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## Lean construction management techniques and BIM technology – systematic literature review

Adrian Michalski\*, Eryk Głodziński<sup>a</sup>, Klaus Böde<sup>b</sup>

<sup>a</sup>Warsaw University of Technology, Poland, <sup>b</sup>Bauhaus-Universität Weimar, Germany

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### Abstract

For the last years lean construction (LC) and Building Information Modeling (BIM) are perceived as important application and research fields. Numerous publications discuss various aspects that need systematization and require further thought related to benefits and threats for an organization. The paper presents systematic literature review that indicates hot topics in scientific studies, such as: benefits related to joint use of LC and BIM, issues related to simultaneous implementation and utilization of LC and BIM, instruments supporting implementation and utilization, potential future application.

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**Keywords:** lean construction; BIM; systematic literature review

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### 1. Introduction

The modern construction projects are facing new and more sophisticated challenges, such as increase of project complexity, implementation of numerous changes by client during execution stage, or operation in uncertainty conditions [1]. In order to manage them experts are looking for new approaches and technologies, searching proper

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\* Corresponding author.

E-mail address: [adrian.michalski.dokt@pw.edu.pl](mailto:adrian.michalski.dokt@pw.edu.pl)

combination of various methods and techniques [1]. One of the proposals is the application of lean approach to management, firstly described as Toyota Production System (TPS) [2] and next as lean thinking [3]. Numerous authors described lean as a style of manufacturing management, but Womack noticed, that lean could be used also to other industries [3], such as construction [4] or healthcare [5]. Lean management in construction in general can be understood as a way to minimize all kind of wastes and generate maximum value of product [6]. Numerous studies describe the mentioned techniques of management in construction. One of the directions of researches is join utilization of lean construction management method and BIM technology [7]. BIM (Building Information Modeling) is defined by BuildingSMART International as „*A new approach to being able to describe and display the information required for the design, construction and operation of constructed facilities*” [8] and is getting more and more popular in construction, moreover also connected with lean approach [9]–[11]. One of the major issue related to the mentioned fields is related to join use not only in design but for optimization in execution of construction works as well. The mentioned area is studied by numerous authors who presented different approaches to lean construction management. The paper aims to systematize the current knowledge, to demonstrate various hot topics, and to indicate possible topics for further studies. Following research questions were formulated:

RQ1: What is the popularity level of lean construction management and BIM among researchers?

RQ2: Why lean construction management is combined with BIM technology?

RQ3: What is the existing research gap in academic studies and/or practitioners issues related to combining lean construction management and BIM technology?

In order to answer the presented research questions the paper was structured in the sections:

- description of the initial studies related to the issue of connection lean construction and BIM,
- presentation of procedure of systematic literature review,
- description of quantitative literature review results,
- demonstration of qualitative literature review results,
- final remarks.

## 2. The beginning of lean construction and its initial linkage to BIM

The concept of lean construction was introduced in 90' [12] and at early beginning has two interpretations. The first one was application methods of lean production to construction, including opportunities of adaptation of well-known techniques from lean manufacturing into lean construction [13]. The second one treated lean production as a theoretical inspiration for new approach in construction management. The second proposal became more popular among researchers and was developed by organization called International Group for Lean Construction. The fundamental principle of lean construction was focused on reduction of waste and better meeting the customer needs [14] along with transparency of the process. The topic of lean construction arises to the hot theoretical and practical issue and resulted with establishing in 2003 by the Lean Construction Institute the Lean Construction Journal. Prepared keyword analysis form papers published in scientific journals between 2000 and 2006 indicated that following topics are strong linked with lean construction: project management, performance measurement, design management, value for client, culture and human aspects, supply chain management, information technology, safety, waste and complexity [15]. The presented findings confirm that lean construction was perceived as approach supporting value creation in construction projects both from contractor and client perspectives. Numerous researchers highlighted potential benefits in combining new approach with emerging innovative information technology, such as virtual building technologies [16]. Technology of at least 3D and often more dimensions was demonstrated as a method supporting improvement of construction project performance [17] and directly lean construction [18]. In almost all of the mentioned publications the authors indicated on BIM technology, as promising solutions to be implemented.

The presented initial analysis evidenced that lean construction is an interesting research area that has potential for development from practitioners point of view. The construct linked with BIM can increase the organization efficiency and effectiveness. Because of rapid growth in knowledge and accompanying utilization of software supporting lean construction an analysis of last year's publications is required. The selected period is time of increasing interactions between BIM and lean construction [19] and hopefully state of the art needs systematization.

### 3. Research method of systematic literature review

A systematic literature review following the procedure presented by Czakon [20], [21] was adopted in the study. The analysis was provided for the period of last 10 years because initial studies emphasized that since then noticeable development in application of information technologies in construction can be observed. It was assumed that growth in number of publications can accompany this digital transformation.

A systematic literature review contains four general phases composing from seven stages. According to Czakon [20], the first phase consists of identifying the purpose of the study. In the second phase, the literature sample is identified. This phase consists of three consecutive steps: identifying primary literature, publication selection and developing a publications database. The third phase is followed by analytical activities such as frequency analysis and content analysis. The final phase is the development of the research report. As it was mentioned earlier the paper aims to systematize the current knowledge, to demonstrate various hot topics, and to indicate possible topics for further studies. The research was based on Scopus, ProQuest and scholar.google.com databases. It was used to identify similarities and differences of the approach of the authors to the subject of cooperation of lean construction techniques and BIM technology in theoretical and case study foundations. Through this systematic check develops strong foundations for future researches in that area.

In the stage of selection of publications the key phrase of the search was "lean construction". The secondary phrase was "BIM". The search was performed for article titles, abstracts, and keywords. The search was performed in January 2021. No time restrictions were applied to the search in the first stage. The results of the search are provided below in Table 1 and Table 2. A language criterion was applied to the search, it was made a filter that limits articles language to English because the phrase of lean construction has different translations in various languages that do not fully reflect its proper understanding. Secondly, the authors want to avoid limitations related to different – than English – papers' languages that could come during the content analysis. The search was restricted to the three influential databases and full-text articles because of necessity of further content analysis. To ensure the timeliness of the selected texts and based on the mentioned search assumptions the period from 2010 to January 2021 was set. Finally to qualitative and quantitative study 58 publications were selected.

Table 1 Stages of literature review search – part 1

Selection criteria	Scopus	ProQuest	Google Scholar
Key words "lean construction" and "BIM"	2 643	2 045	15 300
Articles in English	2 606	2 008	12 200
Full-text articles	960	1 980	not applicable
Peer-reviewed articles	not applicable	172	not applicable
Publications since 2010	958	162	9720
Open access articles	104	14	not applicable
Scientific articles only	25	14	77

Table 2 Stages of literature review search – part 2

Selection criteria	Number of papers
Aggregated number of papers	116
Delete of duplicate	102
Verification of the titles & abstracts	66
Verification of the content	58

#### 4. Quantitative analysis of systematic literature review

The popularity of the issue related to combining of lean construction and BIM technology - in publications was examined. The overview of results is shown in the Figure 1. Based on the analysis, it can be observed that the studied issue is a relatively new and very developing. There is a clear upward trend in the number of publications year-on-year. The number of scientific publications is maybe not extremely high – top of publication in amount of 15 papers was noticed in year 2019. Nevertheless, the issue is very specialized and limited to project management in construction industry.

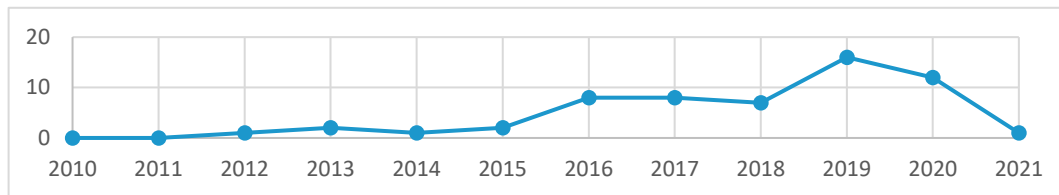


Figure 1 Number of publications in period 2010-2021

Additionally, it is worth to mentioned that the most popular publication [22] as of January 2021 has 93 citations. The next three publications have a score of approximately 20-30 citations. The small number of publications presented in 2021 is due to the fact that the analysis was done at the beginning of the year. The presented facts indicate the timeliness of the issue, and provide opportunity for further analysis. During definition of target scientific papers for qualitative analysis numerous industry publications were rejected (see Table 1, difference between full-text articles vs peer reviewed articles). The presented issue indicates that the fields related to lean construction and BIM are crucial from practitioners point of view, being the hot topics of last years in construction industry.

It is worth noting that many of the analyzed articles are related to project management, hence the popular phrase is "Project management". An important element of the lean concept is also waste reduction, hence the high popularity of the keyword "waste". BIM technology makes it possible to visualize the construction process, and virtual and augmented reality are often used to depict activities. These keywords are also popular in the analyzed articles, as well as construction digitalization. A hot topic is the "Last Planner System" used as one of the most common lean solutions in construction. This analysis confirms the initial literature review presented in the second section of the paper that the concept of lean construction is strongly related to BIM technology and all supporting elements related to these issues. This confirms the multitasking nature of the issues analyzed and their comprehensive use in the implementation of the construction process. In addition, it reinforces the fact that the digitalization of construction is a complex process and an improvement in the execution of investments. The presented cloud analysis pointed out that linking lean construction and BIM should follow to increase of productivity, collaboration inside construction project stakeholders, integration of activities. The mentioned fields will be discussed in qualitative analysis of systematic literature review.

#### 5. Qualitative analysis of systematic literature review

Next step of the systematic literature review is content analysis. As a part of the qualitative analysis aims to evaluate the crucial elements constituting application of lean construction and BIM. The authors in their publications regularly pointed out the valid application of lean construction management concepts along with the use of BIM tools. In various publications numerous aspects were demonstrated simultaneously (Table 3).

The qualitative analysis indicates that following crucial topics of research studies related to lean construction and BIM could be emphasized:

- benefits related to join use,
- issues related to simultaneous implementation and utilization,
- instruments supporting implementation and utilization,
- potential future demand.

The presented fields will be described more in detailed.

Table 3 Selected papers discussed combination of lean construction and BIM

Article	Scope of study					Geographical area		Dominant research method			Level of construction stage				
	D/F	IF	B	Ch&B	LU	SC	VC	LR	ES	DR&oM	C	T	D	CW	M
[23]	+	+	+		+	+			+				+	+	
[1]	+	+	+	+			+			+	+	+	+	+	+
[7]	+		+	+			+			+	+	+	+	+	+
[24]	+	+	+	+	+	+			+				+	+	
[25]	+	+	+	+	+		+		+				+	+	+
[26]	+	+	+		+		+	+		+			+		
[27]		+	+	+		+			+						
[28]	+	+	+	+	+	+		+	+					+	
[29]			+	+			+	+			+	+	+	+	+

Abbreviation description:

D/F: drivers / factors      IF: implementation frameworks      B: benefits      ChB: challenges & barriers      LU: level of utilization

SC: selected country      VC: various countries

LR: literature review      ES: empirical study      DR&oM: desk research or other research method

C: conception      T: tender      D: design      CW: construction works      M: maintenance

Benefits related to the combination of lean construction and BIM are widely discussed (Figure 2).

Numerous studies highlighted improvement of construction project efficiency [23], [30], [31]. The occurrence of synergy phenomenon was pointed out when lean construction and BIM are used together and determines this action as a factor to achieve success in sustainable construction projects [7]. BIM and lean construction together emphasize the increase in the effectiveness of cost control in projects using these tools [24]. Simultaneously use of BIM and lean can lead to a reduction of waste in the execution of the construction planning process, thereof reduction of material resources [32], [33]. Some researchers indicate a significant improvement in quality control by applying lean construction principles and BIM tools [34]. Join use of the presented solutions could reduce the cost of project construction works because of better planning and link with execution of various work packages [11] or could reduce of energy consumption [35].

The second hot topic is related to the issue of simultaneous implementation and utilization of lean construction and BIM. It is argued [30] that the construction industry suffers from low productivity growth compared to other industries. As a result of the assumption the guidelines for implementing lean in the construction industry was provided. Numerous researchers perceive that construction is a low-digitization industry with high manufacturing and general costs and low productivity [36]. BIM was identified as an essential technology to effectively implement lean principles [1]. Example of scenarios of how to implement lean principles in construction site management were described [22]. Nevertheless, problems facing by project team using BIM tools for project development were highlighted, such as resistant to change and lack of IT technical skills [37]. Some study demonstrates that one of the reason could be a significant problem in education among potential users because of lack of subjects and teachers [38]. Consequently implementation of BIM in construction is not occurring as quickly as anticipated [31]. Because of that a roadmap for implementing BIM and lean construction in construction project implementation was proposed [39].

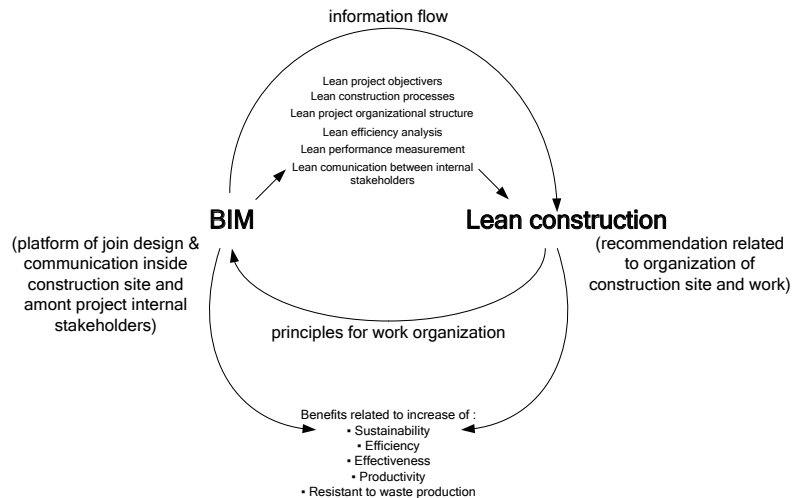


Figure. 2. The crucial linking points of lean construction and BIM.

The third widely discussed topic is related to instruments that can support lean construction and BIM. Some authors propose utilization of AR (augmented reality) [40] and virtual reality [41]. Other complementary instruments could be big room technique, 5S, and LPS (Last Planner System) [25]. The researchers demonstrate that use of the mentioned techniques and technology could be supported blockchain concept [42].

The fourth aspect conducted in scientific studies is related to prediction of the future. It can be observed that lean construction supports mainly optimization of management in construction company of innovative entities. Because of high implementation and utilization costs [33], limited direct benefits for construction company future of BIM adaptation is close depended on investors, therefore public one [43]. Current state of the art indicates that the most common use could be observed in design stage or design process [4] [28]. Future demand is strongly dependent on opportunities related to adaptation in MEP system modelling, energy and environment analysis, constructability analysis and structural analysis [44].

## 6. Conclusions

The presented studies highlighted that lean construction and BIM technology are widely recognized fields of research (RQ1). The topic started its popularity in 90. of XX century and resulted from a need of searching solutions that could support construction entities, increase their efficiency and productivity. Numerous researchers and institutions such as the Lean Construction Institute has answered the needs of business. The quantitative systematic literature review reported thousands of publications in the first step of the search. After final verification 58 papers from top international journals were selected.

Lean construction and BIM are combined because support efficiency, productivity, sustainability of construction projects (RQ2). Lean techniques deliver principles for work organizations and BIM creates IT platform supporting information flow among internal stakeholders. Qualitative analysis allowed to extract four hot scientific topics, such as: benefits related to join use, issues related to simultaneous implementation and utilization, instruments supporting implementation and utilization, potential future demand.

Despite of few studies related to join application and utilization of lean construction and BIM there is still a significant research gap in this area [45]. One of the most crucial issue is to describe what methods and techniques could be adopted from lean manufacturing. The problem seems to be challenging because manufacturing uses more process-based approach while construction project-based [46]. The second research gap highlighted in the study is related with design of framework or model that could support of lean construction and BIM implementation and linkage (RQ3).

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