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Forewords

Building pathology is a very ancient occurrence but it needs new approaches to be dealt with. The building stock has increased exponentially in the last century and there is need for faster and more efficient ways to inspect, diagnose and maintain/rehabilitate current buildings with pathology problems.

The challenge is therefore that of benchmarking and systemizing all procedures linked with building pathology and use advanced tools, knowledge and technologies to improve today's practice, by reaching out to professionals in the field.

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Introduction

Commission CIBW086's scope is specifically focused on the analysis of all the pathological phenomena concerning buildings, their diagnosis and the resulting maintenance and rehabilitation actions and costs. The objectives of the Working Commission include:

- Reactivate the Working Commission with the recruitment of new active members from a wide variety of countries and from existing CIB student Chapters;
- Systemize knowledge concerning building forensic engineering: anomalies, diagnosis methods and maintenance/rehabilitation techniques;
- Provide information to assist technicians during the inspection, diagnosis and management of buildings;
- Systemize and standardize procedures and create decision criteria involving building pathology and all its consequences;
- Analyse the uncertainty/risks involved in pathology diagnosis and mitigation;
- Help estimate costs resulting from building pathology;
- Actively reach out to other CIB Working Commission involved in related areas;
- Disseminate these findings within the building community.

The current CIBW086 work programme is defined as follows:

- Making of a joint glossary of all relevant terms in building pathology, diagnosis and maintenance/rehabilitation;
- Making of an anomalies Atlas including different building components and condition levels;
- Benchmarking of good practice international case studies concerning building pathology;
- Development of a report on New Trends on Building Pathology.

Output:

- Publication of a Research Roadmap on Building Pathology;
- Publication of a report with a joint glossary on building pathology and an anomalies Atlas;
- Active participation on the organization of a Building Pathology International Conference;
- Publication of report on New Trends on Building Pathology.

A Research Roadmap for CIBW086

The CIB Secretariat has created a CIB Roadmap in order to assist the working commissions to create their own roadmaps, to become successful, sustainable, focused on a strategic plan and assist the improvement of the worldwide construction industry, as seen in Figure 1. The CIB research roadmaps provide authoritative guidance and support for national and international research bodies and funding agencies.

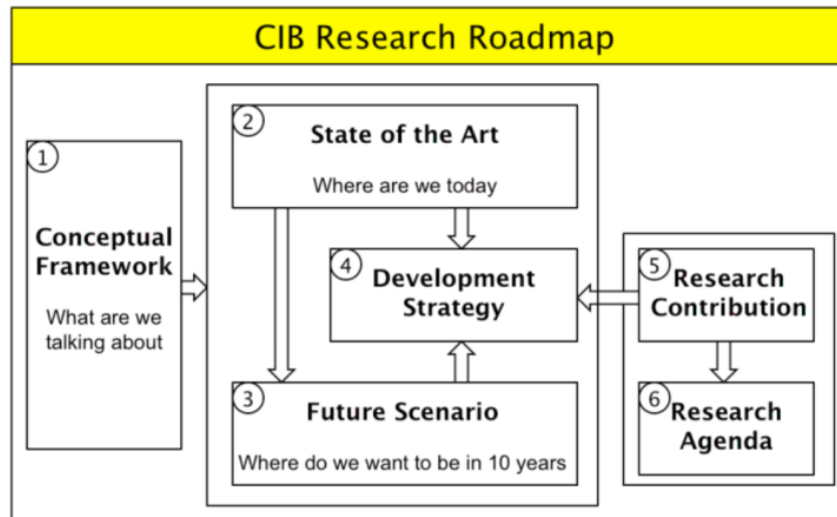


Figure 1: Outline of the Research Roadmap

As the illustration indicates, creating a CIB W086 Research Roadmap requires the following questions to be addressed:

1. Conceptual Framework:

What are we talking about? This question includes the typical: What are the issues, how are these interrelated, what influences all of this, who are the stakeholders, what are the relevant areas of expertise, what are the characteristics of relevant systems, processes, and technologies?

2. State of the Art:

Where are we today? This question includes: State of technology, best practices, international variations, perceived problems and the world's leading centres of expertise.

3. Future Scenario:

Where do we want to be in ten years? The stakeholders' vision is described in section *Future Scenario: Where Do We Want to Be in Ten Years?*

4. Development Strategy:

This section includes: What is needed in terms of knowledge, information, tools, concepts and applications to enable the respective systems, processes and technologies to be developed over time?

5. Research Contribution:

In section *Research Contribution* we describe how W086 research contributes to the development strategy and what the requirements for research are in order to make that contribution.

6. Research Agenda:

Section *Research Agenda* concludes with the agenda for W086 research worldwide. That will include areas of science and technology development, required sequences of development, priorities, international cooperation within the research community, cooperation between research and practice.

1. Conceptual Framework:

What are we talking about? This question includes the typical: What are the issues, how are these interrelated, what influences all of this, who are the stakeholders, what are the relevant areas of expertise, what are the characteristics of relevant systems, processes, and technologies?

The state-of-the-art report from 2013 and 1993 discusses some of the following issues [1-7]

CIBW086 is dealing in general with the **building pathology** issue defined as the systematic study of the nature of building failure and its causes, processes, development and consequences, during the life cycle period. Building pathology provides an undoubted evidence because it involves buildings that have actually been constructed and are being tested in use in a real world environment, rather than being tested or modelled in a laboratory or computer simulation [1]. The practices of building pathology reduce the superficial judgement of buildings and increase the accuracy of this diagnosis, reducing repeated errors from design, construction and/or usage phases. It also helps the professionals to create mechanisms to prevent failures, to apply adequate repair methods and also to improve design and performance of future buildings, constructive solutions and materials [1-5].

CIBW086 is basically concerned with learning from the past and current building failures and encouraging the systematic application of that knowledge to the design, construction and management of buildings. Building pathology is useful to the science and practice of building as medical pathology is to the science and practice of medicine [1]. Building pathology provides guidance to prevent, to repair, to improve design and performance of future buildings. This information is also useful for stakeholders who are involved in the buildings' management and rehabilitation in order to implement suitable interventions, considering the knowledge gained from building pathology experience.

In order to provide an economic and effective remedy to building defects, it is essential to properly identify the causes in order to address the problem. Building pathology should not only offer information to direct involved parties but also information on matters like liability and insurance, costs of defects, quality assurance, regulations and the building community in general. The additional costs arising from building defects affects all the stakeholders of the construction sector: owner, insurance companies, regulatory authorities, builders, architects, engineers, and also the loss of confidence in the industry. Moreover, additional costs can influence the occupant's health or cause accidents jeopardizing life and limb, either during the building's construction or its operation [2].

2. State of the Art:

Where are we today? This question includes: State of technology, best practices, international variations, perceived problems and the world's leading centres of expertise.

The study of building pathology has been performed practically since constructions have been erected by Mankind. Learning was acquired mostly on a trial and error basis with great losses of human and material resources. Nowadays, this learning procedure cannot be accepted anymore and a scientific stance must be adopted.

The growing complexity of constructions, the lack of knowledge systematization, the absence, in many countries, of an effective system of insurance and guarantees, the speed required from the construction process, the new architectural concerns, the new materials application, and the absence in the project team of specialists in building physics and technology are fundamental causes of buildings non-quality [3-4].

In order to accurately access building pathology data bases, it is necessary for countries to commit and make an added effort to establish guidelines for data collecting systems, as well as observations for monitoring the evolution of building defects. In building pathology, one of the most important premises is to “learn from past mistakes”, by carefully analysing each case, determining its causes and elaborating pathology reports, which will allow the acquired knowledge to be available in the future, hopefully contributing to the reduction or elimination of those defects. However, collecting and assessing this kind of data is expensive and time consuming, which explains why most countries have not yet implemented any system whatsoever. Also in many countries no mandatory insurance systems are implemented [6].

But there are successful examples that allowed an overall view about the manifestation of building defects, regarding its most common causes, construction elements affected and accountable stakeholders in the building process [5]:

- The French experience - The Agency Quality Construction in association with the “Foundation Excellence SMA” has developed the SYCODÈS in 1986, a database of several detailed pathology reports;
- The Norwegian experience - The Norwegian Building Research Institute have provided collecting data since 1964, using the results to elaborate Codes of Practice and Building Research Design Sheets. In 2006, The NBI merged with SINTEF, becoming a part of SINTEF's Building Research AS.

The continuous process of evolution and learning from past mistakes must be supported by a vast and reliable database. Various countries have created their own database based on data collected throughout the years, organizing them into pathology catalogues in order to identify the most common defects found in buildings, analyse and diagnose its causes and propose some suggestions/recommendations for its attenuation, based on illustrations/examples [6]:

- Catalogues in printed form - “Defect Action Sheet” and “Good Repair Guide” from BRE; “Anomaly Repair Records” from LNEC; “Cases of Failure Information Sheet” from CIBW86 report;

- Catalogues on-line - “Fiche Pathologie du Bâtiment” from AQC; “Imparare dagli Errori” from Milan Polytechnic; “Maintainability of Buildings” from NUS; Website Patorreb from Building Pathology Study Group - Patorreb.

Since 1997, the CIBW86 commission held several meetings/conferences in different places all over the world (UK, Sweden, Canada, Portugal, New-Zealand, France, Italy, Turkey, Spain) on this subject which was attended by the best international experts. Most of these results are published in the proceedings and in CIBW086 publications [4]:

- CIB Report 155, Building Pathology - A State-of-the-art report, 2013, ed. Freitas, V.
- Collected papers on building technology, 18th CIB World Building Congress, May 2010, Salford, UK
- Construction in the 21st Century: Local and Global Challenges, Milan, Italy, Proceeding, 2006
- 2nd International Symposium on Building Pathology, Durability and Rehabilitation, Lisbon Portugal, 2003, Proceedings;
- CIB Report 155, Building Pathology - A State-of-the-art report, June 1993.

During the last years, a number of significant publications related to Building Pathology were presented in the proceedings of International Conferences on Durability of Building Materials and Components, the last ones in Oporto (12 DBMC), São Paulo (13 DBMC) and Ghent (14 DBMC). In March 2015 there was the 1st International Symposium on Building Pathology (ISBP2015) - Problems on Building Pathology - The Research and the Practice, providing a platform to exchange knowledge from academia, industry and research institutions.

Some special issues and books on Building Pathology are reported in recent Publications:

- Failures in Concrete Structures: Case Studies in Reinforced and Prestressed Concrete, by Whittle, R.; CRC Press, 2018 [8];
- Strengthening and Retrofitting of Existing Structures, Editors: Costa, A.; Arêde, A.; Varum, H., Springer, 2017 [9];
- Residential Building Inspection: A Step by Step Guide, Brinkman, M.; ICC International Code Council, 2017 [10];
- New Approaches to Building Pathology and Durability, Editor: Delgado, J.M.P.Q, Springer International Publishing, 2016 [11];
- Case Studies of Building Pathology in Cultural Heritage, Editor: Delgado, J.M.P.Q., 2016 [12];
- Recent Developments in Building Diagnosis Techniques, Editor: Delgado, J. M.P.Q., 2016 [13];
- Building Inspection Manual, by. Schmid, K.F.; Momentum Press, 2014 [14];
- Durability of Building Materials and Components, Editors: de Freitas, Vasco Peixoto, Delgado, J.M.P.Q, Springer International Publishing, 2013 [15];
- Structural Rehabilitation of Old Buildings, Editors: Costa, A.; Guedes, J. M.; Varum, H., 2013 [16];
- Understandings Building Failures, by Douglas, J; Ransom, B.; Routledge; 2013 [17];
- Hygrothermal Behavior, Building Pathology and Durability Editors: de Freitas, Vasco Peixoto, Delgado, J.M.P.Q, Springer International Publishing, 2012 [18]

- Practical Guide to Diagnosing Structural Movement in Buildings, by Holland M., Wiley-Blackwell, 2012 [19];
- Failure Point. How to Determine Burning Building Stability, by Hill, H.J., PennWell Corporation, 2012 [20].

There are no direct standards on building pathology. But they can be related with other CIB Commissions publications and standards, such as CIB W80 and CIB W70. For example, Building Pathology is the basis for series ISO 15686 “Buildings and constructed assets - Service life planning” standards.

3. Future Scenario:

Where do we want to be in ten years? The stakeholders' vision is described in section Future Scenario: Where Do We Want to Be in Ten Years?

Today's building pathology studies should be oriented to systemize the knowledge from the past, the good previous experiences but also focused on the new challenges of construction and rehabilitation industry. There is a growing need for more ready access to available knowledge, based on new technologies, and more feedback but in a structured and continuous way. The complexity of buildings is increasing and new materials and constructive systems are being applied in new or existent buildings. The monitoring of buildings performance under real exposure conditions should be the basis of new trends in this field.

Nowadays a new concept of sustainable development, primarily based on the quality of life and lower impacts on the natural environment, increase the importance of having specific intervention criteria and methodologies based on a building pathology knowledge. The early detection of building failures can help in reducing conflicts and costs [1, 3, 4, 5, 7].

The future scenario should be based on the effective practice of building pathology knowledge by stakeholders who are involved in the buildings' management and rehabilitation. Designers should also have building pathology data and feedback to improve the design of constructive solutions and materials, taking into account the performance in real exposure conditions and the effects on the users and on the environment.

Several publications are available on databases such as ICONDA or published in scientific journals, however this knowledge is not readily accessible to practitioners. Therefore, building pathology data gathering should be available to allow a better buildings monitoring, optimizing global buildings costs and reducing early-stage conflicts between stakeholders.

Building pathology should have new insights about the ICT technology, internet of things, uncertainty and risk analysis, advanced diagnosis techniques and forensic engineering approaches, with a consensual approach in the scientific and technical community.

4. Development Strategy:

This section includes: what is needed in terms of knowledge, information, tools, concepts and applications to enable the respective systems, processes and technologies to be developed over time?

The development strategy focusses on how building pathology diagnosis is going to move forward in its never-ending quest to improve the quality of the built environment. The following guidelines development are needed:

- Data about building pathology is not equally available in different countries. Therefore, it is important to create a common International Pathology Database, which can be used by different stakeholders, based on damage atlas [21] and on a systemized glossary of terms used in pathology, diagnosis and maintenance/rehabilitation of buildings;
- The best practice examples on building pathology are needed and should be synthesized in a report showing the methodologies, practical and applied studies that can be of use to practitioners;
- Advanced methods and forensic engineering approaches should be discussed in order to understand the point of view of all professionals involved in the process of buildings and make scientific developments, in the area of building pathology more accessible and easier-to-apply in practice based on ICT Technology and statistical methods;
- Strong link to other commissions (CIBW80 and CIBW70) should be followed to establish a clear relationship between building pathology and subsequent maintenance/rehabilitation actions, through a set of rational criteria based on uncertainty and risk analysis;
- Environmental sustainability through Life Cycle Assessment and economic sustainability through Life Cycle Costing should be integrated in building pathology development methods.

5. Research Contribution:

In section Research Contribution we describe how W086 research contributes to the development strategy, defined in the previous section, and what the requirements for research are in order to make that contribution.

In the previous section we illustrated our development strategy. To use inspection and diagnosis of building pathology as the stepping stone to better manage the welfare of the built environment and namely base all decisions concerning its maintenance/rehabilitation on rational technical-based criteria. It is envisaged that access to research on Building Pathology will be offered through the web. As well, guidelines will be prepared regarding the use of different inspection and diagnosis techniques, including the most recent ones. The link between these areas and those of maintenance/rehabilitation will be clearly established. A closer bond with the professional community, namely using forensic engineering approaches, will also be a goal of the works of the Commission.

CIB W086 research is clearly contributing to that, mostly on the definition of methods and tools to update building pathology to the actual needs in construction and rehabilitation industry. The developed knowledge will also constantly be tested for practical application by the different stakeholders of the building process. The research activity should be developed using private or public funds, national or international ones, as for example European Framework Programmes as Horizon 2020. A close relationship between CIBW86 (existent and new members) will be needed to gather information for an international building pathology database and to illustrate good practice international case studies.

6. Research Agenda:

Section Research Agenda concludes with the agenda for W086 research worldwide. That will include areas of science and technology development, required sequences of development, priorities, international cooperation within the research community, cooperation between research and practice.

The new research agenda is to be defined with the contribution of CIBW086 members, starting from the development strategy compared with the research contribution of CIBW086 as defined up to now.

1. Conduct basic and applied research on Building Pathology using public and private funding in the construction sector to develop state of the art practices;
2. Generate research funding from practice with the relevant building process stakeholders to do research in Building Pathology;
3. Have PhD and MSc students develop their work on Building Pathology, diagnosis and maintenance / rehabilitation;
4. Partner with different research groups to proliferate research on Building Pathology. Create partnerships with active research and the CIB to self-fund CIB W086 activities and research, to be self-sustainable;
5. Develop State of the Art Reports on worldwide advancements and new trends on Building pathology;
6. On the base of the results of the base and applied research activities to develop general glossary of all relevance terms and systemize benchmarking of good practice international based on practical examples, to help designers and other stakeholders in choosing methods and applying them, in order to allow a Building Pathology-based approach to become mainstream in the design and management of built assets considering durability, service life and maintenance;
7. To develop stakeholders' survey and using meetings web questionnaires or webinars about needs and the actual application of Building Pathology methods could be useful to check priorities and acceptance about such methods and to help bridge the gap between academic research and industry practices;
8. Hold an annual CIB W086 meeting, to present and discuss the latest results of research in Building Pathology, based on a revised Work Programme;
9. Hold W086 meetings in different countries to expose and assist different countries in implementing Building Pathology;
10. To participate actively and publish research results in the most relevant International conferences on Service Life Prediction and planning and durability as: DBMC International Conferences on Durability of Building Materials and Components (DBMC), CIB World Congress, SBE International Sustainable Built Environment Conferences, International Symposia on Building Pathology (ISBP);
11. Define International preferred journals to publish research results for the practitioners in the construction industry, document information in the construction industry;
12. To strengthen liaisons with the relevant linked CIB commissions as:
 - CIBW080 Prediction of Service Life of Building Materials and Components
 - CIB W 70 Facilities Management and Maintenance
 - CIB W116 Smart and Sustainable Built Environments
13. To participate actively in creating international and national standardization activity in Building Pathology and on relevant Work Committees as: ISO TC 59 SC 14 Design life, ISO TC 59 SC 17

Sustainability in buildings and civil engineering works; CEN TC 350 Sustainability of construction works.

14. To promote CIB W86 meetings within the following events:

- CIB WBC 2019 - CIB World Building Congress - Construction Smart Cities - 2019, 17-21 June, The Hong Kong Polytechnic University, Hong Kong, China
- 8th REHABEND, Granada, Spain - March 2020
- 4th ENCORE, Lisbon, Portugal - June 2020
- 15th DBMC, Barcelona, Spain - 15th International Conference on Durability of Building Materials and Components - 2020
- 2nd ISBP 2021 - 2nd International Symposium on Building Pathology, Porto, 2021.

Conclusions

The study of building pathology has been performed practically since constructions have been erected by Mankind. Learning was acquired mostly on a trial and error basis with great losses of human and material resources. Nowadays, this learning procedure cannot be accepted anymore and a scientific stance must be adopted. Now the time has come to analyse how building pathology diagnosis is going to move forward in its never-ending quest to improve the quality of the built environment.

Building pathology should have new insights about the ICT technology, internet of things, uncertainty and risk analysis, advanced diagnosis techniques and forensic engineering approaches, with a consensual approach in the scientific and technical community. It is also important to create a common International Pathology Database, which can be used by different stakeholders. Best practice examples on building pathology are needed for benchmarking purposes. Finally, a strong link to other commissions (CIBW80 and CIBW70) should be followed to establish a clear relationship between building pathology and subsequent maintenance/rehabilitation actions, including environmental and economic sustainability during the life cycle of the buildings.

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Annex 1: Authors' biography



Jorge de Brito is a Full Professor at Instituto Superior Técnico and Head of the research unit CERIS (2017-2018). He is a civil engineer, with MSc in Structural Engineering and PhD in Civil Engineering, Bridge Management Systems. He is the coordinator of CIBW86, co-coordinator of CIBW80 and member of CIBW115.

The publications in the field of construction and civil engineering include: 7 books (all international); 35 book chapters (6 national and 29 international); 14 book and special issues editions (9 national and 5 international); 793 journal papers (306 national and 487 international); 3 patents (national); 515 reports (234 technical-scientific and 281 advanced consultancy); and 564 congress papers (304 national and 260 international).

The supervision activities, include: 7 Post-doc researcher; 42 PhD students; and 170 Masters students.

Editor-in-Chief of the Journal of Building Engineering since 2014; Associate Editor of European Journal of Environmental and Civil Engineering; Editorial Board Member of 44 journals; Referee in 255 international journals. Participation in 29 competitively-financed research programs (8 international), seven of which as Principal Investigator



Inês Flores-Colen is an Associate Professor at Construction Section, Department of Civil Engineering, Architecture and Georesources, University of Lisbon and research member at research unit CERIS. She is a civil engineer, with MSc and PhD in Civil Engineering. She is the secretary of CIBW86 and member of CIBW70.

The publications in the field of construction, pathology and maintenance include: 7 book chapters (3 national and 4 international); 50 papers in international journals; 1 patent (national); 60 reports (technical-scientific dissemination and institutional consultancy); and 35 international congress papers.

The supervision activities, include: 2 Post-doc researchers; 7 PhD students; and 75 Masters students.

She is the referee in 20 international journals and participates in 5 competitively-financed research programs (1 international), two of which as Principal Investigator.

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