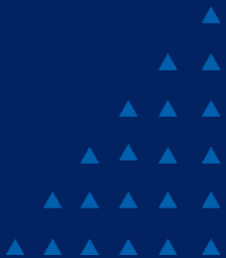


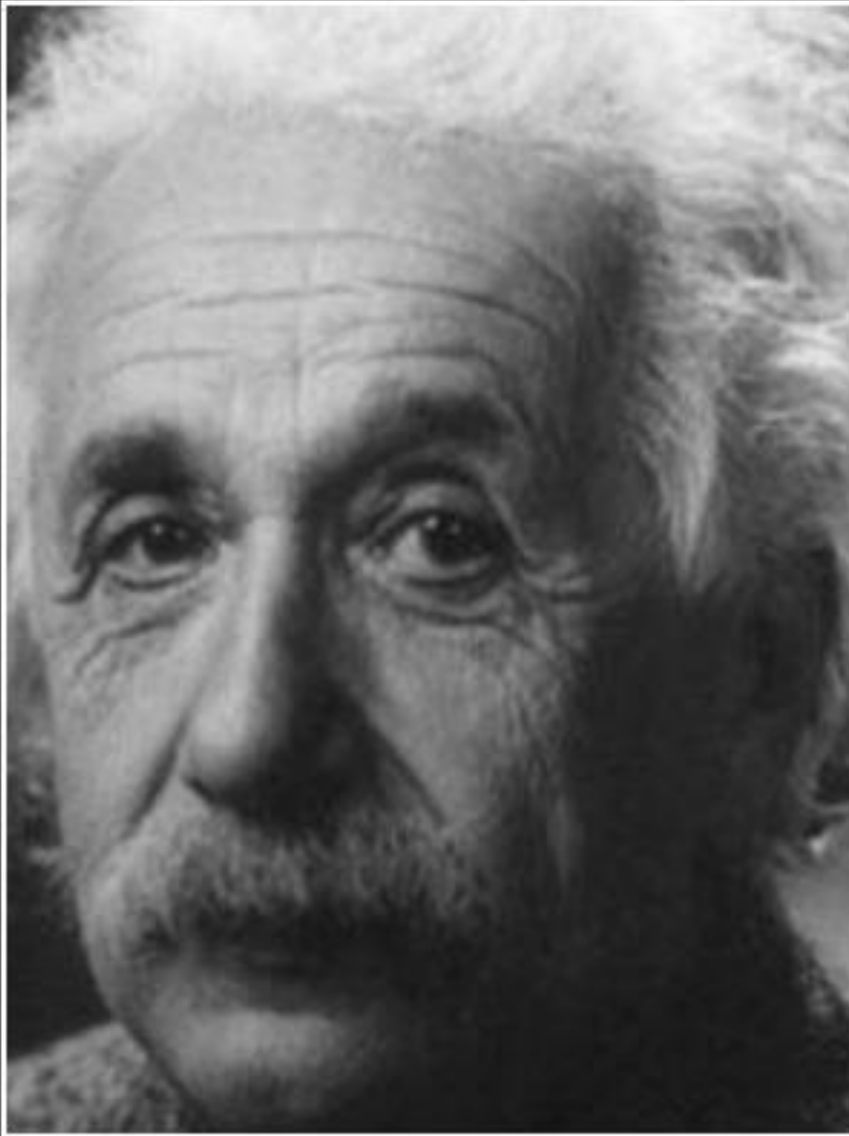
# Construction Performance and Productivity Improvement

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If we knew what it was we were  
doing, it would not be called  
research, would it?

— *Albert Einstein* —

AZ QUOTES

# Recap

- “Scientific research” should develop or contribute to **generalizable knowledge**, which is expected to:
  - Results that are applicable to a larger population beyond the site of data collection or the specific subjects studied.
  - Results that are intended to be used to develop, test, or support theories, principles, and statements of relationships, or to inform policy beyond the study.
  - Results that are likely to apply at other times...



# Recap: Criteria in the evaluation of research

- Reliability: whether the results of a study are repeatable (measures are stable)
- Replicability: the study must be replicable (process)
- Validity
  - Measurement validity: whether a measure captures the phenomenon which it is intended to capture.
  - Internal validity: understanding whether a conclusion that incorporates a causal relationship between two or more variables holds
  - External validity: whether the results of a study can be generalized beyond the specific research context



# Scientific Research?

- Examine which chairs in the market are comfortable
- Examine what factors of a chair affect human comfort
- Examine what factors of Poang chair affect human comfort



IKEA Poang Chair

# Scientific Research?

- Create a chair design that is most comfortable to a human
- Create a chair design that follows ergonomic design guidelines
- Devise a method to objectively measure human comfort in using a chair
- Evaluate human comfort of top ten chair designs



IKEA Poang Chair

# Scientific Research?

- Fabricate a Poang chair, using the given manual
- Develop an optimized fabrication method of a Poang chair, using genetic algorithm.
- Examine which factors in chair fabrication cause potential schedule delay.



IKEA Poang Chair

# Scientific Research in Construction?

- Develop a method to generate an optimized material storage layout, using genetic algorithm
- Create an optimized material storage layout in Project A, using genetic algorithm.
- Develop an automatic method to detect workers with safety vest, using YOLO5 (computer vision object detection algorithm)
- Detect workers with safety vest, using YOLO5 (computer vision object detection algorithm)

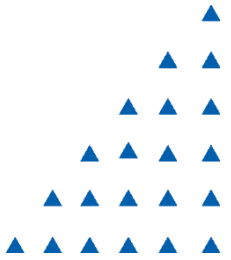


# Scientific Research in Construction?

- Evaluate and compare the environmental impact of RC and SRC structure buildings, using LCA
- Evaluate and compare the environmental impact of Project A, which is RC structure, and Project B, which is SRC structure buildings, using LCA



# History of CEM Research



# Contribution to Existing BOK in Construction

- “Does the manuscript present a specific, easily identifiable advance in knowledge? Is it applicable and useful to the profession? ”
- “Is the subject matter within the scope of the journal? Or is it better suited to another journal?”
  - *ASCE Journal of Construction Engineering and Management (JCEM)*

*=> The best way to learn how to judge about the above questions is to look at the history*

# Emergence of CEM Research Field

- Construction engineering/manager as a profession has a long history.
- CEM emerged as an academic discipline around late 1940s
  - Robert Peurifoy founded an undergraduate degree program at Texas A&M University in the late 1940s
  - Graduate programs were founded in Michigan, Purdue, and Stanford in the 1950s and early 1960s.



# Emergence of CEM Research Field

- Opposition to establish construction as an academic discipline
  - Construction was viewed as a business or commercial, rather than an engineering activity
- Research has played a major role in overcoming this opposition
- U.S. Army Corps of Engineers (COE) has established Construction Engineering Research Laboratory (CERL) in 1968.



# 50 Years of CEM Research

1955-1975

- Initiate as engineering education domain

1975-1995

- Establish as research field

1995-2005

- Diverge/Mature

2005-2021

- Expand the scope

# 50 Years of CEM Research (1955-1975)

- “Circle and connecting line diagram” which underpinned the precedence diagramming approach to the critical path method (CPM) for scheduling. (John Fondahl)
- Using and adapting techniques from industrial engineering to develop operations analysis and design approaches that could formalize, model, and optimize work practices on construction sites (Oglesby and Parker)
- Decade-long intellectual debate about how best to model, simulate, and optimize bidding in construction (Gates, Carr, and et al.)

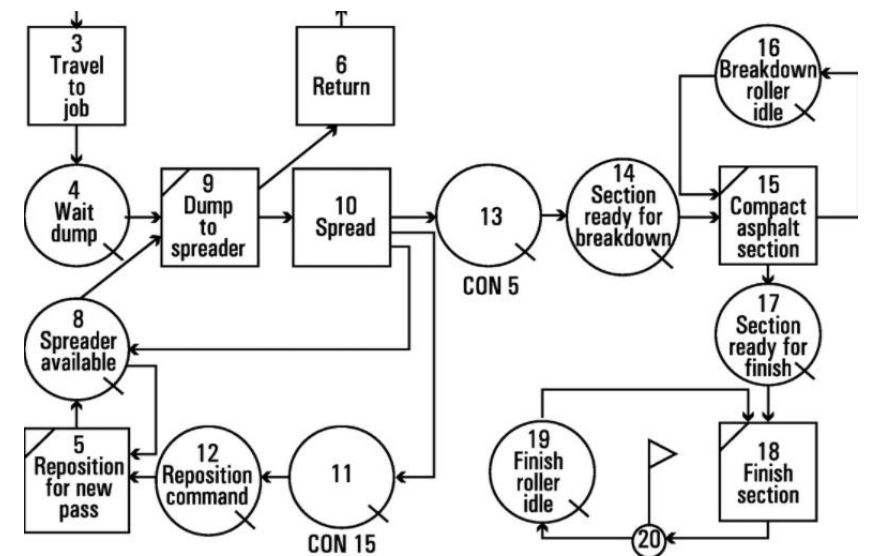
# 50 Years of CEM Research (1955-1975)

- Stochastic simulation models using Monte Carlo simulation techniques to analyze and optimize the configuration of construction equipment fleets (Halpin and et al.)

- CYCLONE:

[https://engineering.purdue.edu/CEM/people/Personal/Halpin/Sim/index\\_html](https://engineering.purdue.edu/CEM/people/Personal/Halpin/Sim/index_html)

- Database management systems (DBMS)
  - Commercialized by IBM and Oracle..



An example of CYCLONE



# 50 Years of CEM Research (1955-1975)

- Apply social science theories to help them understand and enhance many aspects of construction practice
- E.g. motivation of construction workers laid the groundwork for subsequent research on construction safety (Clark Oglesby, Henry Parker, Nancy Samelson, Michal Robinson, Jimmie Hinze)

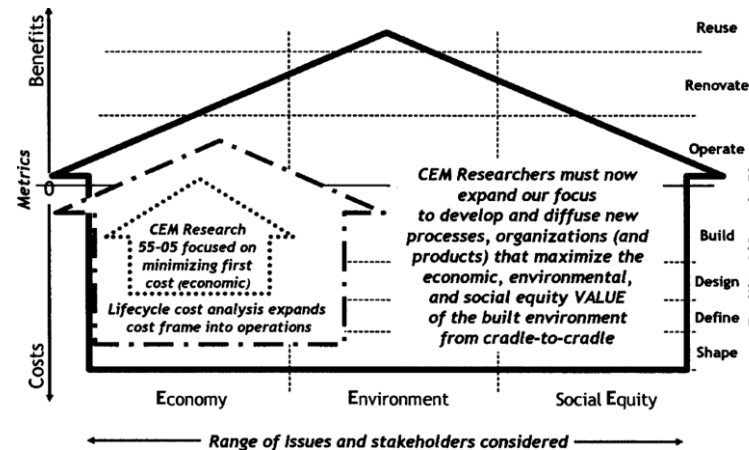


Fig. Framing CEM research for next 50 years

# Second 2 Decades (1975-1995)

- ASCE Journal of Construction Engineering and Management (JCEM; 1957-) and Construction Research Council (CRC) were established.
- Construction Industry Institute (CII) at the University of Texas started in the early 1980s.



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Institute®

# Second 2 Decades (1975-1995)

- Applied probability to analyze contractual risk sharing, and others continued to work in the area of bidding theory (David Ashely)
- More sophisticated social science research
  - The roles of social networks in diffusing innovation (Julia Harkola)
  - Innovation and management of technology (Tatum and et al.)
  - Lean construction (Howell, Tommelein, and Ballard)
  - Organizational design (Levitt)

# Second 2 Decades (1975-1995)

- The Center for Integrated Facility Engineering (CIFE) at Stanford University was launched (industry-funded research center)
  - ✓ Computer-aided design for visualization, Artificial intelligence for automated reasoning, and DBMS
- Expert systems
  - ✓ HI-RISE (structural design problems)
  - ✓ Safety evaluation
  - ✓ Automate the development of construction plans from CAD (De La Garza et al.)

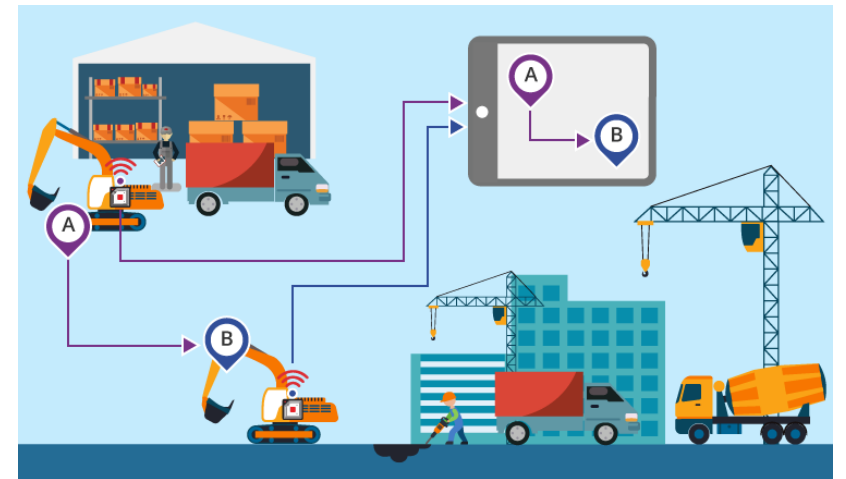


# Second 2 Decades (1975-1995)

- Automated pattern recognition using neural network analysis.
- Evolutionary computing (e.g., genetic algorithms) to support optimization of design configurations from earthmoving to project organizations.
- ASCE Journal of Computing in Civil Engineering (JCCE) was established in 1987.
- CEM researchers were regularly collaborating with world-class computer scientists, social scientists, and management scientists.

# 5th Decades (1995-2005)

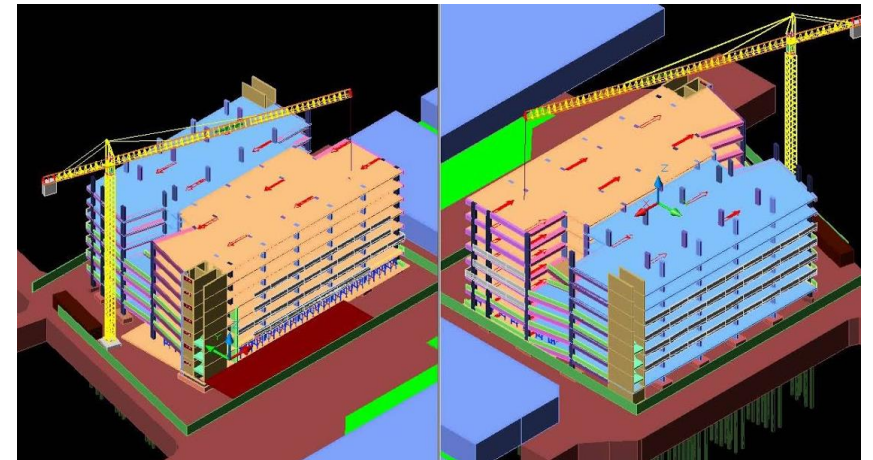
- Pena-Mora added findings from social science to make communication technologies more effective in supporting collaborative design and construction of projects.
- Innovative applications of individual sensors and sensor networks to support automation and optimization
  - ✓ RFID: embedded in structural elements (structure sensing)
  - ✓ GPS: automation of equipment



# 5th Decades (1995-2005)

- Emergence of Virtual Design and Construction (VDC)
  - ✓ Martin Fisher's 4D CAD
  - ✓ Visual construction simulation (Martinez and Kamat)
- Economic Input-Output Life Cycle Assessment (EIO-LCA) (Hendrickson and Horvarth)

Life-Cycle  
Assessment



# After.. (2005-2021)

- Reality capture
  - ✓ Using 3D laser scanning, photos...
- Automation
  - ✓ Using sensors and sensor networks
- Social Science
  - ✓ Safety
  - ✓ Disaster Management
  - ✓ Human-technology interface





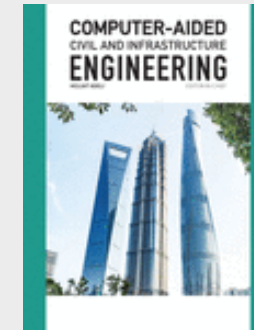
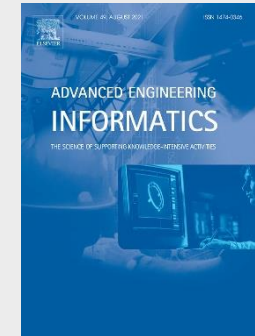
# Current CEM Landscape

## Management



## Social Science

## Computing/Automation



# Current CEM Landscape

## CRC 2022 Tracks

- Infrastructure Systems, Sustainability and Resilience
- Computer Applications, Information Modeling and Simulation
- Advanced Technologies and Data Analytics
- Automation in Construction
- Engineering and Materials Design, Quality, and Value Management
- Project and Organizational Management and Planning
- Construction Scheduling, Estimating, Economics, and Controls
- Contracting, Project Delivery, and Legal Issues
- Construction Education
- Health, Safety, and Workforce Issues

## I3CE 2021 Tracks

### **Computing Technical Areas**

- Visualization (nD, VR, AR)
- Information modeling and Digital Twin Technology (BIM, BrIM, CIM, GIS)
- Simulation and process modeling
- Reality capture technologies (LIDAR, RGB-D, vision)
- Human-technology frontier, data modeling, and computing
- Big data, sensing, and machine learning
- Robotics, automation, and control
- Ontologies and semantic approaches

### **Computing Application Contexts**

- Built environment monitoring, control, and analysis
- Smart and connected health and communities
- Resilient and sustainable urban and energy systems
- Information and communication technologies (IoT, crowdsourcing, social networks)
- Project design, construction, planning, and management
- Asset and facility management, operation, and maintenance
- Technology-enriched engineering pedagogy

# Assignment

✓ Read the following paper:

[https://link.springer.com/chapter/10.1007/11888598\\_20](https://link.springer.com/chapter/10.1007/11888598_20)

✓ Please create presentations that analyze your research idea using horseshoe research method. Define:

- Observed Problem
- Theoretical point of departure (knowledge gap)