RESEARCH WORK ON THE DESIGN PROCESS WITHIN THE IGLC CONFERENCE

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ABSTRACT

The design process has been widely researched and discussed within the International Group for Lean Construction (IGLC). This paper aims at exploring the research on the design process carried out during the period (1993 to 2013) of annual conferences within the IGLC community. The authors have examined all published work over this period and sorted out those considered to contribute to design process research. The annual number of publications on design process was found to have increased. An overview of all the published work is included and sorted after year according to five categories; Theory, Review, Status report, Implementation and IT-tools. The proposed categories indicate there are more practically oriented than theory based publications on the design process.

In light of the findings, future studies ought to be twofold. Firstly, there is a need for further development on how to apply lean principles in design processes. Secondly, more success stories from the early majority will spread the use of the lean principles in design processes. The conclusions of this paper will lay premises for the research questions in an ongoing PhD study.

KEYWORDS

Design Process, Review, Design Management, Lean Construction, Last Planner System.

INTRODUCTION

The goals of the IGLC community are to better meet customers' needs and to improve the Architecture, Engineering, Construction (AEC) process as well as the product. Achieving this, requires – in our view – conducting research that considers all aspects of the building process. The design process is crucial for the whole life cycle of a building (Aquino & Melhado, 2002). Ideally, it defines what to build through input from users and clients, and transforms these into descriptions for the production process.

Management of the design process has, however, proved to be a bottleneck and a root cause of problems in the AEC industry (Ballard & Koskela, 1998). Although widespread research has been carried out on the design process, lean construction

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does in fact seem to have had a far greater impact on the production process than on the design process (Bølviken et al., 2010). Naney et al. (2012) explain the development of Lean Construction using Gartner's Hype Cycle, where one of the key ingredients to success lies in obtaining the *Early Majority*[1] to see proof of success. This early majority depend upon reports of successful implementations to start implementing practices, methods and tools from the field of Lean Construction.

There is still a lack of proven "best practice" for implementation of Lean Construction as a whole. Even though the IGLC has existed for more than 20 years, there are still major stakeholders that have not experienced and are unaware of its benefits. Martins and Cachadinha (2013) report for instance from a survey on owners and designers in the Portuguese Construction Industry, documenting such unawareness of its benefits. Successful reports from implementing systems like Last Planner System™ (LPS), however, do in fact exist.

Although the LPS has proven applicable to the design process (Ballard & Koskela, 1998; Hamzeh et al., 2009; Hattab & Hamzeh, 2013; Wes et al., 2013), authors like Kerosuo et al. (2012) state that it is more suitable for the production process. This is claimed to be due to the fact that the design process involves "grey areas" in terms of achieving goals and meeting quality demands. Of particular interest in this context is that participants in the design process are interdependent. For instance, output from the architect constitute input for the engineers, while output from the engineers hypothetically also constitute input for the architect. This type of interdependency is called reciprocal interdependency (Kalsaas & Sacks, 2011).

The use of Concurrent engineering together with LPS has to some extent resolved the problem in which the participants of the design process are both sequentially and reciprocally interdependent. It appears, however, that the research on the design process has primarily had a sequential production view (Kestle & London, 2002). In the Design Process, the reciprocal interdependence between participants is typically considerable (Kalsaas, 2013). Further research on this part seems in fact to be warranted to improve the understanding of the process.

A traditional approach to the design process has been to get the engineering tasks done, and then manage them as if they where independent. Lean construction proposes that the design process should be viewed simultaneously as a conversion, flow and value generation process (Ballard & Koskela, 1998). The design process is typically conceived to consists of three different phases involving different management strategies, notably (1) the decision process, (2) a relationship between design and production, and (3) preconditions for the constraint analysis in design process (Bølviken et al., 2010). Furthermore, iterations can be both positive and negative, unlike in the production process where rework is inherently negative and wasteful (Ballard, 2000). Excessive rework, however, will typically entail a negative impact on the value generation. Therefore, participants of the design process need an understanding of what value really is and what constitutes value (Drevland & Svalestuen, 2013).

[1] Naney et al. (2012) define Early Majority is a group of the total practitioners. Their implementation relies on practicality. They see many passing fads and wait to see how the *early adopters* are using technology. They look for case studies and established successes before agreeing to substantial trials or investment.

Through our study of research published within the contest of the IGLC, we identified one paper exploring value over a period of nineteen years (Salvatierra-Garrido et al., 2012). Inspired by this paper, we initiated a similar – though not identical – study of the design process. The design process is important for the value delivered to the client and for the reduction of waste in the building process. To our knowledge, no prior study of the design process publications within the IGLC community has been carried out. We think it is important to understand how the research has evolved and to identify where the knowledge gap is.

This paper explores the published research on the design process within the annual IGLC conference. The research questions we intend to answer are:

1. How has the number of publications on the design process within the IGLC developed over the specified time-frame?
2. What kind of research has been published on the design process?
3. How has the research developed over time?

METHODOLOGY

As part of an ongoing PhD study, a thorough examination of design process papers within this community was carried out, thereby constituting a *systematic* literature search as explained by Halvorsen (1993). Blumberg et al. (2011) have specified this approach more in detail, with: 1) the building of an information pool, 2) the application of a filter to reduce pool size, 3) a rough assessment of sources to further reduce pool size, 4) an analysis of the literature in the pool and 5) the refinement of filters or stop search.

To identify all the papers contributing to research about the design process within the IGLC community, a visual search through every contribution in the annual proceedings was undertaken. Approximately 150 papers were chosen after a visual scan of title, themes, keywords and abstracts. The chosen papers were read, and papers not mainly addressing the design process were put away. This left us with 123 papers.

A visual search like this might be prone to some errors. There are over 1000 papers published within the IGLC community, and some publications may have been overseen by mistake. However, we believe that with the 123 publications we are able to identify the main trends in the research on the design process.

Through this study we have focused on finding the best fitting classification. As the analysis proceeded, five different groups of papers emerged, the propensities of which are described in the findings section. We have subjectively sorted the design process publications into these five groups. Although some publications may fit into several groups, we have tried to choose the classification based on what they contribute to the most.

PRESENTATION OF FINDINGS

The presentation of the findings of our research is divided into two parts. Firstly, a classification section, where the identified papers concerning the design process are listed and an explanation for the classification is provided. Secondly, a data analysis section, where the data from the classification section is analyzed according to the

overall number on the design process papers, the number of publications within each group and the development of different groups over time.

CLASSIFICATIONS

The classification into groups proposed in this paper is explained in Table . The publications falling within the theory and review groups are the publications considered to be mainly theory based. Publications dealing with status reports, implementation and IT-tools are typically more practical oriented studies.

Table 1: Explanation of the classification procedure used in this paper, ranging from theory based to practical orientated.

Groups	Explanations of criteria used
Theory	Research that provides or proposes developments of existing theory. E.g. theories on a new method/tool to further enhance the design process. To support the method/tool some papers might also present findings from a case study, but the main part of the paper focus on theoretical development.
Review	Research that is mainly based on literature reviews. Either as part of a state of the art report or in order to underline an analytical point.
Status report	Reports status from construction projects, countries or ongoing research projects, mainly without final results or further development proposals. The focus of these reports is usually wide, meaning that they either look at several projects or that they report the status of lean construction in a country.
Implementation	Reports from projects implementing existing Lean tools or methods in the design process. These papers typically report final results from implementation of method/tools theorized before, either on an IGLC conference or similar.
IT-tools	Reports that use IT-tools to enhance the process or to further understand the process. Even though BIM is more than an IT-tool, papers addressing BIM are included here. Since BIM by definition use IT-tools to support the process.

Table 2 shows the publications contributing to further knowledge on the design process within the annual conference of IGLC. The publications are sorted chronologically in the classification we find best suited.

Table 2: The publications on the design process within the annual conference of IGLC

Theory	
• Huovila P., Koskela L., Lautanala M., Pietiläinen K., Tanhuanpää V. (1995) • Lautanala M (1995) • Koskela L., Ballard G., Tanhuanpää V. (1997) • Melhado S. B. (1998) • Alarcón L. F., Mardones D. A. (1998)	• Tommelein I. D. (2008) • Codinhoto R., Tzortzopoulos P., Rooke J., Kagioglou M., Koskela L. (2008) • Jensen P.,Hamon E., Olofsson T. (2009) • Parrish K., Tommelein I. D. (2009) • Chin C-S. (2009) • Bølviken T., Gullbrekken B., Nyseth K.

- Fabricio M. M., Melhado S. B., Baía J. L. (1999)
- Ballard G. (2000)
- Bogus S., Songer A.D., Diekmann J. (2000)
- Leinonen J., Huovila P. (2000)
- Ballard G., Koskela L., Howell G., Zabelle T. (2001)
- Whelton M., Ballard G., Tommelein I. D. (2001)
- Chua D. K. H., Tyagi A. (2001)
- Kestle L., London K. (2002)
- Mesquita M. J. M., Fabrício M. M., Melhado S. B. (2002)
- Whelton M., Ballard G. (2002)
- Pasquire C. L., Connolly G. E. (2003)
- Brookfield E., Emmitt S., Hill R., Scaysbrook S. (2004)
- Emmit S., Sander D., Christoffersen A. K. (2005)
- Bertelsen S., Emmitt S. (2005)
- Luo Y., Riley D. R., Horman M. J. (2005)
- Codinhoto R., Koskela L., Tzortzopoulos P., Kagioglou M. (2006)
- Milberg C. (2007)
- Parrish K., Wong J-M., Tommelein I. D., Stojadinovic B. (2008)
- (2010)
- Chin C-S. (2010)
- Sampaio J. C. S., Neto J. P. B (2010)
- Furtmeier F. A., Tommelein I. D. (2010)
- Pennanen A., Ballard G., Haahtela Y. (2010)
- Xavier de Lima M. M., Maia S. C., Neto J. P. B. (2011)
- Rybkowski Z. K., Munankami M., Gottipati U., Fernández-Solís J., Lavy S. (2011)
- Orihuela P., Orihuela J., Ulloa K. (2011)
- Nerwal N, Abdelhamid T. S. (2012)
- Oskouie P., Gerber D. J., Alves T., Becerik-Gerber B. (2012)
- Tsao C. C. Y., Beikmann B. (2012)
- Hickethier G., Tommelein I. D., Gehbauer F. (2012)
- Lima M. M. X., Ruschel R. C. (2013)
- Mohamad A., Hickethier G, Hovestadt V., Gehbauer F. (2013)
- El.Reifi M. H., Emmitt S., Ruikar K. (2013)
- Viva A. L., Paliari J. C. (2013)
- Haymaker J., Chau D. H., Xie B. (2013)
- Hickethier G, Tommelein I. D., Lostuvali B. (2013)

Review

- Ballard G., Koskela L. (1998)
- Tilley P. A. (2005)

Status report

- Tilley P. A., Wyatt A., Mohamed S. (1997)
- Formoso C. T., Tzotzopoulos P., Jobim M. S .S., Liedtke R. (1998)
- Lane R., Woodman G. (2000)
- Mendonça L. V., McDermott P. (2000)
- Gil, N., Tommelein, I.D., Kirkendall, R.L., Ballard, G. (2000)
- Miles R. S., Ballard G. (2001)
- Riley D., Horman M. (2001)
- Aquino J. P. R., Melhado S. B. (2002)
- Loría-Arcila J. H., García-García A., Vanegas J. A. (2003)
- Ballard G., Reiser P. (2004)
- Loría-Arcila J. H., Vanegas J. A. (2005)
- Tzortzopoulos P., Chan P., Kagioglou M., Cooper R., Dyson E. (2005)
- Dahl P. K., Horman M. J., Riley D. R. (2005)
- Toolanen B., Olofsson T. (2006)
- Feng P. P., Tommelein I. D. (2009)
- Heidemann A., Gehbauer F. (2010)
- Tribelsky E., Sacks R. (2010)
- Lima M., Rolim L., Alves T. C. L. (2010)
- Sfandyarifard E., Tzortzopoulos P. (2011)
- Alarcon I., Christian D., Tommelein I. D. (2011)
- Mryyian M., Tzortzopoulos P. (2013)
- Leite P. K., Neto J. P. B. (2013)
- Martins J., Cachadinha N. (2013)
- Oliva C. A., Granja A. D. (2013)
- Ferrari Caixeta M. C. B., Bross J. C., Fabricio M. M., Tzortzopoulos P. (2013)

Implementation

- Huovila P., Lakka A., Laurikka P., Vainio M. (1995)
- Kuprenas J.A. (1998)
- Miles R. S. (1998)
- Hamzeh F. R., Ballard G., Tommelein I. D. (2009)
- Jara C., Alarcon L. F. Mourgues C. (2009)
- Ballard G., Hammond J., Nickerson R.

- Tzortzopoulos P., Formoso C. T. (1999)
- Gargione L. A. (1999)
- Freire J., Alarcón L. F. (2000)
- Andery P., Vanni C., Borges G. (2000)
- Tzortzopoulos P, Formoso C. T., Betts M. (2001)
- Emmit S., Sander D., Christoffersen A. K. (2004)
- Parrish K., Wong J-M., Tommelein I. D., Stojadinovic B. (2007)
- Simonsson P., Emborg M. (2007)
- Forgues D. , Koskela L., Lejeune A. (2008)
- Bulhões I. R., Picchi F. A. (2008)
- Parrish K., Wong J-M., Tommelein I.D., Stojadinovic B. (2008)
- Thyssen M. H., Emmitt S., Bonke S., Christoffersen A. K. (2008)
- (2009)
- Gupta A. P., Tommelein I. D., Blume K. (2009)
- Kim Y., Lee H. W. (2010)
- Lee H. W., Tommelein I. D., Ballard G. (2010)
- Cho S., Fischer M. (2010)
- Sombra P. L., Romcy N. M. S., Sampaio J. C. S., Neto J. P. B. (2011)
- Kerosuo H., Mäki T., Codinhoto R., Koskela L., Miettinen R. (2012)
- Parrish K. (2012)
- Tiwari S., Sarathy P. (2012)
- Abraham K., Lepech M., Haymaker J. (2013)
- Arroyo P., Tommelein I. D., Ballard G. (2013)
- Rosas E. (2013)
- Wesz J. G. B., Formoso C. T., Tzotzopoulos P. (2013)

IT- tools

- Atkin B. (1998)
- Hammond J., Choo H. J.,Austin S., Tommelein I. D., Ballard G. (2000)
- Gil N., Tommelein I. D., Kirkendall R. (2001)
- Giandon A. C., Mendes R., Scheer S. (2002)
- Lee S. H., Peña-Mora F., Park M. (2003)
- Woksepp S., Olofsson T., Jongeling R. (2005)
- Khanzode A., Fischer M., Reed D. (2005)
- Rischmoller L., Alarcón L. F. (2005)
- Tuholski S. J., Tommelein I. D. (2008)
- Chua D. K. H., Hossain A. (2008)
- Engelmann H., Gehbauer F. Steffek P. (2008)
- Sacks R., Dave B. A., Koskela L., Owen R. (2009)
- Wong J-M., Parrish K., Tommelein I. D., Stojadinovic B. (2009)
- Venkatachalam S., Varghese K., Shivaji C. Y. (2009)
- Hossain A., Chua D. K. H. (2009)
- Liu J-J., Wang W-C. (2009)
- Gerber D. J.,Becerik-Gerber B., Kunz A. (2010)
- Tommelein I. D. Gholami S. (2012)
- Alarcon L. F., Mandujano M. G., Mourgues C. (2013)
- Hattab M., Hamzeh F. (2013)

DATA ANALYSIS

In order to visualize the development in the number of publications on the design process within the annual conference of IGLC, a bar chart showing the number of publications each year was produced (Figure). The chart shows that with the exception of some deviating years, the trend is an increase in the number of papers.

An increase in published work was in fact an expected outcome. The IGLC has grown significantly and therefore the total amount of published work has also increased correspondingly. This could explain the increase of published work on the design process within the community. However, this trend could equally result from an increased awareness of how important the design process is to the building process.

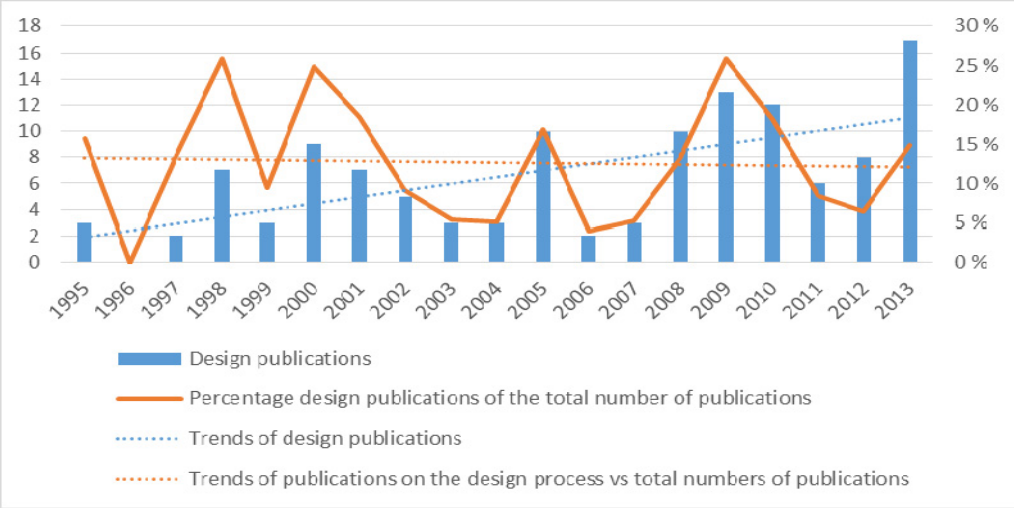

Figure 1: Number of publications on the design process, published in IGLC, the relative importance of these publications and trends of design publications as well as trends of publications on the design process versus total number of publications.

Figure also illustrates the correlation between total amount of publications and publications on the design process by showing the percentage of the latter as part of the total. The graph indicates a decreasing trend in percentage of design publications of the total number of publications. Since the literature manifest on the importance of the design process (Aquino & Melhado, 2002), this is a somewhat surprising result and something that can imply a more rapid increase in the interest for other areas related to Lean Construction. However, one may argue a lack of accuracy in this finding as the amount of published work on the design process fluctuates over the years. There was not published any work with design process as the main theme in the first two years (1993 and 1994), and we therefore did not include these in the graph. It can be mentioned that if we include those first two years in the graph, the relative share of publications on the design process is gradually increasing.

Every year there is a call for papers, where the committee of IGLC selects different themes that need research. Over twenty-one years these themes have changed. This could explain why there in some years is a higher percentage of research concerning the design process than other years. However, in the later years there has been no change in the themes, and the graph is still fluctuating. The deviation could also stem from a breakthrough in the theory or some tools/methods that draw researchers' attention towards or away from the design process.

In order to evaluate what kind of research has been published over the years, we have classified the different publications according to their main contributions. With the proposed groups, we want to visualize what kind of research that has been published on the design process within the IGLC, and how this research has developed with time. A natural development of a new research field seems to be from theory based research to more practical testing. This is because a theory at some point will need practical testing to be able to evolve further. Eventually, when it has evolved to a certain point where the practitioners find the theory promising, they will start testing it out on a larger scale. At this time, reports from these practical studies should then surpass the number of theory based research reports.

Figure 2 shows that most of the published work on the annual IGLC conference is classified as theory. Just looking at the sheer number, the figure could imply that the design process represent a young research field in need of more theoretical studies. However, when held up with the total of more practical research like status reports, implementation, and IT-tools we find that there are more practical than theory-based studies in the IGLC community. It might not be substantial enough to say that the theory has evolved to a point where the early majority will start to adopt the principles of lean thinking in the design process. However, it shows what can be interpreted as a natural development for a promising research field.

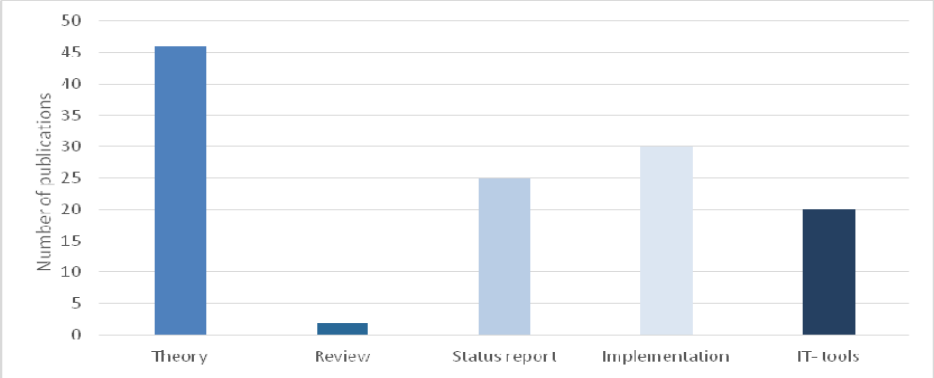

Figure 2: Number of design publications in each group.

The development of the different groups over a timeline is presented in figure 3. As can be observed from the figure from the first years, theory based publications were dominating. Between 1998 and 1999, the more practical oriented publications gained dominance. Interestingly the distribution between the five groups has not changed significantly after this. However, some elements call to attention. The increasing use of Information Technology in everyday life and the fact that this also have had an impact on the Construction Industry leads us to believe that research on implementing different IT- tools will continue in the future. With more tools, there will also be more research on how to apply the tools in the existing method or new methods to support them.

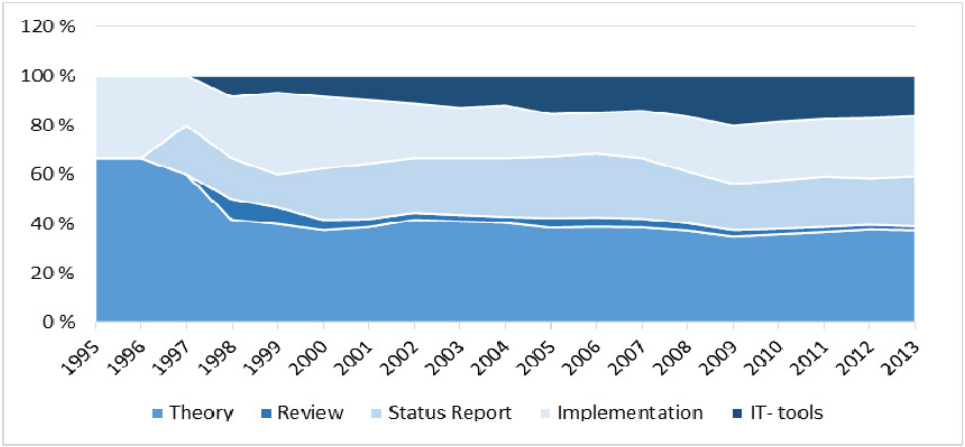

Figure 3: Summarised development of the different groups over time.

DISCUSSION

Ballard and Koskela (1998) claimed that management of design was a bottleneck and the root cause of problems in the ACE industries. There are still problems with implementation of LPS in the design process (Kalsaas, 2013; Kerosuo et al., 2012), which can imply that there is need for more research on the validity of LPS applicability to the design process. However, since the design process consists of more than just work structuring and schedule control, other methods and tools also need more research. This is underlined in several of the examined publications. Since it is important for the designers to know what value is (Drevland & Svalestuen, 2013), the value generation part of the design process is for instance one aspect that still needs more research. Salvatierra-Garrido et al. (2012) concluded that what is value is still an ambiguous question. Other authors like Tilley (2005) and El.Reifi et al. (2013) claims that poor briefs constitute the main cause of problems like document deficiency in the design process. These are just some of the problems that lead us to imply that although a lot of research on the design process has been carried out, the design process is still a bottleneck. Our findings also imply the same, with stagnation in the development of the numbers of theory-based publications. If the implementation of lean methods and tools that thrive from the theory had proven to be successful, there should not be any need for a further development of those theories. Hence, the development of the number of theory-based publications would have a steeper decrease than what Figure 3 shows. Generally speaking, how to implement the lean principles in the design process does not seem to be fully described in the investigated publications and findings.

Furthermore, we argue that the industry needs more success stories from implementation on Lean principles in the design process. Naney et al. (2012) explain that that the Early Majority needs proof of success before they will implement a system like Lean Construction. This can be the case for the design process as well, there needs to be more proof of success before the majority of the industry perceive the benefits. In Portugal, for instance, it has been found that there still exist major stakeholders that are unaware of the benefits from implementing Lean principles in the design process (Martins & Cachadinha, 2013). Figure shows that the relative share of publications on the design process is not increasing. This may imply that the interest in the design process is not increasing, and further support our arguments: The industry needs more success stories and the theory needs further development on how to implement Lean principles in the design process.

CONCLUSION

There are more than 1000 publications from the annual conferences of IGLC. It has grown from just five in 1993 to over 100 publications in 2013. In this paper we have identified the conference publications that specifically deal with the design process, and categorized them in groups according to type of publication.

One ambition of this paper has been to investigate how the number of publications on the design process has developed over time. We have found that the number in absolute terms has increased. If only looking at the period from 1995 until 2013 however, the relative share of design process publications of the total number of publications has not changed significantly. This may indicate that the design process

does not receive the attention expected when looking at the impact of design on waste and value.

Secondly, another ambition of this paper has been to analyze what kind of research that has been published on the design process within the annual conference of IGLC. We classified the papers in five groups – theory, review, status reports, implementation and IT-tools according to their main contribution to the field. Two of the groups – theory and review – were considered as theoretical, the other groups are considered to be more practical in orientation. Summarising the number of papers, it appears that there exist a higher ratio of papers of a mainly practical than of a mainly theoretical orientation. This indicates that the research published on the design process at the annual IGLC conference has been more practically oriented.

Thirdly, the development of the number of publications within the different groups over time suggests that the relative share of theory based publications is decreasing or stabilizing, while the relative share of practical oriented publications has a small increase. This leads us to conclude that there is a shift in the design process publications, from dealing with mainly theoretical matters to more practical matters.

The literature still identifies the design process as a bottleneck and a root cause of problems in the AEC industry. In order for the industry to fully acknowledge the benefits of Lean Construction it needs proof of success and therefore there is still need to spread more success stories. The findings shows no increased relative interest in the design process after over 20 years, which also imply that there is a lack of proven success. We therefore need more research on the design process to prove the success, and generate the momentum Lean needs to be a proven best practice in the design process.

Typically, we would expect an increase in practical oriented research and a decrease in the theoretical, after more than 20 years. However, the findings show that there is a minor change in the amount of theory-based research published. This could imply a need for further development of theory on how to apply Lean Principles in the design process.

This paper presents the initial findings in a PhD study. Further study of the different publications and their contributions are needed to fully understand the development of the design process within the IGLC community.

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