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LEAN DESIGN IN CONSTRUCTION INDUSTRY: FROM THEORY TO PRACTICE

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Abstract: This paper provides a literature review of over 70 published research articles regarding Lean Design from 2002 to 2018. The review focuses on two aspects. Firstly, it provides a comparison between different definitions and terminologies presented by authors, and secondly gives an analysis of how Lean Design methods/*tools* apply to the construction industry. Two main issues have been identified and explored in this review. Indeed, there is still a gap between theory and practice concerning the context of the construction industry which makes the implementation process effortful and not clear for the practitioners. One aspect of this gap is reflected by the lack of a standard definition of what Lean Design means. Another aspect is the lack of consensus on a clear terminology of Lean Design. Definitions and interpretations differed from an author to the other with little emphasis on value. Besides, there is a lack of coherence between the proposed Lean Design definitions and the methods/*tools* used in practice. Thus, the first contribution of this research is providing a better comprehension of current Lean Design literature in the construction sector. The second one consists of presenting the different Lean Design definitions perspectives, and the incoherencies between these perspectives and the methods/tools proposed. Moreover, the last contribution is providing a new Lean Design definition taking into account above-mentioned.

1 INTRODUCTION

Research has highlighted the importance of effectively managing the early project phases to generate clients' value in construction projects (Bertelsen and Emmitt 2005, Tilley 2005). In fact, poor control of the early phases may impact value delivery and lead to hidden problems that appear only in the last phases such as delays in the handover, uncertainty regarding cost and non-satisfaction with the final product (Abdelsalam et al. 2010, Tilley 2005, Ballard 2008).

One of the solutions proposed by researchers, to manage the design phase, is the Lean Design. In fact, Lean Project Delivery System (LPDS) model for managing project aims to deliver what customer needs without waste, and consists of four interconnected phases: Project Definition, Lean Design, Lean Supply and Lean Assembly (Ballard 2000).

The project definition is the first phase of the LPDS project lifecycle and consists of three iterative modules: determining client needs/requirements, translating those purposes into criteria for product and design process and generating architectural concepts based on those criteria. Once the alignment between purpose criteria and concepts is achieved Lean Design begins and aims to align the product and design process with the project definition elements.

It is not the intent of this study to explain all phases of LPDS in detail. Actually, this research is one of the first steps of a larger research project, which is mainly focused on the early project phases including project definition and design phase. In this paper, we limit our scope to understand and analyze the second phase of LPDS, which is the Lean Design.

Ballard (2000) has explained that production is both making and designing, which means that the TFV (Transformation, Flow, Value) theory of production is also covering this aspect (Koskela, 2000). Activities in the design phase should be understood as a Transformation, Flow and Value.

However, unlike flow management that aims at reducing waste, the value aspect is barely addressed (Jørgensen and Emmitt 2009). Moreover, even though the implementation of Lean Design should have a significant impact on the value of the facility delivered since its focus should be on aligning the product and design process with the requirements set in the project definition, the literature on this subject remains confusing in terms of terminology and definitions (Pinto and Winch 2016, Bertelsen et al. 2002).

Thus, this research aims to highlight the gaps raised by Jorgensen (2006) in existing Lean Design literature regarding commonly used terms and definitions. Moreover, it aims at bringing out the different perspectives of the Lean Design definition suggested by researchers, proposing one unified definition, and emphasizing the existing alignment gap between definition perspectives and methods/*tools*. Section 2 describes the methodology used for the articles selection. Section 3 presents the results of terminologies, definitions, and methods/*tools.* Sections 4 and 5 discuss the results and presented the new definition along with the existing perspectives. The final section concludes the paper presenting the main ideas and proposing future research directions.

2 METHODOLOGY

First, in order to ensure an effective review of the scientific publications related to “Lean Design”, the study focused on the abstract, title and author’s keywords of the publications in Scopus database. The selection was based on the literature published in peer-reviewed journals, doctoral theses, conference papers, and research reports between 2002 until 2018.

Second, using the following keywords “Lean Design” AND “construction”, 73 articles were found. Special attention was paid to verify that all articles obtained concern Lean Design in the construction industry. Thus, we excluded those concerning methodological works because of focusing less on Lean Design and more on pure methodology. Also, we considered all papers published in English, French or Spanish because of our expertise in these languages, and we exclude others. However, 90% of the articles are in English.

After verification, we excluded 16 articles concerning methodological works and 2 published in languages others than we above-mentioned, thus, the number of publications decreased to 55, which correspond to the final number of publications retained for this study.

3 RESULTS

3.1 Different Terminologies of Lean Design

After analyzing the articles, a lack of consensus on a “Lean Design” terminology was very clear. In fact, we found five different terminologies that vary according to the authors: Lean Design (e.g. Fitchett and Hartmann 2017), Lean Design Management (e.g. Uusitalo et al. 2017), Lean Design Process (e.g. Mazlums and Pekençli 2016) and Lean Design and Construction (e.g. Umstot et al. 2014).

Publications generally adopt the terminology Lean Design (Table 1). However, the term may change depending on the focus of the article emphasizing that they are specifically addressing the management aspects, using the term Lean Design Management or focusing on the process aspects, using the terminology Lean Design Process.

Table 1: Terminologies according to the authors

Main Terminologies	Authors	
Lean Design	[1] Ede et al. 2018 [2] Torres et al. 2018 [3] Nøklebye et al. 2018 [4] Bosi et al. 2018 [5] Maxwell and Aitchison 2017 [6] Gambatese et al. 2017 [7] Kpamma et al. 2017 [8] Fitchett and Hartmann 2017 [9] Salgin et al. 2016 [10] Munthekaas et al. 2015 [11] Svalestuen et al. 2015 [12] Orihuela et al. 2015 [13]Leite and De Paula Barros Neto 2013	[14] Lee and Cho 2012 [15] Deshpande et al. 2012 [16] Arayici et al. 2011 [17] Furtmeier and Tommelein 2010 [18] Shu and Shi 2010 [19] Venkatachalam et al. 2010 [20] Jensen et al. 2009 [21] Hamzeh et al. 2009 [22] Mossman 2009 [23] Holmes 2008 [24] Arbulu and Soto 2006 [25] Brookfield et al. 2004 [26] Whelton et al. 2002
Lean Design Process	[27] Alves et al. 2017 [28] Mazlums 2016 [29] Ko and Chung 2014b	[30] Ko and Chung 2014a [31] Sødal et al. 2014
Lean Design Management	[32] Vishal 2018 [33] Savolainen et al. 2018 [34] Al Hattab and Hamzeh 2017 [35] Modlich and Cousins 2017 [36] Uusitalo et al. 2017 [37] Al Hattab and Hamzeh 2017	[38] Abou-Ibrahim and Hamzeh 2016 [39] El. Reifi and Emmitt 2013 [40] Thyssen et al. 2010 [41] Thyssen et al. 2008 [42] Tilley 2005a [43] Tilley 2005b
Lean Design and Construction	[44] Umstot et al. 2014	[45] Whelton et al. 2002
Combined Terminologies	Authors	
Lean Design and Lean Design Management	[46] Mazlum and Pekeriçli 2016 [47] Franco and Picchi 2016 [48] Fosse and Ballard 2016 [49]Pasquire and Salvatierra-Garrido 2011	[50] Kestle et al. 2011 [51] Zoya Kpamma and Adjei-Kumi 2011 [52] Jørgensen and Emmitt 2008 [53] Jørgensen and Emmitt 2006
Lean Design Process and Lean Design Management	[54]Emmitt et al. 2004	
Lean Design and Lean Design Process	[55] Freire and Alarcón 2002	

Most of the selected papers used different terms for the same approach of “Lean Design”. The authors sometimes used two different terminologies to refer to the same approach. As an example, in Freire & Alarcón (2002), Lean Design and Lean Design process were treated as the same.

Also, there is no explicit definition of what “Lean Design” means. Jørgensen (2006) was the first to underline this problem, in his doctoral thesis. However, he did not propose a definition, either. Moreover, this lack of a common definition was also in “Lean construction” proposed a solution for the production phase and Lean production. This issue has been discussed by Green and May (2005), Shah and Ward (2007), Bhamu (2014) and others.

Therefore, we will look deeper into the state of the art of Lean Design to understand better what it means according to studies in this field.

3.2 Lack of a clear definition

A clear definition of Lean Design approach is only presented in 23 papers among the selected works and the definitions and interpretations of Lean Design differed radically from an author to the other.

Actually, four perspectives regarding the “Lean Design” definition were identified: 1) Work management and Information Flow, 2) Process and Product, 3) TFV (Transformation, Flow, and Value), 4) Design for X (Table 2). In this study, the term “perspective” refers to the authors’ main definition of the Lean Design concept.

Table 2: Perspectives of Lean Design

N	Definitions	Perspective	Original source	Studies with the same perspective
1	“*Lean Design Management has been promoted as a new paradigm by which the Design process can be made more efficient and better quality outcomes achieved. Design management would simply apply to the managing of people and the flow of information between the various project participants from an internal process perspective*.” (page.23)	Managing work & information flows.	[42]	[14] [31] [32] [36] [55]
2	"*Lean Design incorporates not only the product Design but also process Design. Process Design is commonly one of the components missing in traditional practices together with the lack of support systems, organizational structures, and resources required to obtain a quality Design*." (page.107)	Process and product	[24]	[4] [2] [49] [50]
3	"*Unlike the traditional method of managing Design, the Lean approach considers Design not only as a transformation (T) of inputs to outputs but also considers the issues of material and information flows (F) as well as value generation (V) for the customer at the same time*." (page.7)	TFV	[43]	[8] [15] [17] [20][30][36] [38] [41] [55]
4	“*The purpose of Lean Design is to improve the manufacturability of a product through attention to information coordination and flows at the outset of the project, and the development of "Design for production" solutions to technological, functional and operational requirements. It is here in the upstream phases that value is added and subsequently embedded in the production information*.” (page.1)	Design for X	[25]	

Perspective 1- Managing work and information flows: From this perspective, the focus of Lean Design should be the information flow and design activity management. Tilley (2005 a) and Vishal 2018 define Lean Design as a new approach that aims to improve the processes and operational activities of the Design as well as the flow of information between different stakeholders. Lee and Cho (2012) and Sødal et al. (2014) shared this view, emphasizing the importance of the upstream collaboration between all the professionals in improving the information flow. Freire and Alarcón (2002) explained that the improvement of Design processes is done through the elimination of waste. While Uusitalo et al. (2017) added that Lean Design should take into account the processes, people and technology in a balanced way.

Perspective 2- Process and Product: Holding the second perspective, the authors explain that the objective of Lean Design is to improve the design product created and the management of the design process is to attend to the client value. Arbulu and Soto (2006) with Bosi et al. 2018, Kestle et al. 2011 and Torres et al. 2018 explain that Lean Design’s focus is not only on the final product but also on the Design process. Pasquire and Salvatierra-Garrido (2012) endorse this perspective, but their focus is on the improvement of the product design management.

Perspective 3- TFV (Transformation Flux Value): Some Authors mentioned this perspective are Tilley (2005b), Abou-Ibrahim and Hamzeh (2016), Deshpande et al. (2012) and Freire & Alarcón (2002). They explained that Lean Design is an approach that should take into account the three dimensions of production: Transformation, Flux, and Value of the TFV theory.

Indeed, the main problem of the traditional project management approach is a lack of appropriate management theory. Actually, Koskela and Howell (2008) presented a production theory for the construction industry. They proposed to consider the three dimensions of transformation, flow and value (TFV) in a balanced way. Transformation refers to design conversion from input to output, while flow is related to the concept of reducing waste and value is directly related to the management and communication between stakeholders and the system of the supply chain.

Furtmeier and Tommelein (2010) and Munthekaas et al. (2015) focused on the flow. Munthekaas et al. (2015) proposed to do a Value Stream Mapping of the design process to eliminate waste. While Ko and Chung (2014); Jensen et al. (2009), Uusitalo et al. (2017), Fitchett and Hartmann (2017) and Thyssen et al. (2008) proposed to focus on customers' needs to maximize value generation instead of flow.

Perspective 4- Design for X: The last perspective of Lean Design involves the design development, taking into account the constraints of manufacturing processes for the proposed facility. According to Ehrlenspiel (2003), 75% of the project's life cycle cost is set in its conceptual phase. Thus, to specifically reduce the cost of each project life cycle phase, several manufacturing companies implement the Design For X, which refers to maintainability, constructability, etc. of the specific phase that should be improved during the design phase. This perspective will help designers to choose not only the best architectural but also construction solutions (Brookfield et al. 2004).

4 THE GAP BETWEEN METHODS AND PERSPECTIVES

According to previous studies, Lean Design is a solution to generate value for client. However, most authors do not explain what methods or tools are essential to implement their proposed Lean Design perspective. Besides, those who suggest methods/*tools* (24 articles of the 55 analyzed) do not provide clear explanations on how to apply them in a practical context. The table 3 illustrates this deficiency.

Most of the proposed methods/*tools* are derived from other industries. Generally, they are not specific to Lean Design. Some are based on Lean production (e.g., Value Stream Mapping, set based Design, Quality function, etc.), while others come from Lean construction (e.g., Last Planner System). Furthermore, we found out that some authors (e.g. Salgin et al. 2016 and Fosse and Ballard 2016) qualify the *Building Information Modeling* as a Lean Design tool which was not developed to be so. In addition, the authors do not agree about the operational level of these methods/*tools*. As an example, the Last planer system has been defined by Munthekaas et al. (2015) as a method, and by Fosse and Ballard (2016) as a tool.

The real problem with these is the implementation of the methods/*tools* in practice. This means that the methods/*tools* proposed by these authors require to be empirically validated. We found only 14 case study research papers among 41. Moreover, only 5 of these papers explain how to implement them; however they did not present a generalizable framework. In fact, Uusitalo et al. 2017 present a framework, which has not been tested that takes into account, methods/*tools* of Lean Design used by practitioners in companies.

In addition, it was noticed that there are gaps between different Lean Design perspectives and methods/tools. A method/*tool* can refer to more than one perspective (e.g., Design Structure Matrix) and/or it can just refer to a part of a perspective (e.g. Last Planner System with perspective 3). In fact, as explained before the value is mostly generated during the first phases of the project life cycle. However, for the third perspective, the methods/*tools* existing for the first phases seem to be a skewed focus towards the flow aspect more than the client value generation aspect. As an example, the methods/*tools* Last Planner System, Design Structure and Value Stream Mapping, commonly used for flow

management, have been developed mainly by authors rather than Target costing and Quality Function Deployment presented as client generation value methods. This finding confirms what Jorgensen said in 2006 about the focus of the construction industry authors on the flow aspect more than the value one.

Table 3: Methods/*Tools* and relevant perspective

Methods/*Tools*			Relevant Perspective (P)			
Name	**Related Work**	**Objective**	**P 1**	**P 2**	**P 3**	**P 4**
Last Planner System (LPS)	[9] [10] [21][22] [36] [42] [43] [48]	*"Was developed by Glenn Ballard and Greg Howell is a production planning system that is designed to produce predictable work flow and rapid learning in the programming, design, construction and commissioning of projects (Ballard 2000)."* [9] P. 194	●		●	
Set-based Design (SBD)	[14][48]	*"Is a method in which designers collaboratively explore alternatives and keep them open until the last responsible moment to reduce negative design iteration (Ballard, 2000)." [9] p. 193*		●		
Design Structure Matrix (DSM)	[17] [36] [41]	"*Is a tool where tasks are defined, their relation and information need from other tasks, and from that information an optimal task sequence is indicated in the matrix*." [36] *p*. 573		●	●	
Decision Structure Matrix (DSM)	[43]	*"Is a process that looks at the various tasks and tries to identify an optimal planning sequence, based upon the information flow interrelationships between the various tasks."* [43] *p. 8*	●		●	
Value stream mapping (VSM)	[8] [12] [13] [17] [27] [29] [30] [55]	*"Technique to understand the status quo of the organisation, through the lens of creating value for their customers"* [8] p. 259			●	
Quality Function Deployment (QFD)	[20] [55] [41]	"*Is adapted from the manufacturing industry in the development phase of a Building system….. They also were a part of the development team that introduced the concepts of modularization and Lean Design.* "[20] p. 466		●	●	●
Target Costing	[41] [12]	*"Target cost calculation includes: energy and human resource efficiency; environmental impact of demolition and new materials lack of disruption through relocating or enduring working in a building being refurbished; loss in customers; and loss of continuity in established location."* [8] p. 262			●	
Target Value Design (TVD)	[8] [9] [10] [12] [27] [36] [44] [48]	"*Is a collaborative method in which stakeholders are introduced early in the design process. With the design team, they define the objectives and conditions of satisfaction that will drive the design of the building."* [9] p. 193		●	●	
Dependency Structure Matrix (DSM)	[19]	*"Dependency Structure Matrix (DSM) was proposed as a compact tool for representing and managing the design process (Steward 1981) ….. DSM can be formulated to capture dependencies at various design levels such as component, team, activity, parameter etc."* [19] p. 534		●		
5S	[15]	"*The 5S techniques are designed to ensure that the workplace is well organized for optimal worker performance. They include Seiri (sort: the first step in making things organized), Seiton (set in order), Seiso (regular*			●	

		maintenance), Seiketsu (standardize) Shitsuke (sustain the improvements).” [15] p. 223			
Building Information Modeling (BIM)	[9] [48]	*“A tool that can support lean thinking by providing a platform to verify the design and its value for the customer. BIM enables coordination between specialties and the evaluation of construction strategies during design.”* [9] p. 194	•		•
Choosing by advantages (CBA)	[9] [48] [10]	“*Is a method of selecting from alternatives when multiple factors are relevant to evaluating and differentiating the alternatives. CBA is also well aligned with lean thinking (Arroyo et al., 2012).”* [9] p. 194	•	•	•
Making Design decision	[15]	*“Making design decisions at the last responsible moment is an essential element of the set-based design process used by Toyota, where the designers try to support several design solutions to a problem as late in the design process as possible.”* [15] p. 221		•	
Kanban	[17] [35]	“*The key to get the eight process steps is to value stream map current practice. The individual steps defined by the process map are the activities represented by the Kanban cards that will be placed on the Kanban board*.” [35] p. 666			•

Thus, different gaps have been identified that we will discuss in the following section.

5 DISCUSSION

Serious inconsistencies of Lean Design literature were identified in this study. For instance, the terminologies are presented without further explanation in some research. Also, as we mentioned before we have identified four perspectives of Lean Design definitions without a solid and standard definition, which makes the meaning of Lean Design confusing.

Additionally, the majority of publications analyzed in this review that deals with Lean Design does not generally report how to implement it in a practical context or how to adapt it to fit the design process, in detail. There is no proper valid Lean Design framework to apply in the construction industry. In fact, the main source of Lean Design methods/*tools* are the manufacturing or construction phase, which means that they are not specific to Lean Design. However, designing and making are different processes: “*Designing produces the recipe and building prepares the meal*” (Koskela 2000). In other words, a special effort should be made to adapt the methods/*tools* to the design phase of the construction industry.

Another problem to be stressed is the alignment between the four perspectives of Lean Design and the methods/*tools* proposed. In fact, the proposed perspectives often do not come with specific implementation methods/*tools*. Also, these propositions focus more on the flow aspect than the value one.

Thus, the lack of sufficient know-how and the limited practical techniques is found as the top five barriers of Lean implementation in the construction industry (Tezel 2018). This means that we need a general conceptual framework to implement it. However, the variety of definitions is hindering a consistent response of authors also, it probably would be inappropriate to point out the methods/*tools* without offering a definition of Lean Design. For this reason and for the ones above, we propose the following Lean Design definition that unifies all four perspectives: “Lean Design is an approach based on Transformation Flow and Value theory. It aims to improve information flows, and both product and process design to align them with the project definition element. Considering people, technology and constructability of the product.”

In this definition, we combined the four perspectives mentioned before. The first one is the improvement of information flows, which was highlighted by Tilley (2005-a), etc. The second one is the improvement of both process and product design taking into account people and technology proposed by Arbulu and Soto (2006), etc. The third one is the TFV theory that appears with authors such as Tilley (2005b). The fourth

one is about Design for X that refers to constructability, proposed by Brookfield et al. (2004). In addition, we added the vision of Ballard (2000) that present the as a concept that aim to align the product and process with the project definition element.

Thus, this proposed definition gives a general interpretation of Lean Design and should be broad enough to cover different visions about what constitutes Lean Design. It should also be specific enough to give researchers some degree of concepts in common and help them think more properly about methods/*tools* proposed to develop a general Lean Design framework. This framework should be implemented and tested in practice to improve the implementation of Lean during the design phase, also to ensure the alignment between project definition elements and the design product.

6 CONCLUSION

This research highlights major issues with literature on Lean Design. There is a wide range of interpretations making it difficult to establish what the term Lean Design exactly means. There major inconsistencies between the Lean Design definitions and methods/*tools* proposed, which affects the implementation, as explained before. Another contribution is a proposition for a definition that unifies all perspectives, and which could be a valuable resource for researchers in the field.

Thus, this study was based principally on the literature review. However, we identified a lack of empirical research in Lean design, which could be, as mentioned before, a barrier to understanding and implementing it. Therefore, our future work will consist of providing and testing in practice a framework that aims, first, to facilitate the implementation of Lean Design, and second, to give a better alignment between architectural solutions and customers' needs and requirements using Lean Design.

7 REFERENCES

Abou-ibrahim, H. and Hamzeh, F. 2016. Enabling lean design management: an lod based framework. *Lean construction journal*, **2016**(1):12-24.

Algan, T., Lauri, K. and Zeeshan, A. 2017. Lean thinking in the highways construction sector: motivation, implementation and barriers. *Production Planning & Control*, **29**(3): 247-269.

Al Hattab, M. and Hamzeh, F. 2017. A Process-Social Perspective for Understanding Design Information Flow. *Lean Construction Journal*, 01-11.

Arayici, Y., Coates, P., Koskela, L., Usher, C. and O'Reilly, K. 2011. Technology adoption in the BIM implementation for lean architectural practice. *Automation in Construction*. **20**(2):189-195.

Arbulu, R. and Soto, J. 2006. Understanding and Managing the Construction Process: Theory and Practice. *14th Annual Conference of the International Group for Lean Construction, IGLC-14*, Salford, U.K.,**1**:107-119

Alves,T., Lichtig, W. and Rybkowski, Z. K. 2017. Implementing target value design: tools and techniques to manage the process. *Health Environments Research & Design Journal*, HERD, **10** (3):18-29.

Bertelsen, S. and Emmitt, S. 2005. The Client as a Complex System. *13th Annual Conference of the International Group for Lean Construction. Sydney*, Australia, **1**: 73-79.

Bosi, F., Esposito, M. A. and Sacks, R. 2018. lean-driven passenger experience design. *26Th Annual Conference of the International. Group for Lean Construction (IGLC)*, González, V.A., Chennai, India,**1**: 593–602.

Deshpande, A.S., Filson, L.E., Salem, O.M. and Miller, R.A. 2012. Lean techniques in the management of the design of an industrial project. *Journal of Management in Engineering*, **28**(2): 221-223.

Ede, A. N., Olofinnade, O. M. and Sodipo, J. O. 2017. Use of building information modelling tools for structural health monitoring*. International Conference Computing Networking and Informatics*, IEEE,**1**: 1-4.

El Reifi, M.H. and Emmitt, S. 2013. Perceptions of lean design management. *Architectural Engineering and Design Management*, **9**(3):195-208.

Emmitt, S., Sander, D. and Christoffersen, A.K. 2004. Implementing value through lean design management*. Proceedings of the 12th International Conference*, **1**:361-374.

Fitchett, A. and Hartmann, D. 2017. The application of lean design to space planning and construction. *Transactions of the Royal Society of South Africa*, **72** (3): 255-265

Fosse, R., Ballard, G. 2016. Lean design management in practice with the Last Planner System. *24th Annual Conference of the International Group for Lean Construction*, Boston, MA, USA, **4**: 33-42.

Franco, J.V. and Picchi, F.A. 2016. Lean design in building projects: guiding principles and exploratory collection of good practices. *24th Ann. Conf. of the Int'l, Group for Lean Construction*, Boston, USA, **4**: 113–122.

Freire, J. and Alarcón, L. F. 2002. Achieving lean design process: Improvement methodology. *Journal of Construction Engineering and management*,**128** (3): 248-256.

Furtmeier, F.A. and Tommelein, I.D. 201. Challenging Lean Construction Thinking: What Do We Think and What Do We Know?. *18th Annual Conference of the International Group for Lean Construction*, IGLC 18, **1**:151-160.

Gambatese, J. A., Pestana, C. and Lee, H. W. 2016. Alignment between lean principles and practices and worker safety behavior. *Journal of construction engineering and management*, 143 (1): 04016083.

Green, S. D. and May, S. C. 2005. Lean construction: arenas of enactment, models of diffusion and the meaning of 'leanness'. *Building Research & Information*, **33**(6): 498-511.

Hamzeh, F. R., Ballard, G. and Tommelein, I. D. 2009. Is the Last Planner System applicable to design? A case study. *17th Annual Conference of the International Group for Lean Construction*, Cuperus, Y. & Hirota, E.H., Taipei, Taiwan, **1**:165-176.

Holmes, S. 2008. Removing'waste'. Getting down to essentials through a lean design process. *Health facilities management*, **21**(3):41-44.

Jensen, P., Hamon, E. and Olofsson,T. 2009. Product Development Through Lean Design and Modularization Principles. *17th Annual Conference of the International Group for Lean Construction*, Taipei, Taiwan, **1**:465-474.

Jørgensen, B.and Emmitt, S. 2008. Lost in transition: the transfer of lean manufacturing to construction. Journal of Engineering, *Construction and Architectural Management*.

Jørgensen, B. and Emmitt, S. 2009. Investigating the integration of design and construction from a "lean" perspective. *Construction Innovation*, **9**(2): 225-240.

Kestle, L., Potangaroa, R. and Storey, B. 2011. Integration of lean design and design management and its influence on the development of a multidisciplinary design management model for remote site projects. *Architectural Engineering and Design Management*, **7**(2):139-153.

Ko, C.H. and Chung, N.F. 2014 a. Lean design process. *Journal of Construction Engineering and Management*, **140**(6): 4014011

Ko, C.H. and Chung, N.F. 2014 b. Understanding and Improving Project Based Production. *22nd Annual Conference of the International Group for Lean Construction, IGLC-14*, Salford, UK,**1**: 463-474.

Kpamma, Z. E., Adjei-Kumi, T., Ayarkwa, J. and Adinyira, E. 2017. Strategic considerations for applying choosing by advantages in design process. *Lean & Computing in Construction Congress*, Heraklion, Greece.

Lee, S. I. and Cho, Y. S. 2012. An Application of Lean Design of Structural Floor System Using Structural Building Information Modeling (S-BIM*). Advanced Science Letters*, **13**: 158-164.

Maxwell, D. W. and Aitchison, M. 2017. Design-Value in the Platform Approach. *25th Annual Conference of the International Group for Lean Construction*, The International Group for Lean Construction,Heraklion, Greece, **1**:349 – 356.

Mazlum, S. K. and Pekericli, M. K. 2016. Lean design management–an evaluation of waste items for architectural design process. *Journal of the Faculty of Architecture*, METU, **33** (1).

Modlich, R. U. and Cousins, B. C. 2017. Digital Kanban boards used in design and 3D coordination. *25th Annual Conference of the International Group for Lean Construction*, The International Group for Lean Construction, Hersonissos, Crete, Greece, **1**:663-670.

Mossman, A. 2009. Creating value: a sufficient way to eliminate waste in lean design and lean production. *Lean Construction Journal*,**1**: 13-23.

Munthe-Kaas, T.S., Hjelmbrekke, H., Lohne, J. and Lædre, O. 2015. Lean Design Versus Traditional Design Approach. *23rd Annual Conference of the International Group for Lean Construction*, Seppänen, O., González, V.A. & Arroyo, P., Perth, Australia, **1**: 578-588.

Nøklebye, A., Svalestuen, F., Fosse, R. and Lædre, O. 2018. Enabling Lean Design With Management of Model Maturity. *26th Annual Conference of the International Group for Lean Construction*. Chennai, India, **1**:79-89.

Orihuela, P. Orihuela, J. and Pacheco, S. 2015. Communication protocol for implementation of Target Value Design (TVD) in building projects*. Procedia Engineering*, **123**: 361-369.

Pasquire, C. and Salvatierra-garrido, J. 2011. Introducing the concept of first and last value to aid lean design: Learning from social housing projects in Chile. *Architectural Engineering and Design Managemen*t, 2011, **7**(2): 128-138.

Savolainen, J. M., Saari, A., Männistö, A. and Kähkonen, K. 2018. Indicators of collaborative design management in construction projects. *Journal of Engineering, Design and Technology*, 16(4), 674-691.

Salgin, B, Arroyo, P and Ballard, G. 2016. Exploring the relationship between lean design methods and C&D waste reduction: three case studies of hospital projects in California. *Revista ingeniería de construcción*, **31**(3):191-200.

Shah, R. and Ward, P. T.2007. Defining and developing measures of lean production. *Journal of operations management*, **25**(4):785-805.

Shu, J.Y. and Shi, X.G. 2010. Knowledge transfer and learning race in strategic alliance. *IEEE International Conference on Advanced Management Science*, ICAMS, **1**:276-281

Singh, V. 2018. Towards creative lean (clean) construction: From lean production to lean consumption. *26Th Annual Conference of the International. Group for Lean Construction (IGLC)*, González, V.A., Chennai, India, 952-962.

Sødal, A.H., Lædre, O., Svalestuen, F. and Lohne, J. 2014. Understanding and Improving Project Based Production. *22nd Annual Conference of the International Group for Lean Construction*, Kalsaat, B.T., Koskela, L. and Saurin, T.A. Olso,**1**: 519-531.

Svalestuen, F., Lohne, J., Knotten, V. and Lædre, O. 2015. Ethics of the Design Phase - A Descriptive Approach. *23rd Ann. Conf. of the Int'l,Group for Lean Construction*, Perth, Australia,**1**:609-618.

Thyssen, M.H., Emmitt, S., Bonke, S. and Kirk-Christoffersen, A. 2008. 'The Toyota Product Development System Applied to a Design Management Workshop Model. *16th Annual Conference of the International Group for Lean Construction*, Tzortzopoulos, P. & Kagioglou, M., Manchester, UK, 507-518

Thyssen, M.H., Emmitt, S., Bonke, S.and Kirk-Christoffersen, A. 2010. Facilitating client value creation in the conceptual design phase of construction projects: a workshop approach. *Architectural Engineering and Design Management*, **6**(1):18-30.

Tilley, P. A. 2005 a. Design and Documentation Quality Problems-A Lean Thinking Opportunity. *The International SCRI*, Symposium, Salford, UK,**1**:12-13.

Tilley, P. A. 2005 b. Lean design management: a new paradigm for managing the design and documentation process to improve quality? *13th International Group for Lean Construction Conference*, International Group on Lean Construction, **1**:283.

Torres, L. A., Souza, M. C. S., Xavier, A. C. B., and Melo, R. S. S. 2018. Value Stream Mapping of the Design Process in a Design-Build Firm. *Proceedings of the International Symposium on Automation and Robotics in Construction*, IAARC, **35**(1): 1-8.

Uusitalo, P., Olivieri, H., Seppänen, O., Pikas, E. and Peltokorpi, A.2017. Review of lean design management: processes, methods and technologies. *25th Annual Conference of the International Group for Lean Construction*, International Group for Lean Construction Heraklion, Greece, **1**:571-578.

Umstot, D., Fauchier, D. and Alves, T.D.C.L. 2014. Metrics of Public Owner Success in Lean Design, Construction, and Facilities Operations and Maintenance. *22nd Annual Conference of the International Group for Lean Construction*, Kalsaas, B.T., Koskela, L. & Saurin, T.A., Oslo, Norway, **1**:1495-1506.

Venkatachalam, S., Varghese, K. and Shivaji, C. 2009. Achieving Lean Design Using Design Interface Management Tool. *17th Annual Conference of the International Group for Lean Construction*, Cuperus, Y. & Hirota, E.H., Taipei, Taiwan, **1**:533-542.

Whelton, M., Ballard, G. and Tommelein, I.D. 2003.A knowledge management framework for project definition. *Journal of Information Technology in Construction*, ITcon, **7**(13): 197-212.

Zoya Kpamma, E. and Adjei-Kumi, T. 2011. Management of waste in the building design process: The Ghanaian consultants' perspective*. Architectural Engineering and Design Management*,**7**(2):102-112.