



# LEAN, AUTOMATION AND MODULARIZATION IN CONSTRUCTION

Sara Gusmão Brissi – P.h.D. Student – Purdue University

Dr. Luciana Debs – Assistant Professor – Purdue University

## AEC industry current status

- Low productivity
- Fragmented
- Slow to embrace innovation
- Relatively low financial returns
- Used to schedules delay



Source: Pixabay, Credits: MichaelGaida

## AEC industry to be

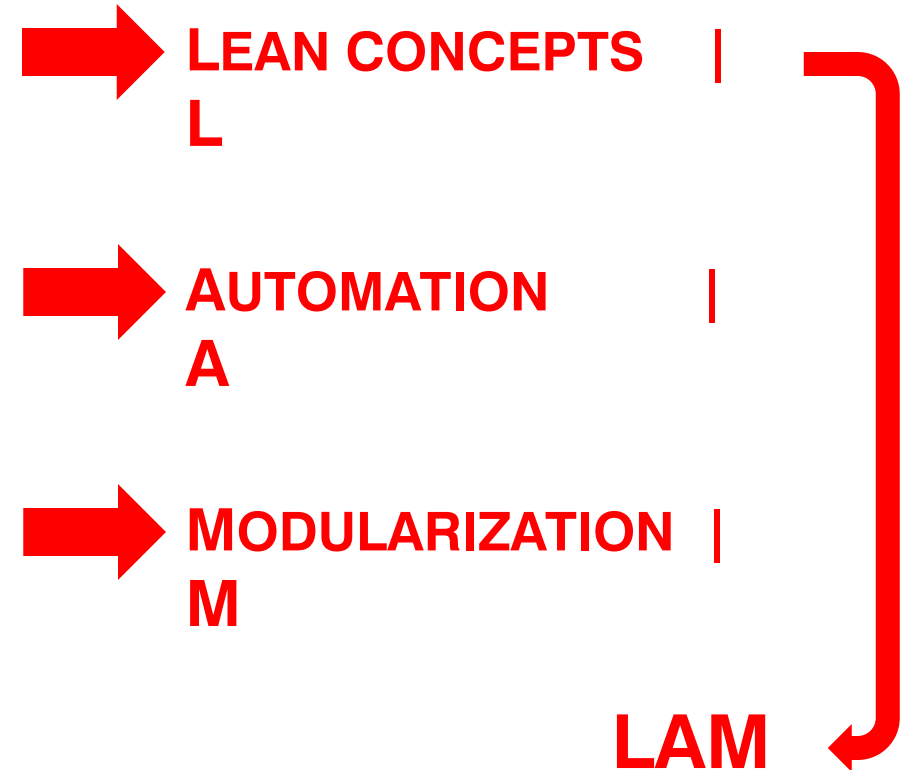
- Increase productivity
- Holistic
- Adopt new technologies
- Increase financial returns
- Speed up schedules



Source: Adobe Stock, Credits: Miljacka

## AEC industry – drivers of changes

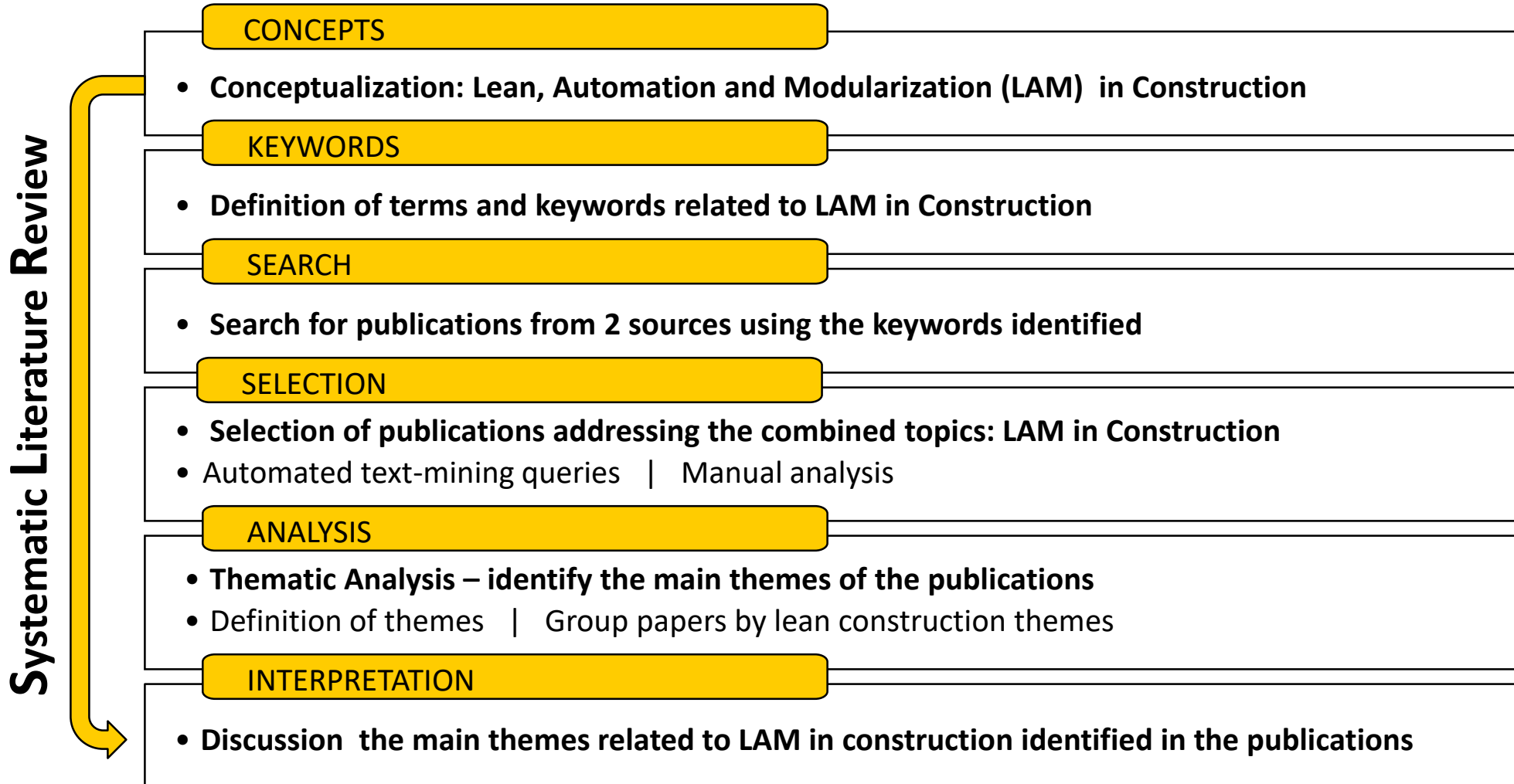
- Efficient planning and control systems
- Value maximization – customer first
- Waste reduction – time, resources, transport, inventory
- Simplification of processes, components, flow of information
- Standardization of processes and components
- Automation of processes and controls



## Research Questions

- How much attention has the academy and the AEC industry devoted to the study of the combined topics lean construction, automation in construction and modular construction?
- What are the most relevant issues presented on publications that simultaneously investigate the topics related to lean, automation and modularization in construction?

# Methodology



## Methodology

### Systematic Literature Review

- Years: 2000-2018 (from January to December, including papers available online before published).
- Exploratory study – evaluate the potential of the connections between the topics under analysis: lean, automation and modularization in construction.
- Sources
  - Automation in Construction (AIC) journal
  - International Group for Lean Construction (IGLC) website

## Conceptualization



*Source: Adobe Stock, Credits: Ileezhun*

Main keywords identified: continuous improvement, elimination waste, generation of value, optimization of process, last planner system, flow, lead time, just in time, JIT, six sigma, etc.

## Lean Construction

- Goal: deliver a quality product built on value maximization and waste minimization.
- Main concepts
  - Value – customers' satisfaction first + stakeholders gains
  - Flow – movement of information and materials through professionals involved with the project
  - Pull – planning techniques to control the flow of information and materials in a collaborative way → constantly monitoring project schedule.

## Conceptualization

### Automation in Construction



Source: Adobe Stock, Credits: Chaay\_tee

Main keywords identified: RFID (and related terms), BIM (and related terms), robotics (and related terms), sensing, algorithm, simulation, parameterization, etc.

- Goal: reduce time, cost and human induced error in production processes
- Main concepts
  - Information technology systems
  - Coding and programming - algorithms
  - BIM tools
  - Robotics applications
  - Automated assembly lines of prefabricated modules
  - Simulations for planning, controlling and scheduling



## Conceptualization

### Modularization in Construction



*Source: Wikimedia Commons, Credits: Alfred Twu*

Main keywords identified: modular, module, prefabrication, precast, parametric design, etc.

- Goal: reduce the variability of components and the complexity of the control processes.
- Main concepts
  - Standardization – simplify components and processes → quality
  - Mass customization – flexible use of standardized modules combined in various ways
  - Prefabrication – off-site construction and on-site assembly

## Results & Discussion

### Relevance of LAM for the academy and the AEC industry

Proportion of LAM papers that were published by AIC and IGLC in 2018:

- AIC journal: in 2018 (Jan-Dec), 6 out of 313 (1.92%) published papers addressed the combined topic LAM in construction.
- IGLC website: in 2018 (Conference IGLC 26 - Chennai, India), 2 out of 134 (1.49%) published papers addressed the combined topic LAM in construction.

## Results & Discussion

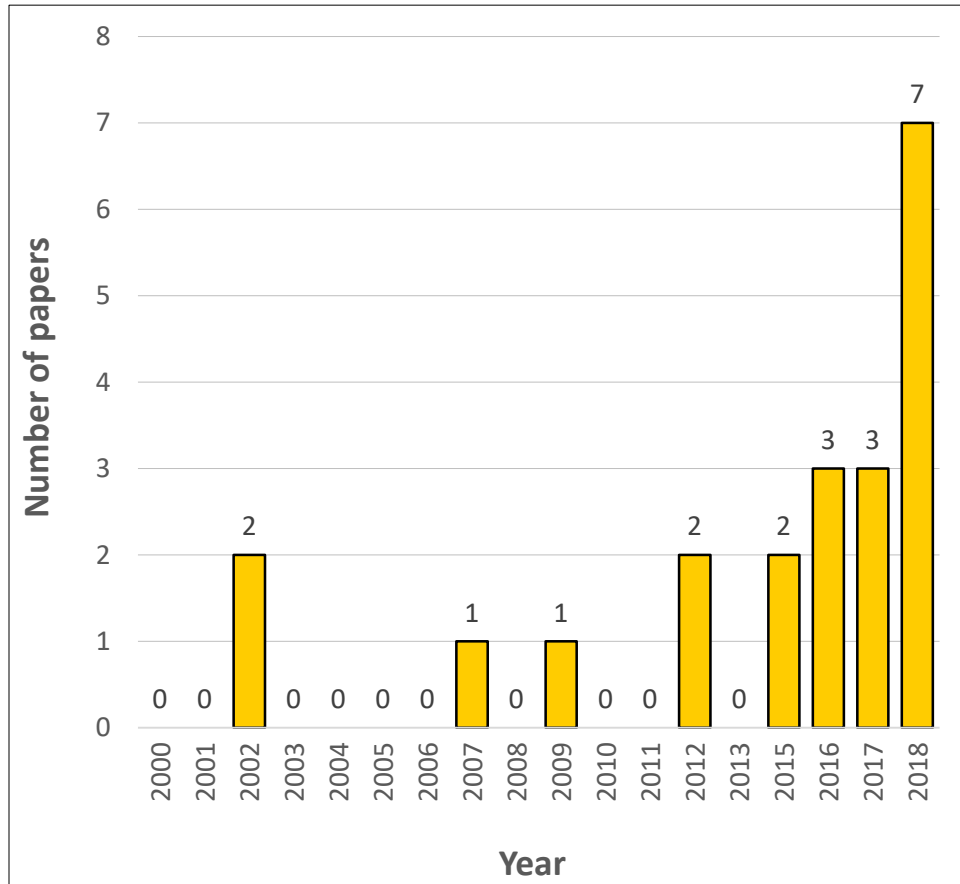


Figure 1: AIC LAM papers (n=19)

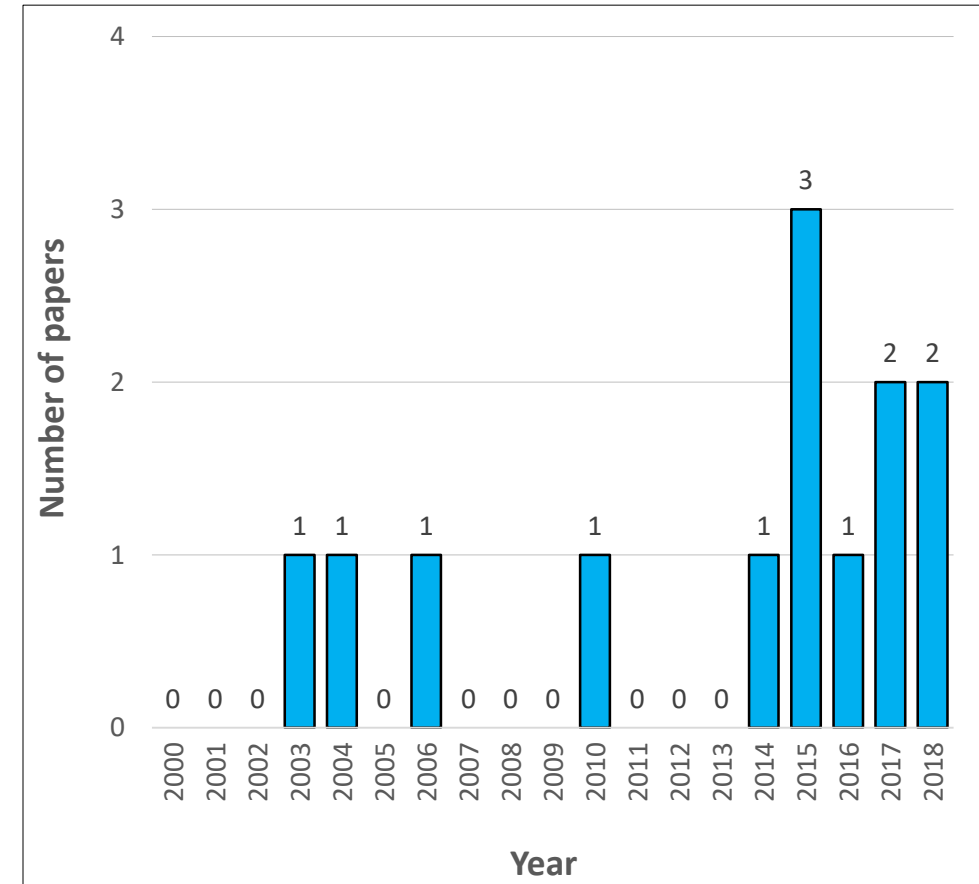


Figure 2: IGLC LAM papers (n=12)

## Results & Discussion

### Lean Construction Themes

- Lean management
- Production flow – increase flexibility
- Waste elimination (non-value-adding activities)
- Lean layout
- Pull system – controlling resources flow
- Visual management – transparency
- Lean construction principles – miscellaneous

## Results & Discussion

### Automation in Construction Themes

- Algorithms (coding, programming)
- Simulations – software based discrete event simulation (DES)
- Robotics
- Automated tracking systems
- BIM (3D, 4D BIM, ND BIM)
- Internet of things (IoT)
- Digital fabrication – CNC machining, 3D printing, additive manufacturing
- Laser scanning + cloud data points

## Results & Discussion

### Modularization in Construction Themes

- Prefabrication – production, transport, delivery, on-site assembly (precast and panelized components)
- Engineer-to-order components
- Off-site construction production
- Parametric design
- Digital prefabrication
- Mass customization

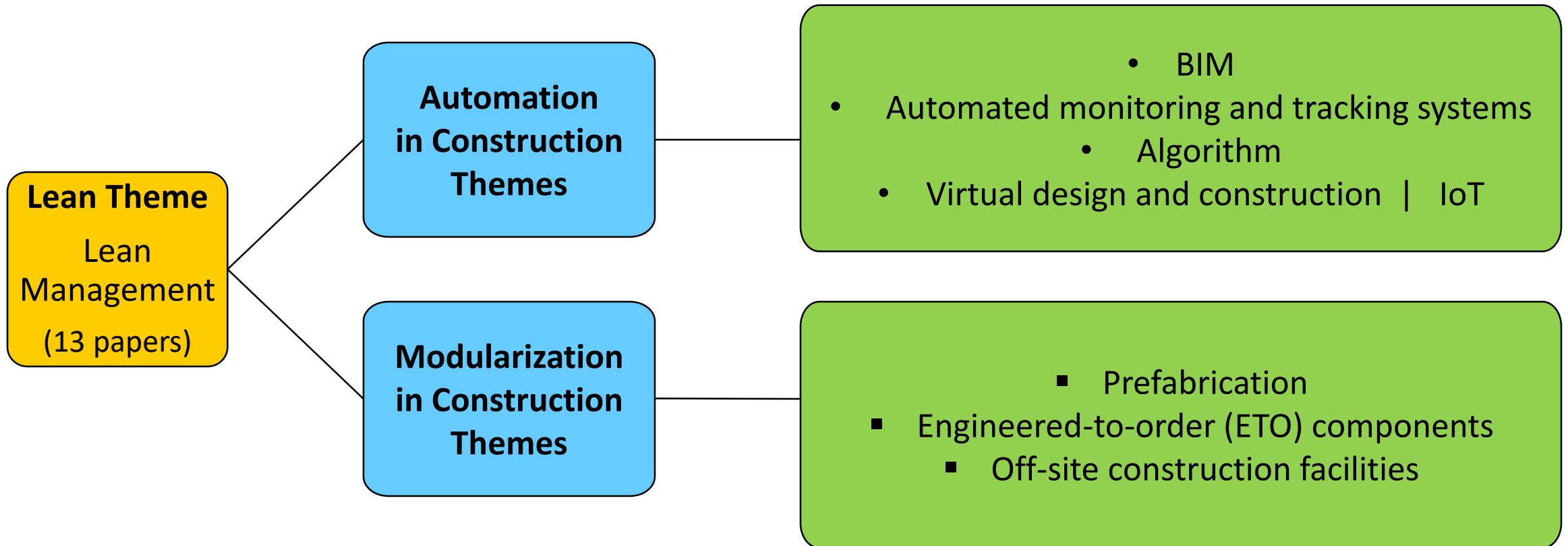
## Results & Discussion

### LAM Most Frequent Themes

- **Lean Construction: Lean Management – 13 papers.** Related topics: planning, control, scheduling, monitoring, predictability, etc. Related terms: production, supply chain, logistics, multi-skilled resources, time, cost, process integration, resources, etc.
- **Automation in Construction: Optimization Algorithm – 11 papers.** Related topics: programming algorithm, genetic algorithm, generative algorithm, clustering algorithm, etc. Related terms: programming, modelling, constraint programming, etc.
- **Modularization in Construction: Prefabrication – 9 papers.** Related topics: prefabricated construction, prefabricated components, prefabricated building design, digital prefabrication, etc. Related terms: manufacturing, logistics, assembly, parametric design, etc.

## Results & Discussion

### Interactions of **Lean Management** with Automation and Modularization in Construction themes





## Results & Discussion

### Interactions of **Lean Management** with Automation and Modularization in Construction

Author	Lean Construction Theme: Lean Management	Automation in Construction Themes			Modular Construction Themes
Altaf et al. 2018	Production planning and control	Monitoring system - RFID	Optimization algorithm		Panelized wall production facility for prefabricated homes
Arashpour et al. 2015a	Production planning and control	Autonomous production tracking			Off-site construction plant: precast concrete tanks
Bataglin et al. 2017	Logistics planning and control	4D BIM modelling			Logistics: Engineer-to-order (ETO) concrete prefabricated structures
Bortolini et al. 2015	Logistics planning and control in construction sites	4D BIM modelling			Logistics: ETO prefabricated building systems
Gerber et al. 2010	Lean construction principles: look ahead planning, design and construction integration	BIM: fabrication processes, design and construction integration			Prefabricated components: various
Murphy et al. 2018	Lean construction principles: predictability	VDC methods and reality capture			Prefabrication: interior wall panels
Peñaloza et al. 2016	Integrated production control	4D BIM: physical flows, control of assembly process			ETO prefabricated concrete systems
Cheng and Chen 2002	Controlling and monitoring construction progress	Automated schedule monitoring system			Precast building construction
Sacks et al 2003	Lean production and delivery: monitoring	Real-time automated monitoring	3D modelling		ETO: precast concrete pieces
Tillmann et al. 2015	Lean principles: lead time, production planning and control	BIM: integrated management			ETO components
Zhong et al., 2017	Monitoring: visibility and traceability in manufacturing, logistics and on-site assembly	IoT	BIM	Real-time automated monitoring	Prefabricated construction: manufacturing, logistics and on-site assembly
Arashpour et al. 2016	Scheduling: resource sharing and job sequencing	Optimization modeling algorithm			Off-site construction plant of concrete panels
Kong et al. 2017	Scheduling: cost and time constraints integrating manufacture, transportation and on-site assembly (JIT)	Dynamic programming algorithm: maximum production efficiency			Precast construction: manufacturing, transport, delivery, on-site assembly

## Conclusions

- Results revealed a low number of papers (n=31) approaching all LAM topics combined.
- Published work connecting the three topics LAM in construction focus on the following themes: (1) Lean construction – **lean production management**; (2) Automation in construction – **optimization algorithm**; (3) Modularization in construction – **prefabrication**.
- Limitations: (1) only using published papers from two sources; (2) findings were limited to the keywords used in the process of paper selection; and (3) the thematic analysis was carried out by only one researcher

## Future Directions

- Expanded research, considering published work from a larger number of academic sources, different keywords used to select the papers and two researchers working the thematic analysis -under way.
- Assess topics that are gaining more relevance in today's construction scenario – such as robotics (automation), integrated project delivery (lean), and parameterization of modules (modularization) – and the results of possible combinations of these topics for the AEC industry improvement.



**Thank you!**

**[sgusmaob@purdue.edu](mailto:sgusmaob@purdue.edu)**