Bamana F., Lehoux N., and Cloutier C. (2017). "Just in Time in Construction: Description and Implementation Insights." In: *LC3 2017 Volume II – Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC),* Walsh, K., Sacks, R., Brilakis, I. (eds.), Heraklion, Greece, pp. 763-770. DOI: https://doi.org/10.24928/2017/0064

JUST IN TIME IN CONSTRUCTION: DESCRIPTION AND IMPLEMENTATION INSIGHTS

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Abstract: The construction industry has long been plagued with productivity and waste management issues on construction sites, unmet deadlines, and client dissatisfaction over the quality of the construction delivered. Having greatly aided the manufacturing industry, this paper investigates how the JIT philosophy could help with these difficulties. The paper illustrates four scenarios of JIT implementation in construction according to the level of coordination required, on-site management, and information sharing. The methodology which consists of a systematic literature review on JIT in construction confirms the need to adapt this philosophy for an adequate deployment in this industry. It also confirms the close ties between JIT, lean construction, and prefabrication for successful construction project management.

Keywords: Just in time in construction, lean construction, prefabrication, systematic literature review.

1 INTRODUCTION

Several authors address the fact that productivity in the construction industry has improved significantly but is still lagging behind other industries (Pheng and Chuan 2001; Asri et al. 2016). A way to address this issue is to embrace the just in time (JIT) philosophy which consists of providing the right materials, in the right quantities and quality when it is needed in order to reduce waste and to provide maximum value (Tommelein and Li 1999; Tommelein and Weissenberger 1999; Vokurka and Davis 1996). More research indicates that JIT in construction consists of producing smaller batches of each component and sending them on site at the required installation time in order to reduce waste, diminish on-site storage space, and meet the deadlines and high standards of the construction industry (Cossio and Cossio 2012). The goal of the paper is to show how JIT may reduce costs, waste, and quality problems encountered in a construction project. To achieve this goal, different scenarios of JIT implementation are proposed determined by the level of coordination required, construction site management, and information sharing. The paper contributes to scholars by identifying elements that influence JIT implementation in construction and to practitioners by presenting requirements for its successful implementation. The paper contains six parts. An introduction, a systematic literature review (SLR), a discussion of results, a conclusion, references, and an appendix.

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2 JIT IN CONSTRUCTION: SYSTEMATIC LITERATURE REVIEW

In order to show how JIT can help to better deal with issues in construction, a scientific methodology called systematic literature review (SLR) is applied. The goal of a SLR is to "improve the quality of the review process by synthesizing research in a systematic and reproducible manner" (Tranfield et al. 2003). As these authors agreed, conducting a systematic review passes through three stages: planning, conducting, and reporting.

2.1 Planning the review

The first phase in the planning stage is to state the need for the review. This review is needed in order to present studies in which JIT has been implemented in a construction project. The studies will be used to equip practitioners with proper strategies of implementation and if not, to highlight gaps in those studies that could be filled in future studies. The second phase consists of preparing questions that should be answered by the review. For this research, the following questions are identified:

1. Is there a presence of JIT in construction mentioned in scientific literature?
2. Which shape does JIT take in construction?
3. Which indicators measure performance when JIT is implemented in construction?

The third phase presents the methodology used while conducting the review. Step one of phase three consists of an identification of keywords that will be used in the review. In the second step, a search in all engineering databases with established keyword combinations is done. The third step consists of an analysis of titles and abstracts of results. In the fourth step, articles that do not respect logical pre-established criteria are eliminated. The fifth step refers to a complete analysis and classification of the remaining articles.

2.2 Conducting the review

2.2.1 Identification of research

The databases used in the search of scientific articles are Compendex and Inspec from the research databases Engineering Village and Web of science. Engineering Village has been selected because it is an excellent choice for rigorous scientific research specific to engineering. Web of science has also been chosen because it covers a wide variety of scientific areas. The research coverage period has been left by default, from 1884 to 2016 in Engineering village and from 1900 to 2016 in Web of science in order to cover all potential articles. The research was done for the last time on September 27, 2016. Key concepts of the subject matter are "just in time" and "construction". Synonyms found for each of them in the synonym database Thesaurus are "JIT" and "Build-to-order" for "just in time", and "building" and "prefabrication" for "construction" (an asterisk is used after *prefabricat* to search all words starting with *prefabricat* and finishing with all its suffixes). The research consisted of equations which are combinations of key concepts and their synonyms while specifying their appearance in the Subject, the Title or the Abstract. The nine research equations are as follow: "just in time" Near/6 construction, "just in time" Near/6 building, "just in time" Near/6 prefabricat*, "JIT" Near/6 construction, "JIT" Near/6 building, "JIT" Near/6 prefabricat*, "Buid-to-order" Near/6 construction, "Buid-to-order" Near/6 building, and "Buid-to-order" Near/6 prefabricat*. In all research equations, "Near/6" is used to specify the presence of at most six words between the two key concepts. After testing all combinations, the Boolean operator OR was used in order to present results of all combinations together. A third database from the International Group for Lean Construction (IGLC) was also used because IGLC has been working on the subject for several years. IGLC conference papers relating to JIT in construction were searched on January 16, 2017.

2.2.2 Selection of studies

A total of 164 articles were found with Engineering Village, 227 with Web of science, and 83 with IGLC. In order to refine the results in Web of science, only articles from categories: operations research management science, industrial engineering, management, manufacturing engineering, civil engineering, and multidisciplinary engineering are kept since they relate more to JIT in construction. Of the 146 articles left in Web of science, 164 in Engineering Village, and 83 in IGLC, titles and abstracts are scanned by using five logical criteria. Articles kept are articles discussing only JIT in building construction, construction supply chain, tools used to implement JIT in construction, JIT success factors, and barriers to the presence of JIT in construction. This leaves us with a result of 23 articles from which critical information is extracted such as performance indicators used to measure the impact of the implementation of JIT in a construction project and tools used to undergo the implementation. Table 1 in the appendix summarizes the findings.

3 Discussion

3.1 Reporting and dissemination

Analysis of resulting papers showed that scientific literature covers Lean in construction (eight papers) and JIT in construction (7) more than JIT implementation in construction (3). Indeed, few articles discuss an implementation of JIT in construction even though some of them underlined the impact of prefabrication and Lean techniques used on construction sites. No paper showed quantitative results on the impact of different levels of prefabrication as well as buffer stock and construction site organisation on the outcome of a construction. Eighteen out of twenty-three articles discussed JIT in construction, JIT implementation in construction along with Lean in construction and prefabrication.

3.1.1 Response to research questions

As the first research question concerned the presence of JIT in construction in scientific literature, we can now confirm that it is the case. The second question dealt with the form JIT typically takes in construction. The case studies from the SLR mention and describe how JIT has been applied in several construction projects whether big or small. However, Tommelein and Weissenberger (1999) and Pheng and Chuan (2001) maintain that in practice a buffer is necessary and its size should be determined strategically. In construction, JIT mostly covers the management of deliveries (Tommelein and Li 1999; Asri et al. 2016) and control of buffer stock levels on construction sites (Pheng 2001; Pheng and Chuan 2001; Ng et al. 2009; Roos et al. 2010; Amornsawadwatana 2011; Cossio and Cossio 2012) through a pull system (Akintoye 1995; Tommelein and Li 1999; Low and Wu 2005; Viana et al. 2015). Furthermore, the implementation of JIT principles in construction seems to require prefabrication (Cossio and Cossio 2012), Lean techniques, an integration of the materials procurement time frame with the construction project schedule, and evaluation of supplier performance to ensure quality of delivered materials while avoiding rework on site (Opfer 1998). Figure 1a presents the number of times these elements are mentioned to support an implementation of JIT in construction. Question three was about the indicators used to measure performance when JIT is implemented in construction. Figure 1b illustrates the number of times KPIs such as costs are mentioned to assess the results of an implementation of JIT in construction. The most frequently mentioned KPIs, in descending order, are costs, productivity, project duration, amount of buffer stock, quality of construction, and waste quantity. Five out of the six KPIs are elements that impact only a portion of the building's life cycle. However, the fifth KPI: quality of construction, which depends on client satisfaction, should have a greater weight since it lasts throughout the project's entire life cycle. Moreover, the adoption of JIT in construction seems to generate qualitative results such as better partnership between suppliers and contractors and improved system of deliveries (Cossio and Cossio 2012).

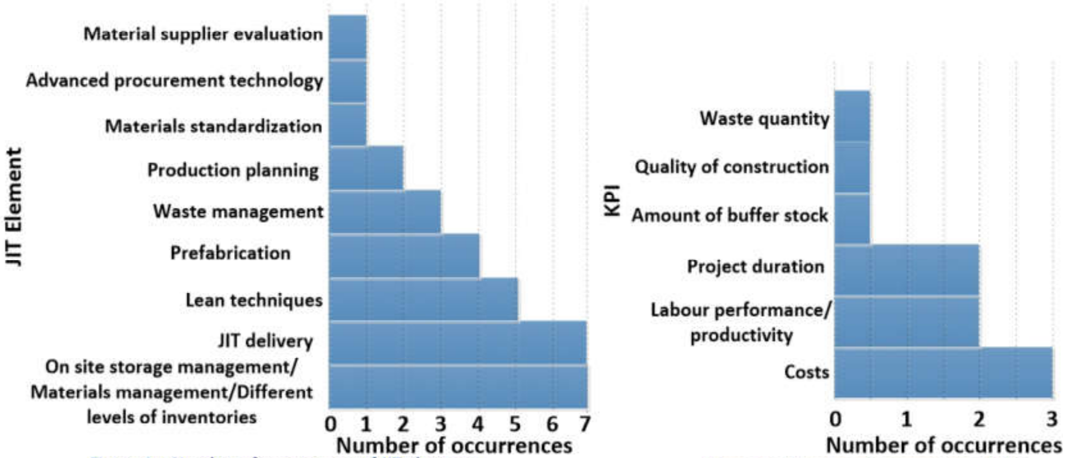

Figure 1a: Number of occurrences of JIT elements mentioned in the SLR

Figure 1b: Number of occurrences of KPIs mentioned in the SLR

Figure 1: Number of occurrences of JIT elements and KPI mentioned in the SLR

3.2 Description of different implementation scenarios of JIT

According to the literature, JIT benefits on a construction project's value chain depend on the prefabrication plant, the construction site, and the flows between them. As pointed out by Pheng (2001), one party trying to adopt a JIT philosophy while the other does not, will realize his efforts are futile and will not achieve the potential benefits. The situation is also depicted in Viana et al. (2015). Figure 2 illustrates four scenarios of JIT in construction. Scenario I shows that low information sharing between the plant and the site and low supply chain coordination are respectively less favourable to (-) prefabrication of components and (-) JIT deliveries while low construction site management suggests (-) low presence of Lean principles on the site. In scenarios II and III, one or two elements are less present, making it difficult to obtain gains on the overall value chain. Scenario IV illustrates the best scenario for JIT implementation in construction where high information sharing and high supply chain coordination are respectively more favourable to (+) prefabrication of components and (+) JIT deliveries while high construction site management suggests (+) the presence of Lean principles on the site.

Pheng (2001) states that prefabrication has come with "the hope of reaping the benefits of factory-styled operations" since it entails benefits such as improved quality, waste reduction, and faster erection of buildings. However, even if an efficient plant makes JIT deliveries, if there are no resources available to unload them on site, the truck and its driver will remain monopolized. Such a situation illustrates the need for JIT deliveries to ensure the fast erection resulting from prefabrication but also the need to use Lean in construction site activities to avoid waste of time (Friblick et al. 2009). For example, Khalfan et al. (2008) used Kanban, "one of the Lean approaches" in their construction project "to pull construction materials through their production systems on a just-in-time basis".

Moreover, Lean tools such as 5S (Deshpande et al. 2012) are used to ensure that the construction site is well organized to improve performance of workers and optimal movements of materials on site. It can be concluded that successful prefabrication needs successful implementation of JIT while successful JIT implementation in construction requires adoption of Lean in construction site activities. However, the scenarios present some limitations. It is supposed that the plant is able to provide materials regardless of the demand and that it can manufacture different levels of prefabricated materials. These scenarios do not apply if the plant does not meet such expectations.

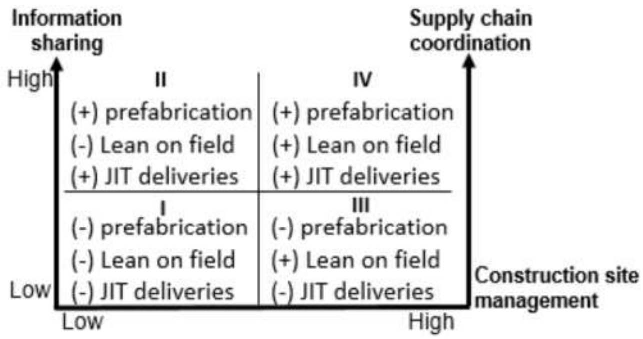

Figure 2: Scenarios of implementation of JIT in construction

4 CONCLUSION

The research showed through the SLR that JIT exists in construction, and helped identify the JIT elements applied as well as the KPIs used to measure the impact of their implementation. Moreover, the research proposed four scenarios to illustrate the influence of three JIT elements (prefabrication, JIT deliveries, and presence of Lean principles) on the successful implementation of JIT in construction. However, the aforementioned scenarios are purely qualitative. Future work will use activity-based software to simulate different scenarios presenting various levels of prefabrication, on-site buffer stock, and Lean on-site activities in order to obtain quantitative KPI measurements.

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6 APPENDIX

Table 1: Results of the SLR

References	Origin	Focus / KPI	Tools
(Akintoye 1995)	UK	JIT in construction/ KPI: -	Materials management, production planning
(Anglin et al. 1995)	US	JIT in construction KPI: Quantity of waste	Waste management
(Tommelein 1997)	US	Lean in construction (LC) KPI: Waste quantity, time saving	Lean techniques
(Opfer 1998)	US	JIT in construction/ KPI: -	Materials standardization, advanced procurement technology, material supplier evaluation
(Tommelein and Li 1999)	US	JIT in construction/ KPI: -	JIT deliveries
(Tommelein and Weissenberger 1999)	US	JIT in construction/ KPI: -	JIT deliveries
(Pheng and Chuan 2001)	SG	JIT implementation in construction, LC, Prefabrication KPI: Costs	JIT delivery, Lean techniques, on-site storage, waste management
(Pheng 2001)	SG	JIT implementation in construction, LC, Prefabrication KPI: Costs	JIT delivery, Lean techniques, on-site storage, waste management
(Low and Wu 2005)	SG	JIT implementation in plant, Prefabrication KPI: Lead time, machine setup time, quality	JIT vendor strategy, JIT production strategy, quality control strategy

Table 1: Results of the SLR (Continued)

References	Origin	Focus / KPI	Tools
(Horman and Thomas 2005)	US	JIT in construction KPI: Labour performance, productivity	Different levels of inventories
(Christensen 2005)	US	JIT in construction/ KPI: -	-
(Hamzeh et al. 2007)	US	LC/ KPI: Costs, time average inventory	Different level of inventory
(Khalfan et al. 2008)	UK	LC/ KPI: Waste quantity, costs, time saving	E-procurement system
(Zimmer et al. 2008)	US	LC/Construction supply chain KPI: Observations	Lean techniques, JIT delivery, material management, last planner
(Friblick et al. 2009)	SE	LC KPI: Costs, time saving, delays	Lean techniques
(Ng et al. 2009)	CN	JIT implementation in construction/ KPI: Project duration, amount of buffer stock	JIT delivery, on site storage management
(Amornsawadwatana 2011)	TH	LC/ KPI: Number of loading activities	JIT delivery
(Deshpande et al. 2012)	US	LC/ KPI: Costs, efficiency, waste quantity	5S
(Cossio and Cossio 2012)	MX	JIT implementation in construction, Prefabrication KPI: Project duration, costs, productivity, quality of construction	JIT delivery, on site storage management
(Tillmann et al. 2014)	US	LC/ KPI: Induction of desired Lean behaviours	Lean techniques
(Trivedi and Kumar 2014)	IN	LC/ KPI: Quantity of waste, costs, quantity of inventory	Pull system, continuous process flow, standardization
(Viana et al. 2015)	BR	JIT implementation in construction/ KPI: -	Production planning/JIT delivery
(Asri et al. 2016)	MY	JIT, LC, Prefabrication/ KPI: -	-