging from those relating to particular techniques, systems, materials or tools to the complete design or construction (or both) of projects. This paper concentrates on the transfer of techniques to contracting firms. Such transfers do not always involve "modern" or advanced technologies (which have been given emphasis), but may be concerned with *appropriate technologies*: some foreign commercial firms specialise in such areas as labour-based road construction, technologies for infrastructure, alternative energy systems, and the production of appropriate materials. Construction technology transfer arrangements can take many different forms including: (1) setting up of a subsidiary in the host country; (2) joint ventures which may involve various degrees of integration of the partners' firms and operations; (3) supply of plant and equipment, sometimes incorporating an agreement to provide training, spares parts and/or technical services; (4) supply of plant and equipment with the *disembodied technology*, an approach widely adopted in the appropriate technology field by both non-governmental and commercial organisations; (5) counterpart training ("liaison engineering") abroad on formal courses and/or at the foreign firms' head office or its projects in other countries and on-the-job training on the project concerned; (6) "downstream" training of operators or beneficiaries of the completed facility; and (7) government-to-government arrangements involving a range of technical assistance projects under a medium- or long-term programme. Others include (a) transfer through delivery of industrial property, approval of licenses, provision of information, training, and technical advice, and assistance in project development; (b) international contract (or sponsored) R&D; (c) agreement on technological co-operation between enterprises; (d) purchase of technical services; and (e) reference to literature, participation in conferences, education overseas and co-operative R&D arrangements (Choi, 1983).

The joint venture appears to be the most widely preferred vehicle of technology transfer in construction. The World Bank favours the formation of joint ventures, although it likes these to be voluntary arrangements rather than the mandatory ones which some countries tend to specify as a condition to the award of major contracts. There are several problems relating to joint ventures including: difficulty of effecting and monitoring the transfer process; finding a local partner able to benefit from the joint venture; and matching the foreign partner's commitment to technology transfer with its technical ability and suitability for the project (Andrews, 1984; Chow, 1985). In a cross-cultural situation, where the partners would have different technical practices and styles of operation, the potential for conflict is considerable. However, some foreign firms use technology transfer as a marketing tool, and have used it to break into, and stay in, particular markets.

Trends and problems

Through government-to-government agreements, the developing countries received "aid" from the industrialised ones (mainly for projects in the manufacturing sector) for pre-investment feasibility studies and market surveys; selection of suitable technologies for manufacturing; design of production facilities; construction of buildings and installation of plant; production management; and marketing. However, several criticisms were, and are, levelled against this form of technology transfer: the technologies are often restricted to particular sectors, techniques or aspects, and are seldom up-to-date, are transferred on unfavourable terms (including, for example, prohibition of the export of the goods produced), and are often inappropriate to the host countries (being capital-intensive, import-dependent, high-energy-consuming and polluting); licensing fees also tend to be high. The technologies tend to lead to the decay of indigenous and traditional technologies (Stewart, 1977; Sharif, 1983). Over the past few years, technology transfer through direct foreign aid has increased in importance. Studies by UNCTAD (1990) show that despite policy changes and liberalisation of investment-control regimes in many developing countries, foreign direct investment in these countries actually diminished during the eighties. Thus, some writers brand technology transfer as a myth, and consider the international firms as using access to key technologies and innovative capacities as instruments of domination. Technology transfer had increased international inequalities, as the transnational corporations were selective in their choice of countries where they would invest, partners with whom they would co-operate or firms (and countries) to whom they would sell technologies (Ernst, 1983).

Construction technology transfer has been supported by public and private sector clients, and lending agencies. There appears to be more resistance to technology transfer in construction than in other sectors (Abbott, 1985). The transfer of construction technology faces hindrances including: (a) unwillingness of foreign firms to nurture potential competitors in a declining world market; (b) tendency of technology transfer to add a time and cost element (and managerial complexity) to the already difficult and risky business of contracting; (c) the usual lack of understanding (among foreign enterprises, local beneficiaries and clients) of what is to be transferred; (d) suspicion of the recipient and the client about the usefulness of what is being transferred; and (e) ineffectiveness of previous transfer, as the trained personnel seldom utilise what they learn (Abbott, 1985; Uko, 1987).

Technology transfer remains shrouded, not only in controversy and emotion, but also in considerable confusion, owing to the complexity of "technology" itself and the multiplicity of channels of its "transfer". Moreover, there is little relevant and accurate data to aid the measurement of the effectiveness of technology transfer which continues to be imprecise (Erdilek and Rapoport, 1985). A main difficulty lies in determining what to evaluate, since technology transfer has two main dimensions: that from the seller to the buyer, and that relating to the effective diffusion and application of the technology.

The way forward

Technology transfer is multi-faceted, diversified and dynamic (De Cubas, 1974; UNCTAD, 1990). Its success is determined, to a large extent, by the ability of the buyer to absorb, adapt, apply and integrate it into its existing technological, social and other systems, and eventually to further improve upon it. Technology transfer should be planned and continually monitored, based on a country-specific policy which recognises the practical limitations in the possibility and effectiveness of transfer. The supplier and the recipient(s) should also be carefully selected. The former should be committed to technology transfer, and the latter should be able to benefit from the transfer. Technologies should be appropriate, and should be considered in a complete sense (both the *hardware and software* of the technology, and related managerial skills), with special regard to their potential for supporting and promoting technological self-reliance (Oldham, 1987). Technology transfer should complement, not substitute for, R&D activities in the particular country. Additional principles for effective technology transfer include: selecting technologies to be imported by correlating national needs with available resources; applying imported technologies only after adapting them to fit local surroundings; and undertaking all repair, imitation and improvements in introduced technology with local trained personnel (Sharif, 1983). The know-how should be packaged with due regard to the background of the target group. Both suppliers and purchasers benefit from technology transfer and need to make some investment in it. The prerequisites for successful technology transfer include: realisation of the nature of the task and a sound policy infrastructure with effective communication channels. Due attention should be paid to the genuine concerns of the transferor: exposure to risk, possible loss of competitive edge over transferee(s), transfer of a property developed at a cost, difficulties concerning the peculiarities of transferees, and political pressures both at home and in the host countries.

Construction technology transfer should be planned and co-ordinated by a central government body such as a unit in the ministry responsible for construction. Policies on the transfer of construction technology should be harmonised and integrated with overall construction-industry policies as well as macro-level policies, and be constantly monitored for possible revision. They should incorporate utilisation of the transferred technologies, and their dissemination, adaptation, integration with existing ones, and further improvement. The experience of other countries and sectors, and the many published guidelines on technology transfer would be useful. Various technologies would require different considerations as to the most suitable source, effective transfer mechanism, form of agreement, administrative system and support services. However, a balanced and integrated approach to technology transfer should be sought: the technologies to be transferred should be prioritised broadly according to national needs, the ease of transfer and diffusion, and the potential of the technology to contribute to national technological self-reliance. Policies which impose conditions in areas normally governed by voluntary commercial relationships (such as joint ventures) should be carefully considered (as to their potential benefits, possible negative influences, and difficulties which might be encountered in their implementation). For example, selecting a partner suitable for a particular project is governed by factors which are different from those relating to the choice of a long-term collaborator. Training arrangements should be monitored to ensure their effectiveness: candidates should be chosen on the basis of their potential to benefit from the expertise to be transferred, and should be provided with opportunities to use and disseminate their acquired skills. There is a limit to what policies can achieve: much will depend on the motivation and commitment of the beneficiaries of the transfer and their ability to make the most out of the opportunities offered.

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Co-operative Research in the Wider European Market

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The European Construction Institute is a co-operative research club formed by major clients, contractors and consultants operating in the European construction market. The features of the European Construction Institute that distinguishes it from others are:

(i) that it is a co-operative research effort by both major clients of European construction and their contractors and consultants. It is not confined to one sector; and

(ii) it also operates across national boundaries and represents a European perspective rather than a national perspective.

Jointly the clients and contractors can make significantly more progress on issues such as quality management, safety, productivity and contractual relations than they can separately. The European dimension allows this group of influential clients and contractors to make some impact on the harmonisation process of the emerging European Single Market.

The European Construction Institute was conceived by a group of major construction clients, their contractors and consultants. These companies, which rank among the World's largest in their field of operation, perceived the need in a market as large as Europe for a research institute dedicated to improving the performance of the construction industry. As a result ECI was launched in 1990 and now has a membership of over 50 major companies based in Belgium, **France, Holland, Italy and the UK**. The stated mission of ECI is: "to maintain continuing improvement in construction performance". Performance is interpreted widely as to include efficiency, productivity, safety and excellence in general.

A final feature of ECI is its involvement of universities and individual academics. ECI chose as its administrative headquarters Loughborough University of Technology and works closely with Loughborough's Department of Civil Engineering. ECI also works with other European universities such as UMIST in the UK and the University of Aachen in Germany.

ECI - MEMBERSHIP

Membership of ECI comprises clients of the construction industry, their contractors and their consultants. Members are drawn from the process plant, building and civil engineering sectors of the industry.

Membership is open to any organisation in Europe with an interest in the efficiency of the construction industry.

ECI - ORGANISATION

The *Board of Advisors* is the main controlling body with a representative from each subscribing organisation.

The *Executive Committee* comprises elected members representing the membership, and an elected chairman is responsible for the policy formulation and the overall management of the Institute.

Reporting to the Executive Committee are three management committees:

Programme	responsible for developing ECI's programme of activities

External Relations	responsible for developing ECI's relationship with other bodies and countries
Membership and Administration	responsible for the day-to-day administration of ECI

ECI - ACTIVITIES

The activities of ECI are:

- to provide an international forum in which senior personnel can meet and exchange views;
- to undertake, commission and supervise specific research projects on subjects that will improve the efficiency of the industry;
- to communicate the results of these projects and information from other sources on technology and management systems to members;
- to assist in the implementation of newly-devised management techniques and procedures; and
- to collaborate with other countries.

FORUMS AND CONFERENCES

ECI has held a number of meetings and the Board of Advisors meets to discuss such varied topics as: European Community directives, part-time and temporary work and working time; Alternative Dispute Resolution; Innovation in Safety Management; Total Quality Management; Comparison of Statistical Estimating Data; and Client Management and its Role in the Limitation of Contentious Claims.

Two major conferences have been held as part of a series entitled: 'Construction in Europe'. The first was in Amsterdam, Holland, in April 1991, the second in Wiesbaden, Germany, in November 1991. These conferences have addressed issues derived from European Community directives and project issues. The concept of the conferences, as well as acting as a major meeting point for very senior executives, is to identify and record the 'best of the best' practice in the management of major projects.

RESEARCH

The identification and control of research and investigation is through 'Roundtables' and 'Task Forces'. Both are formed from enthusiastic and expert personnel from member companies. These groups are augmented by academic staff.

Roundtables are given a broad non-specific brief and are required to define the work required. They act as a discussion group delineating problem areas.

Task Forces, although similar in form to Roundtables, have a more specific brief, are controlled by the Programme Committee and are expected to produce a report of their work for the membership.

The Roundtables and Taskforces existing as at September 1991 were:

Roundtables
- Exchange of Statistical Estimating Data
- Productivity
- European Legislation

Task Forces
- Market Analysis
- Labour Availability
- Client Management
- Health and Safety
- External Assessment
- Total Quality Management
- Information Technology

PUBLICATIONS

ECI's publications to date are:

CONFERENCES:
Construction in Europe. Papers presented to the conference, 25 April 1991, Amsterdam Apollo Hotel. *Publication: C001/1, July 1991.*

EVENING MEETINGS:

European Commission's draft Directives on part-time and temporary work and working time. Papers of an evening meeting, 3 December 1990. *Publication: EV1/1, January 1991.*

Alternative dispute resolution. Papers of an evening meeting, 11 March 1991. *Publication: EV2/1, March 1991.*

Innovation in safety management. Papers of an afternoon seminar held on 22 May 1991 at the offices of BP, Britannic House, London. *Publication: EV3/1, expected July 1991.*

LAUNCH

Presentations made to the public meeting held on 2 February 1990 at Queen Elizabeth Conference Centre. *Publication: PM001, February 1991.*

NEWSLETTER

ECI News. *Dec 1990 onwards.* Quarterly

ROUNDTABLES

Roundtable No 1, 24 October 1990. Comparison of statistical estimating data. A report on the discussion and papers presented. *Publication: RT1/1, January 1991.*

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Client Management Task Force TF003. Client management and its role in the limitation of contentious claims. *Publication: TF003/1, expected July 1991.*

External Assessment Task Force TF004. Directory of research and other organisations: current research activities, May 1991 issue. *Publication: TF004/1, June 1991.*

Total Quality Management Task Force TF006. Total quality management. *Publication: TF006/1, expected July 1991.*

ECI'S ACHIEVEMENTS

ECI's main achievement is that in a short time it has established a co-operative working environment involving the major clients, contractors, consultants and academics. The framework for co-operative research is proving to be valuable in building a strong world-class European construction capability.

The challenges that the European Construction Institute faces are: the creation of the Single European Market and the attendant harmonisation process; the emergence of Eastern European countries and their needs for re-development and the drive for continual growth in efficiency to remain competitive in a global market place.

DECISION MAKING IN LARGE COMPUTER-BASED MANAGEMENT SYSTEMS

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1. BACKGROUND

The past decade has seen an enormous growth in the availability and use of computer-aided systems in the management functions of contruction organisations. These systems, in the main, mirror the manual practices which they have replaced and as such have not always utilised the full potential offered by the computer. This is particularly true for computer-aided estimating systems. They have been established to varying degrees in many of the larger construction companies. In recent years the emphasis has been on providing improved user interfaces and database management facilities. The more advanced systems provide links between the estimating system and project management modules such as planning, valuations, cost control and cash flow. The common feature of these systems is that they still rely on the estimator to physically select resources whose detials are held in a library. Little or no decision making or 'decision suggesting' is allowed to be undertaken by the system.

One recent development which offers significant benefits to management information systems is the advent of knowledge-based systems. These can be viewed as intelligent computer programs that use knowledge and inferencing procedures to solve problems that require significant human expertise for their solution. The knowledge necessary to perform at such a level, plus the inference procedures used can be thought of as a model of the expertise of the best practitioners in the field. However, many knowledge-based systems have either remained prototypes or have addressed relatively trivial applications. It is currently foreseen that knowledge-based systems can effectively operate at two levels:

(i) as stand alone systems, providing expert knowledge or advice to the user; and
(ii) as part of larger systems where the knowledge-based module provides information to the larger system.

In this second application the knowledge-based system is used to partially replace the input from the user and thereby improve the overall efficiency of data use.

This paper will describe a knowledge based system which is designed to feed a conventional computer - aided estimating system for a contracting orgaisation. Drainage cost estimating is used as an example. The paper will illustrate how knowledge-based systems can significantly reduce the burdens on the user, thereby rendering larger systems easier to use.

2 THE DRAINAGE ESTIMATING KNOWLEDGE-BASE

2.1 The Problem

A great amount of effort and knowledge is required in producing a drainage cost estimate. The reasons include: the large number of different pipe types available; the presence of various excavation depths; a high variability in trench widths; and the choice of different beddings and surround materials available. The contract specification usually gives the pipe and bedding combinations permitted within the contract. The estimator then has to select the cheapest combination based upon the quotations received for the pipes and bedding materials, and the method of construction. The estimator uses his knowledge of pipe types, minimum allowable trench widths, relevant specifications of excavating machines, trench support types, labour, plant, and material resources in producing an estimate.

2.2 The System

The knowledge-based drainage estimating system (DRAINEST) described herein, was developed to relieve the estimator of some of the decision making involved in drainage estimating. The system was developed on an IBM PC using the LEONARDO expert system shell [1] and the dBASE IV database management system [2]. The later system was used to store the specifications of different type of pipes, trench support systems, excavating machines, and plant, labour and materials costs. The expert system shell was used to handle rules which contain the knowledge that estimators use when estimating the cost of drainage work, rules that detect patterns in the database for information retrieval, and rules that allow quantity and cost computations to be performed.

A consultation begins with the user responding to a set of preliminary questions posed by the system. These questions concern the details of the drainage contract. The questions relate to pipe run numbers or bill item references, the pipe type, the strength class, the pipe bore, the pipe length, the average, and maximum depths of trench. The system then allows the estimator to choose either a trench box system or traditional sheeting, waling, and strutting support, depending on the ground conditions and the availability of materials. The knowledge-base uses the depth of trench and type of support selected to retrieve the appropriate size and the associated properties of the support system from a database. These properties are used in computing the duration of the trench support activity, checking the lifting requirements, and subsequently for costs computations.

The system then performs the selection of the minimum and maximum allowable trench widths, the recommendation and selection of a suitable excavator, and the computation of the quantity of excavation and duration of the excavation activity. The pipe bore for each run of pipe is used to automatically select the minimum and maximum trench widths by means of simple rules representing the recommendations of the Department of Transport [3]. The job specifications and the computed control parameters are used to check the suitability of all excavators represented within the knowledge-base. The minimum and maximum trench widths determine the bucket width required. The maximum trench depth determines the digging depth of the excavator required. The lifting capacity of the selected excavator should be greater than the maximum pipe weight in the contract and that of the selected trench support system. The properties of the selected excavator are retrieved from a database. The volume and duration of excavation are computed and displayed for each pipe run.

The system performs an automatic selection of the type and size of both labour and plant crews or gangs required for each pipe run. The type and size of gang depends on the type of pipe, the bore of the pipe, and the depth at which the pipe is to be laid. In practice different resource combinations are assembled to make gangs. These were elicited, given unique identifications, and the associated attributes were stored within a database. Rules were then developed to automatically set the gang codes or identifications during a consultation, and use these to retrieve the attributes (including costs) from the database. The quantities of the individual bedding and backfill materials, and surplus excavation for disposal are computed. The unit costs of the bedding materials are retrieved from a database and the costs of bedding materials are computed. Finally, a summary of the overal costs is computated. The summary is given under cost headings including materials, labour, and plant for individual activities and for the complete drainage work. A more detailed description of the system can be found in reference 4.

3. CONCLUSIONS

The system described in this paper has demonstrated the potential of applying knowledge-based systems techniques to facilitate decision making in estimating. The system has been particularly successfull in relieving estimators of decisions involved in the selection of resources to suit particular work conditions. Full and partial automation in decision making have been demonstrated. The selection of excavators and trench support systems have been implemented as partial automated decision processes. This is highly desirable since the final selection of a particular resource in these categories is a matter of availability and personal preference. The selection of labour and plant crews has been implemented as an automatic decision making process as the type and size of crew depends on definitive factors including the type of pipe, the bore of the pipe, and the depth at which the pipe is to be laid.

DRAINEST was designed to run along side a conventional computer-aided estimating system for a contracting organisation. In its present implementation it can run as a stand alone decision tool, providing advice to the user. Future work will concentrate on the development of links with the conventional estimating system. Other knowledge-bases for different types of work will also be developed.

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Impact of Innovative Technology upon the Construction Industry

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Buildings combine a very wide range of technologies. On the one hand computer based technology and robots can be employed, but there is a wide spectrum of trades which require craftsmanship and basic manual labour. Traditionally building has been viewed as a low technology industry, but this view obscures the complexity of tasks being performed and ignores the dramatic changes that have taken place during the last few decades. High technology industries tend to be characterised by manufacturing processes that use technology intensive capital equipment, such as computers and robots. The difficulty is that few processes in the site based activities in the building industry can be subjected to such simplifications for organisation and control. However, a building is the product of many inputs from consultants, contractors and manufacturers throughout the design, construction and operative stages of producing and occupying a building. Gann (1991) believes the two main reasons why Japanese contractors enjoy a much more powerful role in development of technologies than their counterparts in the rest of the world are firstly because contractors have not remained passive while firms from electronics and telecommunications sectors have introduced new technologies. There are many examples where construction corporations have diversified from their traditional roles as general contractors to move up market and become developers and engineering constructors. This could only be done, however, by proving their technological expertise to potential clients. Secondly, large construction corporations in Japan collaborate with large electronic companies in order to develop information network system infrastructures for buildings and to establish network engineering methods, taking into account building use (Kennaway 1991).

Employment of technology in buildings should not be an end in itself, but is only justified if it can help in meeting the rising expectations of clients and the demands by occupants for a better quality human environment, as well as improved building performance overall. Technology can also help to make buildings more flexible and adaptable for users.

Construction is often characterised by the limits of time, money and manpower. There is, however, the need to recognise that the relationship between design, installation and construction, commissioning, maintenance and appraisal in use is essential if buildings are to respond to the needs of people and investment is not to be wasted. Innovative technology recognises that the management of the process, the manufacture of the components, the assembling of the components and the maintenance of buildings are key activities which are all equally important.

Technological innovation needs to be seen as a spectrum across history. It is important that engineers and architects appreciate the ingenuity with which man has adapted buildings to climate throughout the world over several millennia. Buildings need to be designed to have a very low energy consumption, not only because of the finite nonrenewable fossil fuel reserves on the earth, but also because fossil fuel burning contributes to about fifty percent of the greenhouse effect. Throughout history there are many innovative passive design solutions which produce high quality environments with low energy expenditure. Today we need to meet the technical, social and economic demands of our society by using technology to blend with the lessons from history and so produce a high quality product which is durable over time. Technology offers an opportunity for buildings to become more dynamic. The fluid nature of buildings is naturally defined by the flows of people, information, light and air within and across the building envelope. Transmission of information represents knowledge highways throughout the building, and the spacing of people can be varied to give different distances for private as well as social communication.

Much of the recent research on sick buildings shows that fresh air, natural light, some degree of personal control, a sense of aesthetics and some link with the outside world are the main concerns of most people working and living in buildings. The balance of man-made things and those of nature should allow spiritual values to be felt; buildings can be emotive and sensual too because their interiors and finishes awaken our senses of touch, vision and hearing.

In planning buildings it is essential to bear in mind the social changes which are continually taking place. Technology has been viewed at various stages in civilisation as leading to future progress but it must also give the opportunity for individuals to explore and not usurp their creativity. It must also help in solving health and environmental issues which have become a major responsibility for the construction industry today. In planning technological innovation there is a need to use wider avenues of information than in the past covering technical, social and economic issues. For example, the International Research Institute on Social Change (Nelson 1989) carries out annual surveys in twelve European countries, North America, Brazil, Argentina and Japan about social development. Socio-cultural mapping helps to understand how peoples priorities and needs are changing.

Probably the greatest avenues of technological change will continue to occur in material science; information technology with the evolution of the biochip; superconductivity switching devices; optical information transfer systems and the development of measurement sensors which will enable many of the invisible aspects of environmental controls, such as radiant and convective heat transfer, to be measured and visualized more easily.

With the evolution of lightweight materials, surface coatings and selective layers for glass, materials which change their properties as the environment alters, photochromic glass, holographic glass walls, a family of dynamic building adaptive envelopes is being created. These horizons are providing an exciting future for the construction industry. The dynamic structures will mean that there will be a much greater integration between building services and the building fabric. It can also be expected there will be a much greater modernization of components as one off designing specific for use is replaced by flexible servicing with short life plug-in components which can be frequently replaced. Ultimately, with the provision of adaptive envelopes conventional heating, ventilation and airconditioning apparatus should disappear as multi-layered building envelopes incorporate data and environmental sensitive devices.

Communication systems now use attribute addressing where each controller is given attributes which may be confined to a particular floor or a part of the floor in a large building; the controller will handle the data from all of the environmental variables. Sophisticated information systems mean that cabling throughout a building is becoming much more complex, so cable management like access, fire safety and maintenance has to be considered at the early stages in the design process.

The use of fibre optics is causing a revolution in lighting and expanding communication systems markets. With their low attenuation signals can be transmitted over several kilometres with very low error rates; there is very little cross-talk and no electrical interference so that the cables can be installed alongside power lines. Currently, data transmission rates are in the order of ten megabytes per second, but it is already envisaged that rates of one hundred megabytes per second will be feasible in the not too distant future; laser driven fibres can achieve one thousand megabytes per second.

Universal cabling systems bring another dimension into building by which data and voice signal transmission become analogous to fluid flow in ventilation and heating systems. The band-width possibilities of fibre optics means that video conferencing, drawing graphics and other communications will be accommodated easily in a fully comprehensive fibre optic transmission system. The light pipe is another exciting advancement which means that sunlight or daylight can be channelled into virtually any area of a building.

It is envisaged that most superstructures will become component assemblies. Cast insitu concrete is still a versatile material and will be developed to compete in terms of cost and speed of erection with structural steel and precast concrete. Traditional craft skills may well be largely replaced by skills in fixing techniques. Increasingly mechanisation will alleviate on site skills shortages by most of the work being done in factories capable of responding economically to the variability of demand for building.

The scope for participation by the client in the design process is already a reality. With the aid of large visual displays, which may occupy whole walls in designers offices, clients will be able to play with alternative strategies and study different layouts of rooms for their new buildings and see realistic representations of its appearance and environmental quality using information technology techniques. Having made a choice they will be able to be advised almost immediately about the performance, cost and completion date of the selected design. Client requirements in the form of outline designs, building performance, standards, costs and times are likely then to be transmitted electronically from the local computer aided design system, which may be anywhere in the world, to the production office of a multinational construction company, which in turn can make the detailed production plan.

Innovative technology requires the ability to plan for the short, medium and long term future. Croome (1991) describes evidence concerning short termism. Investment in British research requires a return which is almost three times that of an equivalent Japanese programme. The average required rates of return over the period 1977 - 88 showed payoffs of 7.6% for Japan, 14.3% for Germany, 15.6% for USA but a surprising 24.8% for the UK. Requirements for high rates of return on capital preclude many investment opportunities and stifle growth. Dividend yields of 3.5 - 5% in the UK and the USA compare with a world average of about 2.5%. There seems to be a fundamental conflict between the short-term perceptions of financial institutions in the UK and the USA and the need for society as a whole to design and plan for posterity. Long term vision is not restricted in Japan and most of Western Europe as it is in the UK.

For too long the words building construction engineering and architecture have moved uncomfortably together and yet distinctions between aesthetics, form and function are arbitrary to say the least. Human thought and life need the stimulus of proactive and reactive forces to give them creative movement. Innovative technology can be used not only to achieve technical and economic performance, but also to contribution towards the sensitivity and the emotional effects of the built environment, besides meeting social needs.

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LE PASSAGE DE LA RECHERCHE A LA PRATIQUE: UN PROBLEME DE COMMUNICATION

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Une recherche non diffusée est nulle pour la communauté scientifique. En effet, comme l'ont mentionné Corsten et Junginger-Dittel[1], " La recherche et le développement ne se suffisent pas à eux-mêmes, et sont économiquement vides de sens si on les détache de toute optique de rentabilisation efficace des résultats".

Une recherche récente effectuée par Auxirbât[2], grâce à une subvention du Plan Construction du Ministère de l'équipement, du logement, de l'aménagement du territoire et de l'espace, porte précisément sur le problème de l'utilisation des résultats de la recherche par les professionnels de la construction.

L'objectif de cette étude était d'investiguer si les résultats de la recherche étaient efficacement diffusés, retrouvés puis utilisés. Dans ce but, nous avons cherché à identifier, puis à explorer les voies de communication entre le chercheur et le praticien. Nous avons donc fait une étude de la littérature sur le sujet puis nous avons retenu vingt-et-un cas spécifiques, portant une attention particulière sur la diffusion, le stockage et le repérage de l'information. Finalement, nous avons pris en considération les pratiques et les souhaits des architectes et des ingénieurs.

L'étude de la littérature

La recherche bibliographique a prouvé qu'il y a assez peu de littérature sur le transfert de la théorie à la pratique dans le domaine de la construction. Cependant, le peu de littérature identifié fait ressortir qu'il existe un problème réel. Selon la littérature, il y une sorte de scission fondamentale entre la production des connaissances par les scientifiques et l'utilisation de ces connaissances par les praticiens. Les deux communautés ne se connaissent pas, ne parlent pas le même langage, et par conséquent, ne communiquent pas entre elles. D'un côté il y a la communauté des scientifiques qui publient pour être reconnus par leurs pairs et pour être promus, d'un autre côté il a y les praticiens qui, dans une situation d'urgence, veulent avoir des informations spécifiques à un moment précis afin de prendre rapidement des décisions efficaces.

Les recommandations concernant l'utilisation des résultats de la recherche dans la pratique sont très claires. Il faudrait:

- encourager une collaboration entre les chercheurs qui font la recherche et les représentants des utilisateurs éventuels qui pourraient faire part de leurs besoins;
- choisir des modes de communication et l'emploi d'un langage qui tiennent compte très explicitement (a) des façons de penser des destinatiares envisagés et (b) des différents rôles que ceux-ci doivent assumer au cours d'un projet de construction;
- élargir le choix des voies et des moyens de communication;
- exploiter les communications de personne à personne, en s'assurant que les informations provenant de la recherche atteignent rapidement les acteurs-clés de la communication informelle.

Les études de cas

Notre recherche, très orientée vers la pratique, visait à receueillir des informations provenant de l'expérience vécue. Nous avons donc fait une étude de vingt-et-un projets de recherche, d'une part auprès de chercheurs concernés afin de savoir où et comment l'information devait être divulguée, et d'autre part auprès de praticiens pour savoir s'ils avaient trouvé les informations dont ils avaient besoin et, dans l'affirmative, de quelle façon. Nous avons également examiné les systèmes de stockage et de repérage de l'information, de même que les banques de références.

Plus spécifiquement, nous avons étudié la diffusion des résultats de la recherche par son auteur, par son institut, par des tiers, par l'intermédiaire des normes et par la présence de ces résultats dans les centres de documentation et les banques de données. Par ailleurs, nous avons interrogé plus de deux mille personnes sur l'utilisation des résultats des recherches à l'étude. Sur les 6000 questionnaires que nous avons envoyés, les 800 qui nous ont été retournés, nous ont permis de faire une analyse systématique afin de découvrir si les moyens employés pour faire connaître la recherche avaient été efficaces dans la pratique. Enfin, cette étude de cas nous a permis de tirer un certain nombre de conclusions.

L'examen des résultats de cette enquête révèle que la diffusion par les auteurs est plutôt négative. Quatre sur vingt-et-un des auteurs interrogés ne s'en préoccupaient absolument pas. Par ailleurs, aucun d'entre eux ne cherchait à savoir si les résultats de sa recherche étaient présents ou absents dans les systèmes de stockage de l'information. En fait, la majorité des auteurs divulguent leurs résultats dans des livres ou des périodiques scientifiques; malheureusement, ces livres et ces périodiques scientifiques ne sont pas toujours lus par les praticiens. Sept chercheurs sur vingt-et-un participaient à ce qu'on peut appeler un "collège invisible".

En ce qui concerne la diffusion de l'information par l'organisme des chercheurs, nos résultats indiquent que 40% de ces organismes diffusent l'information activement, 45% plus ou moins activement et 15% pratiquement pas. La diffusion de la recherche par des tiers est un moyen relativement efficace. Elle reflète à la fois le dynamisme de l'auteur et/ou de son institut et l'intérêt qu'un éditeur lui a apporté. Sur les vingt-et-un cas à l'étude, seuls les résultats de trois recherches ont été bien diffusés et ceux de cinq autres plus ou moins efficacement. Quant à la diffusion normative, nous avons noté que quatre recherches sur les vingt-et-en cas étudés, ont abouti à une norme ou ont influencé la définition d'une norme. Cette forme de diffusion est intéressante parce qu'elle intègre indubitablement les résultats de la recherche dans la pratique, sans toutefois en donner l'explication scientifique.

La diffusion des documents primaires se fait surtout par l'intermédiaire de collèges invisibles constitués par des spécialistes qui véhiculent la documentation grise. La diffusion secondaire, par les cours et par les livres, est plutôt limitée et par conséquent décevante. Ce sont les colloques qui constituent la source d'information secondaire la plus souvent citée.

Dans les systèmes de stockage de l'information, nous avons trouvé assez peu de documents "gris", ces documents éphémères qui donnent immédiatement les résultats de la recherche et qui, du fait de cette rapidité, sont extrêmement utiles. Le repérage de l'information dans les banques s'est avéré très difficile pour diverses raisons, entre autres:

- la diffuculté du choix des mots-clés; en effet, le choix des mots-clés dépend du jugement de l'indexeur et pose le problème de la normalisation de la terminologie;

- l'incapacité d'indiquer le nom de l'auteur comme mot-clé, à moins qu'on connaisse déjà l'auteur.

Comme nous l'avons déjà mentionné, sur les six mille questionnaires envoyés, nous avons reçu environ huit cents réponses. Ces questionnaires avaient été envoyés à des praticiens qui oeuvraient dans le domaine de chaque type de recherche, autrement dit, à des spécialistes (architectes, ingénieurs, conseillers, etc.) qui, en principe, devaient connaître la recherche. 76% des répondants ont clairement dit qu'ils n'avaient jamais entendu parler de la recherche ni même des résultats obtenus. Parmi les 14% des personnes qui ont affirmé avoir connaissance de la recherche, les pourcentages par catégorie sont les suivants:

- 4.6% pour les architectes,
- 12% pour les ingénieurs,
- 13% pour les fabricants,
- 0% pour les constructeurs de maisons et les services techniques des mairies,
- 16% pour les experts-conseils,
- 46% pour les laboratoires d'essais, et
- seulement 11% des professeurs.

Enfin le nombre de répondants qui avaient utilisé les résultats des recherches sélectionnées est encore plus bas (entre 2 et 3%).

Dans cette situation, nous avons aussi investigué quels sont les pratiques et les souhaits des praticiens en matière d'information scientifique.

Une enquête parallèle auprès de 650 architectes et ingénieurs a permis de recueillir 80 réponses dont

48 provenant d'architectes et 32 d'ingénieurs. Les résultats révèlent que:

- 6 architectes sur 48 et 8 ingénieurs sur 32 consultent les bases de données;

- en ce qui concerne la consultation par télématique ou Minitel, 13 architectes sur 48 et 8 ingénieurs sur 32 ont utilisé ces ressources;

- de plus, selon notre enquête, les architectes ne possèderaient qu'une dizaine de livres techniques dans leurs bureaux, et les ingénieurs, une vingtaine;

- enfin, 17 architectes sur 48, mais la majorité des ingénieurs interrogés, font des stages pour acquérir des informations provenant de la recherche;

- en dernier recours, les praticiens vont consulter les bibliothèques. Mais là, qu'est ce qu'ils souhaitent? Une réponse rapide et immédiatement applicable!

Recommandations

Les recommandations de cette enquête concernent:

- la diffusion à la source,
- le stockage de l'information et la publication,
- le repérage et l'utilisation de l'information.

Pour faciliter la diffusion à la source, nous avons proposé qu'un plan de divulgation soit inclus dans le plan de recherche et soit pris en considération lors de l'octroi de la subvention. En second lieu, la diffusion de la recherche devrait être conçue de différentes façons et en des termes appropriés, selon les destinataires. Troisièmement, la diffusion des résultats, grâce aux relations interpersonnelles qui est efficace, devrait être renforcée. Dans ce but, les chercheurs devraient développer leurs collèges invisibles qui incluer aient non seulement leurs pairs mais aussi un grand nombre de praticiens concernés.

Quant au stockage de l'information et à la publication, il faut souligner que les publications à grand tirage devraient réserver une place plus importante à la divulgation de la recherche. En conséquence, les centres de documentation devraient être plus à l'affût des rapports de recherche signalés de cette façon. Dans un même order d'idées, les bases de données devraient mettre au point des procédures plus conviviales afin de permettre un repérage plus rapide des résultats de la recherche. De plus, les centres de documentation et les banques de données devraient s'engager dans le mesure du possible à répondre à des questions et ne plus se limiter à la fourniture de références ou de documents.

Enfin, pour rendre le repérage et l'utilisation de l'information plus efficace, les praticiens devraient être incités à se servir des résultats de la recherche, par exemple, en incluant les frais encourus pour la recherche documentaire dans l'échelle des honoraires. Par ailleurs, les praticiens devraient aussi être encouragés à participer aux collèges invisibles formés par les chercheurs.

Comme le mentionnait Umberto Eco récemment:

"Une bibliographie de vingt titres est fort utile puisque vous en retenez finalement trois ouvrages que vous lirez. Mais que faire d'une bibliographie de 10 000 titres obtenue en appuyant sur le bouton d'un computer? La jeter au panier! ... Tout le problème est d'arriver à filtrer cette sur-information, et de le faire dans l'instant, car nous n'avons plus, pour opérer ce filtrage, le temps de réflexion dont nous disposions auparavant".[3]

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THE INTEGRATION OF INFORMATION TECHNOLOGIES IN BUILDINGS: A COMPARISON BETWEEN ITALY AND JAPAN

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Introduction

This work represents a first step of a bilateral research project established between two Institutes working in the building field: CNR-ICITE (Italy) and BRI (Japan).
The object of this project is a comparison between Italian and Japanese experiences concerning integration of information technologies (IT) in building. The purpose of the cooperation is to find out exchanging elements in the different context in which the two countries carry out their own research activities. A first consideration might constitute the preliminary remarks for the development of the research: Japan is a leader country in the world as concerns IT; Italy has reached a good level of knowledge in creating well designed human environment in several functional typologies. By this fact, the aim of the research is to join these characteristic advantages of each country in order to define new methods of architectural planning and building equipment system, that are suited for introducing IT in building.
The bilateral cooperation is based, in particular, on two main issues:
-the information exchange between IT in buildings, with examples of built structures and knowledge of the technological tools now up-to-date in the two countries;
-the study, setting-up and implementation of a methodology which, utilizing advanced computer applications, allows to improve the management of a large number of specific facilities with high level integration of IT and the design of new ones.
As a case study for testing the methodology offices and research facilities will be considered at first. By means of this methodology it will be possible:
-to create a detailed and continually up-dated picture of existing facilities, based upon significant parameters concerning the buildings' lay-out, functions, equipment, etc.;
-to provide a substantial support to the designers of new facilities in the form of parameters derived from specific functional requirements and national building-related regulations.
The project implies the realization of a graphic-numerical data base containing information on existing facilities, selected and stored after specific standards; multiple data-bases concerning parameters of standardized units; functional and operative characteristics, building-related regulations, lay-outs of standardized units.

The final result is a user friendly system which allows to reach the fixed objective through the information (graphic, alphabetic, numerical) stored in the multiple data-bases and the appropriate hardware-software tools, and in particular:
-to provide a wide range of information on existing facilities;
-to verify the adequacy of facilities to old and new regulations;
-to provide the optimal in-puts to new facilities design (by means of an iterative process).
In order to respect the objectives we concentrate this study mostly on the aspects connected with the integration of IT.
Within the limits of IT the specific goals of the metadesign project are the following:
- Supporting the design of intelligent buildings
- Creating user friendly IT
- Managing system for specific users categories.

The state of the art in Intelligent Buildings

The analysis of existing facilities represents the starting point of this study and constitutes the basic operation for a first comparison

between the two countries.
Even though all around the world there are similar technologic pressures and the tendency to globalization are asserting themselves everywhere, there exists a precise evidence that shows how the buildings named 'intelligent' are built in completely different ways, depending on the different needs of the various economic market situations and different cultural traditions.
The concept of 'Intelligent Building' was originally coined in the United States. Now it is also called 'Smart Building'. The first building with the name of 'Intelligent Building' is the City Place which was completed in Novembre 1983 . Key concepts of this building were as follows:
1) Advanced communication system
2) Automated energy control and management
3) Service of equipment, office automation , telecommunication.
Since then, computer manufacturers, real estate agents, and other companies developed new building management systems and took part in the construction of intelligent building and shared tenant sevices industry. Now in the US it is commonly understood that newly developed large scale office buildings should have integrated information facilities and equipment.
The Japanese situation seems to be not very different from North America's. In the US, in fact, the office buildings are big towers, even though more pleasant and better built thanks to stronger conservative unions among builders, estate agents and finance companies.
The first big difference between US and Japan is to be found inside the building where the japanese internal design is sacrificed to the need of highest flexibility, assuming an almost casual aspect, with superficial and confused solutions that remind the western buildings of the 40s and 50s.
Japan gives particular importance to intelligent technologies, concentrating on the power of information rather than on real-estate economy.
In Canada, there are 9 telecommunication companies, and they established an association named Telecom Canada for managing items related to the whole country. The largest telecommunication Company is the Northern Telecom, whose PBX (Private Box Exchange) system has world wide share. It has strong technical tie-up relations whit AT&T and both are extending their lines into each other's service area.
Nevertheless, there are resistance against intelligent building from the economical point of view, just as was the case in USA. Integration of information technologies in building increase initial building cost, so that owners normally include wiring space without cables to cope with future utilization. According to this tendency, there are few built examples of full-fledged intelligent buildings in Canada. Shared tenant service was once prosperous, but shared PBX service has the weakness of data security, so that these kinds of service are now falling into disuse.
The interest shown by the Japanese in the intelligent part of the buildings is not in line with the typical spirit of emulation of the nation, but it is a real interest in inventing new building systems and components that arise the users' quality and productive output.
The Japanese approach to the intelligent building depends completely on technology. The problems of planning, completely overcome both in office spaces and in entire cities, are indissolubly linked to the CAD system.As regards office space, the most recent studies focus on environment comfort, and a recent work has shown how technology information development is leading to new problems linked to existing facilities already used in many offices (Iki et al, 1989).
The stress is on how the video terminals need particular lighting conditions, printers and keyboards need sound proofing, while the facilities affect the thermic equilibrium in conventional office-spaces. This kind of work could find a starting point in the latest strategic programs which, with high tendency inversion, point on the inside of the buildings and aim at improving the working environment quality in western standards, in the next years.
The Italian reality is in line with the European scene, which is completely different from the Japanese and North American experiences. What mainly differs in European intelligent buildings is in the planning conception, based on lower buildings, with horizontal rather than vertical development, in order to allow natural lighting and ventilation, high flexibility and emphasis on environment. The role of the real-estate agent is subordinated to the needs of the users except for Great Britain which follows the North American pattern. The logic of architectural design becomes similar to the interior design and is aimed at obtaining the highest level of comfort quality. The attainment of the main purposes, bound to the binomial needs-services, is seen in view of a high interdependence between hardware compo-

nents belonging to information, plant and building systems and 'immaterial' components belonging to the software (Mangano and Casciani, 1990).
Referring to a recent study by an expert in the sector within the Progetto Finalizzato Edilizia (a five-year research program of the National Research Council) we thought it would be interesting to report the meta-design approach to the intelligent building, generically destined to offices, explicative of the actual Italian experiences (Consorzio Tecnedin, 1990). In fact, the meta-design phase coincides with the individuation of a number of guide factors:

- humanization of internal spaces concerning the need of psycho-physic comfort for the users of the building in question;
- 'hidden' technology, in the sense of creating an environment as less as possible artificial and "complicate";
- external relations, concerning the interaction between user, building and environment, not only in using but also in perceptive and sensorial terms.
- information exchange on different levels, concerning the opportuness for the communicative interaction to take place according to different modalities.

The research methodology

A structured knowledge base of characteristics referring to existing facilities allows to improve the following implementations related to design new computer integrated buildings, by means of:

- organizing preliminary data collection in a structured reference frame;
- extracting and elaborating meaningful parameters.

The development of this project is based on the interaction of three main elements which play a fundamental role in the integration of IT in buildings:

- Information technologies requirements: electronic systems and equipments supporting building automation, office automation and telecommunication;
- Design requirements: requirements related to specific functional type and IT;
- User needs: the needs related to specific users categories in terms of functional, social and spatial requirements.

As concern the analysis, for the IT requirements, the three main components of an intelligent building have been considered: Building automation, Office automation and Telecommunication. (see Tab.1)
In order to organize information we underline two different kinds of specifications in every functional area and its control system:

- Equipment specification
- Specific design requirements

To extract appropriate design requirements, the information related to the context and the facility's functional type have been classified in the following categories:

- Site and environment
- Historical, social and cultural context
- Economic requirements
- Spatial and functional requirements
- Technological requirements
- Equipment requirements

The investigation fields to define the requirements imposed by the user needs must be related to the following exigencies:

- functional
- social
- physical and environmental

BUILDING AUTOMATION	OFFICE AUTOMATION	TELECOMMUNICATION
- Energy management	- Electric hall	- Communication costs
- HVAC System	- Word and data processing	- Tele-conference
- Lighting	- Internal communication	- LAN, VAN network
- Security control		
- Multi-building management		

Tab. 1: Functional areas subdivision.

Conclusions

The subsequent phase of this study provides the set-up of structured exigential schedules, by means of a detailed sub-classification related to:

- -functional area connected with IT requirements;
- -design requirements categories;
- -exigencies related to the user needs.

Referring to the last point, the aspects connected with human factors will be the object of particular attention, especially as concerns office facilities; in fact, they represent an actually unsolved and rising problem.
The classification of these data will be based on homogeneity and quantitative criteria, suited for subsequent computer elaboration. In fact, the creation of this schedule represents a first structured set of information to be stored in a design management system, which will be developed further and which constitutes the subsequent phase of this work.

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THE MANAGEMENT OF SMALL WORKS & MINOR MAINTENANCE PROJECTS

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1.0 Background

May 1991 saw the commencement of a major new research project aimed at investigating the management of small works and minor maintenance projects within major client bodies in the UK construction industry. The study is being undertaken by the Department of Building Engineering and Surveying at Heriot-Watt University, Edinburgh, in collaboration with British Telecommunications plc and is being supported by the UK's Department of the Environment (DOE) and the Science and Engineering Research Council (SERC) under the LINK Programme in Construction Maintenance and Refurbishment which seeks to promote collaborative research between academic institutions and the construction industry.

2.0 The need for the study

The procurement and management of small works and minor maintenance projects is widely acknowledged as being frought with difficulty for the inexperienced client. Such works are often given only a minor priority due to their size and nature although they account for millions of pounds of construction turnover in both the private and public sectors. Small works and minor maintenance are essential aspects of running any estate and as such there is a clear need for clients to better understand the inherent nature of this type of work. In this regard, the way in which the work is procured, managed and carried out, in order to maximise efficiency and cost effectiveness, is of paramount importance. There is also a need to fully understand the types of contractor who carry out the work in the subject area. The many problems surrounding small works require to be addressed, and especially the ways in which these works are actually carried out in practice, so that potentially better ways of securing their accomplishment might be proposed. The need to acquire accurate and reliable information concerning management processes and procedures within this field is vital in order that the main issues and problem areas might be identified and addressed. In this regard, the resources that certain large client bodies might be able to provide, by virtue of their expertise and experience in the research area, require to be tapped.

3.0 Research objectives

The research objectives of the project may be summarised as:

* To examine the current methods of procurement, management and execution of small works;
* To assess the effectiveness of the current approach; and
* To identify and define major problems and suggest possible solutions.

The work is not intended to be a comment on the operating procedures of any organisation. Instead, it is hoped that, by studying the alternative approaches currently employed, guidelines may be proposed which could help clients and contractors avoid any pitfalls, which undoubtedly exist, as well as serving to improve the existing limited research base in this field.

4.0 Characteristics of small building works

"Small works" is a term which, although often used, is one to which a definitive, all-encompassing description is difficult to apply; largely because works categorised under the label of small works, depending on the original source, may vary considerably in scale, value and complexity. It is possible, however, to identify certain distinctive characteristics which arise from these differences and this enables different classes of small works to be identified. It was therefore necessary at an early stage to clearly identify the distinctive categories of small works to which the general term "small works" can be applied and which shall form the focus of this study.

Three distinct categories of "small works" have been identified at this stage and each shall be examined in the course of the study.

* Small / minor building projects
* Ordered small works
* Jobbing works

The distinguishing features of these categories are listed below:

4.1 Small / minor building projects

* Standard defined form of contract
* Comprehensive control documentation
* Structured contract organisation & management approach
* Describes in detailed clauses the form of agreement between the client & contractor & deals fairly with the interests of both parties
* Applicable to small works of greater cost value & complexity than "Ordered small works"

4.2 Ordered small works

* Carried out under written agreement between client & contractor - often client's or contractor's own (not standard)
* Undertaken on individual basis procured by works order
* Alternatively, may be carried out under term contract (form of agreement more comprehensive in this case)
* Used where element of competition (tendering) in procurement preferred - may not always be competitive due to nature of the work
* Undertaken with reference to control documentation: drawings; specifications; schedules.
* Procured in formalised way using official written orders (works orders)
* Procured after request for quotation issued & after written quotation received (except where non-competitive procedure used)
* Procured from small general / specialist building contractor or small works division of larger contractor
* Limited value range - up to say £5,000; most £1,000 - £2,500
* Includes formal & structured management procedures that may be similar to other building work

4.3 Jobbing works

* No formal agreement between client & contractor
* Order placed without written quotation
* No guarantee for client
* Casual basis
* Work procured verbally, often over phone
* Low cost (normally)
* May be carried out by unskilled / semi-skilled labour
* Work often paid for in cash

4.4 Small building works contrasted with major works

Small building works can be said to differ from larger projects procured by traditional methods in several key areas in terms of their procurement and management. Due to their smaller size they are commonly not given the attention that they perhaps should warrant within many organisations and the departments charged with the management of these works are often viewed as the poor relation of major works departments. Generally, the less sophisticated procedures employed in small works procurement reflect the lower value and less complex nature of such works. Small works in the categories already outlined may range in value from apparently trivial amounts for very simple operations to more significant sums for works of a greater size and complexity. However, the total amount of small works expenditure to an organisation holding a large building stock represents a very significant amount and if even a relatively small percentage could be saved by employing more appropriate or more sophisticated management procedures this would potentially recoup sizeable amounts. For example, a low value item of work, which may be procured under an informal jobbing arrangement with a jobbing builder, may cost as much to administer as a much higher value job, in terms of the time spent in its management by the organisation's staff. Although more appropriate frameworks for procuring the work may exist it is common for the preferred method to be chosen more for reasons of simplicity than efficiency. It is hoped that this work may serve to promote good practice in the small works and minor maintenance sector of the construction industry through the dissemination of the research findings and the consequent improvements in the knowledge base in this area. This will help to ensure that any risks in the procurement of small works and minor maintenance projects will be minimised and the efficiency of their procurement is successfully managed.

5.0 Research methods

The primary source of information will be key individuals within the property management departments, or devolved property companies, of certain large organisations whose experience in the administration of large property asset holdings potentially provides a most valuable resource. The qualitative nature of the data collected by this means should give a feel for the practical realities of managing large building estate property maintenance and small works and enable the central problems inherent in this area to be identified. Observations and document analysis will be employed where possible to reinforce the validity of the findings of the interviews. One of the strengths of the research project is the association between Heriot-Watt University and British Telecommunications plc; the latter being an organisation having in the region of nine-and-a-half thousand individual building assets. It is not intended that the study will focus on the actual work of the collaborative organisation but will instead utilise the knowledge, experience and expertise of British Telecommunications in carrying out work in this area.

SESSIONS 5C & 5D
INFORMATION AND ITS COMMUNICATION

Questions and Discussion

Question

Ferrers Clark
National Research Council of Canada

It was a very useful quotation you made from Robert Duitco. He talked about filtration of information or decisions about which informations are passed on. Do you have any thoughts about how that might be done?

Colin Davidson

Yes. My other work that I have been doing in the area of information and the response to questions, leads me to believe that for a long time in the future, the human interface is necessary in an information centre service. The human, who would be a hybrid between a documentalist and a building practitioner, will be supported by systems such as the one that Jamie has just shown us and the many other sources of information that he or she will know about, but he or she will have the responsibility of firstly listening to the question, finding out what the problem is (and these two things are not the same), consulting the sources of information that he or she knows about and is supported by, and then finally translating back and filtering back. Filtering to the person who asked the question the bits of pertinent information that solve his problem.

I know we are in an era where it is fashionable to talk about information technology, minitel, and things of that sort. But research into automating what is called the reference librarian is at its very early stages and I see very little evidence that an automated reference librarian will replace the person I have just spoken about, for quite a while.

Speaker

Maybe I can add to that, just one more step, because it is my experience that their sources of information to the practitioner are often in conflict, so this information person who he references, will come up with two or three answers which don't necessarily match. Somewhere in the equation there is a person that helps the decision maker quantify the information he has received and come up with the specific answer that he needs.

Colin Davidson

The person that requires the information, can in no way replace the responsibility of the decision maker. The person that provides the information, I believe, has to quote the sources and he has to say, the information I've just relayed to you is an amalgam of information that I, in my better judgement, have obtained from source X, source Y and source Z, but you still have the responsibility of making the decision. But you cannot any longer say that you did not have at least some information, where possibly you had less beforehand.

Question
Paul Siega
University of Nairobi

My question relates mainly to the Singapore experience. What has been assumed here, or in the majority of the cases that have been presented here, we have been dealing mainly with communication and it is assumed that the information is available. From the context of many developing countries, the main problem is the availability of the information. In other words, what information is it that is required, for instance, for the construction industry, like for instance, productivity, quality control, standards and the rest of it. The major thing is, what is the information that is required if you are going to run an efficient construction industry? How is this information to be gathered and this makes me make reference to my colleague who gives a very simple way of getting that information being gathered. Then, of course, you are going to analyze it, store it and disseminate it. What it looks like here, it is assumed that information is readily available and therefore your problem is only how to disseminate it and how to get the specifiers to use it.

The other problem that pertains mainly to the developing countries is, for instance, within the professional firms, where are you supposed to get your own information? The manner in which they keep their information is such that it is not retrievable and therefore the information communication needs also to get the person who has that information, organize it in such a manner that it is retrievable.

Do you have any experience in the developing countries?

Anthony Thorpe

Yes, I think you are quite right. I was, in my presentation, making an assumption that the data is available. I guess that I am quite fortunate, coming from Singapore, a small country where very plentiful data and very plentiful information about the nature of construction, the size of the market, the levels of productivity, forecasts of the future, is very regularly and in a detailed way provided by many of the government authorities. I was trying to say in my description of Singapore, that it is a place that is very well governed and very small and I think that we don't have the problems of collecting information that many of our close neighbours in Southeast Asia, notably Indonesia, Philippines, Malaysia, etc., would have.

The situation that we faced is having plentiful information but what are we going to do with that? How are we going to use that to the benefit of the economy, and that is really why the focus in my research had been in the way that I presented it. You also went on to make a comment about some of the professional firms and them having data and it being relevant to national development. Again, that is very much a part of the plans that we have made in Singapore for some national level framework.

The situation before we had developed these plans was that a dangerous situation was developing, where many different institutions were developing their own solutions to problems, their own information systems, and a problem of islands of information forming which were quite impossible to breach. Really, that should not be the case, and it was the reason for us trying to set up such a national initiative, to try and bring together those different information sources that were otherwise developing.

I see planning frameworks being an important part of linking together information developments from a number of sources and at a national level in Singapore.

Colin Davidson

To try and deal with the last part of your question, none of the projects that we studied were destined particularly for developing countries and we have no specific information about the information transfer problem in or towards developing countries.

Having said that, I can only imagine that the problem is more complex than ever, because of the international aspect of what ought to be being done.

George Ofori

This morning we have seen how it is difficult to transfer research results; that was Mr. Davidson's speech. We have seen one of the examples of the United Europe Fever, this is ECI, but it exists in other networks in Europe like ENCI. It tells of the assumptions connected with the fact of how it could be competitive information technology also in the building process.

There are some attempts to solve the problem of excessive information; this is the real problem of our sector.

I would like to conclude with two observations. The first one is in advertising. There is a new Canadian issue, which is at your disposal on the speaker's table. The second one is that, if I am not mistaken, was a report which said if I exchange a dollar with another person, at the end of the day, each one will have just a dollar, but if we exchange an idea with another person, at the end of the day, two people will have two ideas. This is the sense of the transfer of knowledge.

SESSION 5E
On-Site Productivity and Efficiency
Productivité et efficacité sur le chantier

AN AUTOMATED CONSTRUCTION SYSTEM FOR HI-RISE BUILDINGS: AN EXAMPLE OF COMPUTER INTEGRATED CONSTRUCTION

Yasuyoshi Miyatake
Shimizu Corporation, Japan

I feel it a great pleasure to be given this opportunity to present our current technology developments in automated construction systems. I would like to begin my presentation by briefly describing computer integrated construction, that is, CIC. Application of innovative computer technologies to architecture, engineering, construction industry is viewed as a major factor to improve productivity and efficiency in these disciplines.

The recent improvement on computer technologies in such areas as computer-aided design, computer-aided engineering, database management systems, knowledge based systems, and automation and robotics have expanded the spectrum of potential applications. Remarkable progress in the application of computer technologies in the manufacturing industry have been made, through the development of computer integrated manufacturing systems, that is, CIM.

This technology, when adapted to construction, is known as computer integrated construction, CIC. It promises to allow the construction industry to reach higher levels of sophistication.

Let me introduce one approach to computer integrated construction and present current examples in Shimizu. Current approaches to develop CIC are generally classified into the following three aspects. The first approach to develop CIC is to integrate computer-aided design and computer-aided engineering systems for the improvement of design and engineering productivity. The second approach is to integrate planning and management systems, such as concurrent design and construction planning and real time monitoring of the project. The third approach is to integrate the building systems and construction systems, such as industrialized composite and automated systems and robotics.

CIC consists of these three systems by utilizing innovative computer technologies such as ARA, database, hypermedia, computer graphics and robotics. This scheme shows conceptual bill of CIC at Shimizu. CIC is realized by efficiently integrating these systems. Design and engineering system and planning and management system in the previous slide are integrated into one concurrent design and construction planning.

On the other hand, the construction system is divided into two separate systems. One is site automation systems and the other is the factory automation system. Common database plays an important role for exchanging design and construction information throughout these three systems. As management of logistic information really becomes more important, due to the discomposition of construction functions.
I would like to offer an example of CIC systems in Shimizu. Shimizu Corporation has been developing an automated high-rise building construction system. The system is called SMART Shimizu Manufacturing System with Advanced Robotics Technology. This system is being applied to a real office building construction project in Japan. SMART system is a part of Shimizu strategy for developing construction systems which integrate the high-rise construction process from the foundation to the site management, including structuring, finishing and installation work. By introducing a SMART system, the amount of labour required in the construction period is reduced significantly and the poor image of a construction site is dispelled. This one shows the Durok Bank Building in Navoya City in Japan. To reach a SMART system is really a pride.

I would like to briefly explain this building. The site area is about 2 000 m^2, the total floor area is 20 665 m^2, the standard floor area is 900 m^2, the height is 80 m with 20 stories and the main structure is steel. The construction period is 28 months, including 11.5 months of construction work by the SMART system.

In this project the SMART system automates a wide range of construction procedures, including the erection and welding of steel frames, replacement of previous concrete floor panels, exterior and interior wall panels and installation of various units. The system utilizes pre-fabricated components extensively, including columns, beams, floors and walls, and the assembling of these components is simplified by the use of specially designed joints.

The heart of the SMART system is composed of the lifting mechanisms and automatic conveying equipment, installed on the operating platform, which is ultimately to reach to the roof of the building. Steel frame columns, beams, floor and walls are automatically conveyed to designated locations, where they are effectively assembled and mounted with specially made joints.

Our steel frame process is also automated with the invention of an automatic welding machine. When one of the floors of a building is completed, the entire automated system is lifted vertically and the work for the next floor commences immediately. Thus construction work proceeds systematically, floor by floor, until the whole building is completed.

The SMART system also provides complete all weather enclosure for a site, accommodating satisfactory working conditions and safety, and leading to higher quality for the product.

Let me show the first application of SMART, especially the automated erection system, to construct one of our laboratory buildings. Through this experimental application we investigated the efficiency of automatic conveying and assembling system by computer control and we also evaluated availability of special joints of steel frames and lifting mechanisms of operating platform.

This slide shows the conveying and setting of steel columns. Both conveying and setting of steel columns were controlled by the computer, based on the operator's instructions. The entire process is displayed on the screen on real time. Control on the management of construction was conducted from the computer in this control centre. The design of steel column joints were developed so that assembly can take place without workers' help. Also beams, joints were developed to allow for automated fabrication. After the completion of installation of steel frames on one floor, the entire steel erection machine was lifted up smoothly to the next floor, using the step lock of the jack. This process is also controlled by the computer in the control centre and was displayed on the screen in real time.

The steel frame erection of floors in this building was repeated four times and was finally found to be completed, the entire erection process, in a four day cycle without any delay.

After examining data collected through experiments, we improved the lifting mechanisms to be applied without design constraints. We also developed automated building systems and automated transportation system of building elements and the materials based on the experiment.

This slide shows the automated building machine. This machine determines the building conditions using laser sensors and database in positioning of building equipment. This system allows only one worker to control and transport two or three machines. This automatic material transportation system is also introduced as a component of the SMART system. In contrast with automatic conveying systems, which mainly transfer building elements such as steel columns, beams and previous concrete panels, this system mainly transports materials and parts for fitting, decorations, which are not fully automated at present.

Several information systems have been developed and tested as sub-systems for SMART in a lot of ordinary construction projects. This slide shows a current architecture of information management system applied to SMART, which includes not only real time monitoring but management of design information, construction process information and logistic information, utilizing several kinds of media and network.

In addition, the sophisticated simulation and real time computer control orchestrates the whole assembling process, resulting in construction site operation in a highly automated way.

This slide shows a meeting board system which utilizes drawing boards as an input and display of computers. The meeting board system incorporates the production and the process information at site and improves efficiency of communication in site management. Thus, information management at the site is made efficient with the SMART system as well, thereby reducing the amount of waste and improving overall site management and scheduling.

I would like to summarize the efficiency and productivity of SMART system at the present. Through simulation using the data, corrected through the experiment on construction and applications of sub-systems, we plan to reduce 20%, both in productivity and construction period, in the Durok Bank project in Japan. With steel frame erection activities, we forecast labour reduction by 35% and time saving by 35% compared to ordinary tower/crane erection system, because in SMART we can utilize synthesized and simultaneous application of assembling systems and transportation systems. With steel column joint activities, we forecast 100% to 200% increase in labour productivity by introducing automated building machine.

With efficiency of SMART always a condition, it makes the construction process more stable. Prefabrication and automated construction system increase, reliability of quality and synthesized and simultaneous application robots, the machines improve their efficiency.

We plan to develop the SMART system even further, by developing more effective information management system for SMART, an automated construction system for underground. In the not-so-distant future, we plan to reduce labour and construction period to half of the present time.

In conclusion, I would like to say that the greatest impact of higher efficiency, the productivity and the safety in AEC industry will be brought by construction process innovation, that is, CIC. Shimizu is trying to establish CIC efficiently now. One of the key applications of CIC is the SMART system. The SMART system is to be applied to actual construction projects, defining its sub-systems and the functions to a real integration of computer and robotics.

Australia fails to take the initiative in ROBOTICS

Ian M. Eilenberg
Senior Lecturer - Construction Technology
RMIT - Dept. Building & Construction Eco.

1.BACKGROUND

The building industry has experienced large increases in its production costs over the past ten years. This is reflected in both labour and material as shown by the costs published in the Cordell Building Cost Guide for New Construction and the A.B.S. over this period as set out below.

Since the early 1980's the domestic building market has been going through a period of ever increasing demand for new houses. The result has not only been a large increase in house prices, but also long delays in getting projects finished, a lowering of the standard of work and a growing shortage of skilled labour.

Many tradesmen have established their own sub-contracting companies and have been able to negotiate very high figures for particular work. This has put the builder under greater pressure and has added to the lack of quality control and an increasing number of complaints against builders, by their clients, for shoddy workmanship.

The domestic building industry has now entered a period of down turn, as reflected in the preliminary December 1989 which show an approximate 10% reduction in the quarter of house commencements and nearly 100% less house starts compared with the same quarter 2 years ago.

The result will be even greater pressure on the builder to perform, with a growing competition to win work, thus reducing tender prices at a time when material prices and wages generally are still rising. The outcome will be a growing number of builders closing down, either voluntarily or from pressure from their creditors.

The use of robots on building construction sites may be one solution to the problem. Whilst no robot yet exists in the industry which will carry out a task totally on its own, there are many units being developed which will work via remote control - usually radio controlled or from the installation of laser control gear - such as concrete slab screeding robots.

2) LABOUR

Tradesman (costing rates)

	1981	1990	% change
Bricklayer	$11.60	$21.19	2.50%
Carpenter	$11.24	$21.19	8.25%
Painter	$11.23	$20.73	4.50%
Plasterer	$11.24	$21.19	8.74%
Plumber	$12.02	$21.98	8.70%

3)MATERIAL

3.1 Timber - F8 Hardwood - per meter

75 x 50 mm	$0.86	$1.20	40%
100 x 50 mm	$1.15	$2.20	92%
100 x 75 mm	$1.73	$3.30	91%

3.2 Bricks - per 1000

Pressed Reds			
Common	$181	$351	94%
Face	$210	$371	77%
Extruded-cream	$210	$368	75%

3.3 Mortar - average per 1000 bricks

$32.5	$49.92	55%

3.4 Concrete per M3.

20 MPa	$59.00	$ 94.50	60%
25 MPa	$62.00	$ 98.50	59%
30 MPa	$65.00	$103.50	59%

4. Cost per square meter for construction of a new house based on good quality, single storey brick veneer construction

$334.57	$652.1	895%

5. CPI This is in line with the consumer price index over the same period.

Index 1980 = 85.8
1988 = 164.7

increase = approx. 91.958%

6.Extensions By comparison the cost of extensions - ground floor extensions such as a brick veneer Granny flat style.

$495.76	$1,078.00	+120%

The cost of extensions has always been higher than new construction reflecting as it does the additional labour to make new work fit existing construction.

7. INCOME:

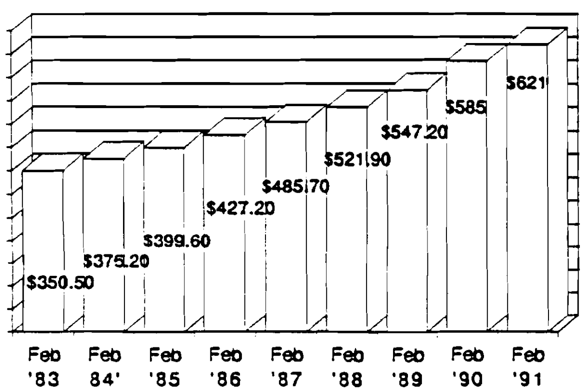
During that period the average weekly earnings were:

Year	Earnings	% Change
Feb. 1983	$350.50	
Feb. 1984	$376.20	+9.3%
Feb. 1985	$399.60	+9.4%
Feb. 1986	$427.20	+9.35%
Feb. 1987	$454.40	+9.4%
Feb. 1988	$485.70	+9.35%
Feb. 1989	$521.90	+9.3%
Feb. 1990	$585.00	+8.9%
Feb. 1991	$621.00	+9.42%

(at current prices adjusted to 1991 equivalents.)

The overall increase in this period is approximately 80%. In this respect the general earnings have kept pace with cost increases in building. This does not take into account the increases in interest rates and the general cost of money.

Average Weekly Male Wage



8. Housing Commencements:

One indicator of housing activity is reflected in the number of Council building approvals.

The figures for the same period and their values are:

Year	Nos	$ (millions)
1982 - 83		$ 4,063.2
1983 - 84	109,225	$ 5,013.9
1984 - 85	113,519	$ 5,665.2
1985 - 86	101,010	$ 5,552.4
1986 - 87	88,414	$ 4,808.4
1987 - 88	113,061	$ 5,316.4
1988 - 89	133,653	$10,218.2
10 months Jan-October only		
1988	108,211	$7,563.2
1989	97,044	$7,845.0

9. Safety.

In the past safety as been a dirty word in the construction industry. It was considered a dirty industry and as such employed 'rough' people who were not 'frightened to get dirty'. When compulsory safety helmets were introduced most building workers considered them 'sissy' and did everything possible to avoid wearing them.

Today the situation is very different. With the advent of the Health and Safety Act and the WorkCare system generally, safety is no longer a matter of chance. Considerable time and money is expended to improve workers conditions and the overall safety of the workplace.

The problem in the recent past has been the peculiar position of housing in the safety, and other, arenas. The housing industry has generally been a 'no-go' area for the unions. The unions have concentrated on the larger projects and left the building industry, largely because it is so diverse and has so many single, or at best two man, operators within its compass that the unions have not thought it worth their while to pursue this side of the industry.

Slowly this attitude is changing. In small areas such as toilets and general provision of a safer site, the unions are taking more interest in the domestic scene. However the requirements for shedding, safety officers and associated regulations are still to make much impact on the housing scene. Most building agreements between the employer bodies and the unions, still expressly exclude the housing industry.

10. Solutions

The growth of the automation in industry is well documented. This has spread from the manufacturing industries through to the building site. So great is this impact that the various people involved in the area got together to form

To quote Associate Professor Naruo Kano of the Waseda University in Tokyo;

"The robotization of building construction is expected to represent a breakthrough in terms of construction productivity, improvements in safety and quality and the speed-up of the work itself."

- Fourth International Symposium on Robotics and Artificial Intelligence in Building Construction.

The developments in the area of building construction include concrete placing and concrete finishing equipment, external painting and facade cleaning equipment, steel stud partition erection machinery as well as several units for use in hazardous circumstances. Remotely controlled demolition equipment was used on the Five Mile Island nuclear reactor to assist in cleaning up the contaminated material.

There have now been six symposium held on Robotics and Automation in the Construction industry. In addition there are now regular articles in the 'Australian' newspaper and various trade magazines providing information on current developments of robotics in the building industry. These however have been, in the main, aimed at the larger project.

With the rising costs as detailed earlier and the difficulty being encountered by people to purchase a house it was considered that the introduction of some form of robotic/automation onto the domestic site, may provide one solution to the lack of skilled labour. A robot does not come and go as does the trained apprentice. Thus money invested in the right equipment will continue to provide a steady income as long as its economic life is maintained.

11. THE SURVEY

A questionaire was prepared and sent out to 70 of the larger house builders in Melbourne and adjacent areas - Mornington Peninsular and Geelong. Of those, 24 replies were received (30% response) which was considered a high response rate for this type of questionaire.

Question 1 sought to discover the extent of knowledge of robotics in the building industry.

No one said they were very aware or had used robots.
30% said they had vaguely heard about robots in the industry and
70% said they had never heard of robots being used in the industry.

Question 2 asked those who had heard about robots in the industry,

30% had read about them in the HIA Journal,
15% had read about them in the MBAV Journal,
30% had read about them in trade journals and
25 had not actually read about them anywhere.

Only 2 respondents said they had ever used robots, 1 being in Joinery work and the other in drafting.

When asked if they had heard about robots being used in a range of specific tasks the responses were:

Joinery	17%
Window cleaning	8%
Excavation	4%
Bricklaying	12.5%
Painting	4%

This was an interesting answer as to the knowledge of the researchers, little, if anything has yet been done to robotize the bricklaying operations in Australia.

Question 5, asked if a respondent was informed that there was a robot available that could carry out a specific task, would they be:

Not at all interested	4%
Vaguely interested but not follow it up	8%
Obtain information only	33%
Interested with view to purchase	55%

This high level of positive response was then broken down to those who had, and those who had not, said that they had heard about robots.

Of those who had heard

42% would look to purchase,
42% would obtain information only
16% were not at all interested.

Of those who had not heard about robots before,

59% said they would look with a view to purchase,
29% said they would obtain information only
12% said they were vaguely interested

No-one in this group said that they were not interested at all.

Question 6 was aimed at obtaining a feeling for the possible union attitude to the use of robotics.

The response was 100 % that the unions would oppose the introduction of robots in any form onto the building site.

The main reasons given for NOT using robots on the building site were: (the respondents could list all or any of the items so the percentage is out of a possible 100% for each item)

Level of flexibility (One machine per task)	50%
Initial purchase price	50%
Maintenance costing	25%
Unions	25%
Cost of training operators	20%
Concern about losing skills	20%

The main reasons given FOR using robots were

Efficiency of the robot in time and man power 80%
Ability to overcome shortage of skilled labour 40%
Improved safety - lower WorkCare costs 20%

The final question related to the suitability of using Robots in the housing construction industry. This response was overwhelmingly against the use of robots.

Not suitable 75%
Suitable 25%

Of those who said that they had heard about the use of robots to some extent (30% of respondents) 60% did not believe that robots were suitable for use in housing construction.

12. SUMMARY

The overall findings of the research were in the negative and can be summarized:

1)Few people in domestic construction have heard about Robots
2)Of those who had, very few believe there is any place for Robots in the Housing construction arena,
3)Of those who had heard about Robots in construction, it was mainly in 'off-site' type operations - joinery especially
4)If Robots were introduced, the builders would meet opposition from the Unions.

If there were moves to introduce any form of robotics or automation into the 'on-site' operations of domestic construction, considerable education of both the builders and the unions would have to be undertaken.

CONSTRUCTION APPLICATIONS FOR REAL-TIME POSITIONING INTEGRATED WITH CAD

Yvan Béliveau
Spatial Positioning Systems, Inc., U.S.A.

The title of my talk is SPIDERS, which stands for site positioning with information delivery and recovery in real time systems, and we believe it will transform the construction site in productivity, quality, timeliness and safety.

This SPIDERS is the acronym for a consortium that has been set up. This consortium is set up with several industry participants, some funding partners and I served as the director of that consortium.

My presentation is going to look a little bit about background and motivation. It will talk a little bit about Spacy and its positioning system that it has developed, some potential applications, I will have a few conclusions and then I will talk a bit about the research projects that are being put together between CERF and us and a few other participants.

First off, the motivation of this technology. I started off as a carpenter many years ago and the idea of positioning forms, anchor bolts and imbeds into construction process is a very difficult task and I want to be able to do it better. That is really how this all started, also we want to be able to control equipment to install complex geometries. This should do some significant things; we should be able to eliminate batter boards, lines and staking. When you think about this thing, what I am going to talk about is the product or thing that we have developed, which positions in 3D space instantly and very accurately. We take this information, we integrate it with CAD; this will augment information delivery and also recovery from the site.

This will make obsolete the ancient systems of lines, plumb bobs, batter boards, as is currently used. The industry should help a lot with wind, which currently mess us up as well. With this system, we simple move about on a site and we can go to exactly where we want to be, sort of like a human cursor that moves in and about a 3D video game, which is full scale. That will give you an idea of what I am going to talk about.

This is a construction site in Michigan, a Bechtel project that I played with for a bit. It has millions of positioning requirements on that site; we hope to be able to reduce the current hours by at least tenfold in that operation. This little company that Harvey mentioned is called Spatial Positioning Systems, Inc. We are located at the Virginia Tech. Corporate Research Centre in Blacksburg, Virginia. It is the laser based technology which can measure those points in space instantly and accurately and there is no other technology that can do this.

This technology is not simply an evolution of current EDM's or range finders current technology. It is very revolutionary in the way it works.

What are the specs for this system? We set out with a platter of things we wanted it it do. We set out and we said we wanted real time and that meant many times per second and it had to provide X, Y, Z position at the same time. It just couldn't give us plainer information, we had to pick out unique points in space. We wanted to be able to eliminate the current crew that went out on a site, so we wanted a one person operation, we wanted accurate information. What I posted there is what we think a 50 by 50 m area will actually provide in a short term, with our next generation system a quarter of a millimetre, which is actually pretty accurate. It is also very accurate, when you think about real close sites like a 15 by 15 m site, down to about machine tolerances.

Our next generation system, which we hope to have out some time at the end of the year, will provide 5 mm for a 200 by 200 m area and less accurate as you get longer distances.

The other thing is that this system provides graphical information to user location, is actually a computer on board a pole, which is being carried about by a craftsman or a surveyor. Once you have positioned these laser lights, you have concurrent position determination, which means many people can use that same light, to determine where they are.

The system comprises transmitter units and these things look like big light bulbs and they scatter light about 3D space. A receiver unit has two optical pieces; that is so if you are really a bad surveyor, you can hold it crooked and it will still give you a position at the point. It will also give you a position if you hold it upside down or sideways, which is kind of important, because we want to model and be able to interpret what has been built and a lot of times pipes are overhead or to the side. There is a little computer on board and with that computer we can put and output that graphical information. Such a system will look something like this on a site, where you put these transmitters about the site, you have a set of control points which are pre-established, you back calculate the positions of those transmitters. From then on, any number of users can position and locate themselves. Not only that, we can control equipment as it goes about their business. The idea is, as long as you see any two of those transmitters you will be able to determine where you are.

You also can make a very small portable receiver, for when you are trying to model interior space. In fact, as we look at long term generation, this little portable receiver can be the size of a pencil. This is current technology, we have seen this, it takes several people and it requires tremendous skills by the users. Also the person over there has to know something about what the little plumb bob is doing or that little optical level.

We look at this current state of the art we have designed, which then filters information and provides something called plans and specifications. This is then converted to sketches and hand calculations, which is given out to site. We then typically do a control survey, which is then transferred to batter boards and grade stakes and lines and all those other things we talked about. Further sketches, lines, levels, transits and plumb bobs are used to position a unique point in space. Many of these unique points are required. We finally install a component, because it took us so much effort to get it there, we don't do much more. What we should have done is, we should have recorded how it was installed and where it was and since this information is typically not collected, it usually impedes further work.

As we look at the ability to take that CAD data directly on this pole, we should be able to interact directly with it. We start off with a design, generated by CAD and this does require that you have CAD as the system, at least for full implementation in use of such a system. There is a control survey, just as today, from there we move about and locate spots directly from our X, Y, Z location provided by CAD. We install the component, we have immediate as-built record of what we have done, we now have instant review of as-built to design. We can actually do things about downstream effects, about new pipes, additional pipes or additional components.

This is the prototype system as it currently exists. There is a couple of transmitters and there is a sensor, a little computer that we have built and sits on that pole, which currently is heavy. It is going to become significantly lighter. It will be somewhere around ten to twelve pounds when it is done. This is one optical piece, our next version will have two optical pieces.

What we have done is put this little circuit of pipes. We went about and collected a number of spots and from that we were able to immediately output where the location of that pipe is and its profile. This took about a minute to do, we collected about 25 points. We also wanted to show that you could run it on equipment, we had this high powered piece of equipment, called a wheel horse lawnmower, and we put the thing on it and we drove it around that same circuit and from that we were able to get many bits of information. Notice that it bounces somewhat, much more than the circuit that we did before. This is because we are collecting upwards of five times a second, which means a lot of additional information is going to be collected. Then we did the same thing by putting it on a wheel and we modelled it over a little burrow, down to the road and a little ditch and we collected a few thousand points and were able to output a direct surface profile. This is very useful in determining how much earth you just moved.

That's a quick look at what it has done. Now let's look at some potential applications as we see them. We want to look at craftspeople applications, equipment operation and control and then some real information, delivery and recovery and then you can think of what other things can be used with this kind of technology. We will look at CAD. This is a very big piece of information, it is very rough, but it can be brought down to anchor bolt level.

Usually you output a whole bunch of drawings, so that the craftsperson can go out and put a footing down. Well, they don't want to see this because there is just too much information, so what we would like to do is segment the data and to provide very simple user screens so that these people can install this information without having to deal with all of that data.

What you would like to do is where the red and where the little black spot is what we have selected as the point of interest, we then would move it until that upper scale, we could get the red out, sort of like the Visine commercial, which you might have heard. We are just going to move that and once the red is gone, it is at the correct spot and it will automatically scroll and scale downward, to more accurate scales until we finally get to the correct spot and we are, when it turns blue, in the correct location. Imagine how different that is from current operations of today.

We should be able to use it for equipment control. If we look at that, that's a craftsperson type of augmentation. There are many of those available, but equipment is a tremendous problem today. Here are piles of dirt, where grade stakes were installed and we have seen these on jobs, the reason is you have got to save those stakes because that is where we are supposed to grade to. It is actually real tough to figure out, when you are twenty feet down, it is hard to get that information, just to find out how deep it is. We could do away with this, it would eliminate that whole process. If we could have direct control on graders, we should be able to a sensor on both ends of the blade as this complex surface geometry is being installed; we might get it right the first time. The reason I used this one, is because it was done incorrectly the first time. In fact, it was somewhere around fifteen feet off at some points. Which is typically what happens.

Pavers, we have all seen pavers. It is really hard to make sure there is no ponding. People have automatic control on the screws on this, since we are getting X, Y, Z information, we could put multiple screws on a piece of equipment and control that grade very critically and accurately.

Pile driving, a lot of leaning piles here at the other end and some straight up and down piles. It is really kind of a real nasty bit of business to actually locate that pile driving rig and so if we had a little video screen on board in the cab, we put a couple of optical centres up and down the rig, we should be able to move right to it and also tilt it to have the correct angle of the pile, as we do our work, and again, we would scroll into it as we moved closer.

As we look now at a slightly different process, we look at integrated geometric modelling for construction manufacturing. We have a thing we want to build, a module. Right now it's a module of a ship and there is a segment of pipe that has to fit fairly critically within that ship. What we would like to do is build that component in CAD, we would like to put some control points, that we can model and measure some time in the future. We would like to fabricate it; as it is fabricated, we should be able to measure the surfaces to match what they are going to fit within the overall model, which means we can just scratch the outside surfaces and model that directly into CAD, especially the bolt holes, as they are going to match to other components. Deviations can be recorded and we should be able to put some kind of identification label. We bring it out to site and we would like to be able to, when we set it down, to find it some day, so we would like to be able to locate approximately where we set it down, so we don't loose parts out on a six hundred acre site. Once we have got it, we would like to put it into place. We get it out of lay down yard and put it into place and once it's in place, we can actually touch our prior set control points and we know exactly where it was installed. We now have an as-built control of what we just put. This would be very useful for large scale modules and for very small scale modules, some time in the future.

I will conclude a little bit about what this means for the construction industry and then I will talk a little bit about these research projects that CERF and us have been involved with.

In conclusion, what we have put together, and what we hope to implement in the construction industry, is enabling technology, which has many applications. We believe it establishes a revolutionary state of future in positioning and measurement. We believe it will change the way things are done, in construction and ship building, in manufacturing and also any applications where critical measurements are required.

This system has performance improvements for construction but also for many other technologies, certainly for robotics control. You should be able to put these sensors on end actuators and position them in space as they do their job and since we believe we will be able to achieve machine tolerances, that should be very useful in the robotics control area. The same thing with crane control, to avoid hitting objects. It will work underwater, as long as the water is not too turbid and it should be used in space docking, and space and lunar assemblies, also this instant geometric modelling I talked about, and maybe some active control of structures.

Wouldn't it be nice if everyone on this construction site knew where they were? If you installed it in the right spots you wouldn't have all the rework which currently exists on a construction site.

We may be able to change how we measure forward progress in this fantastic game of football. We wouldn't have to put those crazy ropes out there or chains, as they call them.

Let's talk a little about the research. We have several research projects, all of them are sort of pivoting around the consortium that has been put together and I will talk a little bit more about the participants of that consortium in a bit. We have put in an N.S. proposal, and that proposal is to look at the human factors in the industry acceptance of such technology and all of the issues of integration of CAD as they relate to this technology. The consortium is being put together to do a demonstration project to see how and to quantify what the real benefits of this system will be. The consortium will be heavily involved in R&D. It will be involved in a lot more than R&D of our own system. They would be looking at other systems, like microwaves, because the idea of a real time positioning and integration of CAD to be able to position objects in space instantly is such a tremendous advantage to the construction industry, that it requires a full consortium effort. From this we hope that CPAR will participate in this project. There has been a proposal put out that way again, under CERF. The consortium should lead the industry into the implementation of such technology, into achieving some of the benefits, that I hope you have realized from what I have discussed.

Consortium members, we have many people: CERF, SPACY, CII, the National Science Foundation, Bechtel, who is a major participant, Motorola, Amoco, Intergraph, Virginia Tech., which will doing significant work in the human factors area, and the University of Texas at Austin.

As we look at what this consortium is all about, the consortium is about putting together all the pieces that are required, not only the technology but also all of the human factors issues, the implementation issues and also the system integration that is required to make CAD actually useful. You can't just go out and take CAD and say I want to put a footing. There has got to be an interrelationship in a way to extract data without having to mess around with the designers, who are pretty happy with the way they design things already. We need to be able to enter and get into that data without messing with it and we need to be able to put it back, as we look at as-built data and how it works with that and there will be a significant amount of research required to make that happen.

As we look at the National Science Foundation proposal, we will analyze applications for today and look at what the construction industry of the future might look like if this kind of technology is available. We will look at data issues for integration, data structures, data presentation formats, data distribution formats and data gathering formats, as well as other human factors, the political, economic issues as well as some future implications.

Construction Robotics: the search for technological trajectories.

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Introduction

There is much current intellectual debate concerning the technical and other implications of the diffusion of programmable automation and robotics into site-based construction operations. This paper describes the epistemological basis of a research project which aims to contribute to that debate. The project is one of a number being undertaken within the Construction Robotics Research Unit at Bristol Polytechnic.

The Research Project

This particular project takes the Neo-Shumpeterian theoretical concept of technological paradigms and trajectories as a general model. It investigates the specific claims that the diffusion of programmable automation and robotics into site-based construction tasks will be limited by technical, economic, institutional and social factors unless new technological trajectories are developed. These trajectories will require shifts both in present robot performance and the manner in which buildings and civils works are designed and procured if an appropriate symbiosis of robot and construction technology is to be achieved.

Therefore, a vital component of the project is the provision of a rational and systematic method for establishing links between the construction community and the robotics community (and its robotic devices).

The methodology to be adopted involves developing conceptual models to represent conventionally organised and resourced site-based operations. The model of each operation is being analysed and its constituent work-tasks matched against a taxonomy of robot attributes, in order to identify the critical factors which facilitate or constitute complexity for automation and robotics.

One of the advantages associated with such an approach is that it takes into account the need to carefully select appropriate areas of construction activity for robotics research, bearing in mind the lack of commitment of resources to R and D by the construction industry. In addition, it also allows the more 'robust' aspects of existing construction technology to be retained so that any changes demanded by robotisation are compatible with product performance.

A further advantage is that the methodology accommodates the hierarchical structure of the construction industry and developments in robot control architecture. Early results indicate that it may be possible to establish the level, or point, at which the symbiosis of construction technology and robot performance can be considered. If symbiosis cannot occur, or lacks technological robustness, the construction models can be used to identify suitable enabling technological trajectories which can be developed through changes in the products and processes of construction and/or future developments in robot technology.

At this early stage in the project, recommendations for the diffusion of robotics into site-based activities are being made solely and expediently on the basis of technical feasibility. However, it is hoped that the results from the first part of the project can provide a basis for measuring the assertiveness of this particular form of microelectronics technology and establishing the extent to which it will demand changes in the present construction paradigm.

Technological Innovation

Successful technological innovation is one of the major forces in economic and social development throughout the world. However, at present there is limited understanding of the mechanisms through which these changes are effected.

Recent thinking about technological change has been strongly influenced by the theoretical work of Joseph Schumpeter who, as far back as 1912, recognised the importance of technological development and its subsequent economic significance through a process of diffusion. He also drew attention to the vital importance of the links between organisational, managerial, social and technical innovations.

The authors of the influential critique of economic theory, *Technical Change and Economic Theory (Dosi et al. 1987)* propose that technologies develop along relatively ordered paths shaped by the technical properties, the problem-solving heuristics and the cumulative expertise embodied in **technological paradigms**.

Each technological 'paradigm' entails a definition of the relevant problems that must be addressed, the user-demand requirements to be fulfilled, a pattern of inquiry, the material technology to be used, and the types of artifacts to be developed and improved. User-demand requirements are articulated in the socio-economic environment in which the technology is to be applied and will reflect a valuation by the market of a set of product or service characteristics.

The path enclosed by the upper and lower bounds of this range of user-demand characteristics is termed a **technological corridor** within which **technological trajectories** evolve. This socio-institutional framework will *".... always influence and sometimes retard processes of technical and structural change, co-ordination and dynamic adjustment." (Freeman et al. 1988).*

A technological trajectory *(eg. Nelson and Winter 1977 and Dosi 1982)* is then the activity of technological progress along the economic and technological trade-offs as defined by a paradigm.

It is only when productivity along the old technological trajectories shows persistent limits to growth and future profits are seriously threatened that the high risks and costs of adopting new technologies appear as clearly justified. It is the mismatch between what the technological regime provides and what the customer requires which provides the potential to influence the direction and rate of technological change.

Within such a framework the resultant technological and technical changes are not discrete but are grouped into *Nelson and Winter's concept of "**technological regimes** which dominate engineering and management decisions for decades."* Their analysis closely corresponds to the **techno-economic paradigm**, an idea first advanced by Carlota Perez (1983). Her concept is one of a 'meta-paradigm'- a dominant technological style whose 'common sense' and rules of thumb affect the whole economy.

The New Techno-economic Paradigm

In this context automation and robotics are part of the contemporary techno-economic

paradigm which Freeman has defined as:
"...*predominantly based upon cheap inputs of information derived from advances in micro-electronics and telecommunication technology.*" *(Freeman 1988).*

Robotic devices are in the earliest stages of development and like all new inventions their costs are high and their performance modest, especially in unstructured environments. Their future performance and pattern of diffusion is uncertain. Although robotic devices have been applied in the manufacturing sector for more than a decade their diffusion still fails to conform to a unique technological trajectory or distinct regime (Tidd 1991).

These findings challenge the Neo-schumpetarian model of a single, unique trajectory based on technical imperatives but support the concept of *"configurational technologies having no clear system level dynamic,"* as argued by *Fleck (1987)*. It may be, therefore, that the patterns of development and adoption of robotics will depend heavily on the context of use, with users determining the precise direction and rate of technological development and diffusion.

This then raises the question of the construction industry's receptiveness to technological innovation and its ability to successfully control and direct the adoption of programmable automation and robotics.

The Present Construction Paradigm

The diversity and complexity of the construction process implies a total production function incorporating different skills, materials, technologies and perspectives which suggests that construction does have many characteristics which probably make it unique among other economic activities.

Unique or Backward?

It has been suggested that it is this perceived uniqueness of the construction industry that contributes to its present deficiencies. A number of researchers have identified its shortcomings. For example, *"technologically stagnant" (Business Roundtable 1982), "fragmented" (Barrie and Poulson, 1978), and "negligible R and D" (National Economic Development Office, 1985).* It is perceived by its customers as being *"slow" and "costly" (NEDO, 1985 and Financial Times, 7 January 1981) and delivering "poor quality" (Which, July 1984 and the Financial Times, 9 September 1985).*

The lack of R and D in the industry has given rise, in part, to the charge that the industry is *"backward" (eg. Clarke 1985)*, and that its technological growth has been retarded. *Ball (1988)* suggests that *"the absolute physical constraint thesis"* may be responsible for this reluctance to embrace new technology. According to this thesis the technical advances associated with the manufacturing sector are impossible to achieve on construction sites because of the uniqueness of each building project and the production process. As a result, it is concluded that construction is doomed to technological stagnation.

This deep-rooted pessimism regarding the ability of the industry to make a fresh and dispassionate analysis and review of its products and practices casts doubts over its ability to accommodate robotisation. However, the industry's present deficiencies have resulted in a mismatch between its performance and its clients' expectations. This constitutes a growing potential for the development of alternative, competing production paradigms - even if this demands major shifts in construction products and practices.

Drewer (1990) draws our attention to such a possible shift in the present construction paradigm. At present, the industry distinguishes between 'product' technologies and 'production' technologies. He argues that, "*... these 'product' technologies, having been defined, limit and constrain the choice of 'production' technologies.*" Therefore, " *... the distinction between product and production technologies is fundamental to an understanding of the technology choice function.*"

Within the traditional construction procurement process the technology choice function is biased towards the design of the product and not the means of production and *Drewer (op. cit.)* goes on to predict that, "*The innovations in automation and robotics will effectively restructure the construction process and effect a shift in the centre of gravity of the choice function towards production*". This research aims to create a means of conveying information and evoking understanding between the construction and robotics communities in order to identify the extent of that shift, the nature of the resultant emerging production paradigm, and hence, the implications for the ultimate performance of the built environment, its procurement processes and the wider community.

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Cost-Time Forecasting for Housing Rehabilitation by Intelligent Simulation

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1.0 Introduction

This paper, when read together with the Conference Poster, gives a brief outline of a one year feasibility study which is nearing completion at the time of writing.

The objectives of the work and the theoretical structure of the computer system proposed are outlined by the Poster, and described in more detail by Marston (1991). This paper deals primarily with the working structure of the system under development, as this aspect is too involved to be adequately communicated by the Poster.

2.0 Background

The intelligent simulation approach which is at the core of this investigation, is essentially a hybrid of knowledge based systems and stochastic simulation. In this implementation, the key elements are: (1) use of a construction planning model as the basis of the simulation, (2) use of a knowledge based approach to provide automatic formulation of the model and (3) an attempt to emulate site management control action within the system. The first two areas have been the subject of extensive work in recent years; a brief review of the literature is given in Marston and Skitmore (1990). The work of Bennett and Ormerod (1984) on simulation, and Levitt and Kunz (1985) and Hendrickson et al (1987) on knowledge based approaches to construction planning, are particularly relevant.

3.0 Working structure

Fundamental to the working structure is an object oriented approach. In the pilot system this is implemented using the GoldWorks II development environment. A detailed description of how this approach has been implemented for the system can be found in Retik et al (1991). Some of the primary features of the development environment are outlined below.

The basic structural component is the *frame,* which is used to represent a class of objects. Many *instances* of a frame can be created to represent the individual members of a class. Frames have the power to inherit information and features from one another, facilitating the creation of related classes of objects and hierarchical structures. The information in a frame is held in *slots* and may take the form of values, labels, rules, references to other frames, or procedures. Slots have facets which define and add functionality to them. Messages are passed between frames by *handlers,* which are procedures attached to the frames.

There are significant advantages to object oriented representation in this application:

- it allows activities to be represented as objects and their precedencing to be achieved by rules and message passing, rather than the use of complex algorithms;
- through inheritance facilities, the repetition in multi-unit housing projects can be represented very efficiently;
- the ability to implement a procedure from within a frame provides an elegant mechanism to effect stochastic simulation;
- integration of heuristic knowledge for plan generation and simulation is straightforward.

3.1 Knowledge base structure

The basic structure is an hierarchical lattice of frames. Four class levels connect high level user input about the proposed works through to low level technical detail. Strategic decisions about the requirements and context of the proposed works are thus linked to resource consumption.

Level 1: the Project level carries information which is common to the whole project. In part this information is descriptive i.e. project name, project location etc., in part it provides data for calculation and decision making i.e.number of houses, house type, whether the properties are decanted or tenanted during the works etc. All information at this level is obtained interactively from the user through a window menu and is stored in an instance of the frame 'Project'.

Level 2: The Elements level consists of groups of activities i.e. major work sections such as plumbing operations, electrical renewal, internal finishes, internal joinery, etc. Ten Elements describe the full range of internal modernisation works. All of these are unlikely to be activated in a typical live project. Each Element frame contains a predefined menu, which helps to specify the kind of works to be done under this element. The information obtained from the user is stored mainly in the Element instances.

Level 3: The Activities level includes all works that are likely to occur within a particular Element - in effect a kind of library of activities (around 50 in total). Each frame includes default data to be used in the duration calculation during both the planning generation and simulation stages (criticality, order of activities, possible gang sizes, etc.). Creation of the instances for each activity will be automatic. The number of instances is usually equal to the number of houses in the project, giving an instance for each activity in each workplace.

Level 4: The Items level allows the connection of activities to their component resources. There are approximately 150 items and their slots contain the data necessary for duration calculation during the simulation stage (productivity ranges, quantity of work for different house types, etc.) as well as data necessary for cost calculation (material costs per unit, labour and trade costs, etc.)

3.2 Knowledge acquisition

The knowledge domain to be represented in the system (multi-unit housing internal modernisation works) covers three related areas:

1. Technology and resources. This is knowledge of the technical imperatives of the proposed work. It includes construction methods, operational precedence and resource requirements. The main sources used were technical publications, records of live projects and the expertise of contract planners and contract managers from construction companies. It was found that the operational sequence of the works is essentially dictated by the technological relationships between the activities; for example plastering can only start after the joiners', electricians' and plumbers' first fix have been completed while the respective second fixes can only commence as soon as plastering is completed. This is a sequence of work which cannot be altered whatever the context and extent of refurbishment. There are also some activities which will or will not take place depending on whether the housing units are tenanted or decanted, for example the provision of temporary services (temporary immersion heater and sink). Resource requirements were found to be determined by the extent of work required. It is the established wisdom that gangs of specific size and composition can carry out certain activities in a housing unit with satisfactory productivity (for example 1 joiner and 1 labourer for joinery work or 2 plasterers and 1 labourer for plastering). These gang sizes therefore become the basis for the estimation of the duration of the respective activities during the planning stage. Some duration values are well established, almost as standards, and are widely used.

2. Planning and organisation. This is knowledge about the planning and scheduling methods employed. Techniques are well established and documented, but it was necessary to elicit heuristic knowledge on both the choice of technique and its method of application to this type of project. The source was contract planners from construction companies with experience of housing modernisation work.

3. Site management. This is the knowledge necessary to represent the monitoring and control actions taken on site during the construction process. In particular, it is necessary to represent decisions that would be made on site as a result of deviations from planned progress. This knowledge is central to the process of intelligent simulation. The source was contract managers and planners. There was good consensus amongst them on the range of actions used in practice. More specifically, they all indicated that to increase productivity and therefore accelerate delayed activities, the preferred policy is to reallocate existing manpower or bring additional labour on site, rather than use bonus schemes or overtime work. Bonus schemes are not favoured because only the gangs involved in delayed activities will benefit, causing a discincentive to good performance while where overtime is used, productivity tends to reduce as workers try to increase its amount for the increased rates of pay.

4.0 System operation

As indicated in Fig 1 there are two main stages of system operation which are separated in the working structure: first the generation of a planned schedule and second the simulation of site production.

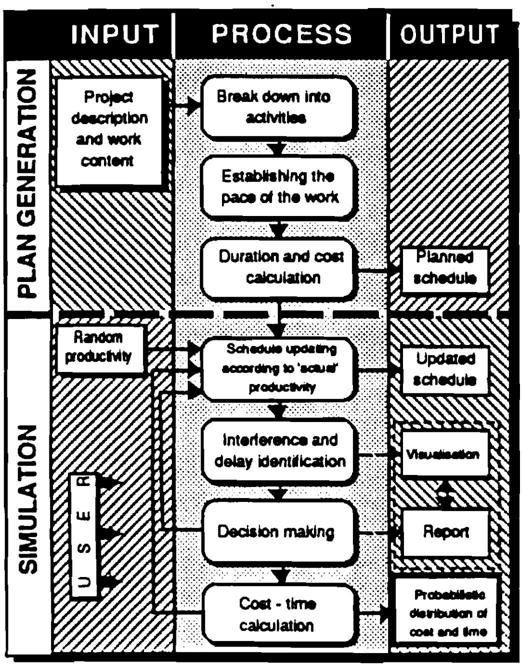

Figure 1 - System operation

4.1 Plan generation

An operational plan for the works is generated automatically according to the description of project requirements and constraints provided by the user, and the knowledge and data that are contained in the system. The aim is to formulate a realistic rather than optimal plan.

The project requirements and constraints are obtained interactively from the user at the first two levels (Project and Element). Establishment of the sequence and pace of the activities is based on elicited knowledge. Default values about both the sequence and pace are contained in slots in the third level (Activities) for the full range of modernisation works. In the planning stage, the same working pace is applied to all activities. The sequence values may be modified (if necessary) by a special set of rules and functions according to the context in which the work is undertaken.

The planned duration is calculated using the line of balance technique, which was found to be the universally preferred method in practice, because of the repetitive nature of the works.

The activities taken into account in the duration calculation are those which are critical. Default values about the criticality of the activities are contained in slots in the third level (Activities), and defined for the full range of modernisation works. These values may be modified by a special set of rules according to the work context. An example of a rule determining the criticality of an activity is given in Fig 2.

```
Rule name: CRITICALITY-R6
Rule text:
 IF
   (INSTANCE ?ELECT-SECOND-FIX IS ELECT-SECOND-FIX
             WITH TENANTS OUT)
 THEN
   (INSTANCE ?ELECT-SECOND-FIX IS ELECT-SECOND-FIX
             WITH CRITICAL Y)
```

Figure 2 - Criticality rule

The planned cost calculation uses data concerning trade and labour costs, material costs and specialist sub-contractors' costs. For the present feasibility study these data have been extracted from technical publications and records of live projects and have been defined as default slot values at the Activities and Items levels. For an operational system these values would be drawn from a linked database.

4.2 Simulation of site production

The site production process is simulated by assigning 'actual' start and finish times to each activity in turn, following the precedences in the plan. Activity durations are determined by random selection of productivity rates from probability distributions. 'Actual' starts are affected by 'actual' completions of preceding activities where buffers have been absorbed. Fig 3 gives an hypothetical illustration of this simulated 'actual' progress plotted against planned progress.

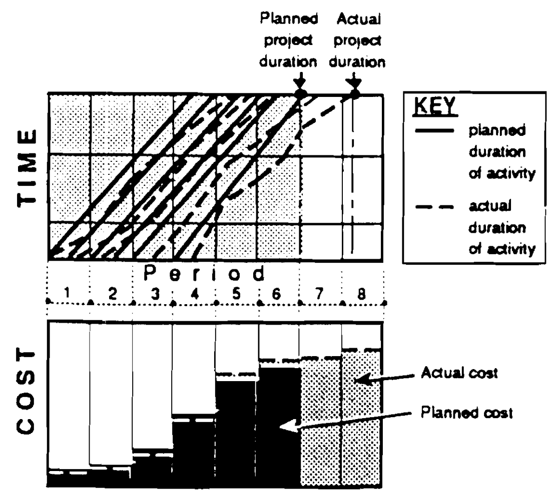

Figure 3 - Hypothetical plan and simulation

At intervals status checks compare actual with planned progress to detect delay and interferences. Messages passed from affected instances of activities trigger the application of rules. These rules seek to encapsulate site management expertise, and so a simulated management decision is implemented. The pilot system design includes trace reporting of simulated status and the control action taken, to allow user validation. The cost of the decision is calculated by attributing deterministic values to the resources consumed.

The production process is simulated repeatedly, using the same production plan each time. Cost and duration are recorded for each iteration, and the results plotted as probability distributions with supporting statistics. If the outcomes plotted are unsatisfactory to the user, the plan generation process can be repeated with amended inputs.

Although not implemented in the current pilot system, there are three desirable features that are feasible within the system structure as it has been developed: (1) the parameters of the probability distributions of productivity rates used should be a function of key context variables, for example season of the year and position on the learning curve for repetitive operations; (2) uncertainties other than variable productivity could usefully be represented, in particular, significant interferences with progress such as weather stoppages, late instructions, subcontractor default etc.; (3) variability in resource costs may be relevant, and can be incorporated by drawing cost data from representative probability distributions.

5.0 Conclusion

The simplified planning methods used in multi-unit housing rehabilitation render feasible semi-automated simulation of the kind described in this paper. It must be accepted that the planning model developed will be realistic rather than optimal and that the range of technical solutions considered must be limited for example, as in the pilot system, to projects involving straightforward modernisation of traditional housing stock. Without these constraints, the problem rapidly moves beyond manageable proportions.

An object oriented approach has proved to have great potential, allowing simple integrated structures to be developed.

Acknowledgements

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DEMONSTRATION OF CONSTRUCTION CAE BENEFITS IN THE FIELD

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The construction CAE CERF project, as Harvey mentioned, was a joint venture and the goal behind this, and I have some information reported here in 1976 from the American Association of Cost Engineers, that about 20% of the time on medium to large construction projects is spent with tools and materials, pick-up and traveling. Another 29% of labour time is spent in waiting for a variety of things. If we couple that with the fact that instructions are 8% of the time, we have well over 50% of the time on construction projects, on medium to large projects, that we think we should try to do something about, to manage more effectively.

In answer to the question, who is CERF, Harvey introduced him as a Civil Engineering Research Foundation, which was created by the American Society of Civil Engineers to establish a unified civil engineering effort and create industry and coordinated, directed research and development programs for construction technology.

In this case, Bechtel and CERF worked together to identify and define a project using a tool we have been working on in development within Bechtel for almost five years, that uses a 3D model and concentrates on advanced modelling, post modelling applications for planning and assisting construction work.

The tool itself, runs on an engineering workstation, Silicon Graphics, and is very menu driven. The tool itself is very directed toward visualizing the 3D model, incorporating the scheduling parameters and dependencies, providing a linkage between a component and a scheduled activity and, not shown in this screen, but a bill of materials or your materials list on the side.

CCAE works with planning and scheduling and we call it a planning tool, but it is much more than that. It's a material management tool; we are using it for modularization of construction and we are using it for 'what if' scenarios on construction; will things fit.

We are, in the case of this project, looking at installation planning, pipe spooling, coordinating with a sub-contractor for steel, and major equipment erection and development of the detailed construction plan in the field.

The Scrub-Grass project is a co-generation project, an 82 megawatt co-generation facility that consists of a steam turbine, coal fired boilers; it's called Scrub-Grass. It is located in the Scrub-Grass township, near Kenerdale, Pennsylvania. The plant is scheduled for operation in the summer of 1993 and, as we are talking, we are mid-stream through our implementation on this project and it is difficult to draw conclusions at this point, but I can tell you what we found up until now and actually we have probably pretty well concluded the first phase of this research.

The facility itself consists of the turbine building and the boiler building, and what we were looking at doing in tracking with construction CAE, was two or three things. The first, the erection of the steel was sub-contracted, and the sub-contractor was responsible for development of his own schedule and installation schedule, however, the boiler and major equipment that you see was not sub-contracted and that was part of Bechtel's engineering procurement in the construction scope of work.

One of the first things that we did was target the structural steel erection schedule and coordination of placement or construction of the boiler and major equipment. A second item was a vertical pipe chase in the building and we wanted to pre-fabricate as much of the pipe as we could and make sure we could still get it in, so we pre-fabricated that as well.

In dealing with the steel erection schedule, one of the first things that was done, is the schedule was imported into the system. This can be done through a batch interface or it can be built interactively in the system, either way. If you import a batch schedule, it appears much as you see here. What the planner has done, is under one of the operations, has popped up a scheduling window that will then allow him to create a new activity, name an activity, put constraint parameters, durations and place it in the schedule windows.

Similarly, the structural steel CAD model can be displayed in the window as you see. Here are two views, a perspective view on one side of the screen and on the other side, more of a plan view. Over in the menu prompt area, you see a bill of materials, so as I point to a graphical picture of a beam, it will highlight in the bill of materials list. Similarly, I can point to the bill of materials list and highlight on the screen.

The planners then have a series of built-in rule based and knowledge based tools that they can use for planning the sequence of erection, creating dependencies between different commodities or, in this case, between the subcontractor's work and our work.

Part of the result of that progress is a simulation, what we call a simulation playback or an animated playback. You play the schedule and it will show you your facility appearing piece by piece as the schedule bar comes across and you will see the model constructed on the screen in the lower part of the menu. The user has control of the speed, using a speed bar and if you index at zero in the middle you can actually play forward or backward for simulation replay. Over on the side is an indicator bar telling you what percentage complete, based on time of your simulation plan.

The results in the field from the steel boiler erection were that we didn't have any major interference problems, either identified from the schedules we imported or coordinated, and it went pretty smoothly. We did have work process conflicts, and I will talk a little bit more about that as we go into this, but we were running this implementation parallel to a very manual work process as a demonstration project and we learned that in the future we want to think real hard about that and coordinate it more carefully, because the automated approach required us to revise the work process and the manual approach didn't really allow it. We inflicted this one on ourselves.

One of the second things that the field planners and the field engineering complained about was the incomplete model at the start of the project. Kind of the evolution staging of this project worked in the manner that we defined and designed by commodities for the first two months of the design effort and these were delivered in stages so, as steel was complete, steel was delivered and as equipment was complete, equipment was delivered and as piping was complete, piping was delivered. It took at least two months of time before they had representations of all commodities engineering to date. In some cases that was not enough to do the planning and coordination they needed to do.

We started after that with weekly and bi-weekly updates to the model; we went to bi-weekly after they got most of the quantities in and were working on the detailed engineering and we had much better success once we got to that point, but it was very difficult working with an incomplete 3D model set.

The second major area of simulation and planning on the Scrub-Grass project was installation of the spooled and pre-fabricated pipe into the pipe chase in the boiler building.

Construction CAE has a knowledge based system built into it for spooling pipe. We have had a lot of misgivings in Bechtel about it being in Construction CAE and not the CAD system and in the case of Scrub-Grass it proved very difficult. We have two ways of spooling the pipe; one is using the knowledge, artificial intelligence information system and the other is to just go through and manually spool the pipe.

In the case of Scrub-Grass, because of the work process conflicts, we ended up having to manually spool the pipe. The reason for this, is there was an iterative loop in the engineering cycle, where they produced or extracted drawings without complete 3D information. Part of the information that was incomplete was the labelling of components. All of our intelligence for construction CAE is based on labelling of components and with iterative downloads, we would wipe out labeled information with a blank label information.

The process that engineering had implemented on the project early on, was to extract isometrics, send them to the field for markup for spooling, issue those from the field to the fabricator and back to design engineering for final incorporation into the 3D model. This loop caused us not to be able to effectively utilize the spooling in the program and it's one of the things that we would revise, as I alluded to earlier, in our work processes on our next implementation.

The way it was used in the Scrub-Grass experiment, however, was to take a piece of pipe, as you see here, and manipulate the pipe in amongst the steel beams, for installation. All of Construction CAE is mouse user interface driven and in the corner is a prompt on what the mouse buttons do in any specific application. Here there are scroller bars that, as you move them, the pipe will tilt or move in basically X, Y and Z directions.

Within interference detection on, it will set and identify collisions during installation. What we found with one spool, is that with the adjacent spools installed, we could not turn it for installation in the other direction and the spool was too long to be installed in the direction it needed to be installed. This happened before that material was fabricated and delivered to the site, so we were able to go back to the fabricator, revise the spooling and have that made in a shorter length, where you could clear the structural steel above and tilt it in under the beam.

In another instance in piping, we had a pre-fabricated spool that its installed location is back in the corner behind the cross bracing and there is literally no way to get it there without removal of the bracing. Neither of these were highlighted as a design interference because there are no design interferences, they are construction interferences that occur when you are trying to stage the materials into place.

Our results on piping were actually, probably more rewarding than on structural steel. We did re-spool one section and we did remove the steel brace and everyone felt a little bit vindicated in that they did find things that could not be built that probably would have resulted in lost time had we actually got there. Whether we would have gotten there or not, or someone would have noticed, is a $64 million question and that is one of the problems we have had in quantifying the savings of automated software. It's always easy to say, well I would have seen that anyway, but we know from practice on waiting and waiting on materials and stoppages, that we have pretty high rework, up to 5% of the cost on most projects, as an industry average and we also have quite a bit of waiting time.

We encountered quite a few problems with this implementation of the software. This was not the first project that we had run Construction CAE on, it was about the sixth. However, it was the first project where we put a workstation in the field at the construction site and it was also the first time that we had designed the engineering scope of work in another office other than Los Angeles Regional Office, where the software was developed.

As usual, when you run into problems, you run into them when you hand off work from one group to another and we had problems with model translation, going into Construction CAE. Those problems can basically be summarized by telling you they didn't follow the design spec, they modelled in 2 1/2 D and not 3D and I cannot read surface polygons, they are 2-dimensional shapes, they are not 3-dimensional shapes, so I had some time, going back and fixing a model that we should have been able to avoid on the front end, with better coordination.

Secondly, as I pointed out earlier on spooling, we had coordination on releases of engineering, but the field construction manager's feedback is the coordination was much more than just the spooling problem. He needed a larger percentage complete of the model to do his preliminary planning work up front, and we are working now on brainstorming with our construction people on how to do that and also trying to identify for automated projects, what the zero base of deliverables would be to the field.

Under the problems with design interface, as I pointed out earlier, the work process has to be tailored for implementation of the automated tools. In this case, we wanted to run a parallel; we found out that does not work too well.

There is a larger issue of training as a whole category of problems. The way I worked Construction CAE deployment on this project is we sent a person trained from the home office to the field, but in reality that person is not a part of the work process team in the field and it is difficult to incorporate him in. So we are recommending to Bechtel Engineering Management and Construction Management in the future, and to CERF, that we have to make the field personnel less foreign to the 3D environment. They have to be familiar with it and we have to spend whatever it takes, training-wise, to do that.

Thirdly, although it's great to use people from the home office, it's probably not a good idea to have people who are not project members driving the schedule and the field totally dependent on their work. They have to be a project team member.

On coordination, engineering, construction planning, coordination issues, I think are even more intense in the automated environment. You certainly run into the issues faster on the front end and I point out, it was parallel to a non-automated work process and that absolutely did not work.

We showed several benefits; the first has been alluded to in every implementation we have had of this and every time we have taken a 3D model to the field. Visualization produces paybacks, it produces big paybacks. It results in shorter instruction time to the crafts, even if they don't have a computer in their field shack or field office, if you can bring them into a viewing area or a group session around a monitor and they can view the constructed model, the feedback you get is astronomical and if you get into the animated replay of what your schedule is, the feedback is even further astronomical.

Two projects ago, the simulation operator was a plant design engineer in the home office and he says, "I tell you, if a picture is worth a thousand words, Construction CAE and animated playback is worth twenty thousand." We are able to complete design reviews for these projects in two to four hours with no pre-review time by anybody, other than the engineering and presenters and we have included effectively at very early stages of the project, construction, client and operations people in these reviews. Very enhanced understanding of the configuration and quality paybacks; here we avoided interferences and the field prefer doing the work in this way.

I have a slide of lessons learned. Our lessons learned slide is you have to plan ahead, you have to plan for Construction CAE before the modelling starts. 3D modelling and the work process have to both be identified and changes made to accommodate it. We, in general, in Bechtel, on our construction side, need to invest more time in training and it isn't just time, I think, it's quality of training as well.

Timing between engineering and field on design, zero-based deliverable type thing is an issue. We are having meetings to try and identify and zero in on what we need to do there, but again we learned that the value of 3D visualization, probably holds a potential to give us big paybacks in time savings in the future.

Discriminant Analysis Model for Predicting Contractor Performance in Hong Kong

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F.C.Harris, School of Construction, Wolverhampton Polytechnic, England

1. Introduction to the Problem

Construction clients commonly try to gauge a contractor's potential performance on a past record of finishing on time, to cost and with good quality of work before inviting bids. However, the tendering method can only measure a portion of the cost component as contractors often succeed in obtaining claims for extras. Unfortunately, the other two components, time (completion on time) and quality of work, are even more difficult to assess at the tendering stage. While careful pre-selection may help in judgement, decision making is subjective and often not accurate.

Other methods need to be devised to include as much quantitative and objective factors as possible in assessing the contractor performance. This aspects form the basis of the research described in this paper where a quantitative model has been developed.

2. Determination of Contractor Performance

The mathematical technique of Discriminant Analysis was adopted in the research to evaluate the performance of contractors.

Discriminant analysis is a procedure used to classify an object into one of several a priori groupings dependent upon the individual characteristics of the object. After the groups are established, data are collected for the objects in the groups. The discriminant analysis then attempts to derive a linear combination of these characteristics which best discriminates between the groups. If a particular object, for instance a contractor or a project, has characteristics which can be quantified, the discriminant analysis determines a set of discriminant coefficients. The discriminant analysis technique has the advantage of considering an entire profile of characteristics of a project or a contractor, as well as the interaction of these properties.[1]

By applying the discriminant analysis technique in this research, it is hoped that the discriminant function of the following form is developed to transform individual properties of construction projects to a single discriminant score or Z value which is then used to classify the performance behaviour:

$$Z_1 \text{ score} = C_o + C_1 V_1 + C_2 V_2 + \dots C_n V_n$$

Where:
Z_1score is the contractor perfromance index which is a value describing the contractors' performance on a scale between good to bad.

C_i are the coefficients which produce the desired characteristics in the function.

V_i are the variables in the function which govern the contractors' performance.
In order to derive the function, the authors have spent one and a half year to collect data of thirty-one completed projects through interviewing clients and contractors and these views are being used to separate the samples into two groups- good and bad.

The types of project included in this research are as follows:

Contract sum	Number of projects
Below HK$ 1 million	1
HK$ 1 to 5 million	4
Above HK$ 5 to 50 million	9
Above HK$ 50 to 100 million	9
Above HK$ 100 million	11
Total :	34

The number of contractors involved are fourteen. Their size ranges from having 12 number of staff to 1000.

3. The Attributes of Contractors included in the Z_1 Model

The main task centres on ascertaining the attributes of contractors and the variables influencing performance based on the premise that two or more groups exist which are presumed to differ according to the degree of these attributes measured in terms of the variables.

Discriminant analysis then helps in analysing the differences between the groups and/or provides a means to assign (classify) any case into the group which it most closely resembles.[3] The most difficult part of this procedure is to sort out precisely the factors which can delineate the difference in contractors' performance. At this stage, it is better to include as many attributes as possible as long as they are obtainable and considered as attributable to the performance behaviour. The model will remove those attributes which are not significant.

The factors included to date are as follows:-

Internal Factors:

3.1 Staff training programme*
3.2 Plant ownership policy*
3.3 Size of the company*
3.4 Quality of management team - Percentage of professionally qualified staff*
3.5 Quality of management team - Project leader's experience*
3.6 Past performance of the project manager*
3.7 Contractor's experience in the type of job*
3.8 Contractor's work load*
3.9 Contractor's past performance or image*
3.10 Number of years in the business*
3.11 Origin of the company*
3.12 Amount of directly employed labour*
3.13 Listed on the stock market*
3.14 Decision making centralised in head office or de-centralised to site*
3.15 Contractor is client's subsidiary firm*

External Factors:

The above are all internal attributes of contractors, however, there may be many external influences which affect a contractor's performance such as:

3.16 The Architect' performance*
3.17 Architect's or client's supervision and control on the quality of work and work progress*
3.18 Punctuality of payment by the client*
3.19 Complexity of the project*
3.20 Profitability of the project*

(Owing to the limitation of space, the ways to quantify the variables are not described here. For those who are interested in them, please refer to the authors.)

4. Statistical Package Used

As mentioned at the beginning, discriminant analysis provides a potentially useful technique for the purpose but requires considerable calculation. Hence, a computer software package was selected to aid the process and SPSS(x)PC was chosen and appears to be quite adequate in performing the following tasks:

4.1 Estimating coefficients and derives the function.

4.2 Comparing the significance of variables and eliminating unnecessary variables.

4.3 Testing the formula's and the coefficient's level of significance.

4.4 Calculating the discriminant score for the test samples.

5. Results

By applying the discriminant analysis technique, the formula for Z_1 turns out as follows:-

Discriminant function = -2.116197 - 0.4960918(COMPLEX) + 12.85458(PROF_STA) + 0.09186742(LEAD_EX) - 1.730167(PAST_PER) + 0.9040884(ORIGIN) + 1.105466(CONTROL)

where
COMPLEX: The complexity of the project
PROF_STA: The percentage of professionally qualified staff
LEAD_EX : Project leader's experience
PAST_PER: Contractor's past performance or image
ORIGIN : Origin of the company
CONTROL : Architect's or client's supervision and control on the quality of work and work progress

Table 1 Unstandardized Canonical Discriminant Function Coefficients

COMPLEX	-0.4960918
PROF_STA	12.85458
LEAD_EX	0.09186742
PAST_PER	-1.730167
ORIGIN	0.9040884
CONTROL	1.105466
(constant)	-2.116197

Table 2 Standardized Canonical Discriminant Function Coefficients

COMPLEX	-0.79039
PROF_STA	1.01346
LEAD_EX	0.63551
PAST_PER	-1.09492
ORIGIN	0.57734
CONTROL	0.92512

The unstandardized coefficients are the multipliers of the variables when they are expressed in the original units. The standardized coefficients are standardized to a mean of 0 and a standard deviation of 1.

Since the variables are correlated, it is not possible to assess the importance of an individual variable. The value of the coefficient for a particular variable depends on the other variables included in the function.

Sometimes, it is tempting to interpret the magnitudes of the coefficients as indicators of the relative importance of variables because variables with large coefficients are thought to contribute more to the overall discriminant function. The magnitude of unstandardized coefficients, however is not a good indicator of the relative importance since the variables have different units in which they are measured.[3]

From the standardized coefficients, it is noted that the past performance has the highest magnitude and the rest in descending order of importance are the quality of staff- percentage of professionally quality staff, architect's or client's supervision and control on the progress and quality of work, the complexity of the project, the project leader's working experience and the origin of the company (refer to table 2).

Another way to assess the contribution of a variable to the discriminant function is to examine the correlations between the values of the function and the values of the variables. The computation of the coefficients is straight forward. For each case the value of discriminant function is computed, and the Pearson correlation coefficients between it and the original variables are obtained.[3]

Table 3 The pool within groups correlations between discriminating variables and canonical discriminant functions are:-

PAST_PER	-0.45310
ORIGIN	0.37160
CONTROL	0.34601
PROF_STA	-0.14815
COMPLEX	-0.14628
LEAD_EX	0.00592

In comparing the orders in table 2 and 3, it will be noticed that PROF-STA has the second highest contribution in table 2 and carries a positive sign while in table 3, it falls to fourth and has a negative sign. The order of contribution of ORIGIN in table 2 ranks the last but second in the table 3. This occurs because PROF-STA has a very high correlation with the ORIGIN (correlation coefficients of 0.69184). Thus the contribution of PROF-STA and ORIGIN are shared and the individual coefficients are not meaningful.

There are some variables which were eliminated in the model but which were expected to fall into the group, like the profitability of the project since most contractors interviewed expressed the importance of this variable in their performance motivation. This may be due to the inaccuracy of the pre-tender estimate (the variable was guaged by the tender price over the pre-tender estimate).

Other variables were removed because the model has considered them not signifcant in the F statistics calculation[3].

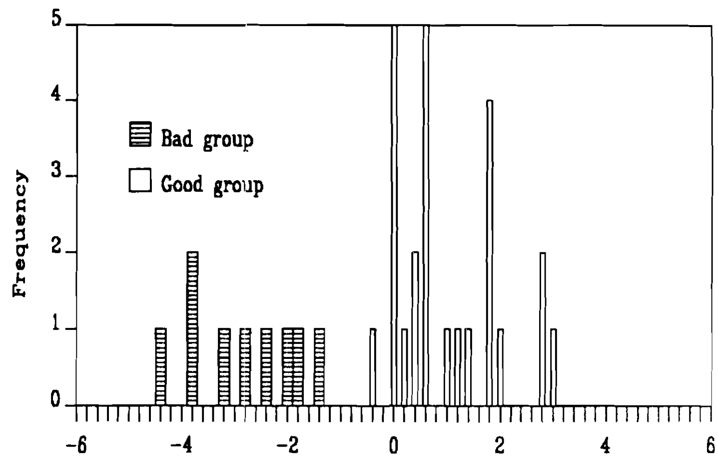
5.1 Quality of classification

Fig. 1 shows the frequency distribution against the discriminant scores of the two groups.

The classification result can be summarised as follows:

Actual group	No. of cases	Predicted group membership 1	2
Group 1	23	23 (100%)	0 (0%)
Group 2	8	0 (0%)	8 (100%)

Figure 1: Frequency Distribution Histogram against Discriminant Scores for Good and Bad groups



Percentage of "grouped" cases correctly classified is 100%. The canonical correlation is 0.8671 and the significance is less than 0.00005 when using chi-square to test the model.

5.2 Variables shortlisted in the model:

5.2.1 Past performance of contractor:

From the model, it can be noted that the past performance of the contractor ascribes their future performance very much. This reflects some of the top management's hard attitude in managing projects cause they tried to maximise the profit in every project irrespective of the relationship with the clients. Some contractors stand very firm in the position of claims. Some may have hired claims consultants at the outset of the contract. These may upset the clients.

5.2.2 Origin of the company

Local Chinese contractors have their own way of running business. They would prefer commercial settlements rather than bringing the case to arbitration or court in order to maintain a good relationship with the clients.

Most overseas contractors in Hong Kong (especially those from the Western countries) are very claim conscious. Further they may have difficulties in managing local subcontractors; particularly the labour only subcontractors. (Japanese contractors are deliberately excluded from this catagory as they do not care about claims in order to 'please' the clients.)

5.2.3 Architect's or client's supervision and control

Early signalling of the client's dissatisfaction on the work progress and the quality of works by issuing architectual instructions and warnings can reduce disputes at the end of the contract.

5.2.4 Quality of management team- percentage of professionally qualified staff and project leader's experience

Both of these have an impact on the contractor performance since they measure part, although not all, of the management team's quality.

5.2.5 Complexity of the project

The degree of importance of this variable may be suppressed in the way that clients may choose large and well established contractors for the complicated and large jobs while keeping the simple and small jobs to the small and young contractors and thus the data collected is biased. Further, the architect's or the client's supervision on complicated jobs would be tighter. These can be revealed from the relatively high correlation between the variables of complexity and the company size and control which are 0.54326 and 0.59469 respectively.

5.3 Conclusion

The purpose of this paper was to investigate empirically the characteristics of contractor performance behaviour and attempt to develop an accurate performance prediction model. Discriminant analysis was used to accomplish this with the intrinsic characteristics of contractors and the external influence by the architects and the clients serving as predictive variables.

By observing the variables shortlisted in the model, the analysts concluded that there were differences in them of good performance compared to bad. The model contained six variables which serve as the predictive variables. These variables have been explored in section five.

Results of the study indicate that it is possible to classify contractors into either having good or bad performance using the variables included in the model.

6. Further Research Work

The authors will carry out tests on an independent sample of projects to verify the reliability of the model. Furthermore, investigation of models for independent Z_2 scores based separately on cost, time and quality will be studied.

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FLOATING METHOD OF CONSTRUCTION OF POWER ENGINEERING PROJECTS AND ITS RELATION WITH SOCIAL, ECOLOGICAL AND ECONOMIC FACTORS

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1. Floating Method of Construction (FMC)

With the FMC the major volumes of construction work are transferred from the construction sites, which are located in remote and difficult to reach costal regions, to almost industrial production conditions in areas with mild climatic conditions and developed social and manufacturing infrastructure.

With the FMC a project unit is broken down into independent building and technological block-modules (e.g., a section of hydroelectric station, block-stage of thermal power station with a machine room, boiler unit, reactor section of a nuclear power plant, etc.).

Block-modules (BM) prefabricated to a maximum possible degree of readiness from the constructional and technological point of view are assembled (or completed) in a special dock or a ship building plant. The BM should be of a temporary or inherent buoyancy. Simultaneously with BM assembly activities, work is being carried out related to construction of necessary foundations, utility lines and other items needed to land and install the BM into final permanent position.

After assembly and trials are over, BM are delivered to an adjacent aquatorium and transported along waterways (by sea, river, channels) to the site of installation. The transportation may be effected by towing, by semi-submerged ships of "Wysmuller" or "Transshelf" type, or by feeder lighters of "Boris Polevoi" type. Having reached the spot of destination, the BM are delivered to the foundation and then erected into their final permanent position.

The U.S.S.R. is a pioneer in the floating construction technology. Well back in 1968, a tidal power station was built by floating method in Kola Peninsular above the Polar circle. The mass of a BM amounted to 5000 tons and overall dimensions to 30 x 18 x 15 meters. In 1983 the floating method was used to build support masts of a 300 kV high tension electric power transmission line to cross over the Kakhovka water reservoir. BM's mass was 8000-9000 tons, diameter 45 meters and height up to 126 meters. In 1985-1986 the method was used to build water discharge dams as a part of the engineering works intended to protect St. Petersburg against floods. BM's mass was 30 000 tons and dimensions 130 x 50 x 12 meters.

A project is already developed to build a gas-turbine power plant at Yamal Peninsular by the floating method. BM's mass will be 2000 tons, its dimensions 116 x 21 x 15 meters. The BM will be manufactured in a construction dock on the coast of the Gulf of Finland. Project development and prospecting activities are now underway to build a large tidal power station in the far east region of Russia with the BM's mass up to 240 000 tons.

Research and project development work is launched which is aimed at construction of small plants to be produced by the FMC, including nuclear plants using naval on-board reactors and the BM to be manufactured by ship building enterprises. When it was decided to stop construction of the Crimea nuclear power plant with VVER-1000 reactors, a scheme was designed to take the structures off the foundation, to transport them by sea to the Primorye Territory in the far east and to install into the final position by the FMC. The mass of BM of the reactor section is 220 000 tons.

Structural and technological concepts are being developed and feasibility studies are underway to use the FMC to build the chain of low-head hydraulic power stations at large

Siberian rivers like the Enisei, Lena, Amur, Kolyma, etc., as an alternative to high-head multiple-use developments of Turukhansk and Mid-Enisei hydraulic power projects.

FMC facilities are entering into the floating technology now. In particular, in the U.S.S.R. there is a project of a multi-purpose floating civil construction complex which would allow to build multi-storey buildings, cottages, hotels and so on in coastal areas along seas and rivers or on islands.

2. Interrelation Between the FMC 2 0 and 2 0 Social, Ecological and Economic Factors

2.1 Social Factors

With the FMC the major volumes of work are shifted from remote areas with severe climatic conditions lacking residential accommodation, welfare and social facilities, to regions with developed manufacturing, dwelling and social infrastructure thus significantly improving social conditions of life and work for the construction and erection workers.

2.2 Ecological Factors

a) Due to a considerably reduced volume of activities at the construction site and a more compact general layout, the FMC provides for a major reduction of a technological impact upon the Nature and cuts down the land allotment requirements for the construction sites. Reduction of the number of construction and erection workers lessens anthropogenic effects upon Nature.

b) The FMC makes it feasible to build chains of low-head hydroelectric plants instead of superlarge stations at the rivers of Siberia and the Far East, thus practically eliminating the problems related to flooding of vast territories, as the head of chain-type stations is limited by the upper marks of seasonal fluctuations of river levels.

2.3 Economic Factors

a) The FMC cuts down construction duration by 30-40% due to:

- overlapping of preparatory jobs at the construction site with the prefabrication period of BM in the construction docks or a ship-yard;

- performance of main job volumes in favourable conditions approaching the conditions of an industrial plant.

b) the FMC allows to reduce construction and erection personnel at the construction site by 50 to 60% and by 20-25% in general due to application of production line technology when manufacturing the BM.

c) The FMC reduces the costs of construction and erection due to:

- reduction of expenditures for residential and other services for a smaller number of construction and erection workers at the construction sites (see above);

- reduction of expenditures for the manufacturing and production facilities;

- reduction of unit cost of project construction in remote areas with severe climatic conditions, stipulated by the transfer of major volumes of construction work to regions with favourable climatic conditions and developed social infrastructure.

Thus, unit cost of construction work at the penisulars of Yamal, Taimir, Chukotka, Kamchatka and Yakutiya is 2-5 times higher as compared with the unit cost in the middle part of the European part of the country. Overall cost reduction provided by the FMC is around 20-50%.

Thus, the FMC of industrial projects in remote areas from the social, ecological and economic point of view is a competitive and advanced modern technology, which, during the last decades, is also being developed by advanced companies in Japan, France, U.S.A., BDR, Holland, Canada and other countries.

Prefabrication vs. Conventional Construction in Single Family Wood Frame Housing

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1. Introduction

The 1980's saw important changes in the North American homebuilding industry. New economic realities affected production cost and retail-prices, while demographic changes affected the cross-section of clientele in most markets (Fig. 1 & 2). As a result, some builders are considering prefabricated wood-frame low-rise housing as an alternative to stick-built on-site construction. At present, prefabricated housing accounts for approximately

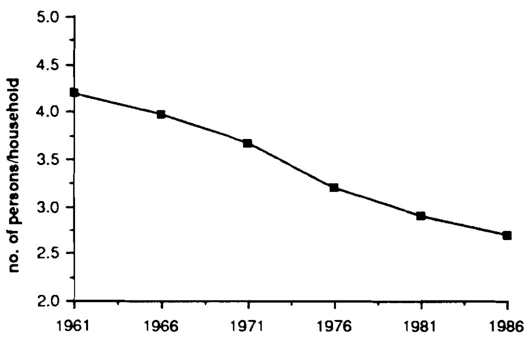

Fig. 1: Average Household Size in Quebec
(Source: Census of Canada)

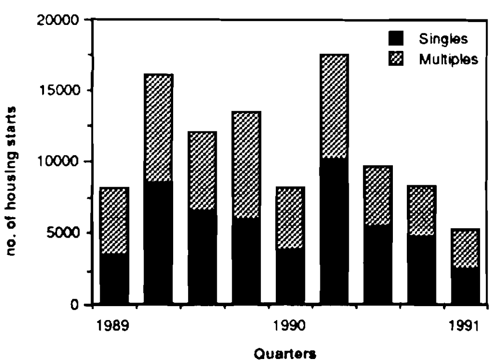

Fig. 2: Housing Starts in Quebec
(Source: CMHC)

3% of housing production in Canada[1] compared with over 90% in Sweden[2] and 54% in the U.S (Fig. 3)[3]. However, over 95% of the

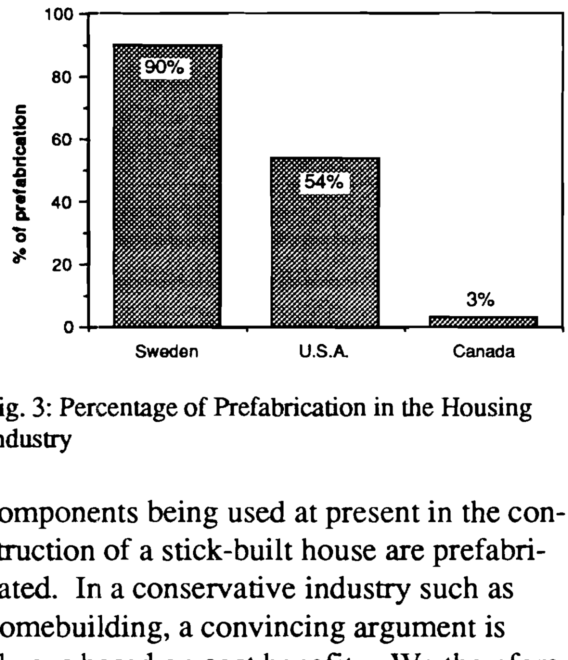

Fig. 3: Percentage of Prefabrication in the Housing Industry

components being used at present in the construction of a stick-built house are prefabricated. In a conservative industry such as homebuilding, a convincing argument is always based on cost benefits. We therefore set out to compare the cost of conventional and prefabricated homes in the provinces of Quebec and Ontario and the length of time required to produce such homes. We have also examined some aspects of construction quality. Prior to the presentation of findings and their analysis, some recent changes that have brought the idea of prefabrication to the interest of builders at present are discussed.

The recent affordability crisis has had a far-reaching effect on the industry: housing prices have doubled in most North American urban centers since the mid 1980's. As some forecasts show, large future buyer groups will be first-time buyers, seniors trading large homes for smaller ones, and "baby boomers" planning to purchase a vacation home. Many builders envision trends towards small size lower-cost units for which prefabrication is well suited.

The present economic slowdown is sending shock waves throughout the industry. The small building firm[4] is further trying to reduce overhead. The option of becoming a dealer/ broker rather than a general contractor is quite appealing to small builders. Being associated with a large manufacturer who can deliver a home on relatively short notice and even guarantee after-sale service is convenient. Most builders wonder how competitive they will be if they purchase a prefabricated home and compete with a "conventional builder" in the same region.

In their realization that the current (early 1990's) economic slow down may last 2 to 4 years, some builders are exploring the option of building in other geographical markets. Exporting prefabricated houses to foreign markets is a direction that many builders are considering. Some builders are currently examining possible export from factories in Eastern Canada to such locations as Germany, USSR, and Israel, for example, and are examining the merit of using prefabricated houses.

First-time buyers who want to be homeowners are also ready to try new techniques and directions[5]. It also seems that the preconceived image of the prefabricated home as boxy and cheap-looking is changing. Buyers are examining the qualitative advantages of industrialized production compounded by the fact that many manufacturers are investing more in new attractive designs. These changes have generated openness to prefabrication at present by buyers and builders.

2. Research Method

Prior to the introduction of findings, I would like to explain briefly the main differences between various fabrication methods. Researchers tend to divide the systems into three main groups: *Modular, Components and Mobile houses* (Fig. 4)[6]. *Modular* refers to three-dimensional elements that can be either part of or form the entire home. *Components* are elements such as wall sections (panel) or even pre-cut elements (studs). Despite the fact that *mobile homes* are three-dimensional, they are considered a separate sector.

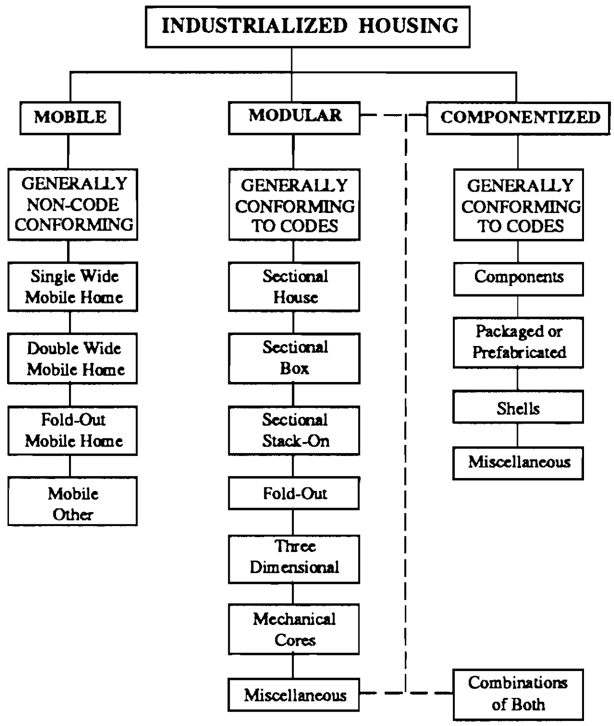

Fig. 4: The main groups in the industrialized housing industry (Source: Dietz 1971, p.315)

We have selected at random 15 (fifteen) manufacturers from Quebec and Ontario who were ready to collaborate with us and allow us to visit their facilities[7]. We studied the retail cost (i.e. cost to conventional builder) of two models from each manufacturer. We then gave the architectural set of plans of a single-family house to 6 (six) conventional builders for pricing. We compared the results from the two industries in terms of cost per square foot of habitable space, production time and quality.

3. Findings

3.1 Cost

We found that the cost per square foot of single-story modular homes is $63.96. Panelized prefabricated homes averaged $66.54 per square foot. Pre-cut prefabricated structures averaged $66.84 per square foot. The conventional industry's average is thus $7.46 per square foot below the least expensive prefabricated option (Fig. 5).

	Modular	Panelized	Pre-cut	Conventional
Cost per sq. ft.	$63.96	$66.54	$66.84	$56.50
Difference per sq. ft.	$7.46	$10.04	$10.34	0

Fig. 5: Average construction cost per sq. ft. by category.

3.2 Production Time

Production time is influenced by factors such as time of the year (i.e. production will take longer in a busy construction season) and management. The following information was provided by the manufacturers and builders, and indicate production time in peak season (Fig. 6). The prefabricated industry has between 10-15 days overall advantage over the conventional building industry.

	Modular	Panelized	Pre-cut	Conventional
Time in factory	52	30	45	------
Time on site	10	40	45	95
Total production time in days	62	70	90	95

Fig. 6: Production time (in days) of manufactured and conventionally built single family homes.

3.3 Quality

Our assessment of quality was based on site observations and examination of typical construction details and manufacturing techniques such as exterior wall sections. We did not find major evidence demonstrating that prefabricated housing has a significant quality advantage compared to conventionally built homes. We found that the use of power tools and techniques that prepare the modular home or the panel for transportation have in some cases a slight quality advantage.

4. Analysis

Examination of the results and interviews with manufacturers can further explain the above findings. Most manufacturers made a large initial investment that must be amortized over the life of the factory (i.e. investment of between 5-10 million dollars is needed to set up a small to medium-sized factory). Because a conventional builder is not bound by the economic liability of a factory, he will try to reduce his inventory to a minimum in a soft market as a strategy for survival and thus have a competitive edge over a manufacturer. We also realized that due to the cyclical nature of the industry, manufacturers cannot keep up the high production volume necessary to create economies of scale--the average number of units produced is 250 units per manufacturer/ per year in a "good" year.

Most manufacturers had an average of 100 full-time employees. About half of them were seasonal employees and the rest are year-round that must be kept. A conventional builder has only a handful of permanent "on payroll" employees, mostly in administration, and thus, lower operating costs[8]. We also found that the notion that factory employees earn much less than trained sub-contractors or laborers on-site is also not fully correct. Key quality employees earn as much as trained sub-contractors. In addition, due to union regulations, manufactured houses have to be finished on-site by union members; this further cuts potential savings.

We found that the "production-line" image, where all manufactured units look alike and where the trades do the same repetitive work does not exist. In fact, all the manufacturing facilities we visited would be willing to custom produce one unit only. Thus, the time and the cost saving advantage is greatly reduced by the fact that every production task has to be thought of prior to execution.

5. Future

There is no doubt that there are indirect inherent advantages to prefabrication. The notion of doing most of the work in a physically and quality controlled environment can be relevant to some builders. Given the harsh Canadian winter and the idea of reducing on-site production and selling houses all year round might be appealing to builders. The price difference is not high if one considers the indirect monetary advantages (e.g. no thefts or vandalism on-site).

Several steps must be taken by the prefabricated home industry to further lower prices. In order to increase production, new markets must be explored. More goal-oriented marketing strategies that see foreign markets such as the U.S. and Europe have to be initiated. The prefabricated industry must also educate builders about the advantages of using prefab houses in relation to the builder's mode of operation (i.e. reducing on-site management, leaving more time for marketing). Concentration on the lower end of the market (i.e. small, affordable units) which has high-volume potential for prefabrication can be a strategy for a small manufacturer. If these measures are taken, the manufactured industry stands a chance to close the price gap and become more attractive to conventional builders.

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[2]Swedish Housing: Has Factory Construction Come of Age? Inside *Housing,* Vol.1, No.2, Jan/Feb 1990.

[3]*Automation in Housing & Manufactured Home Dealer,* March 1988, p. 37.

[4]The overwhelming majority of building firms build less than 20 housing units a year.

[5]The housing shortage of the 1940s and 1950s generated openness to a large number of innovations such as drywall and prefabricated trusses that were accepted by the buyers.

[6]Dietz A., Cutler L., *Industrialized Building Systems for Housing,* MIT Press, Massachusetts 1971.

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RELIABILITY STUDY IN COMPLEX CONSTRUCTION PROCESSES

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1. Introduction

The analysis of a production process focuses on the discovery of the optimal technological process - with the least possible usage of manual labor, materials and energy.

The analysis of the technological process (the study of the technological process) should make the choice of the most rational technological process possible. This analysis includes the study of: existing documentation about the technological process (evaluation of its feasibility), the structure of the system (the plan for and organization of work stations), the optimal choice of machines and equipment, the necessary labor force (and the qualifications of workers needed in its structure) and the needed work time.

In the analysis of the production process, several methods of investigation can be used efficiently and they are:

- the flow diagram method
- the process chart method
- the graph and network method
- system structures (reliability networks)- types of component links
- operational research.

When using these methods of analysis, the production process should be broken down into its essential parts - operations and procedures. The analysis includes the study of the mutual relations between individual operations, the flow of materials, labor force and machines, and it can also include the quality control and storage of the products.

It is characteristic of a production process that the composition of a work crew does not change during the period of the development of the production process, but the material, tools and equipment may change.

The production process is carried out by a group of workers or by one worker. In that case, an individual production process is under consideration.

All of the mentioned methods can be used to demonstrate technological construction processes.

In traditional construction processes which develop on the construction site, manual and partially mechanical work processes are often prevalent, while completely mechanized processes are rare (and these are usually transportation processes).

In this paper, several systems of construction processes and some complex technological processes in the prefabrication of concrete panels produced in prefabricated element factories for residential buildings are analyzed.

2. The structures of technological systems in construction

Modern technological construction processes are formed in accordance with a high degree of mechanization. On the construction site, series of construction machines are formed to carry out the necessary tasks. In prefabrication on technological lines of various kinds, with the help of special equipment and form-making machines, the serial production of concrete and other precast elements is possible.

The basic elements for such a technological system are the work instruments (machines and equipment), the objects being made and the workers. In a structural sense, technological systems are most often composed of the flow of materials and movement of workers to the various work places. At the work places the machines and equipment stand ready.

The means of linking the components of the system can be varied. Most often these are serial links, parallel links, or complex links (combinations of the foregoing).

Systems with components in series and in parallel are often found in construction. Complex systems, with serial-parallel links, are rarer in construction, but are characteristic of machine and electronics technology.

3. System state - function and failure

The concept of the reliability of technological construction system means that it can work for a long period without breaking down, that it is lasting and easily maintained. Since the system is composed of several components, the reliability of the whole system depends on the reliability of each of its components. The work capacity of the system is a variable quantity which the completion of function criteria insures in the area of "system working", while in the area of "system failure" the system does not function. Therefore, in terms of time, the system is either at work or it has failed. Data about these system states can be obtained by measuring (recording) the process.

4. System reliability in construction

System reliability presents the probability that the system will successfully carry out the function of the criteria in a given field, according to entries into the field of acceptable deviation, by projecting the time and the given environmental conditions.

In general, reliability is defined by the function of uninterrupted system work and is expressed:

$$R(t)= 1-F(t)= 1- \frac{m(t)}{n} = \frac{n-m(t)}{n} \qquad (1)$$

where:
$R(t)$ - survival function
$F(t)$ - distribution function of lifetime
n - total number of occurrences of conditions "at work"
m - total number of occurrences of conditions of "failure" for the observed time period
$m(t)$ - the cumulative number of occurrences of "failure" up to the chosen time t.

The reliability of the whole system depends on the means of linking the components of the system, so that for systems with serially linked components, the reliability of the system can be expressed by:

$$R_s(t)= R_1(t).\ R_2(t).\ ...R_n(t) \qquad (2)$$

In the given phrase, $R_s(t)$ is the reliability of the system for a defined period of time, and $R_i(t)$ for $i(1,2...n)$ represents the individual reliability of the system components.

The reliability of the system with components linked in parallel is defined as a complex probability:

$$R_s(t)= 1 - \prod_{i=1}^{n} (1-R_i(t)) \qquad (3)$$

where n is the number of components in parallel linkage.

5. Characteristic models of connected system elements in construction in the prefabrication of panels

On construction sites, technological systems with serially linked elements most often appear. Typical examples are the excavation of earth with a dredger, the transportation and depositing of dug up earth, or the production of ready mixed concrete, its transportation to the site, transfer on the site and usage. From formula (2), it is seen that the total reliability ($R_s(t)$) of the system quickly diminishes if there are more components, or if the reliability of one component is low, because $R_i(t)<1.0$ for i(1,2...n).

In the building construction of residential and other buildings (schools, administrative buildings, etc.) panel construction systems are often used, although their application is also possible for other types of buildings (industrial, agricultural).

The elements of a concrete large panel building are: wall panels (external and internal), floor/ceiling panels, and roof components.

In technological systems which produce panels, the production can be developed on systems which emphasize the movement of equipment for the tasks, or on systems which emphasize the movement of the elements themselves.

In the first group of technological systems, lines with horizontally fixed work stations (in the plant or on site) can be classified, as well as vertical batteries, and prefabrication tracks.

On lines which stress the movement of components to be worked on one can include aggregate and conveyor lines.

The production process on technological lines for the production of panels begins with the transportation and deposition of basic and accessory materials, the laying of reinforcement and preparation of forms for the concrete components, which is followed by further reinforcement and then the pouring of concrete.

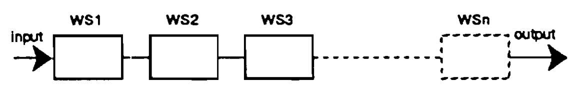
This paper will especially analyze:
- horizontally fixed (immobile) work stations
- vertical batteries
- aggregate lines
- conveyor lines.

The enumerated kinds of technological systems can be considered characteristic of panel production systems (walls and floor/ceilings).

Lines with horizontally fixed work places, if they are placed in a plant, on an open polygon or work site, are planned so that the work places, equipment and mechanization as well as the work phases and operations, are serviced by the workers who move from one station to the next. The number of working places is directly related to the number of components made daily on the line.

Such a technological system could also be shown as system with serially linked components. In Figure 1, the schematic plan of a line with horizontally fixed work stations is shown.

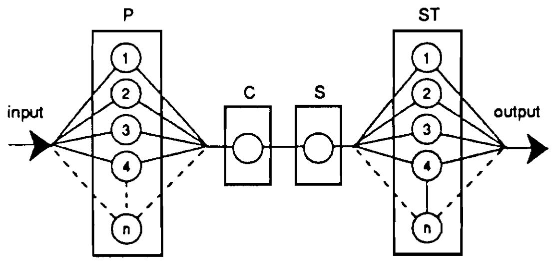
Figure 1. The graphic representation of a line with horizontally fixed work stations - system structure with components in series



WS - fixed work station

Lines for the production of components on a vertical battery (special equipment)are most often located in a plant, and the plan of the equipment and mechanization as well as the schedule of the development of work phases and operations presupposes that the production of components which do not move takes place. In a vertical battery - form machines usually produce 10-14 components in one production cycle. See Figure 2.

Figure 2. The graphic representation of a line for producing concrete panels on a vertical battery

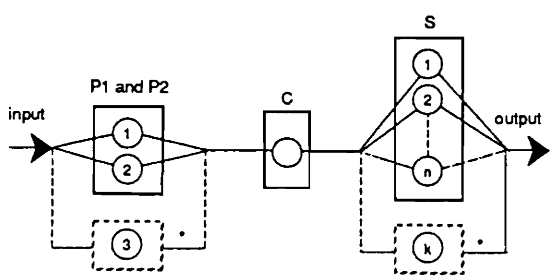


n - number of components in the battery
P - preparation and reinforcement
C - pouring and setting of concrete
S - steam curing
ST - storage of the components

The spatial solution of aggregate lines are adapted to the process, and generally these are technological lines which are located in specially designed plants. These are lines where the objects to be worked on are moved from one work station to another, which means that they are transferred by a transportation system(bridge cranes, portable cranes, etc.). See Figure 3.

In principle these technological systems can be understood as systems with components linked linearly, although certain anomalies exist.

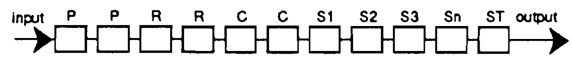
Figure 3. The graphic representation of an aggregate line for panel production



*connections can also be understood as being partially parallel.

In Figure 4, the model of a system structure with a conveyor line is given. Each work station on the line is shown as a component of the system, and this is a typical serial connection.

Figure 4. Conveyor line - a typical example of a system structure with the serial linking of components



6. Conclusions

On the basis of the results of this investigation of the reliability of complex construction processes, the following can be concluded:
- general methods of analyzing the reliability of a technological process can also be applied to processes in building construction.
- systems with serial and parallel links are often found in building construction. On building sites and in prefabrication, system structures with serial links exist.
- system structures with parallel links are less often found in prefabrication, except in cases when two (or more) parallel lines are in question, on which the same or similar components are being produced. The typical parallel link on such lines consists of a common group of machines.

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SESSION 5E
ON SITE PRODUCTIVITY AND EFFICIENCY

Questions and Discussion

Question
Harvey Bernstein

When you get done with this plan and document the results, are there any considerations to how to try and get it adopted or implemented by the construction industry itself?

David Riley

(A client) has requested that I implement this system into their firm, but it is by no means proprietary research. The plans for getting other firms involved are right now limited to the round table group which comes to Penn State to look at our research, but as industry is sparked, and if this thing is a success, then the presentation there will hopefully carry out and get this research implemented in other areas.

Question
Harvey Bernstein

How many companies are involved in the CAR?

David Riley

Approximately 25 companies involved right now.

Question
Tony Thorpe
University in the U.K.

I would like to first say how impressed I was with the concept of what you are doing, and I would love to have something like that to be able to simulate the construction process with my graduates so I could change programs and see the effects on the actual construction.

My question is quite simple. Can you tell us how many man years of effort have gone into producing that software?

Daniel Wickard

Yes, we have been working on it for five years this fall, as I pointed out. The core development team is a group of five people; there have been from five to twenty people on it in the course of that time. I would say that there is close to 25 man years in it already.

Question
Tony Thorpe

Is all the software purpose written, or is there any proprietary software built into that?

Daniel Wickard

It is basically all proprietary. It does use Silicon Graphics GL libraries and it also does take advantage of some of the other proprietary software routines that Bechtel had written for model display in our walk-through product. It interfaces to commercially available schedule processors, either Panorama, Project 2 or Primavera systems.

Question
Tony Thorpe

Did you have already in place some of the knowledge basis that you have accessed through that?

Daniel Wickard

We did research starting with some shells and we went out and bought third party shells for knowledge base. In the end, we found that they were very difficult to integrate and cumbersome to use and we ended up building our own, internal to the application where we needed to do it.

Question
Harvey Bernstein

One thing, maybe you could clarify. Isn't there some plan in the future with the software by Bechtel that they would either sell it, or make it available under some sort of agreement so that it can be used within the industry under certain circumstances?

Daniel Wickard

It is available now, through Bechtel software in San Francisco. We are not out marketing it in the open market, but a decision has been made to make the software tools we are using on projects available to customers and clients and we have sold a copy to a client. So, it is available commercially through Bechtel software.

Question

What are the interferences on this system? Why are you putting a computer on the pole?

Yvan Béliveau

The interferences, there are very little. There is multipath; if you had a mirror that got in the way it could cause us some confusion, but there is an amplitude measurement on it, so you should be able to differentiate that. The only thing that is required is that you have two lines of sight to any two transmitters, so that would be the real critical issue for interference.

I want the computer on the pole so that this person has full control of what ever it is they are about to install. They on the pole, select a corner of the footing, they then move the pole until they are at the correct spot, without the need for someone to say, go left, go right. If you have seen that on a construction site, there is a real nuisance with all that and it doesn't work very well.

Question

With all the economic problems everybody is facing, can we use it in the construction field? Is it going to be very expensive, because there is a lot of research and development that has been done? I would like to know the uses, because we really don't have the money to spend a lot of money on that kind of measurement system.

Yvan Béliveau

The system is inherently very simple, much simpler than any current theodolite system. The only thing that is much more complex is the computer, and it is a set of micro processors which are becoming very simple, also very robust, so it doesn't have very many mechanical parts. The cost should be, in the long run, the same as an EDM, which can range, depending on what you are doing, but at least an upscale electronic distance measuring piece of equipment.

In terms of the uses in the industry, I think there are so many, it would be very difficult, beyond the few that I pointed out, to go much more into. Certainly it isn't going to be \$100 000; nobody could buy it. It should be somewhere in the \$20 000 to \$30 000 range for a system and then also, because you put the lasers out on site, the incremental costs of an additional person being able to go out and do their job, would be significantly less than another theodolite and it will also require only one person to operate it, as opposed to the current crew that is required.

I think we are sort of touching on the surveying aspects of what this is, but because it goes so much more than surveying. It goes into fundamental issues of design, since we can position things now, untethered by going in straight lines, we can put serpentine things and circular things almost as easily as we can straight things. I suspect that it has got a lot more implications about how we actually look at buildings and how we look at design.

Question
Toshiaki Fujimori

In the European community, who will invest to develop architecture construction robotics?

Martyn Jones

At the moment, we are hoping to receive some financial support from the funding agencies within the United Kingdom. We are also in the process of assembling a bid for European funding and I would be pleased to let you know the outcome of that application.

Question

Have you done a comparison on the Bank building of the costs using this system versus the cost doing conventionally, right now, recognizing that it's not commercialized? I am curious what projections you are looking at in cost difference between convention and the system now and how many years into the future before you think it will be cost effective?

Mr. Miyatake

We had one experimental project and now the construction is in the second phase, and this time 20% reduction is expected, but mainly this project we are going to do very carefully, because we are correcting many kinds of data or many kinds of applications to new systems. At this time, cost reduction, we do not expect, but I think in the near future, maybe 3 to 5 years, we expect to reduce 50% of labour and construction period. So total construction cost reduction will be about 20 to 30%.

Question

What percentage of the efficiencies are due to management technique improvements and what percentage would be due to the improvement in the robotics or equipment?

Mr. Miyatake

I think two elements cooperate, using robotics and information systems; both are necessary to reduce much of the construction period or cost and labour. I cannot separate these.

Question

So you would say that it is more or less even, each contributes equally?

Mr. Miyatake

Yes

Question

Is the design being configured to suit the automation or will automation be sufficiently flexible to meet a variety of design parameters?

Mr. Miyatake

So far we are thinking about this automatic building system and it is very effective for high rise building, but we have to build many kinds of other low and medium buildings. We are thinking about how to apply to such areas, but as of now, I have no idea.

Question

Do you feel you would get better and greater efficiency if the design was done in-house by Shimizu?

Mr. Miyatake

Yes, in my opinion; I agree with you.

Comment

This is just by way of a comment. I think those of us that are having to represent owners or build in Japan are shocked by the high price of construction in Japan. I think it is reasonable to say that a high rise office building would run a million and a half yen or something in that percent and that is twice New York prices, which means it's three times prices almost anywhere else and I think you have got to do something and I hope you are on the right track.

SESSION 5F
Project Management: Construction and Maintenance
La gestion de projet: construction et entretien

Dynamic Project Control Utilising a New Approach to Project Control

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Mr D.Fong, South Bank Polytechnic, London.

1. Introduction

The fundamental principles associated with the development of network based project management control systems have remained largely unchanged since the 1950's. This has resulted in the proliferation of computer software which does not meet the needs of the project manager. As a consequence, planning specialists are required to prepare and monitor project programmes, utilising one of the many software packages available. Hence the project manager and the project planner must have the ability to achieve a high level of communication relating to complex processes and decisions in order that the project programme can be used as an effective management tool.

Difficulties exist with the preparation of the network programme and the considerable amount of data input which is both time consuming and to some extent error prone. This situation does not assist those project managers who wish to examine the effect of adopting different courses of action in order to select the best solution to a problem. In addition, the monitoring and updating process is too slow and the facility to predict outcomes only exists in a very limited number of packages. Although development is progressing at the current time, there is no effective commercial project management system which utilises a knowledge base to determine construction methods, work sequences and the allocation of resources.

2. Research Aim and Objectives

The aim of the research is to develop a powerful project planning and management system which will allow the project manager to undertake full planning and monitoring of the project as part of the management and decision making function. The planning and management system proposed is based on a powerful personal computer utilising MS DOS. Software is written in "C" and graphics are provided by Clipper 5, but this is subject to review.

The prime objective is that the system allows for project programmes to be prepared on screen by the project manager utilising libraries of standard data relating to the activity breakdown of the project.

Project activities are presented in a hierarchical framework which permits the preparation of a timescaled network analysis with automatic activity numbering. Hence the user simply schedules the project activities and indicates the dependencies with a mouse. Up to 99 links can be made for any one activity. Dependent links between activities can be made based on either percentage completion or percentage expenditure. In this manner the rate of progress or expenditure can be plotted for each activity and for the project as a whole.

Another objective associated with the above methodology is to provide interactive planning and control which allows the manager to iterate solutions to project based problems at sufficient speed to meet the dynamic demands of the project. This has been further developed by the production of a prototype which incorporates risk analysis based on selected milestones and overall project completion, together with the production of a criticality index.

3. The Development and Concepts Associated with the Project Orientated Evaluation Technique (POET)

The prototype developed to test and validate the principles and concepts referred to above has established the feasibility and practicality of an on screen interactive planning and control system utilising existing PC hardware and operating systems. A major problem has been the amount of information which can be shown on screen at any one time. This is particularly relevant to the introduction of zooming, scrolling the screen and changing the timescale. However, it is intended to provide a navigation system to show the user at any time which part of the overall project programme is being analyzed. One way of achieving this is to trace the earliest and latest start sequence, together with the critical path and that part of the programme currently under consideration being shown in a box.

Cost optimisation is seen to be an optional feature of POET whereby the resource allocated project programme can be expedited step by step to an optimal solution in accordance with the determined criteria. It is intended that the optimisation process will be controlled by a heuristic algorithm. The function of the selected algorithm will be in accordance with determined normal and crash activity times, together with their respective cost slopes.

Resource scheduling will be supported by POET in two stages. Firstly the incorporation of constraints when allocating resources to individual activities and the determination of links between activities. Secondly, the rescheduling or spreading of float activities together with complete manipulation of the programme and the introduction of target starts and completions. In this manner the issues and problems directly relevant to the project will be properly accounted for and several iterations may be needed before a solution is found. Theoretical pool limit rescheduling is not seen as an ideal solution to the majority of resources scheduling problems, but it is accepted that this approach might be useful in a limited number of applications. It is therefore proposed to include this as an optional feature where appropriate.

A further extension is envisaged to provide multi project scheduling for those clients requiring a number of projects to be procured at the same time. The prime use of this facility is considered to be in the area of cash flow analysis, but other critical resources will also be handled by the system. Up to ten links will be allowed between projects and the individual project schedules will be utilised to provide the master schedule. In cases where more than ten links are required the programme will be treated as a "Superproject" with the first level of breakdown representing individual projects.

The implementation of risk analysis is based on the application of monte carlo analysis and the user is required to make use of experience to assess the probability of achieving a range of completion times. The advantage over PERT is that a whole range of possibilities can be taken into account and the user has complete freedom in selecting probabilities. A random number seed generator is built into the software with a consequence that each run will be unique, The accumulation of simulation runs will produce a distribution of results which can be subject to statistical analysis utilising measures of central tendency. This can be undertaken for the final project completion, or it might relate to any intermediate point in the completion of the project. The selection of random outcomes relating to activity times causes a variation in the critical path. Such a variation may be limited, but in circumstances where there are many near critical paths, there will be a considerable variation in the route that the critical path takes. Consequently, the criticality index becomes an important factor in assessing the influence of non critical activities as the project progresses.

POET version 1 has been developed as a core project evaluation system incorporating cost and time analysis. It has been further developed to provide a system for target cost reimbursable contract cost and progress control. The system supports cost and progress recording, control, management overview and reporting. It supports strict financial and progress control throughout the project and aids the final out-turn costs. The performance control gives the manager a direct influence upon the project completion date and rate of spend.

Modules relate to: Programme, Labour, Materials, Plant, Supervision, Sub-Contractors, Sales Income, Variation Schedules and Cash Flow Forecasting.

It is envisaged that a number of versions of POET will be developed to meet particular user requirements. The underlying principle is that the system will offer a 'no nonsense' implementation designed to optimise the input, effort and time committed by the user. The options described will form the basis of the standard system, but it is anticipated that the needs of individual users can be accommodated by adding to, or amending the basic software.

4. The Human Computer Interface (HCI)

Considerable attention is being given to the development of the human, computer interface and the ability of the system to meet the natural needs of the project manager in the decision making process. This implies that information displayed by the system is adequate and in a form which will permit the correct decision to be taken.

Because the system is being actuated through a screen capable of presenting limited information at any one time, considerable attention is being given to movement and navigation. Hence the principle of consistency is paramount in the design, coupled with logical development and the absence of irrelevant actions and procedures.

Attention is also being concentrated on the input and output of data, together with the presentation of information. The most important feature of the system is the graphics screen which must produce reactions by the user which will ensure efficient use of the system in achieving the objectives. The system must also be easy to use and although the instructions will be fully documented, there will be adequate help screens to provide the user with immediate answers to problems and queries.

5. The Proposed POET Knowledge Base

Concurrent with the final development of the system will be the incorporation of a knowledge base to determine forecasts of costs and durations relating to activities and cost centres. Much information already exists in the form of published data, construction indices and company based information in both quantitative and qualitative forms. Unfortunately because there is a general lack of facility to conserve knowledge and research relating to individual projects, this is often lost once the initial project demand of the task has been fulfilled. A means needs to be established where this knowledge is captured and stored in such a manner that it can be readily recalled to assist the determination of future project methodologies and plans.

The research will concentrate on the most appropriate means of constructing a knowledge base which can be interrogated by the project manager in order to facilitate initially the formulation of adequate project plans and subsequently the efficient monitoring and control of the project.

6. Conclusion

The research previously conducted has provided the basis for the development of a prototype which has fully tested the methodologies and supporting algorithms. It has been proved that the planning process can be simplified to allow dynamic interaction between the manager of the project and the system software without the need for an expert planning engineer. Further, the dynamic nature of the system allows the project manager to adopt a 'what if' approach, otherwise unsurpassed by software currently available. The effect of decisions relating to the construction methodology and the rescheduling of activities, or the allocation of resources can be readily appreciated before a final selection is made. The facilities incorporating cost optimisation and risk analysis will also add to the ability of the system to approach ultimate project management decision making.

Finally it is anticipated that the financial analysis developed in POET version 1 will be further enhanced to incorporate development feasibility, multi project evaluation and financial outcome predictions.

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FORMING OF OPTIMUM METHODS OF CONSTRUCTION AND RECONSTRUCTION OF UNITS

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In the practice of construction and reconstruction of units, flow method of work organization, which are providing combination of different types of work according to time and their getting together in space, and parallel and flow methods, assuming together with the combination of different types of work according to time, simultaneous fulfillment of one-typed work in different individual fronts are widely used.

And mostly used in different countries through all the history of mankind are flow methods and parallel and flow methods with critical and non-critical work in the variant of earlier beginning of the latter, that is with immediate beginning of each work if fronts and resources are available (worker and technics).

In 1957 G.E. Kelly and M.P. Walker suggested methodology of calculation of the given variety of flow work organization with addition of forming and calculation of flows at later periods of fulfillment of work. As a result a possibility of forming intermediate variants of work from the early (earliest) up to the late (latest) date of fulfillment of each non-critical work and preservation of constant dates of critical work is provided.

The methodology of calculation was called Critical Path Method, renamed later Method of Net Planning.

G.E. Kelly and M.P. Walker used the theory of graphs and computers for calculating and it was undoubtedly a valuable contribution to the development of theory and practice of work organization. The use of computers provided reduction of labour and acceleration of calculation, possibility of projecting in many variants and selection of the variant mostly corresponding to the concrete conditions of the work production.

Elaboration of competitive variants and selection of the variant which was the most corresponding to the concrete conditions of work production were made by different investigators and workers in different countries according to absolutely different methodologies but as a result optimization either came to decrease of the elimination of stoppage in using resources or mastering the working fronts, in particular, at the expense of changing the intensity of work and its displacement from the earlier to the later dates.

The authors of this article, who, on the one hand, revealed community of flow methods of work organization (which have been investigated and used in the USSR since the thirties) and network planning (critical path) and on the other hand their difference follow another way.

It was discovered that network method of planning (critical path) is one of the varieties of the flow method or more general, concerning the flow method-parellel and flow method of work organization as it assumes combination of different-typed work according to time (which is characteristic for flow method) and simultaneous fulfillment of one-typed work parallel and flow method.

However their own peculiarities are characteristic for every variety of flow (parallel and flow) method, namely:

- in construction in the USSR and some other countries flow method of work organization with continuous use of resources is widely used. In this case there occur the stoppage of working fronts in unrythmical flows;

- in engineering (machine-building) in the USSR and some other countries the flow method of work organization with continuous mastering of the working fronts (with continuous treatment of details) is widely used.

In this case in unrythmical flows there occur the stoppage of resources (workers and machines). Nowadays this type of flow methods has begun to spread in construction with mass transition from new construction to reconstruction of buildings and structures.

In construction and engineering both in the USSR and in all other countries, when corresponding calculations are made, the flow method with continuous fulfillment of critical work at earlier period of fulfillment of non-critical ones, is widely used, that is the method of work organization provides for the immediate beginning of every next work after finishing the previous one. When making calculations this variety of flow methods is added (by) with flows with critical work and later dates of fulfillment of non-critical work, and also with intermediate between earlier and later ones.

Demarcation of varieties of flow (parallel and flow) methods of work organization allowed to put a question about the necessity and purposefulness of working out and optimization for every concrete case of all the mentioned methods of work organization and selection of the best variant from those which are able to compete, that is the most corresponding to the concrete conditions of the work production.

We have worked out and are still working out the algorithms and programs of work organization according to the following criteria:

- minimum duration of the whole complex of work;

- minimum duration of using resources, that is the fulfillment of resource complexes of work (types of work);

- minimum duration of mastering of the working fronts, that is fulfillment of resource complex of work (types of work);

- minimum duration of mastering of the working fronts, that is fulfillment of the front complexes of work (construction of individual units);

- total minimum duration of the stoppage of resources and working fronts;

- minimum quantity of the cost of production, etc.

Optimization is carried out at the expense of changing the intensity of types of work and individual work within the type (if it is advisable), at the expense of changing the order of mastering of the individual working fronts (if changing the order is possible), at the expense of transition from the flow (individual and flow) and parallel and flow work organization and search for the optimum order of mastering of the working fronts in parallel flows.

In this case the optimization of flow work organization at the expense of the search for optimum order of mastering the fronts should be given special attention (if changing the order is possible as the given optimization does not require the increase of the quantity of resources but is only directed to revealing the conditions of their rational usage and in the long run ensures decrease of demand for resources their more effective usage. In working out of the algorithms of search for optimal order of mastering of the working fronts together with the authors of this article, L.E. Agilyar, V.T. Astashenkov, V.K. Valeeva, V.Z. Velichkin, V.G. Dropeko, E.A. Drachev, M.M. Kalizhnyuk, V.V. Karelin, O.N. Krasavina, G.V. Krylov, B.X. Mena, L.L. Pronchenko (1-5) took part.

The algorithms of forming and optimization of complex flows (construction of some buildings and units) from previously made individual flows (for the construction of every separate building and unit), which are being worked out nowadays, are of some interest too.
Here varieties of complex flows are being formed and optimized. They are:

- with full preservation of the structure of individual flows, so called combined (CFC);

- with the guarantee of continuous transitions of brigades from one individual flow to another, so called aggregated (CFA);

- with the guarantee of the least duration of the complex flow, so called dense (CFD).

When there are limited initial data, the algorithms of forming, calculation and optimization of harmonious complex flows worked out by A.V. Afanasyev are of great interest. The peculiarity of these flows is identical (the same) duration of the types of work within every individual flow when the duration of different individual flows is different. Harmonious flows can be formed in all the variants of the complex flow (as CFC, CFA, CFD) /4/.

The considered variety of flow methods of work organization can and must be worked out and optimized according to accepted criteria applied to every concrete task with the aim of selection of the most corresponding variant.

However, the considered varieties don't comprise all the list of competitive methods of work organization.

For example, besides the mentioned one-principle methods, many-principle-methods can be formed. (They are with changing the principles of forming either of resource complexes of work or of front complexes of work, or of resource and front complexes of work simultaneously).

In addition to the mentioned classic flow and consecutive methods there can be formed methods with intervals with break-rank connections (according to types of work or to working fronts) both methods with constant intensity of work and methods with changing intensity of work; both methods with determined structure and duration of work and methods with the probable structure and duration of work, etc.

All these methods in their turn can and must be optimized according to the accepted criterion. The presence of the mentioned competitive methods of work organization and getting the optimum variants (according to the accepted criterion) puts the problem of choice of the variant which is the most corresponding to the concrete conditions of the production.

The authors of this article suggest a number of differentiated criteria, united according to their significance into the integral one, they are: timely work, correspondence of the need in resources to their presence, the efficiency of using the resources, the combination of different-typed work, continuous use of resources, work being critical, regularity of using resources, continuous mastering of working fronts, the presence of resources for the working fronts, the efficiency of using resources, and mastering of working fronts, the efficiency of the dynamics of capital investments and the efficiency of the duration of work.

All the suggested differentiated criteria are of relative character and are formed so that their quantity can vibrate from 0 (a very bad work organization) to 1 (a very good work organization).

The significance of every differentiated criterion, applied to the concrete conditions of work production, is fixed as a result of the demands of the task which is more general than the considered one.

In conclusion of considering the problems of forming optimum methods of construction and reconstruction of units, we should point out that the success of forming mainly depends on taking into consideration the experience of the organization of the construction and reconstruction of units. That is why the summary and analysis of the real organization of construction and reconstruction of units is of great interest. It can be carried out by making the so-called executive calendar graphs and the documentation for them.

The idea of making up executive calendar graphs appeared simultaneously with the idea of working out planning calendar graphs but, unfortunately it wasn't acknowledged practically and wasn't widely used.

However, the experience accumulated by the authors of this article together with V.P. Khibukhin and others, the experience of making up, analysing and further use of executive calendar graphs, as a foundation for making up planning graphs for identical units showed their undoubted value.

Executive calendar graphs (ECG) are made up during the construction and reconstruction of units according to the real data of the fulfillment of work and completion of events with the indication of the conditions of the fulfillment of work, the presence of the stoppage and their reasons.

ECG should be made up in the scale of time and space, that is in the form of cyclegrams with the purpose of fixing the time and place of work of every specialized brigade and also the stretch of resource connections (in resource complexes of work) and front connections (in front complexes of work). Making up the executive calendar graphs in the same form or sometimes just on the planning graph is also advisable (if the latter is steady enough). When making up ECG for the unit which is being built, it's purposeful for the best visuality and documentation to take photos of the unit after some intervals (marked on the ECG).

ECG can and must be the main pivot of operative-technical registration and reporting. The analysis of ECG can and must be made, according to the same differentiated figures (united to the integral) with the coefficients of significance taken into consideration when planning. The comparison of the meanings of the integral criterion of evaluation of planning and executive calendar graphs (for one and some units) can serve as the evaluation of the quality of real work organization.

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Handling Uncertainty in Automated Construction Data Collection Systems

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Introduction

An important prerequisite for establishing cause-effect relationship in construction productivity is the availability of large amounts of high quality data. Manual data collection schemes are often subjective and labor intensive. The need for automated data collection system is well established. An automated data collection system can be built by using different sensors connected to a portable computer. During the early stage of development of a comprehensive automated data collection system, it was found that the present state of sensor technology and pattern recognition capability is not fully adequate for gathering construction data. The problem lies in the area of recognition of construction workers and equipment by pattern recognition, acoustical signature analysis, and so forth. The inference structure of the system must, therefore, consider uncertain environments. If some of the input data are incomplete or unavailable, the system should still be able to arrive at a logical conclusion with a certain level of confidence.

The objective of this paper is to investigate the suitability of four established approaches of solving uncertainty in construction data collection application. The four approaches are the Bayesian approach, the Dempster-schafer approach, the Fuzzy logic approach, and the Model of endorsement.

Bayesian Approach

The Bayes theorem provides a mathematical method for updating the probability of a hypothesis given an observation of evidence. For example, suppose one wants to know the probability that a mason is actually working on the construction of a concrete block wall. The available evidence is that the mason is located within 2 ft of the wall in question. If the 'PRODUCTION' stands for the event of productive activity and 'PROXIMITY' stands for the location of the mason, then P(PRODUCTION/PROXIMITY) denotes the conditional probability of a productive activity given the location of the worker. A common form of Bayes Theorem is:

$$P(X/E) = \frac{P(X)\ P(E/X)}{P(X)\ P(E/X) + P(-X)\ P\ (E/-X)}$$

Here, P(X) is the probability of productive activity, the item of primary interest. P(E/X) is the probability of observing an evidence E, given that the productive activity, X is the progress. P(X/E) is called the likelihood function. If at a given point in time t_1, the value of P(X) is known, then it is called <u>Prior probability.</u>

Dempster-Shafer Approach

The Dempster-Shafer approach can be explained with the help of an example. Suppose, in a masonry construction situation there are two sensors and four pieces of evidence collected by these sensors. The sensors are a video camera and an acoustical sensor. The evidences are: Location of the mason, motion of the mason, tapping sound, and troweling sound. In the Bayesian approach, one considers the likelihood function (i.e., probability of the occurrence of the

Suppose, in a masonry construction situation there are two sensors and four pieces of evidence collected by these sensors. The sensors are a video camera and an acoustical sensor. The evidences are: Location of the mason, motion of the mason, tapping sound, and troweling sound. In the Bayesian approach, one considers the likelihood function (i.e., probability of the occurrence of the evidence when productive activities are in progress) for each of the evidences separately. If for some reason the signal from the acoustical sensor is not clear, for example, one can not distinguish between the tapping sound and the troweling sound, then the likelihood function for the sensor must be divided arbitrarily between the tapping sound and the troweling sound. the Dempster-Shafer approach overcomes this difficulty and allows likelihood function for a sensor as a whole or a group of evidences.

Thus, the Dempster-Shafer approach is an extension of the Bayesian theory. To further elaborate on the above example, assume that the likelihood functions for the evidences are 0.8 for the location of the mason, 0.85 for the motion of the mason, 0.86 for the tapping sound, and 0.82 for the troweling sound. Now, suppose the signal from the acoustical sensor is not distinguishable, and that the likelihood function for the sensor is 0.9. In the Bayesian approach, this likelihood value must be divided arbitrarily between the sound of tapping and the sound of troweling, which can lead to an erroneous result. The Dempster-Shafer approach provides for the use of the combined value directly, without any artificial division. Thus, the Dempster-Shafer approach can handle uncertain situations where the evidences cannot be characterized clearly. In this approach, updating the probability values is performed by Dempster's rule of combination. The rule is fairly straightforward.

Fuzzy Logic Approach

Lotif Zadeh introduced the fuzzy logic approach to describe sets whose membership criteria are imprecise [Zadeh, 1965]. A set is a collection of similar items. In the traditional set theory approach, a member of a set of 'complete wall' must be a completed wall. So an item is either in the set or not in the set, i.e., the wall is either complete or not complete (membership is 1 or 0). According to the Fuzzy Logic approach, an item is not simply in or out of a set, but has a degree of membership. Thus, a nearly completed wall is only marginally a member of the set 'complete wall'. Rather than representing a nearly completed wall by a fixed probability, it is represented by a number called a <u>membership function</u>. For example, the membership function for a 15/16th complete wall can be expressed as 1 [15/16] = 1), but for a wall that is 12/16th (or 3/4) complete the membership function is 0.1 ([12/16] = 0.1).

The Model of Endorsement

An analogy of the model of endorsement is a bureaucracy. For a piece of work in a bureaucracy to proceed from one state to the next, it is contingent on the endorsement of a bureaucrat. In a construction situation, before placing concrete, a foreman must have the endorsement of the foreman in charge of formwork and rebar placement. The job must satisfy certain requirements before it is endorsed by each person. In a place of bureaucrats or foremen, a collection of rules watches over the development of a line of reasoning. Each group of rules endorses a step in the argument if the conditions satisfy the specified requirements. Bureaucrats can require a job to be cleared by the person below him before signing it. Similarly, an endorser may require the condition of a rule to have a certain level of previous approval before it endorses the condition. In the construction data collection system, different sensors my act as individual endorses.

Comparative Analysis

The four methods discussed in this chapter have advantages and disadvantages, depending on the nature of the problem being examined. The following is a brief comparison of these methods based on the five most relevant attributes of automated construction data collection application: multiple sensors, real time update, sensor reliability, statistical manipulation of the production data, and developing and organizing the date base. The comparison is summarized in Table 1.

Table 1. Comparative Analysis of Different Approaches

Criteria	Bayesian Approach	Dempster-Shafer	Fuzzy Logic	Model of Endorsement
Multiple Sensors	0	0	X	0
Real Time Data Update	0	0	X	X
Consideration for Sensor Reliability	0	X	X	X
Statistical Manipulation	0	0	0	X
Developing and Organizing Data base	0	X	X	X

0 = Appropriate/Easy to Implement
X = Not Appropriate/Difficult to Implement

Conclusion

Considering the above criteria, the Bayesian approach is the most suitable method for an automated data collection system. The Fuzzy Logic approach and the Model of Endorsement are not suitable because they cannot satisfy most of the selection criteria. The Dempster-Shafer approach does not accommodate sensor reliability, and it is difficulty to develop and organize a historical data base for this method.

The Bayes theory is well established, while the other methods are quite new, there is still some degree of controversy among the researchers with respect to their validity.

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PRODUCTION MANAGEMENT CONTROL SYSTEMS

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1. DATA CODING

Production control data originates in transactions and coding is required to facilitate data allocation, processing, storage and retrieval for accounting purposes. This process also calls for a convention to be adopted by the organisation concerned which is readily understood by those who input, process and interpret output.

Progress control based on a programme of activities will facilitate the allocation of cost centres to an operational coding system. The activities used in network analysis, should adopt the same codes for inter-project comparison. Detailed site subcodes need not be standardised, but be available for reference in explanation of significant differences.

A coding hierarchy is suggested in the poster. The coding must provide uniformity for transfer and comparison of information between projects, while including all items of building construction, although only a few items may be used on any one project.

The structure of the coding system requires stratifing for overall (eg. subcontractor) or detailed (eg. plant) control, with reporting taking place at weekly or monthly intervals. A molecular coding which is capable of synthesis will reduce the number of items that have to be allocated codes on site. The coding hierarchy being a faceted structure should suit computer supported data files and their sortation.

1.1 Criteria for Coding Systems

Activity codes should be simple, concise and easy to interpret, with only essential and readily identifiable activities used. The main criteria for the analysis of coding systems are summarised as follows:

* Provide feedback on production performance.
* Classify all essential production activities so that variation in performance can be correlated with their location and situation.
* Classify resources applied in performance (labour, plant, materials, subcontractors and overheads).
* Be consistent in application from activity to activity, job to job and contract to contract, over a period of time.
* Give data base capability, through which to research values and particularly variations in value.
* Minimise coding discrimination at point of input.
* Be stratified in structure for reporting at various levels.
* Be faceted in structure for transfer and comparison of information.
* Be related to existing, nationally recognised coding.

2. ACTIVITY BASED SCHEDULES

If data drawn from activity schedules are appropriately coded then the computer can sort by operation sequence, trade, phase or element. Items having been sorted can then be listed The system can then respond to the manner in which a demand for information occurs. It was not until the advent of the site based micro-computer that the opportunity occured for the contractors to produce their own data, as with design and build, and investment in research offered a compensatory set of benefits.

3. WORK BREAKDOWN STRUCTURE

A systematic way of defining and identifying the division of production activity is required. Work Breakdown Structure (WBS) descriptions which are synonymous with network activities in a master or overall programme create the link between elements and their progress. By allocating resources one can then proceed to cost analysis.

3.1 Work package

The work package classifies the varying resource requirements of network activities. The dominating influence on classification will be work section, trade, construction form or material and location. A clearer statement of construction logic is produced for short-term or stage planning. It should aid measurement for progressing. The work package breaks down the WBS for example: a suspended concrete floor slab could appear under three work packages. It is important that work packages are defined in a standard form for transfer to a data base. Retrieval for future planning or estimating is important for the full economic utilisation of such a system.

A standard system of WBS will be required that has to be consistently applied to a firms work to reconcile accounts with and between jobs. It will be necessary for the level to lie between summarised general information (too crude for meaningful comparison from job to job) and too detailed a collection of information (requiring too much administration). The standard classification of network activities will include physical characteristics, resourcing and pricing data.

The WBS is at a summary level for reporting time and cost in relation to master programme activities. The work package is at a detailed level for allocating labour and plant or labour-only subcontract use of resources. An example of coding application for an insitu reinforced concrete internal wall is shown in the poster. Additional coding digits will be required for location and subcontract identification which are contract specific.

3.2 Criteria for WBS

The criteria devised for production control models based on a WBS are as follows:
* Each work package is to be identified as a network programme activity.
* The definition of each work package for each contract will have to be identified and agreed by all who use the

system (estimator, planner, contracts surveyor and site manager).
* Data will have to be collected in relation to the work contained in each activity.
* Activity data will have to include resources that are to be the subject of control (labour, plant, site overheads and materials in order of priority).
* The input of data will be site based and the output of information reported for both contract and company.
* Updating of work package content will be necessary for any variations in quantity or value.
* The coding of work packages in a standard form that is transferable from contract to contract for comparison.
* A statistical data collection facility in relation to an hitorical input to a data base (mean, range and distribution).
* Recognition that different criteria will apply to subcontractors who are controlled on site by performance and quality only.
* Easily understood by all those who use the system.

4. INTEGRATION OF TIME AND COST

The integration of a planning (time control) system and a budgeting (cost control) system gives rise to a number of problems. However cost information cannot be meaningful unless it is related to a time frame. The functions of a control system are:
to set standards (performance aims,
to measure output and compare it with standards,
to react to unacceptable deviations by signalling them,
to respond to signals by providing a basis for decision making in respect of any corrective action,
to facilitate that action and to review standards.

Control of time and cost can be integrated through work packages. These can be defined in a standard form for continuity of feedback. The objectives and functions of each contributing resource data system should remain unaffected. A work package will relate to a programme activity and to an estimate of cost for that activity. It is the presentation of processed data in the form of variances in time and cost that should assist managers in controlling projects. The control system should also afford strategic aims against which the satisfying of user needs by the system can be measured.

4.1 Criteria for project control

A model to represent the process of project planning, monitoring and control will have the following objectives:
* Model the projected work in terms of planned progress and cost using a common data base.
* Permit a comparison of actual progress and cost against planned.
* Identify the sources of variance and quantify them in terms of time and cost.
* Provide a means to explore operational decision making by allowing independent access at varying levels of detail.
* Record data on resource useage for performance and cost to facilitate future planning and estimating (historical records).
* Relate the flow of funds for

the project to the policy and performance of the organisation as a whole (accounting records).

* Recognise that user requirements are of paramount importance and that information from the system must be capable of influencing the decision maker.

5. COSTS AND BENEFITS

When a management information system is designed, installed and used the quantifiable benefits of the system are used to justify its cost. It may be possible to estimate the cost of collecting, sorting and analysing data but the influence of the system on managers' decisioning making will be difficult to measure. Costs can be accrued from purchasing computer hardware, software development costs or purchase of application software, maintenance and administrative overheads. Benefits can be from cost savings, time savings, improved decision making, increased income, early project completion, improved client relationships, increased employee job satisfaction, improved quality of projects and improved understanding of computer technology.

5.1 Tangible benefits and costs

When the introduction of a system is being considered its benefits and costs have to be determined. Some factors can be measured precisely, where others are intangible and require subjective evaluation. The final analysis of the present information system and the proposed alternatives compares tangible benefits and costs first. If a system alternative meets the requirements for return on the investment, then it is unlikely to be questioned. However if the selected system falls below the required level of return, less tangible factors have to be taken into account.

5.2 Intangible benefits and costs

The development of each potential system will uncover a number of intangible benefits or qualitative factors. Their impact should also be reflected in the management accounting of an organisation. Many intangibles can be regarded as indirect benefits that will have long term outcomes that can be quantified. Any system should offer increased income and decreased operating costs with better client service, facilitating increased sales to to present clients and potential ones. An interactive system should also benefit an organisation internally with better reporting and by allowing managers more time to plan and control activities. Perhaps the main benefit perceived from the use of computers in planning and control is a marketing one, which implies to clients that the contractor is progressive and up to date.

PRICE MODELLING WITHIN A COMMUNICATION FRAMEWORK

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ABSTRACT

Current price models are assessed within a communication framework in terms of their ability to handle uncertainty. A classification for evaluation is presented. Expert systems are seen as a suitable modelling environment for uncertainty minimisation.

INTRODUCTION

The success of any price forecast stems from the accurate and meaningful transfer of information and ideas between the client and the design team. However, problems can become manifest when interference is present within the communication process. This can be partly attributable to the imperfect knowledge available to the design team members in the early stages of a project, as well as differing perceptions held by individual design team members. This, in turn, impacts on the provision of design-to-price advice by the building economist.

In the communication process, the objective is to create shared meaning, a process whereby the message transmitted by the sender is decoded and clearly understood by the receiver. Feedback is one mechanism for establishing the degree of shared meaning achieved by the exchange. Interference is the result of 'noise' acting on one or more of the variables in the communication equation, causing a form of uncertainty that can lead to suboptimal communication.

Various communication problems exist within the building procurement process generally, and within the design stage in particular. Differing levels of abstraction, the unrepresentative manner by which price models purport to "model" the construction process, the nature and communication of uncertainty and its effects, are but a few.

In this paper, the writers discuss the provision of price advice during the design stage within the context of a communications framework. This, it will be shown, provides criteria for specifying and evaluating the characteristics of price models, and provides the means of evaluating the contribution made by expert systems. Finally, suggestions will be made regarding means of overcoming the problems of the communication of price advice in the servicing of the design function.

PROCESS OF COMMUNICATION

Prior to discusing the relevance of communication to an analysis of the provision of price advice in general, and price models in particular, it is necessary to provide a brief description of the communication process.

Drawing from the interpretations of human communication provided by Ruben (1979) and Thayer (1979), communication can be seen as a process; a continuous sequence of actions through time entailing a dynamic mutual exchange between participants. Bedford and Baladouni (1962) consider 'process' as 'the dynamic, on-going, ever-changing phenomenon of events and their relationship', whilst Fisher (1978) defines 'process' as the events or occurrences, actions and behavior, fundamental to human communication.

The components within the mechanistic perspective on communication, proposed by Fisher (1978), consist of the message (travelling across space from one point to another), the channel (the mode of conveyance of the message), the source and receiver, encoding and decoding (the process of transforming a message from one form to another at the point of transmission and destination), noise (the extent to which the fidelity of the message is reduced), and feedback (a message that is a response to another message).

Shannon and Weaver (1949) developed a linear model of information processing (see Fig. 1) to measure the correspondence of speech patterns. Although the Shannon/Weaver model was only concerned with the *fidelity* of information (a correspondence in pattern between input and output), and not the *reference* of information (Berlo, 1977), the model does indicate how noise (resulting in uncertainty), becomes manifest in the process of information transferal.

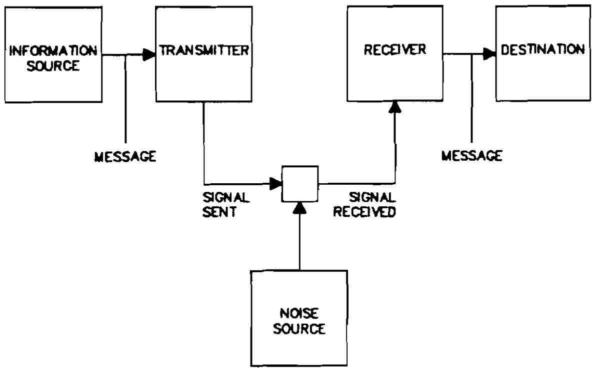

Fig. 1. Model of information transfer (Shannon and Weaver, 1949)

Feldberg (1975) offers three classifications of noise, namely, physical noise, psychological noise and personal defence mechanisms. Physical noise is self-explanatory. Psychological noise refers to noise caused by fear, anxiety, and insecurity on the part of the receiver. This psychological noise can stem from fear of the sender and/or the contents of the message, and serves to distort the communication process. The personal defence mechanism refers to the fact that many of the receiver's personal defences are based on deep-seated experiences and values, many of which may be affected by the relationship with the sender or on prejudices. The Feldberg (1975) model is represented in the accompanying poster diagrams.

MODELS OF COMMUNICATION

Various models have been developed in attempts to explain the communication process. Examples of such models include those developed by Lasswell (1948), Shannon and Weaver (1949), Newcomb (1953), Gerbner (1956), Westley and Maclean (1957), and Feldberg (1975). These models all view communication from different standpoints and, consequently, can be loosely categorised into one of the perspectives on human communication presented by Fisher (1978). For the purpose of this paper, communication is viewed as a transaction, in which the participants create shared meaning. The point to note here is that meaning is not something 'handed over' by one person to another, but is created between the participants to the communication process as they interact.

PRICE MODELLING AS A COMMUNICATION PROCESS

Research has shown (Hawkins and Soloman, 1989), that until fairly recently, the provision of uncertainty within price modelling has been described by practitioners in phrases such as 'the preliminary nature of the budget' or 'indicative appraisal only' or 'contingency allowance'. With time, clients' need for greater financial surety have placed pressure on quantity surveyors to produce more accurate forecasts, along with an indication of the certainty attached to that forecast.

Price models should be seen, not as messages *per se*, or the encoding of those messages, but rather as heuristic processes conducted prior to encoding. As such, the knowledge derived from the application of the heuristic processes is the essence of the information that needs to be encoded into a message for transmission to the receiver. Consequently, the encoding and transmission of the eventual message aside, the ability of the heuristic processes to facilitate the creation of meaningful messages is of paramount importance. No amount of skilful encoding and careful transmission of the message, although also important to the creation of shared meaning, negates the need for meaningful information to be gleaned from the application of an appropriate heuristical price modelling process.

The framework adopted for this analysis is similar to that provided by Raftery (1984), but is oriented towards a communication-based appraisal. In terms of a communication-based approach to price modelling, the desired characteristics of price models *vis-a-vis* their ability to facilitate meaningful communication should be examined in terms of a model/data/design/output interface.

In terms of such an interface, the modelling techniques utilised by the quantity surveyor are assumed to be appropriate to the stage of design at which they are applied. In terms of this criterion, price models are deemed to be capable of servicing the informational needs of design at the relevant stage of design, facilitating the attainment of the objectives of price planning and price control in it's interaction with the design process. As such, price modelling should not interrupt the flow of design, should be dynamic, enable the provision of proactive rather than reactive advice, and relate proposed solutions to previous, comparable solutions (Newton, 1982). In addition to these desired characteristics, Bowen and Edwards (1985) and Bowen *et al.* (1987) noted the need for models to display logical transparency in their ability to represent the workings of the modelling process, be representative of the process of building, and be stochastic in their representation of the variability associated with the building process.

Finally, price models applied at any one particular stage of the design process should be capable of being related to other models employed at different stages. In other words, models should display continuity of process throughout the design stages, preferably even being applicable to the post-tender stage of the project. It is assumed that the models employed by quantity surveyors in servicing the design function possess the majority, if not all of, these attributes.

The issue of the nature and availability of data to service the input needs of models is also important. The informational output of the architectural design function at each stage of the design process is deemed to be of a form suitable in nature and extent to satisfy the requirements in this regard of the price models used by quantity surveyors. These models are presumed to be capable of incorporating the probabilistic nature of price data, with the data *per se* being assumed to be representative of the building process i.e., the data should be process-biased. Quantity surveyors are believed to possess adequate amounts of price data, both in terms of quality and quantity, to service the needs of their price modelling techniques. Price indices, a prerequisite for the management of price data over time, must be current and representative of the systems they purport to represent.

The output of the price models must be appropriate to the informational requirements of the architect at the appropriate stage of the design process. Furthermore, this output should be probabilistic in nature, taking cognisance of the variable nature of the input data.

Having applied the appropriate (heuristic) model at the relevant stage of the design process, the quantity surveyor is charged with conveying the import of this information to the architect and/or client. This involves interpreting the results of the application of the heuristical process, encoding the essence of the information, formulating an appropriate message, and transmitting that message to the receiver in an suitable form. It is assumed that the quantity surveyor is aware of the responsibilities in this regard, formulating and transmitting the price messages accordingly. To minimise the effects of interference, both physical and psychological, the contents and import of the message should be explained to the receiver and an assessment of the level of shared meaning gleaned through the use of feedback mechanisms. These feedback mechanisms will not only inform the quantity surveyor whether or not the import of the message has been successfully decoded, but will provide the quantity surveyor with an indication of the extent to which the communique has influenced the receiver.

ABILITY OF PRICE MODELS TO HANDLE UNCERTAINTY

In assessing the ability of price models to handle uncertainty, consideration must be given to two factors. Firstly, the **potential** of the individual model *per se* to **induce** uncertainty as part of the heuristical process of price modelling must be considered. The second issue to be addressed is the **ability** of the price model to handle uncertainty emanating from the building process itself.

The writers have developed a classification for the assessment of models' ability to handle uncertainty in either form. This evaluation is presented in the accompanying poster diagrams. In terms of this classification, it is clear that traditional price models have considerable potential for the inducement of uncertainty into the heuristical process of price modelling. In addition, these models perform poorly in the treatment of uncertainty emanating from the building procurement process. Expert systems, seen more as a modelling environment than a model *per se*, appear to hold potential in the treatment of uncertainty.

CONCLUSION

It is evident that, in terms of a communication framework, there exists a great potential for uncertainty inducement by the application of traditional price models. Furthermore, these models' ability to handle the uncertainty emanating from the building procurement process is limited. Expert systems seem a suitable environment in this regard.

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TOTAL QUALITY PROJECT-MANAGEMENT

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Today, the purchaser of construction services and products is rarely a single entity with both land and money. Today, the construction client could very well be a corporate entity seeking new product facilities, government and municipal agencies involved in buildings, housing and infrastructure construction and renovation, developers seeking to building on land bought with borrowed money from investors, banks, financial institutions, etc. Although the client will rarely be the final user, one can divine the interests of the different parties involved, the corporate body with responsibilities to shareholders and customers seeks adequate profits, the financial instituting lenders and investors seek a good rate of return on their lendings and investments, the developer a reasonable profit and a financial partnership for future work, the government and municipal agencies obligations to meet societal needs at as little cost as possible and so on. In other words, all have different needs and aspirations coming together in a built facility.

Once a project is defined different specialists - architects, specialty engineers, contractors, etc. - at different stages - concept, design, construction, etc. - work together to bring about a satisfactory constructed entity be it an airport with runways and terminal facilities, buildings, housing, dwelling units, sewers, roads, etc. And, when the project is finished, all the specialists go their different ways to perhaps co-operate and maybe work together another time.

A truly successful project is defined as one that is completed within budget, on time and of good quality that satisfies all the functional requirements, is both innovative and imaginative and is also aesthetically phasing. One may conclude this to be a tall order, but it is an order that must be filled if one is to be successful and this requires integration of project construction activities through good management of and good communication amongst the many different specialists, all with their different loyalties to their different professions, institutions and organization and by good estimating. Traditional method of procuring construction and its many variations including construction management with its view of meeting technical, schedule and cost objectives is not sufficient to achieve client satisfaction.

Construction industry will have to adopt Total Quality Management just like the manufacturing industry. And here, Information Technology has a role to play. And IT is computers which the constructor has used ever since they first became available, to increase productivity. Indeed they were the first to use computers for structural analysis in design and for accounting purposes. Both manufacturing and the service industry have left construction behind with their systems for integrated material control, financial analysis for new product developments, production, etc. Information Technology (IT) can thus be used to integrate the total construction endeavour and the many construction actors by improved information flow leading to efficient and profitable enterprise, win-win for all and ready for the adoption of automation and robots. This paper discusses the current praxis in design, estimating, project and quality management.

Information Technology used properly and to its fullest benefit can be the central core which can relate design, estimating, construction drawings, the client requirements, costs, schedules, communication needs, correspondence, filing, etc. It can be a strategic resource to strengthen the relationship between the client and construction activities, and to develop new business, improve productivity and performance and enable new ways of managing and organizing. There is no reason why the different players from the site worker to the project manager, the client and the financiers, etc. cannot go to a central data base and obtain the right information or indeed input information that is then available to the others - without fear of error or loss. Everyone has current information at all times.

Although estimating of costs have been computerized for some time, the full benefits of the computer and information available have not been realized. There not exist databases with prices of completed projects so that it is possible to model costs, bills of quantities, provide estimates by and for trade groups, etc. Easy to use, user-friendly, software can be used for reliable rapid estimates of the cost of buildings during the initial stages of design – even at the line drawing stage. With minimal user defined data input, it is possible in a short time (in minutes) to determine the costs for all trades, bills of costs and quantities, cost breakdown by functions, etc. In France such software for use in PC's and Apple Computers is used for development of housing and buildings. The many software programmer provide costs and estimates to 'what if' types of questions related to layouts, sizing, etc. (Urien, 1987). It can be and is a strong marketing tool, especially as the difference between the actual and estimated costs has never exceeded a few percent. The paper by Jaggar (1992) presents a process of determining costs during the design stage of a project. It is a hierarchical system of cost modelling, so that the cost impact of design changes can be studied before final decision. The work by Gowri and Fazio (1992) develops a methodology for automating the conceptual estimating process. It is a database approach not unlike the many different French programmes discussed here. Gowri and Fazio do not provide any indication of the commercial availability of their programme.

Similar developments have happened in Britain where the Building Cost Information Service's (BCIS) data bank of cost analysis, indices, average building prices and background information can be accessed by on-line subscriber users. The BCIS has developed an Approximate Estimating Package which allows the user to use their own cost analysis in the BCIS format if desired, to produce elemental or total cost analyses. It allows manipulation of the cost plan as the design develops (Pegg, 1987). Similar developments of cost modelling are occurring in the petrochemical industry as well as the construction of institutional buildings.

A survey by the Royal Institute of British Architects found that although 59% of all practices were using computers, only 25% use 2 Dimensional CAD, 17% use 3D CAD and 13% use 3 Dimensional modelling. Auto CAD is probably the oldest program around. However, newer programs abound giving 3D modelling. With a three dimensional solid model on a computer one can obtain projected views at different stages of design and construction. This is beneficial not only for interaction with clients but also with other professionals whose input is necessary for both project design and completion. Indeed construction workers can use the 3D modelling to understand the 2D construction drawings with which they normally work. It goes without saying that 2D construction drawings can be easily extracted from a Computer 3D solid model. All kinds of visualization, axonometric, isometric or true perspectives are possible. The 3D model database can also be used to general Bill of Quantities. Interestingly, the British Standards Institution has developed guides for structuring of computer graphic information in its construction drawing practice series (BS 1192), etc. ArchiCAD (Strittmatter and Todd, 1991) is one such commercially available programme amongst others. The North British Housing Association Architects Department has been using both ArchiCAD and AutoCAD software for the preparation of design and contract drawings. They are planning to add a Walkthrough facility.

Bechtel, a construction design and build contractor has its own patented 3DM, WALKTHRU and construction CAE, and so has Stone and Webster and Fluor, etc. These software programmes allow the user to move through the Computer 3D solid model "seeing physical objects much as they appear in the real world". Real-time animated images, (are) "displayed in colour with perspective, (and) provide a life-like simulation of the user's movement". It is but a step to train construction journeymen to use the 3D computer models to plan and understand design details. In process work, where Bechtel are using these models it has proven to be a great boon to visualizing piping runs and co-ordinating erection sequences. It is also "used to visualize conceptual design alternatives, assist project management reviews, enhance client progress meetings, prepare videotapes, plan complex construction tasks, and assist constructability/ buildability and operability reviews" (Killen, 1991).

A 1989 study (Choi and Ibbs, 1989) by the Construction Industry Institute of its members to assess finance and operation benefits of CAD in design and construction came to the conclusion that the financial savings associated with better materials management, improved scheduling and reduced rework along justify CAD. 3D modelling takes it one step further in that it eliminates mismatch of dimensions and instructions. The system automatically updates all the myriad drawings, cross-sections, etc. for any single input. It can thus also be an excellent communication tool for project/construction management.

In the completion of a successful project, the design professionals and the contractors must work very closely and requires the three C's of management – co-ordination, communication and control. Co-ordination recognizes organizational form and defines the role of each separate entity/activity in the organization. Communication is the flow of information amongst the different entities as they effect each other, the contractors and the project team. Control is to ensure that the project is properly executed. The number of participants is the greatest on a project during the construction phase and the relationship amongst the entities very complex. Communication becomes paramount at this stage so that everyone works in cohesion towards the common goal of a successful project. New informal communication channels need to be developed and 3D modelling can be one such vehicle, to achieve integrated management and control.

There are many ways in which projects can be organized and delivered but at no time can the project management modify the design, direct work, or enforce project safety. However, what management can do, is facilitate pre-construction planning, improve communication, adjudicate, eliminate omissions or mistakes, ensure that specifications are met and undertake many other actions too numerous to list. All management can do is to give advice, control costs and like a good conductor orchestrate each participants actions. Technology can to a very large extent help mitigate the errors, misunderstandings and conflicts by providing clear cut information devoid of ambiguity by enabling the recording of charges and changes as and when they occur and in building a history of the records for later retrieval. In an ideal project world every participant from the environmental guardians to the client to the designers to the constructors to the user occupiers would know all there is to know so that problems will simply not occur. This, however, is not possible but technology can help irrespective of the organizational or delivery system. Integrated management through the help of IT is possible, judgements by IT however are not.

France has found major productivity gains by intervening in the area of interprofessional relations and modes of organization. Experimental work in 217 pilot schemes involving 9000 dwellings showed cost reductions of more than 13%, showing the importance of integration of the role of the different actors. The construction professions and public authorities realized that computerization of the building sector could play a key role in working towards integration. This was in 1985 when work was started on structuring Information Technology products and services by bringing together software publishers, companies research and development teams, research units and IT manufacturers. In 1990, in succession to the 1985 initiative, the French authorities launched the Communication-Construction programme which apart from the information technology hardware aspects such as Electronic Data Interchange structure is also examining 'qualification and requalification of trades in accordance with the development of new means of inter-professional communication; and valorizing the improvement in the quality of construction works and building project'. Vast areas are to be covered including 'construction site management, relations with materials and component suppliers, exchanges of graphical documents until such time uniform standards are adopted, capital flows, setting up and conceiving operations, etc.' (Ramelli, 1991). Fifteen pilot operations are expected this year.

Efficient storage, analysis and retrieval of information is absolutely essential in today's complex projects where money is a crucial restraint. As mentioned, the use of computers for capturing data and electronic data interchange is already being planned in France and other countries. One of the aims indicated in the British report Building IT 2000 "is for a greater integration of software in the construction team with all parties having access to project information in a central database". In today's high tech environment only a quarter percent of the construction industry revenue is spent on information technology/computers, substantially less than in other countries.

The fifties and sixties saw construction industry increases in productivity due to industrialization and pre-fabrication especially in the housing sector of the industry. High technical quality possible due to industrialization should have enabled the industry to produce top quality goods.

Today, the construction client is demanding proof and assurance of quality akin to industrial levels. Quality, quality management, quality assurance standards in production and installation leading to certification are covered by the ISO 9000-9004 Series, Quality Systems. The ECE has adopted these same standards, and with the advent of 1 January 1993 and the European Single Market there is a great movement to bring construction management to meet the new situation by achieving 'certification of the construction process' to the ISO standards. It is felt that this will be absolutely necessary in order to survive and in order to produce a high quality product.

Implementation of Total Quality will not only provide greater customer satisfaction but will increase profits and decrease losses. Quality can only be achieved by good and sound management. Studies indicate that Prof. Deming's 80/20 ratio also applies to the construction industry in that 80% of the causes of lack of quality can be attributed to management, by its careless implementation, inadequate preparation, improper use of materials, etc. (Cnudde, 1991). Studies also indicate a remarkable similarity across countries in Europe with respect to the causes of the lack of quality. The cost of the lack of quality in construction is estimated to be between 15% and 20%, of total construction volume or turnover.

Total Quality in the construction context can be defined as the satisfaction of the requirements of:

(1) technical quality specific to the use of the constructed facility (user needs);

(2) quality due to the technical specifications and drawings; and

(3) quality due to the environment (societal needs).

The work by Pepin and Gauthier (1992) provides a computerized means of rapid identification of hazardous materials and the different danger levels in the construction workplace. It is a PC based programme and very necessary with the use of all the new materials in construction.

Prof. Dr. Juran, one of the American gurus of quality defines it succinctly as "Quality = Fitness for use" which applied to construction and project management translates as 'Project Wide Quality Control' from the initial brief to delivery and in-use. Everyone in the process is involved, be it the client, the users, the architect/engineer/consultants, the contractor/the sub-contractors and so on. Responsibility for quality must be accepted by all the partners, in a project leading to Total Quality Project Management.

The quality of design affects the quality of construction and unlike the manufacturing industry which has standards for the components making up the final product the construction industry has none. To achieve quality in the constructed product/facility will therefore require a quality management system. A quality management system cannot be implemented in an organization with different players with different definitions of quality and different loyalties. The system of procurement necessary for quality will not favour the traditional method with its separate responsibilities but will require some variation of Design and Build and/or Manage. The most likely will be the combination that provides an integrated and continuous approach to design and construction. The project/construction management approach with the direct involvement of the client as a team partner will ensure the greatest quality. The paper by Bowen and Stretz (1992) nicely points out the problems of modelling price and the communication process. The problems of creating a shared meaning without which Total Project Management will not be possible are discussed.

The implementation of Total Quality is going ahead in many countries. The Norwegians have developed a 'five step development program' based on small increments. The Norwegian Quality Management System and Methods of implementation are translated into English, Dutch and Finnish and licensed in Holland and Finland. They have found economics to be the driving force for successful quality work. The process in step 1 requires a statement of objectives, including tasks, responsibilities and involvement in each task, time limits and budget. The next 2 'starts with small improvement programs where the main objective is to get rapid and measurable results'. Interestingly, the last step is the feedback of results obtained into the system itself (Sjoholt, 1991) so as to auto improve.

The Danes have developed a ten step process for quality in a joint effort by the organizations in the building industry, the companies and the public sector. It is instructive to note the ten steps:

1. The building owner is responsible, for ensuring that design professionals and contractors provide quality assurance for their work and services.

2. A Quality Assurance Manual and a quality plan for the project ensure order and systematization.

3. Systematization of design to prevent misunderstandings and mistakes.

4. Design reviews during the design stage of more than one design.

5. Designer/Contractor dialogue in order to better comprehend the design documents and execution methods.

6. Supervision plan by the building owner during the construction stage.

7. A control plan where the building owner states documentation required from the contractor of parts of the contractors quality assurance work.

8. Contractor's Quality Assurance Manuals and quality plan to ensure order and system in their quality assurance work.

9. Documented quality assurance as a set of documentation at building handover.

10. Operating manuals for the operation of the constructed facility.

The Danish experience indicates that 30% of projects lack a supervision plan, a control plan or a design/contractor dialogue. The worst situation is in the development of Quality Assurance Manuals and building operational plans (Olsen, 1991). Other entities in Europe including the UK are exploring ways and means of upgrading their quality aspirations because they see it not only as a competitive edge but a basic strategy for survival. The Danish system once again highlights the involvement of all the actors.

Echoes of the Danish ten steps appear in what a French construction company is doing to meet the quality challenge which is defined as "customer satisfaction", "internal customer satisfaction", and "satisfaction of company personnel". Their seven steps to quality are:

1) understanding the work schedule;

2) making sure the project matches the schedule;

3) defining the company's supply;

4) detailed preparation of work;

5) total conformity during execution;

6) transparent delivery; and

7) high-performance after-sales service, i.e., maintenance.

Continuous feedback is maintained to ensure Quality Progress (Anquetil, 1991). The steps are self explanatory.

The Hong Kong Housing Authority and the Singapore Housing Development Board as clients in conjunction with the Contractors Association as executors have introduced measures to improve quality both internally and externally with a view to contractor registration to ISO 9000 by 1992. All this indicates that Project Management as presently practised will change to recognize not only the quality requirements but also the change in organizational delivery that will be necessary. In today's construction, plant, equipment, machinery, components have to be designed, manufactured, transported, assembled on site before installation and use which requires detailed planning and co-ordination. Items have to be identified, ordered, delivered and stored until needed unless its JIT. Allocation of workers, materials and machines has to be optional and as per construction sequence. Schedules have to be generated, networks developed, initial activities and paths determined. Contracts and quality specifications have to be written, salaries, wages, financial requirements have to be documented and the list is endless. All this has to be on a common database, for project management to be effective. A comprehensive project wide IT will come into existence to achieve total quality in all aspects. The technological barrier is the structuring and coding of data (Waterhouse, 1992). There are predictions that this may come to pass in the mid

1990's but others say it is more like the beginning of the 21st century. 3D modelling may well be the tool which will make this feasible (Morris, 1991).

It will be noticed that apart from the definition of Quality by Prof. Juran, this paper has stayed away from defining it, and discussed the process of achieving Quality not unlike the ISO standards. This is deliberate as quality is related to cost/price, quality is consensus, quality is dependent upon time and place and so on. No mention has been made of any of the myriad other items related to construction such as risk, cost systems, pricing, contracts, measurements, claims, value engineering, earned value, etc. and the list is unending. Construction industry is as yet not ready to have definitive and distinctive marks of quality. Total Quality Project Management will bring about integration of all the diverse and disparate parts of the construction industry and put forth successful, functional and aesthetical constructed facilities, at acceptable costs, like the structures of earlier times that exist and are admired today. Instead of little independent successes there will be one big success as the result of interdependence and integration.

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SESSION 5F
PROJECT MANAGEMENT: CONSTRUCTION AND MAINTENANCE

Questions and Discussion

Question

Could you tell us who is using the (Planning Oriented Evaluation Technique) system now?

Rodney Howes

The system is being used on the Thames Water, the water company that really controls all the distribution in London. They are constructing a ring main around the periphery of the capital and this system is being used as a cost recording and control system for that project. It is also being used on a large tunnelling project in Denmark, to actually control and record costs, and we are certainly looking at other clients who are very interested in bringing this system forward.

Question

What would be the smallest type of project that this type of program would be fitted to? You are aiming at what type of project when you are developing such a program?

Rodney Howes

I think the point is, it can be used on quite small projects or on large projects. Something that I didn't mention just right now is the fact that we are developing multi project scheduling and the idea is to be able to schedule up to ten projects, using level one but then extending the level down another hierarchy to level four, and probably having up to ten macro links between the projects themselves.

Question

The other question, these projects that are using this program, are they using it for the purpose of validating the program or are they using the program to actually manage the project?

Rodney Howes

They are using it to manage the project, as it stands at the moment, but we do see that we will be able to apply this to testing the feasibility of certain designs, in terms of their constructability or buildability. We also see the possibility of analyzing cash flows, of doing investment appraisal, and so on. The company already link in to a computer aided taking off system, whereby the actual work in the project is quantified, and are looking at ways and means of linking that in with this system. The other dimension to that is that one of the contractors who is using a system has a full accounting system, payroll, materials, and so on, that they feel that they could link in with this in the point of view of integrated cost control.

Question

This has to do with the various activities, regardless of the distribution used, in order to run a Monte Carlo simulation. You have further to assume, either you have an independent set of activities or correlated and I assume that you have done independent. But in real life there could be correlation.

Mr. Howes

Yes, that is right.

Question
Lorna Tardif

Where does one get the expertise that you need to feed the systems?

Mr. Howes

Of course, I was alluding to the fact that in all expert systems, obviously you must have an expert and if we are looking for an expert in wine tasting or in music, we may find that person, but in a broad area such as project management, how do we find the expert and ensure that that expertise is, in fact, correct or certifiable? That is one problem. The second problem is, once we know this is an expert, how do we glean out of the expert his or her expertise so that that expertise can be used to build a knowledge base?

Comment

As for experts, there are groups out there like the Project Management Institute, that specialize in project management and have a whole 5000 members that are project managers in every kind of facility that you want. There is a lot of expertise out there. It is just a matter of asking them the questions that you want answered.

Professor Brandon

We have actually, in the U.K., built several expert systems, which are now being sold. The way that we did it, was to use a similar organization, in this case, the Royal Institution of Chartered Surveyors, as the vehicle for getting the experts together. We went for consensus. One of the problems, of course, is that the consensus may not reflect a particular manager or a particular view, of the way you should manage a project and where there is personal expertise involved, this consensus view in fact may not be an appropriate one. One particular example of that is, if you were choosing a procurement path using an expert system, the procurement path may depend on the expertise of the individual, rather than on a consensus view on which is the best procurement path. You would want to go down the procurement path in which this person is expert, so you have a problem there, and occasionally you get conflicts between the experts which, again, have to be resolved through discussion, debate, and what we did, we actually used a group for knowledge provision and there are a number of knowledge elicitation techniques, which I can't go into now. Then we had a control group which was completely outside the knowledge providers, and that group's job was to actually look at what the knowledge providers had created and who were very close to the development of that particular expert system and to check it and validate it as if it is in a code, without any prior knowledge of what was going on. You had a control group that was actually validating the knowledge that you had created. It is a very short process and we have a very large project, about £1 million actually to develop a methodology or formalize our methodology.

Professor Miroji

There is one technique that one can examine; you have to narrow the domain of knowledge by generalizing the knowledge. We could have fuzziness or disagreement among experts, so one way would be to have the knowledge elicited in a narrow and highly specialized field. Then, there are the techniques of knowledge elicitation that were mentioned earlier and that could be through a general introduction to all those that will be approached as experts and then a well structured questionnaire, and guide it so that we can ensure uniformity. There is no bulletproof vest for this sort of thing, we have to live with some uncertainty.

The second thing would be the domain itself. Sometimes even with all the effort, if you narrow it down, you are bound to find a lot of problems with that and, therefore, maybe we can have a case-by-case, case studies, rather than asking the experts and forcing them to follow a rule, which might not exist, and there I can see a promising application of newer networks, for example, where we can train it for a given case which can be taken from previous histories, previous projects and so on.

Question
Lorna Tardif

What are you researchers doing this stuff for? Can someone comment on that?

Rodney Howes

With regards to the POEM system, for a very small sum to cover postage and so on, you can have an evaluation copy of the full system. I think it self destructs after about two months. If one was to purchase a full system, then that will be refundable, if somebody wants to have a go at it to see what it was like and use it in the real world, there is an offer on the table.

Lorna Tardif

You are making a very kind offer, to make your system available at no charge to the industry, to at least allow it to make a decision, to invest in its acquisition. Is that enough?

Professor Halpin

I think that the obvious problem is the transfer of technology and what we have been talking about today is research, some of it very practice oriented, in fact, as Professor Howes has mentioned, already being used. The real difficulty is openness to try new things and there is always the problem of risk involved and, hopefully, as these systems demonstrate their power and cost effectiveness, this can be overcome.

The thing that comes to mind very quickly as a breakthrough type of thing that was accepted almost overnight, was the fabulous success of spreadsheet programs, the original Visicalc and later the Lotus 1.2.3., which I must say myself, when I first heard about this, I couldn't understand what it was used for, but it obviously hit a very resonant tone and so the problem of transferring it to use was a very small one.

In construction systems development of the type that we heard today, this tends to be more problematic and so I don't know what the answer to that is, but, hopefully, these systems will be more and more accepted.

David M. Jaggar

I think a particular problem is one of confidentiality. The work that I am going to describe a little later was for a large utility company, North West Water, but the data that we actually managed to get from them, and that they are now using, is in fact confidential and they are not prepared to let that data out. So, unfortunately, it is actually a hiding, a putting away of ideas in development, simply to get a market leadership in a particular piece of research or work. I think that is the problem that we are now facing in the United Kingdom, that of confidentiality and lack of willingness to give out information to a broader audience, to actually take ideas on board and develop it further, so I do see that as a particular problem that we are now facing.

Comment

I am neither industry nor government, so I am sort of very neutral and I am trying to be very kind in giving a response, but hopeful, in a sense that I teach in a very small technical college and I have been in private practice for many years before I began teaching. While I was in private practice, I never used any of these systems, for the simple reason I didn't have enough money. Naturally, I didn't buy any of these things, I didn't accept the test copies because I always felt sort of guilty that I didn't have enough money to buy the real thing. The only thing I can say is that we are now, I have suddenly moved into an environment where we very easily laid out $200,000 Canadian, to buy ourselves a very nice computer laboratory and I trained myself and I actually know what everybody has been talking about today. So the encouraging thing that I can say is that yes, these things are around, or lesser evolved versions of them are around, certainly Mac Project and Precision Estimating Light, in terms of construction costs, and we are teaching architectural technicians and possible architects and people who will go into the industry, to work on these programs, so that in the future, we are going to be getting a generation of people who are more comfortable with these kinds of programs and although maybe the people who are sitting here, are possibly the precursors of a very much more informed public who will gradually, with time, come to be users and I think that we are just the beginning.

Question

I am from the industry. If I wanted to make a metaphor out of the systems that are presented here, the level of accuracy or the level of sophistication of these systems, reminds me of the problem of having a watch that is accurate within a quarter of a second each year, but then the bus can be late a half an hour.

I don't think the problem is a transfer of technology, but a transfer of culture. Project management is not that widespread as a way of approaching the management of projects. I see many places, I have talked to a lot of construction contractors, you cannot even ask them to do a flowchart. They think that it is something out of this world, they think it is something that you use to launch rockets into space. I speak for this area, I don't know about United Kingdom or other places in the United States, where I know that it may be a bit more common, but there is a lot of effort that has to be put into spreading the culture around that these things can actually help and maybe better than the traditional ways of doing things.

The other thing is that, these systems do not take into account that the logic of what happens on the field is not necessarily the logic of the way things should be. Let's say that if you prepare a work breakdown structure for construction of a house, I have yet to see an example that takes into account the actual division of the work between trades, as is governed by laws or regulations or codes, so when you try and implement the WBS, you find that it is not really connected to actually how the work is spread around when it occurs, whether it is union or non-union.

The other note that I have here is that I don't think, as far as Canada is concerned, or Québec at least, I don't think there is enough incentive to adopt such techniques. There are too many barriers to want to improve productivity through the use of such techniques and there is not enough incentive to do it, either. The only one that I could think of would be maybe international competition in the construction industry, but we don't really see that here and it's not really a problem yet.

The problems that we have had, trying to implement a project management system in our office, we tried with Super Project, which is basically the latest version and a pretty good package and pretty cheap for what it is. What we found, that contrary to Lotus or other programs like that, Lotus gives you information, it just calculates things. Systems like that, you have to feed them a lot of information before they begin to be useful, which means that the entire organization that uses this kind of software has to have that information, has to be geared with an information system that collects all that information and has it stored or collected in a way that can actually be used by the system. If you have all the information, except this or that, then the entire system, in its full capability, is useless. It is not a system that you just start using. You have to gear up your entire organization around this type of tool. It is a bit like adopting the CAD system, you have to adapt to it.

Question

I was wondering if this national system of cost estimating for civil engineering projects is something that planners or developers might use, but it is also something that contractors might use, right? So the level of accuracy of the prediction that you are making of the costs, isn't it wholly dependent on the fact that you're building consensus on what the costs should be on both sides of the fence?

Professor Jaggar

Yes, it is reflecting the price and not on the project. As you said, it is nationally subscribed to and anybody can have access to that information. So it is not necessarily the right answer but, hopefully, by statistically looking at enough projects, you should be able to get some direction, to actually go in, and certainly on the building side, it has proved to be reasonably successful over the years in terms of predicting costs.

In terms of civil engineering, certainly in the United Kingdom, the ability to predict cost at an early stage, it is non-existent as far as I can find out, from the research that we have done. I am not suggesting they give us the right answer, but it might at least focus in the right direction to get some early idea of what the right cost might be in some civil engineering type projects.

Question

I am speaking of consensus, because often on the planners side, when you are trying to estimate the cost of the project, you also try to factor in how the contractors are going to estimate their own costs and on their side, how you have estimated the budget for the project to fit into that. What it seems to me that what you are doing, is that you are building a base for consensus on what the fair price is for any given work, a price that is all right for the planner or developer to pay and a price that the contractor is comfortable with and that he can make a profit with.

Professor Jaggar

In response to that, the contractor still submits his tender bid. All this is doing is, at the early stage, allowing the civil engineering organization, the design company, to get some idea as to what the cost might be when it comes in from the tender, based on different contractors. So it is not imposing a limit on the contractor, except it might well point the designers in a way that maybe says that tender is too high or perhaps too low, using a better handle to understand why it might be costing what it is.

Comment

I think one of the problems that industry has is, they keep on talking about the cost and that is why the confidentiality problem arises, but actually what we are dealing with is pricing, really not costs. Cost is something we all hide, price is something we all know, because price is in the public domain.

David Jagger

It is price that we are reflecting here, not cost. They are different, depending on the market, although in civil engineering, I think the relationship is closer between cost and price, because there is no real market view as to what the price of a reservoir might actually be, because there are not many of them. But clearly in building, the price mechanism works differently because you do have lots of skills and libraries and clinics and so on, so you can get some kind of opportunity cost idea.

Question

In Britain, are they using the divisions one through 16 that we are using in North America for determining our construction costs, or are you using a different system?

David Jaggar

I think we are using a different system; most of our cost information comes through from the quantities that was prepared on this nationally agreed standard.

Question

Is the standard divided into divisions like, and it's really standard throughout North America, zero is the contract, one is general, two is preparation of the site, three is concrete, four is masonry, five is steel, are you using that in Britain?

David Jaggar

We have our elemental breakdown, which the building cost information service evolved. No, we are not using that and, in fact, the reason we are not using that, is that these things are not functional entities. The cost of concrete or masonry is not really functionally dependent. What we are trying to find out is some supportable unit which we can use, for example, the cost of a wall, we can move that from one project to another and get some idea as to what it should cost in another project. A sub-structure, a superstructure, a roof or whatever, which is made of the various construction forms that go into concrete work, brick work, masonry, etc., we are using a functional kind of model which, hopefully, gives use portability.

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