

# Construction Management of Civil Engineering, Industrial Engineering, and Business Engineering through Lens of Industry 4.0 within Scientometric and Bibliometric

**Meilani**

Civil Engineering Department, Faculty of Engineering  
Bina Nusantara University  
Jakarta, 11480, Indonesia  
[meilani@binus.edu](mailto:meilani@binus.edu)

**Khristian Edi Nugroho Soebandrija**

Industrial Engineering Department, Faculty of Engineering  
Bina Nusantara University  
Jakarta, 11480, Indonesia  
[knugroho@binus.edu](mailto:knugroho@binus.edu)

## Abstract

Construction Management, in both developed and developing countries, is deemed country's principal factors in construction industry to boost countries' future in the full swings. This paper considers the digital era within Industry 4.0 as one of indispensable factors to escalate future sustainable development goals. The research stages comprise the quantitative analysis, within hundreds paper of scientometric and bibliometric perspectives of Construction Management. Precisely, the stage comprises data collection, data analysis and compilation of those perspectives. This paper has objective to elaborate both theoretical and empirical perspectives of construction management in general, including its implementation in construction industry. To some extent the mentioned elaboration includes the following but not limited vis-à-vis Industry 4.0, construction supply chain management, Building Information Modelling (BIM), lean construction supply chain, system dynamics applications in construction management. Simultaneously, those elaborations involve Civil, Industrial and Business Engineering. This paper provides comprehensive construction management in utmost overview not only in its Industry 4.0, but also construction management within Indonesia, Southeast Asia, Asia, and other continents that implement construction industry including Europe and United States. Ultimately, this paper provides the aforementioned overview in term of the following but not limited to vis-à-vis building information management (BIM), Internet of Things (IoT), cyber-physical systems (CPS), 3D printing, augmented reality, additive manufacturing. Future research emphasizes scientometric analysis on wider perspectives.

## Keywords

Construction Management, Industry 4.0, Sustainable Development Goals, Building Information Modelling, Lean Supply Chain

## 1. Introduction

Construction Management, in both developed and developing countries, is deemed country's principal factors in construction industry to boost countries' future development in the full swings. This paper considers the digital era within Industry 4.0 as one of indispensable factors to escalate future sustainable development goals.

This paper has objective to elaborate both theoretical and empirical perspectives of construction management in general, including its implementation in construction industry.

Assorted scholar works on construction management and industry have been conducted on the implementation of Industry 4.0, not only in Indonesia but also across the globe. Yet, to some extent, the challenges refer to the implementation in construction management and industry and wide range of engineering lens (Glaas and Kleemann 2016), (Lu 2017), (A Rüßmann et al. 2015). There are dominant implementations in trilogy of industrial and system engineering, manufacturing and electrical (Oesterreich et al.2016); and room for improvement are still available for both theoretical and empirical perspective as resonated by scholar works in construction industry (Liao et al.2017).

The implementation of Industry 4.0 on construction management and industry is deemed indispensable in this digital era (Klinc and Turk 2019). The aforementioned implementation is deemed indispensable, as it is represented by the publication-countries distribution (Zabidin et al. 2020) in Figure 1 on Industry 4.0.

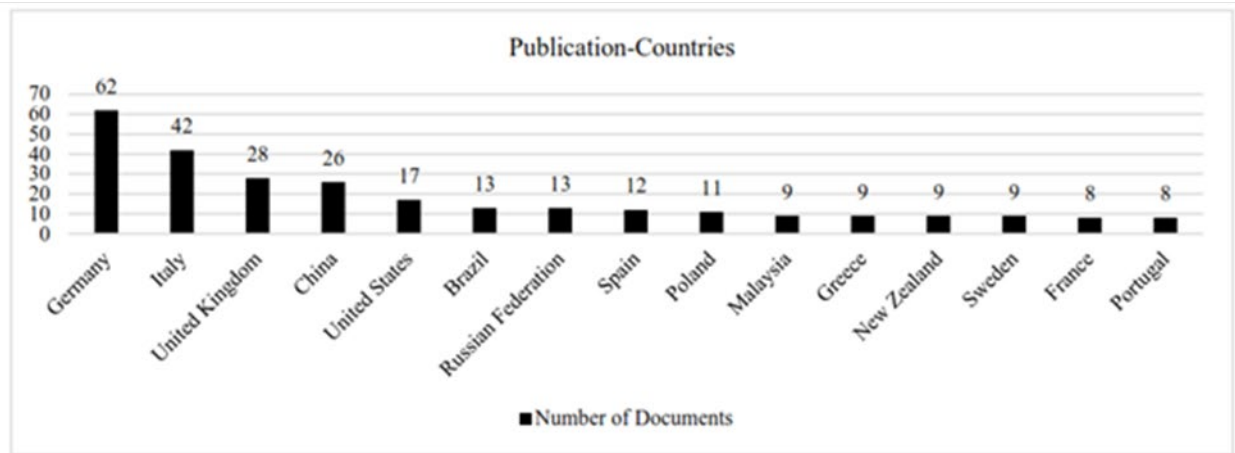


Figure 1. Industry 4.0 Policy Publication-Countries Distribution

## 2. Engineering Trilogy of Civil, Industrial, and Business Engineering

This paper has objective to elaborate both theoretical and empirical perspectives of construction management in general, including its implementation in construction industry. To some extent the aforementioned elaboration includes the following but not limited vis-à-vis Industry 4.0, construction supply chain management, Building Information Modeling (BIM), lean construction supply chain, system dynamics applications in construction management. Simultaneously, those elaborations involve Civil, Industrial and Business Engineering.

To begin with, construction supply chain involves in particular the domain of civil engineering in term of construction management. Furthermore, elaboration of supply chain is needed in the domain of industrial engineering. Ultimately, the business engineering is the arching and umbrella to ensure that the construction supply chain complies with the cost and benefit.

Construction supply chain in the Figure 2 constitutes 19 areas that relate construction not only to supply chain but also to other trends in scholar works (Krainer et al. 2021). These 19 areas of Construction Supply Chain Management (CSCM) depict the compositions of the mentioned areas accordingly



Figure 2. Construction Supply Chain Management (CSCM) and 19 Areas

Subsequently, Building Information Modeling (BIM) constitutes important part in this paper as it relates to construction management and industry. BIM has provided contribution to construction management and industry. Precisely, BIM augments project collaboration among stakeholders (Sun et al. 2017) and improves synergy within construction design, plans and implementation (Rokooei 2015).

Subsequent to BIM, this paper elaborates lean construction supply chain (LCSC). This LCSC reveals 4(four) major pillars of intellectual structure, known as, school of thoughts on lean concept as it is integrated with construction and supply chain. Those 4 pillars are summarized into: a. Concept of Waste reduction, b. Concept of Just in Time (JIT), c. Concept of Integration and d. Concept of Prefabrication.

The waste reduction in the first pillar resonates that waste is originated from the concentration of each construction project itself, in which it was trigger but inadequate flow of information, that affects the construction integrity (Ballard 2007), (Koskela et al. 2013), (Koskela et al. 2007).

Then, the JIT in the second pillar resonates that waste constitutes the principal aspects of LCSC, yet this waste is unable to be eliminated, if the main trigger of construction integrity is not eliminated (Liker 2004), (Saurin 2017), (Womack and Jones 1997).

As the third pillar, Integration Concept resonates that the engineering to order, known as prefabrication, has to be prioritized to generate effective LCSC (Dallasega, and Rauch 2017), (Dallasega et al. 2018).

Ultimately, the fourth pillar in term of Prefabrication Concept resonates that Just in Time (JIT) techniques, need to be implemented (Matt 2014) to ensure success of LCSC.

### 3. Scientometric and Bibliometric on Construction Management

Scientometric and Bibliometric constitute big contribution in the equation and discussion within Construction Management. Precisely, Bibliometric analysis is deemed as the triggers for the scientometric analysis. Subsequently scientometric and bibliometric analysis are intertwined with the Systematic Literature Review on Industry 4.0 in scholar work paper on construction (Oesterreich and Teuteberg 2016).

The aforementioned paper elaborates the triangulation approach toward Digital Transformation and Automation in the Construction Industry that comprise 14 elements of Industry 4.0 within construction management and industry ranging from 2011 until 2019.

### 4. Results and Discussions

These Results and Discussions session constitute continuation of prior sessions in both theoretical and empirical perspectives from 2011 until 2019, including the ones of the scientometric and bibliometric analysis as depicted in Table 1.

Table 1. Implementation of Industry 4.0 in Construction Management and Industry

Number	Title
1	Industry 4.0: Future and Challenges in Construction Management.
2	Automated design and modelling for mass customized housing. A website-based design space catalogue for timber structures.
3	Construction 4.0 Implications toward workforce and organization
4	Digital construction: From point solutions to IoT ecosystem
5	IoT for Structural Health Monitoring
6	Cyber-physical systems for construction Management
7	Dynamic model of implementation efficiency of Building Information Modelling (BIM) relevants to complexity of buildings and the level of their safety
8	Industry 4.0 fostering construction supply chain management: Lessons learned from engineer-to-order suppliers
9	Can constructal law and energy analysis produce a robust design method that couples with industry 4.0 paradigms? The case of a container house
10	Towards the generation of digital twins for facility management based on 3D point clouds
11	Industry 4.0 Concept Introduction into Construction Small Medium Enterprises
12	A decentralized and pull-based control loop for on-demand delivery in ETO construction supply chains

Furthermore, it is interesting to observe the scholar works from 2011 until 2019, in which the authors and co-authors have occurrence keywords in their publications on Industry 4.0 as relates to construction management and industry, as depicted in Table 2.

Table 2. Occurrence Keywords of Publication on Industry 4.0 toward Construction Management

Keywords	Occurrence
BIM	459 times
Virtual Reality (VR) / Augmented Reality (AR) / Mixed Reality (MR)	78 times
Simulation	43 times
Additive Manufacturing	42 times

3D Print	39 times
Robotics	28 times
IoT	24 times
Cloud Computing	23 times

In term of Construction Management and Industry, the scholar works from 2011 until 2019 on construction has variety of keywords, yet most of them are related to keywords as depicted in Table 3. It is interesting to observe that “Technology” including Information is part of the equation, that complies to the industry 4.0, not to mention to “Automation” in the Digital Transformation Perspectives.

Table 3. Keywords of Scholars Work on Construction from 2011 until 2019

<b>Keywords</b>
Construction
Information and Communication Technology
Construction Safety
Sustainable Construction
Construction Education
Automation in Construction
Project Management

Ultimately, construction management and industry are deemed as a complex and dynamic system. (Figure 3) In years of 2021 onward, system dynamics (SD) within industry 4.0 has been implemented and contributing toward complex and dynamic problem solving in the domain of construction management and industry. In the empirical perspectives, System Dynamics (SD) has contributed to several aspects within construction management and industry, as depicted in Figure 3. First, SD contributes to manage and control the over budget and construction delay within its project management (Han et al. 2012), (Hwang et al. 2016). Second, SD plays its vital role in detecting (Mhatre et al. 2017) the construction management risks (CMR), in addition to SD’s third contribution in participating at green ecosystems

(Tang and Ng 2019), not to mention the fourth contribution with SD's Industry 4.0 toward Building Information Modeling (BIM), in term of technology innovation (Wu et al. 2019).

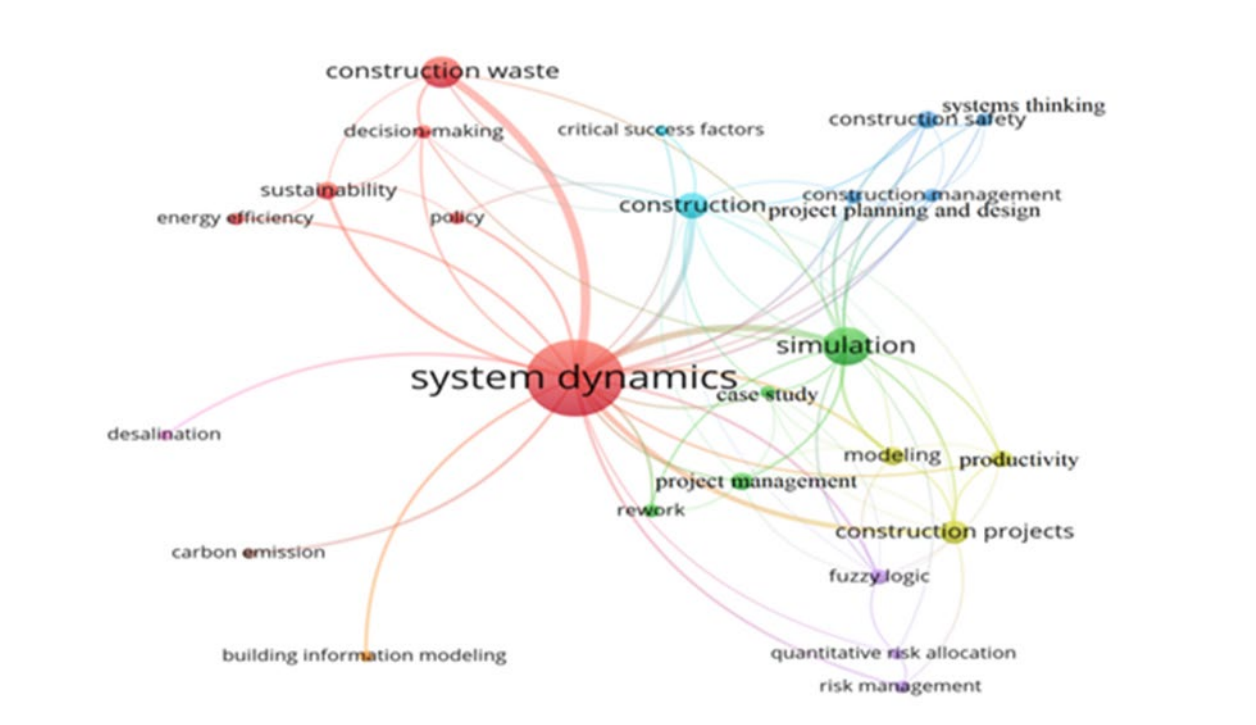


Figure 3. System Dynamics in Construction Management and Industry

## 5. Conclusions

Construction Management, in both developed and developing countries, is deemed country's principal factors in construction industry to boost countries' future in the full swings. This paper considers the digital era within Industry 4.0 as one of indispensable factors to escalate future sustainable development goals. The research stages comprise the quantitative analysis, within hundreds paper of scientometric and bibliometric perspectives of Construction Management. Precisely, the stage comprises data collection, data analysis and compilation of those perspectives. This paper has objective to elaborate both theoretical and empirical perspectives of construction management in general, including its implementation in construction industry. To some extent the aforementioned elaboration includes the following but not limited vis-à-vis Industry 4.0, construction supply chain management, Building Information Modelling (BIM), lean construction supply chain, system dynamics applications in construction management.

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There are dominant implementation in trilogy of industrial and system engineering, manufacturing and electrical and room for improvement are still available for both theoretical and empirical perspective as resonated by scholar works in construction industry. The implementation of Industry 4.0 on construction management and industry is deemed indispensable in this digital era. Future research emphasizes scientometric analysis on wider perspectives.

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## Biographies

**Dr. Ir. Khristian Edi Nugroho Soebandrija, B.S.I.E, M.M** is one of faculty members in Binus ASO School of Engineering (BASE), in Bina Nusantara University, Jakarta, Indonesia. He earned Bachelor of Science Degree in Industrial Engineering (BSIE) from Wichita State University (WSU), Wichita, Kansas, USA, master's degree in management from Indonesian Institute for Management Development, Jakarta, Indonesia. He obtained Doctoral Degree in Doctoral Program in Research Management. Since 1991, He has professional working exposures in

Thompson CSF Corporation (Versailles, France), Cessna Aircraft Company (Wichita, Kansas, USA), Frigoglass Group (Cikarang, Indonesia), Citibank, N.A (Jakarta, Indonesia), Perfetti Van Melle Indonesia (Cibinong, Indonesia). As in Education Professional and Consultancy, he has been winning several professional global awards and involving in teaching in several National and Multinational Companies and State-Owned Enterprises. He is a distinguished member of Sigma Gamma Tau (Aerospace Engineering Honor Society) and Tau Beta Pi (National Engineering Honor Society), Strategic Management Society (SMS).

**Meilani** earned her bachelor and master's degree in civil engineering from Tarumanagara University. She previously involved in various construction of buildings and houses when she served as project planner in contractor company. Her passion in education led her to Bina Nusantara (Binus) University where she serves as Deputy Head of Civil Engineering Department since 2010. She is actively involved in Institution of Civil Engineers (ICE) and currently serves as faculty advisor of ICE Student Chapter Binus University.