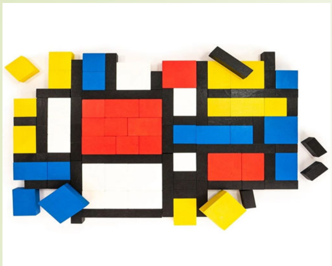

Construction Industry Challenges and the need for Innovation

Prof. Makarand (Mark) Hastak, PhD, PE, CCP, CRIS

Professor and Dernlan Family Head of Construction Engineering & Management
Professor of Civil Engineering

President CIB
International Council for Research and Innovation in Building and Construction

Purdue University, USA

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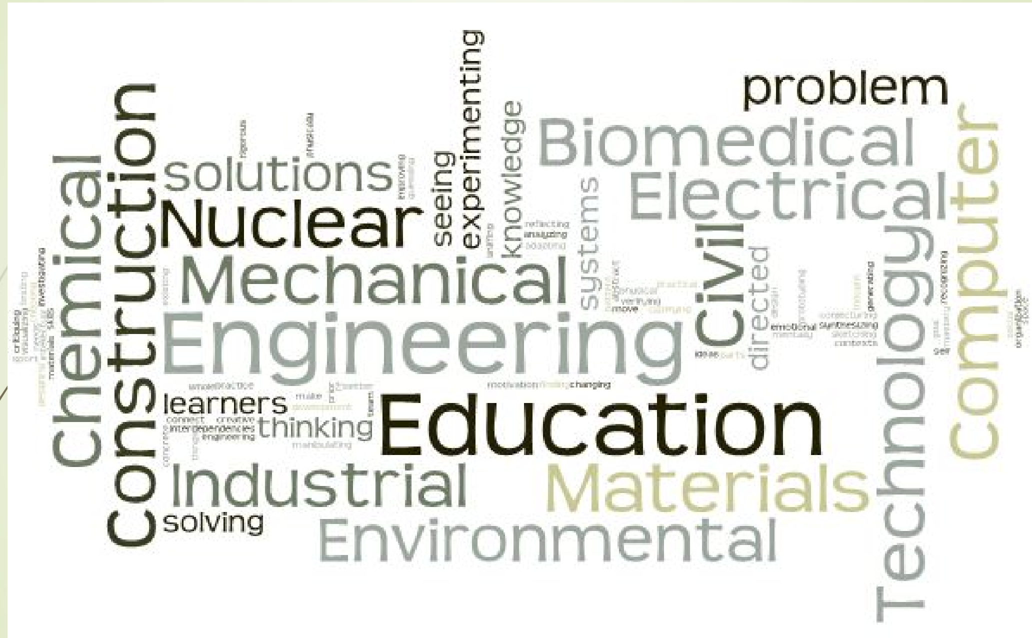


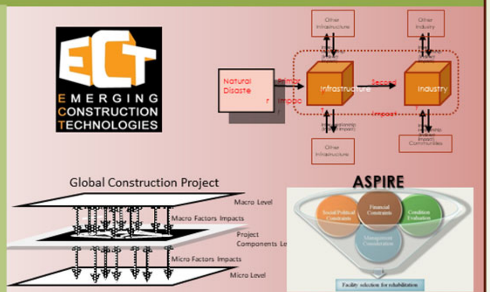
Purdue College of Engineering

13 Schools and Divisions
Aeronautics and Astronautics
Agricultural & Biological
Biomedical
Chemical Engineering
Civil Engineering
Construction Engineering and Management
Electrical and Computer
Engineering Education – First-Year Engineering/Multidisciplinary/Interdisciplinary
Environmental and Ecological
Industrial
Materials
Mechanical
Nuclear

RESEARCH IMPACT - SPARC Lab

RESEARCH AREAS

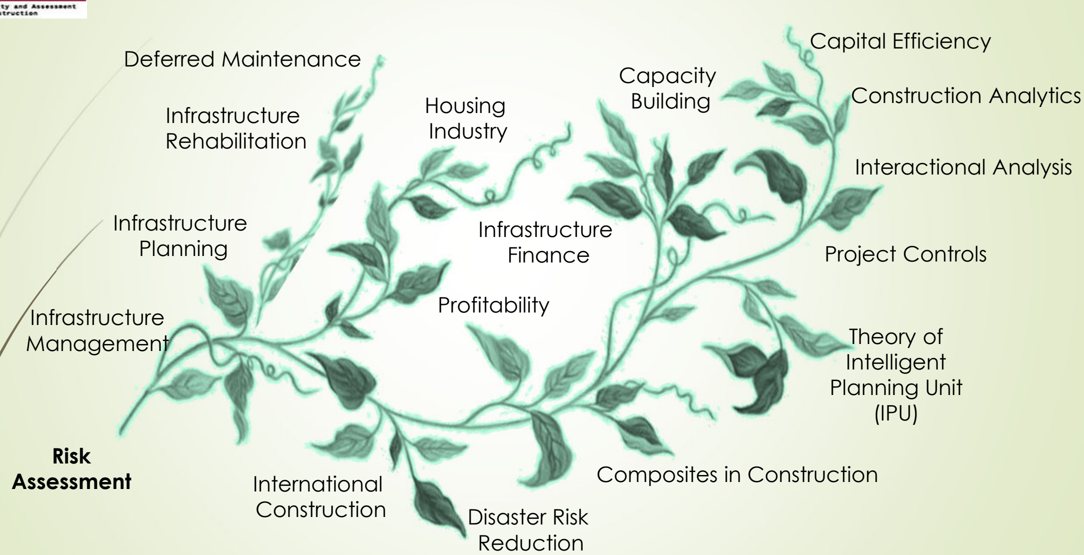
- Infrastructure Management
- Disaster Risk Reduction
- Profitability and Strategic Planning
- International Construction
- Contemporary Issues
  - Housing Industry
  - Intelligent Planning Units (IPU)
  - Composites in Construction
  - Construction Analytics
  - Interactional Analysis



BENEFITS TO THE INDUSTRIES

- Capital Rehabilitation Planning
- Deferred Maintenance
- Post Disaster Housing
- Disaster recovery/rehabilitation of industries/ communities
- Resilience and Capacity Building
- Profitability of construction firms
- Dynamic interactive risks in global construction
- Composites in Construction
- Protocol for Construction Analytics
- Theory of Intelligent Planning Units (IPUs)

Solutions for **P**rofitability & **A**ssessment of **R**isk in **C**onstruction



6

History of Construction

***Neolithic buildings in Skara Brae**, Scotland, a UNESCO world heritage site* (9000 BC to 5000 BC). Tools – mostly stone, bone etc.)

Archaeological Ruins at Moenjodaro (present day Pakistan)
whc.unesco.org/en/documents/108235

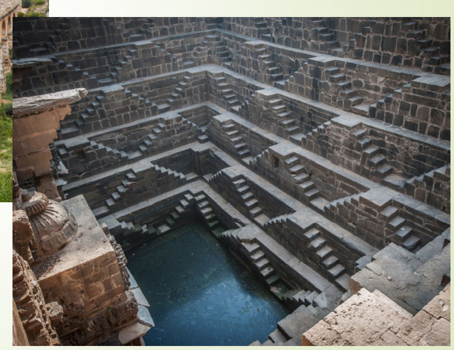
3000 BCE
Water proof great bath, sanitation, water delivery system throughout the city 5x Vatican City. City layout on a grid pattern….

https://www.britannica.com/place/Great-Bath-Mohenjo-daro

History of Construction

Pyramids of Djoser (2630 BC). Tools – over 100,000 slaves worked on these pyramids over years

The Roman Aqueducts – Italy (145 BC). used to bring in water for the Roman Empire using gravity flow



AchitChand Baori – India (900 AD). Constructed to solve the water problem, v-shaped structure 13 stories high, 100 ft deep with 3500 perfectly level steps

https://www.readersdigest.ca/travel/world/10-architectural-wonders-ancient-world/
https://engineering.rowan.edu/_docs/civilenvironmental/cee-materials-reading-assignment.pdf

History of Construction

Sacsaywaman, Peru (900 – 1200 AD)
A stone fortress in Cusco, Inca Empire. Stones weighing ~200 ton
https://www.readersdigest.ca/travel/world/10-architectural-wonders-ancient-world/

Great Wall of China, (7th century BC)
A great engineering feat in history, 21000 Km long.

A Roman street, Pompeii (300 BC)
https://en.wikipedia.org/wiki/Roman_roads

History of Construction

Golden Gate Bridge, USA (1937)
1.7 miles long.

Burj Khalifa, Dubai (2010)
Tallest building in the world, 828 meters high with 160 stories https://www.ice.org.uk/news-and-insight/ice-community-blog/august-2021/wonders-of-engineering-world

Three Gorges Dam (2003)
181 meters tall

The Millau Viaduct, France, 2004
At 343 meters the tallest bridge in the world

History of Construction – use of Material and Technology

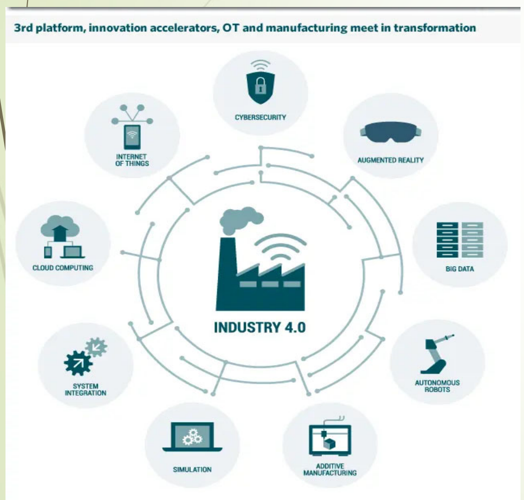
- Earthen Bricks
- Stone
- Wood
- Copper/Bronze
- Iron/Steel
- Mortar/Pozzolans

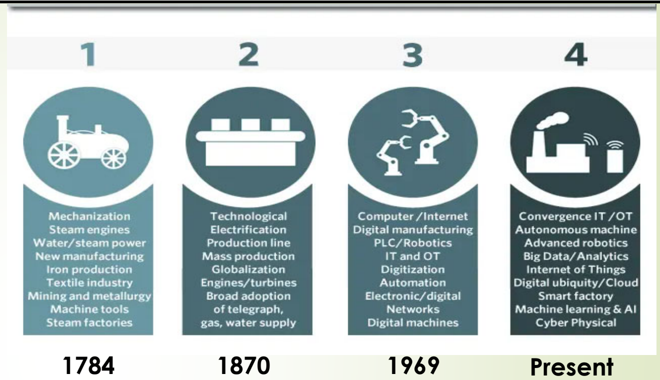
History of Construction – Challenges faced

- Labor intensive,
- Manual tools,
- Rudimentary technology,
- Environmental issues,
- Disease
- Safety

Construction Now

Construction 4.0 – Digital Transformation



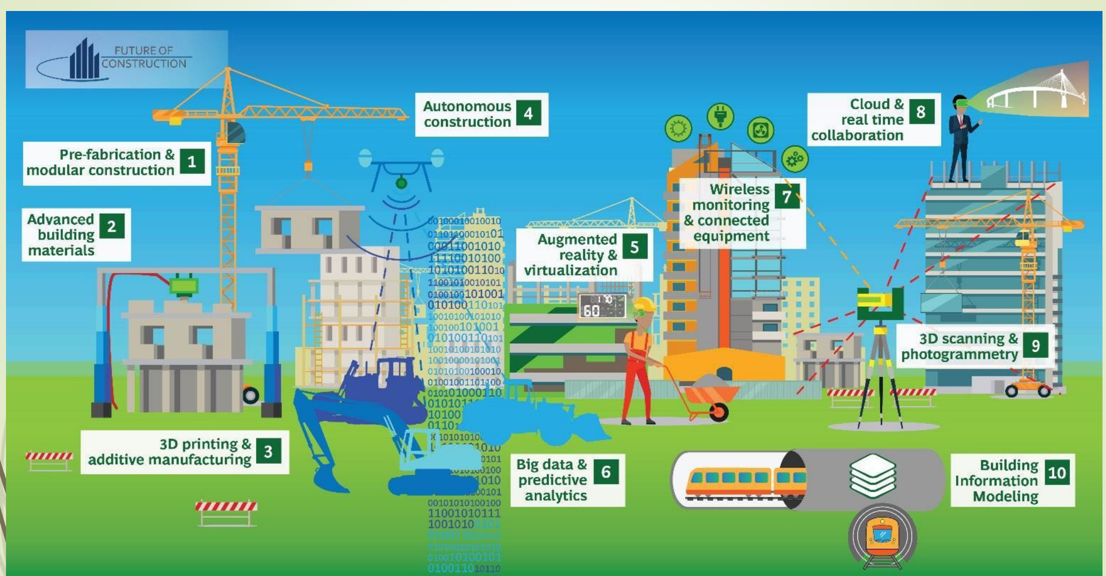


Universal connectivity and real-time decentralized decision-making

- Internet of Things,
- Digital Twin,
- Additive manufacturing (3D Printing),
- Cloud computing,
- Cyber-Physical Systems (CPS) and,
- BIM.

https://www.i-scoop.eu/industry-4-0/
https://www.buildingtransformations.org/articles/construction-4-0

Rapid Change in Society with Advances in Technology



Source: Top 10 disruptive technologies in construction Image: World Economic Forum, Boston Consulting Group
https://www.weforum.org/agenda/2018/06/construction-industry-future-scenarios-labour-technology/

Construction Now – New Challenges

Hastak\2023

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Construction Now – New Challenges United Nations SDGs (2015 – 2030)

Construction Now – New Challenges

- ❑ Cost, schedule, quality, safety, and sustainability
- ❑ Shortage of skilled labor
- ❑ Adoption of technology
- ❑ Contractual constraints
- ❑ Low productivity
- ❑ Pandemic
- ❑ Supply chain issue
- ❑ Interdependencies
- ❑ Environmental Issues/Sustainability

Construction now – use of Technology

Universal connectivity and real-time decentralized decision-making as an outcome of Construction 4.0

- ❑Internet of Things,
- ❑Digital Twin,
- ❑Additive manufacturing (3D Printing),
- ❑Cloud computing,
- ❑Cyber-Physical Systems (CPS) and,
- ❑BIM
- ❑Laser Scanning

Additionally

- ❑New material/FRP
- ❑Intelligent Planning Units
- ❑Smart Objects

Construction Industry/University Collaboration for Innovation

- ❑ Center for Intelligent Infrastructure
- ❑ Missouri Consortium for Construction Innovation
- ❑ Purdue Consortium for Construction Innovation
- ❑ Construction Industry Institute
- ❑ CIB (International Council for Research and Innovation in Building and Construction
- ❑ CICID, Hong Kong
- ❑ Construction Research Institute of Canada
- ❑ Etc.

Construction Industry Institute 17 Best Practices

- ❑ Advanced Work Packaging
- ❑ Alignment
- ❑ Benchmarking & Metrics
- ❑ Change Management
- ❑ Constructability
- ❑ Disputes Prevention & Resolution
- ❑ Front End Planning
- ❑ Implementation of CII Research
- ❑ Lessons Learned
- ❑ Materials Management
- ❑ Partnering
- ❑ Planning for Modularization
- ❑ Planning for Startup
- ❑ Project Risk Assessment
- ❑ Quality Management
- ❑ Team Building
- ❑ Zero Accidents Techniques

https://www.construction-institute.org/resources/knowledgebase/best-practices

Adding value for global research

Global network for collaboration

- 40 expert Working Commissions & Task Groups
  Conferences, webinars, publications, 30 partner journals, research database, research roadmaps
- World Building Congress 2025

Supporting tomorrow's talent

- 18 Student Chapters
- New global network for Early Career Researchers
- "CIB in Conversation"

Campaigning on issues which matter, eg impact, research classification

www.cibworld.org

- 53 Countries
- 75 Organisations
- 215 Individual Members
- 1351 Experts
- 35 Working Commissions
- 6 Task Groups
- 18 Student Chapters
- 30 Partner journals
- 27,000 Research papers

40 Working Commissions and Task Groups (March 2022)

CIB 'Vistas': Global Collaboration - People and the Planet - Futures

Architectural Design and Management
Building Pathology
Clients and Users in Construction
Construction in Developing Countries
Construction Industry Economics
Construction Materials Stewardship
Culture in Construction
Customised Industrial Construction
Disasters and the Built Environment
Education in the Built Environment
Facilities Management and Maintenance
Fire Safety
Global Construction Data
Heat and Moisture Transfer in Buildings

Informal Settlements and Affordable Housing
Information and Knowledge Management in Building
Information Technology for Construction
Infrastructure
Innovation in Construction
Intelligent and Responsive Buildings
Law and Dispute Resolution
Nature Based Solutions for Climate Resilient Buildings and Communities
Offsite Construction
Open Building Implementation

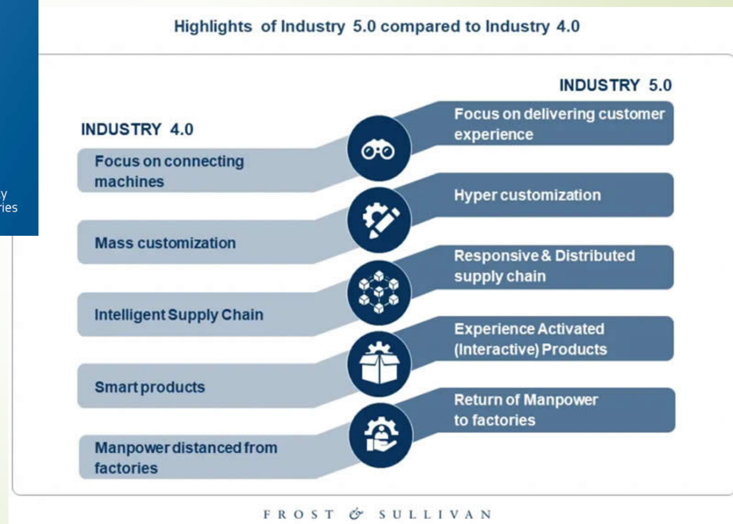
Organisation and Management of Construction
People in Construction
Performance Measurement in Construction
Prediction of Service Life of Building Materials and Components
Procurement Systems
Public Private Partnership
Residential Studies
Roofing Materials and Systems
Safety and Health in Construction
Sandwich Panels
Smart and Sustainable Built Environments

Smart Cities
Spatial Planning and Infrastructure Development
Usability of Workplaces
Wall Structures
Water Supply and Drainage
Zero-Carbon Building & Infrastructure Design and Construction

www.cibworld.org

Industry 5.0

Towards a more sustainable human-centric and resilient industry



https://www.platforme.com/blog/industry-5-0-building-a-more-sustainable-human-centric-and-ethical-industry

https://www.i-scoop.eu/industry-4-0/industry-5-0/

Sustainable development

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UNISDR 2009, Brundtland Commission in 1987).

- Sustainability addresses the time continuous effects of any strategy on the economy, environment and society over the lifecycle of the infrastructure
- Therefore, strategy selection for capacity building should address <u>resilience</u> as well as the <u>sustainability aspects</u>.

Interdependence of Infrastructure for Societal Resilience

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Failure of infrastructure after disasters and their impact on community recovery

Disasters - Global Issue

Types of Infrastructure

CYBER

Civil	Civic	Social	Environmental	Financial	Education
Utility Systems	Emergency Centers	Homes	Landscape	Disaster Funds	Training
Water, Gas, Electricity	Hospitals	Religious Centers	Wastelands	Insurance	Programs
Transportation Systems	Police	Community Centers	Mangroves	Donors	Feedback Mechanism
Roads, Bridges, etc.	Governance, etc.	NGOs			

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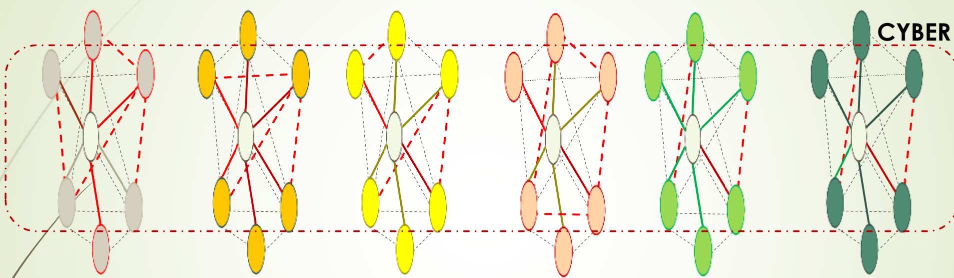
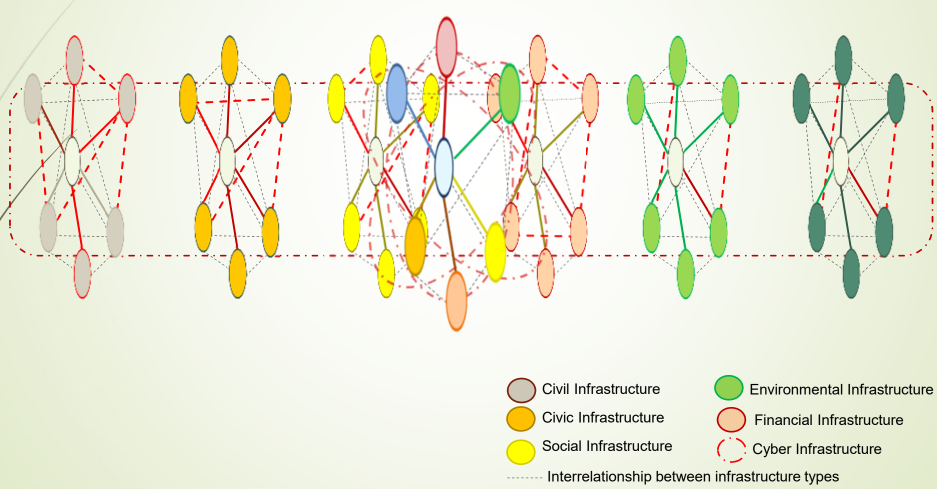
Interdependencies between the seven infrastructure layers



Civil	Civic	Social	Financial	Environmental	Educational
Utility Systems	Emergency Agencies	NGOs	Disaster Funds	Mangroves	Training
Water, Gas, Electricity	Schools, Hospitals	Religious Centers	Insurance	Debris Site	Programs
Transportati on Systems	Police, Governance	Households	Donor Funds	Forests	Feedback Mechanisms

Criticalities between the seven infrastructure layers



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Sustainability in the Context of Resilience and Capacity Building

- ***Sustainable resilience-enhancing strategies* should be considered** while selecting various alternate strategies for capacity building to enhance resilience.
- *Sustainable resilience-enhancing strategies* are those strategies **that contribute indefinitely to the development & well-being of both the consumers & infrastructure** whilst not overdrawing natural resources or over-burdening the environment in an irreversible manner.

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Global Leadership Forum for CEM Programs (GLF-CEM)

Task Force on Resilience in Construction Industry

Pandemics and recessions have revealed the **need to extend the definition of Resilience in construction industry**. This Taskforce aims to explore and perhaps define Resilience in the Construction Industry by looking at:

- **Different shocks and stresses**: Natural hazards, Pandemic, Supply chain delay, Recession, Legislation
- **Different levels**: City, Community, Organization, Individual
- **Different technical infrastructure**: engineering, networks, and assets
- **Different mitigation strategies:** Local supply chain, Modularization and Prefabrication, Remote Working, etc.

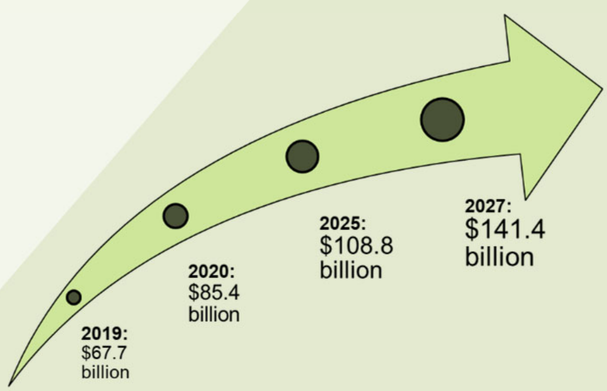
Getting Ready for 2030: A People, Process, and Technology Roadmap for Offsite Construction (CII RT371)

Motivation

- Why 1 — Shortage in Skilled Labor
- Why 2 — Suboptimal Project Outcomes
- Why 3 — Poor Productivity
- Why 4 — Inadequate Leverage of Technologies
- Why 5 — Uncertainties Associated with Jobsites

PI: Islam El-adaway, Mark Hastak and Kim Needy

- **Size of Global Offsite/Modular Construction Market**



Compound annual growth rate (CAGR) ≈ 9.6%

Key Quotes on the 2030 Vision for Offsite Construction

*"The **percentage of offsite construction will continue to increase**"*

*"**We will get more and more automated**…like video games…to reduce the number of workers on the jobsite"*

*"Going offsite will be **huge and advantageous to hiring and attracting more or higher qualified people into the industry**"*

*"The **definition of construction workforce will change**…people at the job site and on the manufacturing floor"*

Most-used Offsite Construction Characteristics

2020		2030
Single-trade Prefabrication	Offsite construction typologies	Modularization
Customized Components	Type of components for offsite construction	Standard Components
Permanent Structures	Type of structures for offsite construction	Portable/relocatable Structures
Single-skilled Labor	Labor skillset for offsite construction	Multi-skilled Labor
High-skilled Labor	Labor skill level for offsite construction	High-skilled Labor

Top 3 Workforce Occupations in Highest Need for Training in Offsite Construction

Category	Rank #1	Rank #2	Rank #3
Design and Engineering	BIM and 3D/4D/nD information modeling	QA/QC engineers	Planning engineers
Construction and Management	Construction managers	Constructability specialists	Field interface management personnel
Administrative	AWP professionals	Computer IT professionals	Project controls professionals
Onsite Craft	Offsite module installation personnel	Lifting, cranes, and rigging personnel	Instrumentation and control personnel
Offsite Fabrication	Computer-aided manufacturing professionals	Assembly, fabrication, and production personnel	Planners, expeditors, and sequence managers

Key Offsite Construction Skills to Incorporate into Training

Design and Engineering

- **Fabrication package** creation and detailing
- **Stability and constructability** of components and modules
- **Supply chain** and procurement
- **Logistics** and transportation
- **Offsite construction philosophy**
- **Design for manufacturing and assembly**
- **Design freeze**
- **Offsite typologies**

Construction and Fabrication

- **Automation, robotics**, and computer-automated technologies
- **Placement, assembly, and installation**
- Manufacturing and **fabrication processes**
- **Operation management** and process planning
- **Good manufacturing practices**
- **Integration of onsite and offsite** activities
- **Offsite construction philosophy**

Administrative

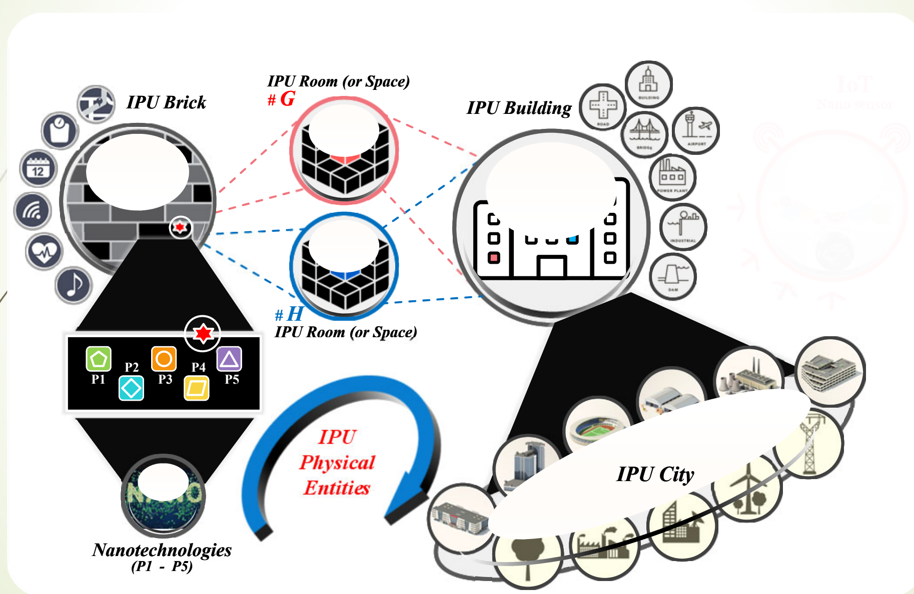
- Manufacturing and **factory knowledge**
- **Offsite construction philosophy**
- **Systems thinking** and integration
- **Process streamlining**
- **Personnel information systems**

Top 5 Technologies To Invest In and Train the Workforce on for 2030

Remote Monitoring | Smart Sensors | Artificial Intelligence Interface | Extended Reality | Integrated Real-Time Management Information Systems

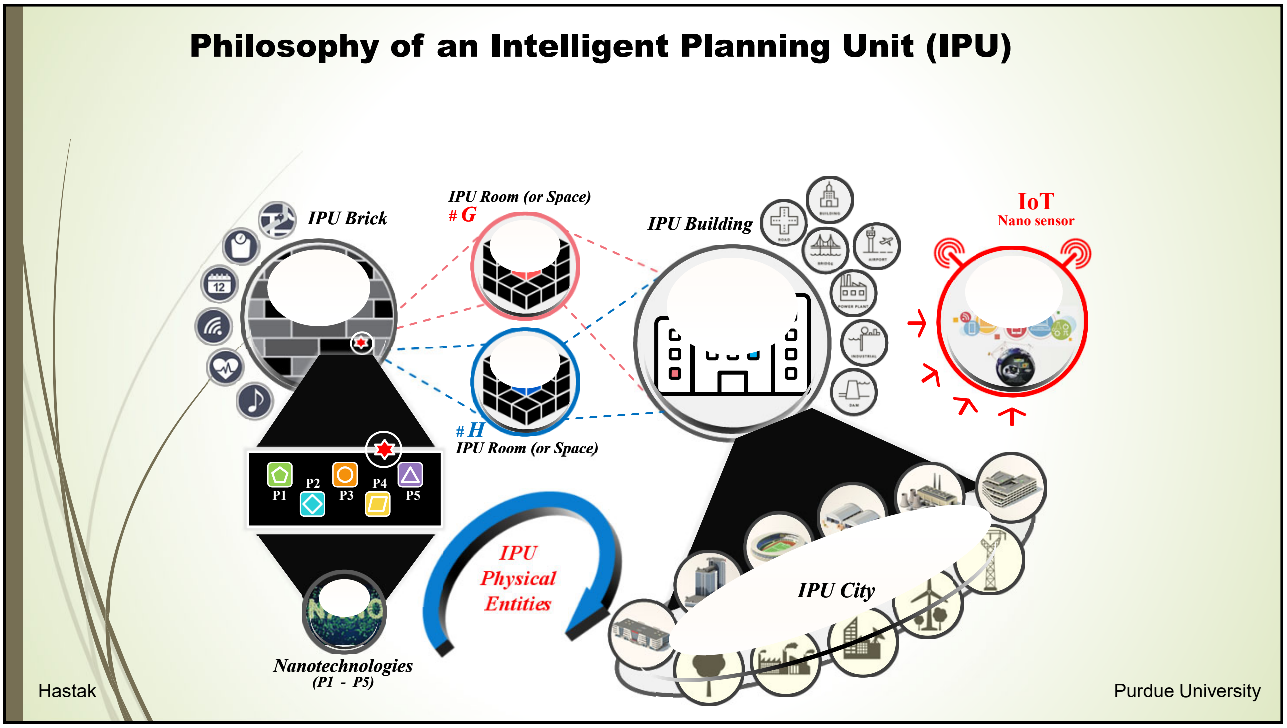
We still need to address the issue of complexity in the built environment

Philosophy of an Intelligent Planning Unit (IPU) to facilitate offsite construction



Hastak

Purdue University


Philosophy of an Intelligent Planning Unit (IPU)
IPU Brick
IPU Room (or Space)
G
H
IPU Room (or Space)
IPU Building
IoT
Nano sensor
P1
P2
P3
P4
P5
IPU
Physical
Entities
IPU City
Nanotechnologies
(P1 - P5)
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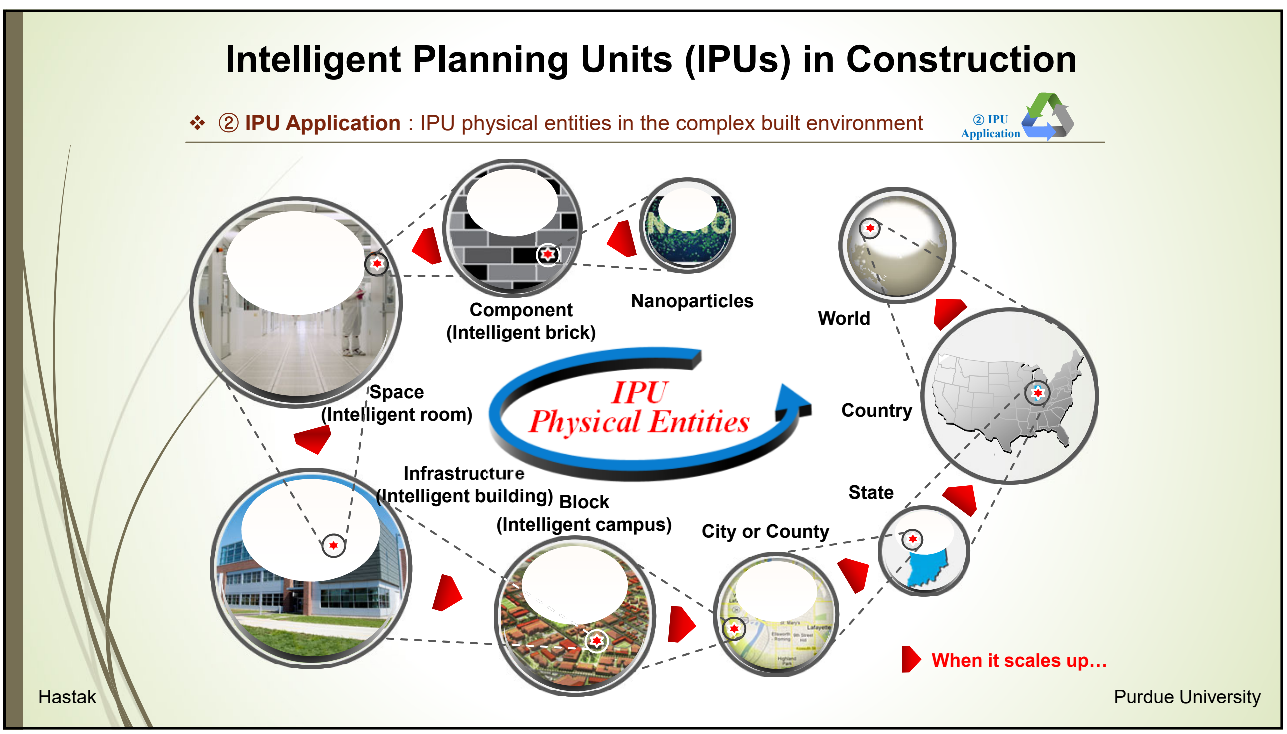
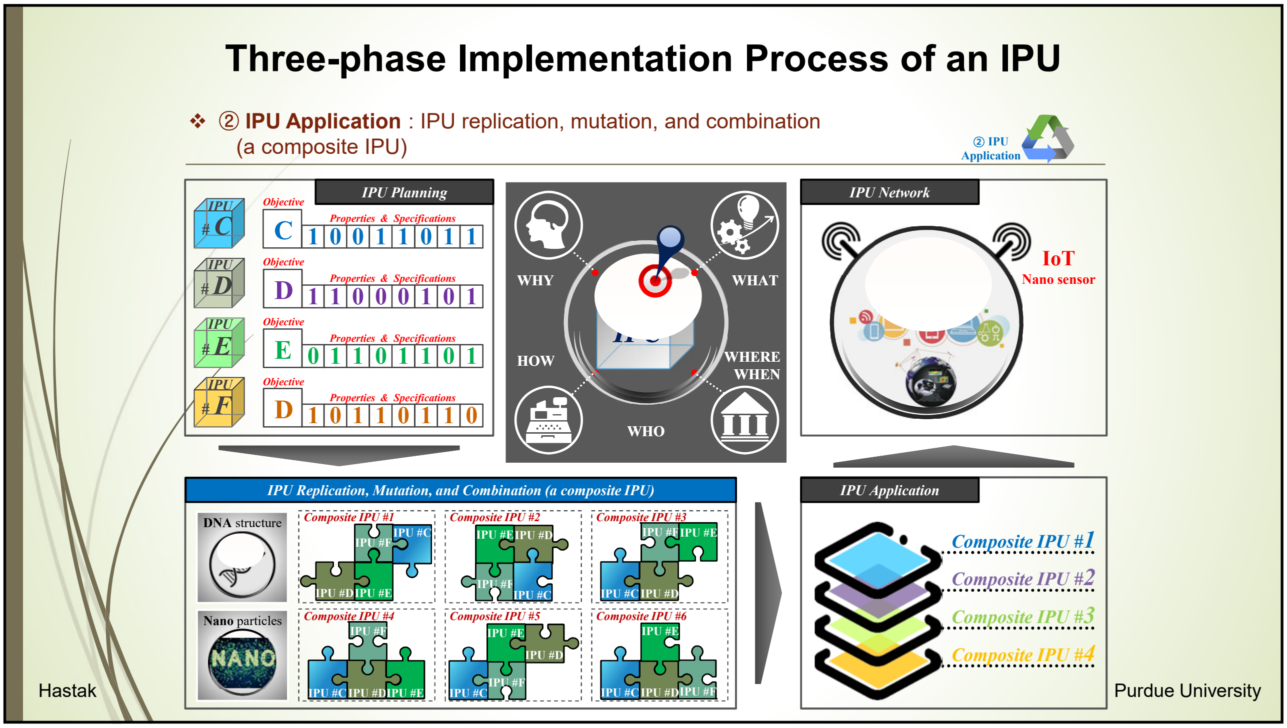
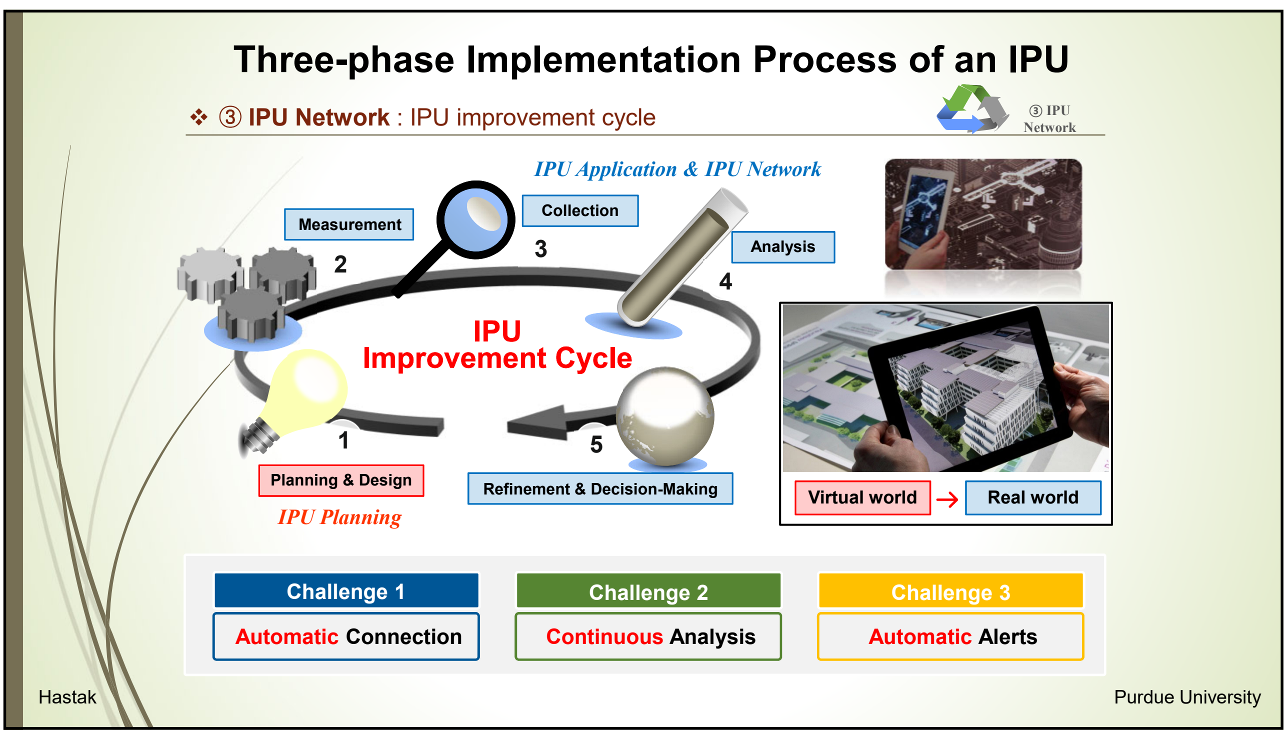
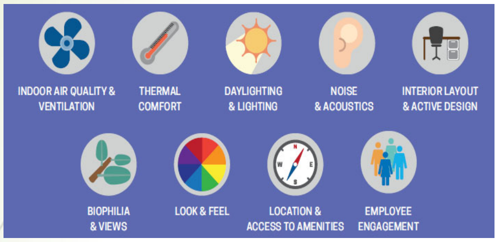

Intelligent Planning Units (IPUs) in Construction
❖ ② IPU Application : IPU physical entities in the complex built environment
② IPU
Application
Component
(Intelligent brick)
Nanoparticles
World
Space
(Intelligent room)
IPU
Physical Entities
Country
Infrastructure
(Intelligent building)
Block
(Intelligent campus)
State
City or County
When it scales up…
Hastak
Purdue University


Three-phase Implementation Process of an IPU
❖ ② IPU Application : IPU replication, mutation, and combination (a composite IPU)
② IPU Application
IPU Planning
Objective
Properties & Specifications
IPU #C
IPU #D
IPU #E
IPU #F
WHY
WHAT
HOW
WHERE
WHEN
WHO
IPU Network
IoT
Nano sensor
IPU Replication, Mutation, and Combination (a composite IPU)
DNA structure
Nano particles
Composite IPU #1
Composite IPU #2
Composite IPU #3
Composite IPU #4
Composite IPU #5
Composite IPU #6
IPU Application
Composite IPU #1
Composite IPU #2
Composite IPU #3
Composite IPU #4
Hastak
Purdue University

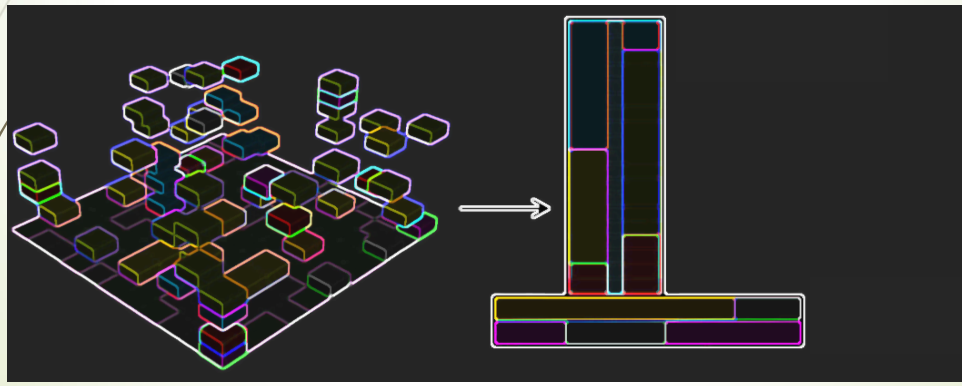

Three-phase Implementation Process of an IPU
❖ ③ IPU Network : IPU improvement cycle
③ IPU Network
IPU Application & IPU Network
Measurement
Collection
Analysis
IPU
Improvement Cycle
1
2
3
4
5
Planning & Design
IPU Planning
Refinement & Decision-Making
Virtual world
Real world
Challenge 1
Automatic Connection
Challenge 2
Continuous Analysis
Challenge 3
Automatic Alerts
Hastak
Purdue University

IPU : Impact on the KPIs



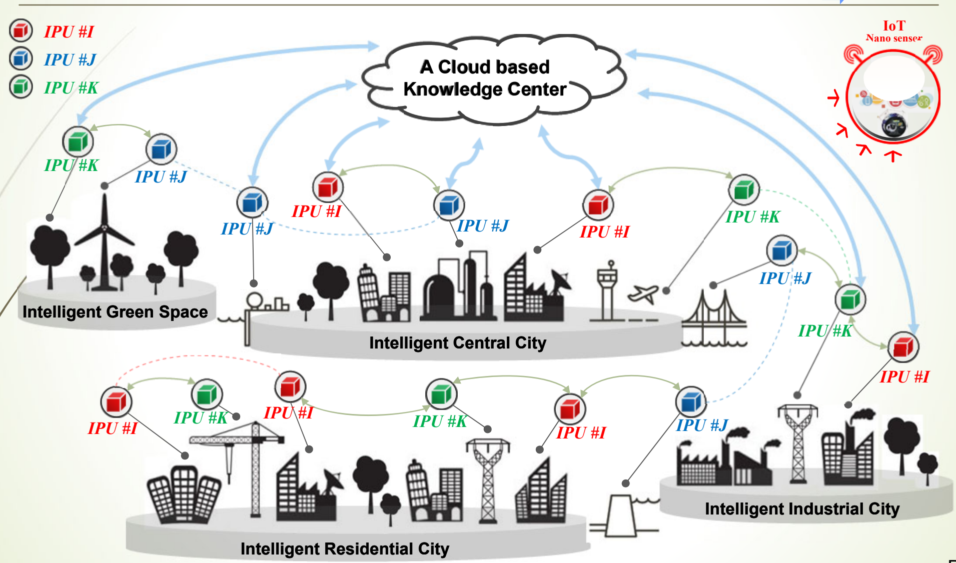
Positive Impact on the KPIs

1. Cost
2. Schedule
3. Quality
4. Safety
5. Sustainability
6. Variety in IPUs available
7. Competition among IPU developers/Suppliers

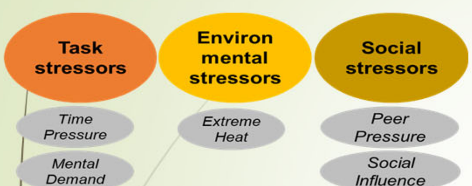


Three-phase Implementation Process of an IPU

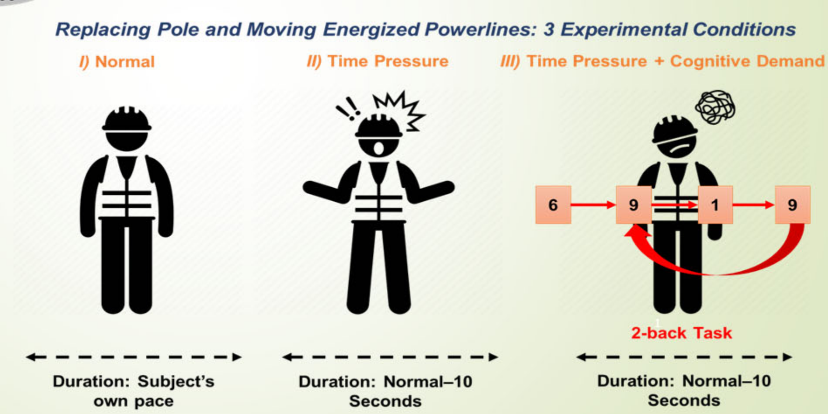
❖ ③ **IPU Network** : IPU interaction using the emerging concept of IoT technology ③ IPU Network



Impacts of Mental Load and Time Pressure on T&D Line Workers

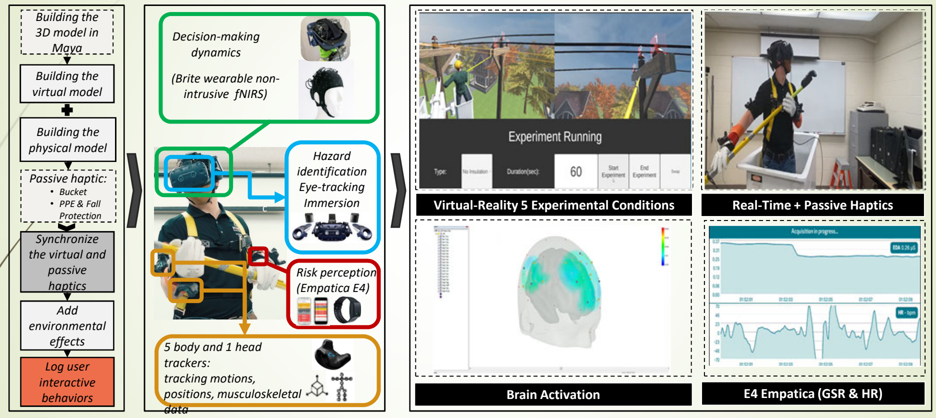


External Stressors in the Construction Industry



Dr. Sogand Hasenzadeh - sogandm@purdue.edu

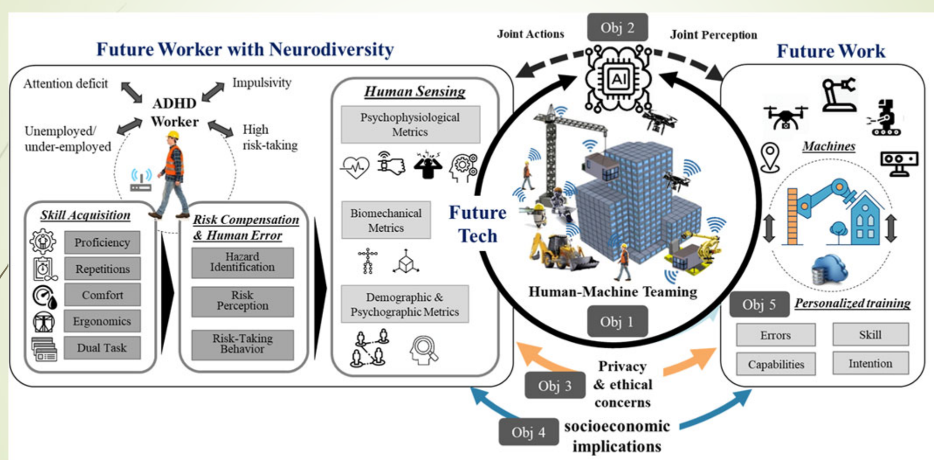
Impacts of Mental Load and Time Pressure on T&D Line Workers



Multi-Model Mixed Reality (MR) Environment

Dr. Sogand Hasenzadeh - sogandm@purdue.edu

Worker-AI Teaming to enhance inclusivity in the Construction Industry of the Future



Dr. Sogand Hasenzadeh - sogandm@purdue.edu

Construction – Future

Construction on Moon?
NASA Artemis Project

https://www.nasa.gov/press-release/nasa-icon-advance-lunar-construction-technology-for-moon-missions

Construction on Mars?

https://www.busstheworld.com/elon-musk-said-mars-is-independent-will-he-build-his-own-country/

Construction Engineer of the Future Engineering Areas of Growth?

Required Knowledge Areas

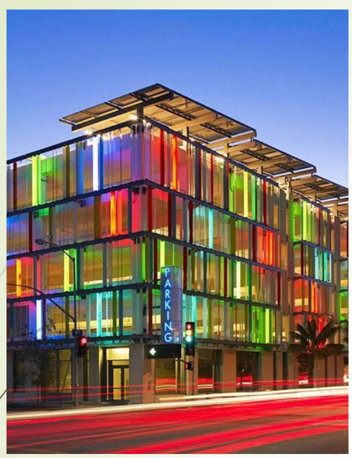
Engineering Education Research and Recommended Practices

In Conclusion

- A snapshot of "Construction Industry Challenges and the Need for Innovation"
  - Construction is a very robust industry that has innovated for ages in delivering complex and challenging projects
  - Cost, Schedule, Quality, Safety, and Sustainability remain the KPIs
  - Challenges exist
    - Shortage of skilled labor
    - Adoption of technology/Human-System Interface
    - Contractual constraints
    - Low productivity
    - Pandemic and Supply chain issues
    - Resilience of the industry
    - Interdependencies
    - Environmental Issues/Sustainability
    - Safety
- Lot of opportunity exists but there is a strong need for innovation to resolve the challenges ahead that could be addressed with Industry/University Collaboration

Hastak

Purdue University



Thank you

Prof. Makarand (Mark) Hastak, PhD, PE, CCP, CRIS

Purdue University, USA

hastak@purdue.edu