IGLC 2019 PhD Summer School Book of Extended Abstracts.

"Defining the Research Problem and Research Methodology for Lean Construction Research"

Waterford Institute of Technology, Waterford City, Ireland

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Editors:
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INTRODUCTION

The PhD Summer School is part of the annual research event organised by the International Group for Lean Construction (IGLC). The IGLC 2019 International PhD Summer School provides an opportunity for PhD research students from across the globe to present their work and receive feedback from a panel of senior lean construction academics and experts. This two-day event that supports in-depth discussion of current research in the field of lean construction and related topics was held at the *Waterford Institute Technology*, Ireland.

The interest of doctoral student in participating in the IGLC PhD Summer School has been on the increase over the years because of the opportunities it offers. However, there was an unprecedented surge in the application for the 2019 IGLC Summer School. Twenty eight applications were received from eleven countries. Out of this number, three were not sent for review because they were late submissions while the remaining twenty five applications were sent out for review. This was done to provide formative feedback to the candidates and to support the Summer School Deans to determine presenters and listeners at the Summer School. See Table one for the distribution of the application received from different countries.

Countries	No. of Applications
United Kingdom	4
Ireland	4
United State of America	3
Brazil	4
Norway	2
Finland	2
India	2
Germany	1
Italy	1
Austria	1
Australia	1
Total	25

At the end of the reviews, twelve candidates where selected as presenters, three as sponsored listeners and the remaining candidates were considered as self-sponsored listeners. Additionally, a scholarship was awarded by the IGLC local organising Committee to one of the Summer School candidate which enables the candidate to participate in the main IGLC Conference for free. Participation in the Summer School was also free for the presenters and the sponsored listeners.

We would like to thank the local organising Committee for the 27th International Group for Lean Construction and Boxmedia Ltd (for the organisation of the Summer School), the reviewers, the IGLC professors and more importantly all the presenters and listeners.

We believe the extended book of abstracts would be a useful tool for both the participants and the IGLC professors to engage with the each candidate’s work and as a reference material after the Summer School.

Dr Emmanuel Daniel & Dr Ritu Ahuja
IGLC2019 Summer School Deans
12 June 2019

LIST OF REVIEWERS

Dr Gao Shang	University of Melbourne, Australia
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Paul Ebbs

Requirements for Performance Measurement Systems from a Lean Production Perspective

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Purpose of research

Performance measurement (PM) is a theme that has received much attention in the literature both in the field of Operations Management (Neely et al., 1997) and in Construction Management. Regarding the construction industry, several contributions can be found in the literature, including conceptual approaches (Kagioglou et al., 2001); guidelines for assessing performance measurement systems (Costa and Formoso, 2004); implementation models (Yu et al., 2007; Love and Holt, 2000); comparisons between metrics adopted by different companies (Costa et al., 2006); and performance measurement in specific sectors or processes (Robinson et al., 2005; Wegelius-Lehtonen, 2001). Moreover, there has been several initiatives promoted by industrial organizations that have proposed key-performance indicators or benchmarking clubs (Costa et al., 2006; Bassioni et al., 2004).

A Performance Measurement System (PMS) comprises a set of indicators (or metrics) for quantifying the efficiency or effectiveness of processes and organizations (Costa and Formoso, 2004). A PMS design involves more than the selection and definition of appropriate measures. It also requires an effort of integration between measures and between measures and the organizational environment.

PMS play a key role in business management, as it provides the necessary information for process control, enables the establishment of challenging and feasible goals, and facilitates communication between different managerial levels (Hall et al., 1991; Neely et al., 1997). Moreover, it helps to align efforts and resources to the most important aspects of the business (Waggoner et al., 1999; Lantelme and Formoso, 2000), and produce data that can be used as a reference for process improvement (Pavlov and Bourne, 2011).

Despite its importance, many problems concerned with PM in construction projects have been pointed out in the literature, such as: (i) most companies use traditional lagging indicators that are focused on results (Bourne et al., 2000; Kagioglou et al., 2001; Kennerley and Neely, 2003), making them ineffective to support timely decision making (Sarhan and Fox, 2013; Formoso and Lantelme 2000); (ii) some PM systems contain too many measures, most of them linked to supporting rather than critical processes (Costa and Formoso, 2004); (iii) the implementation of performance measurement systems is limited to the selection of isolated measures, neglecting the necessary changes in decision-making (Beatham et al., 2004); and (iv) PM systems are not properly integrated to improvement initiatives (Kennerley and Neely, 2003).

PM should play a key role in the implementation of some Lean Production principles, such as reducing the share of non-value-adding activities (waste), increasing process transparency and continuous improvement (Koskela, 2000). However, the literature on PM for Lean Production Systems in the Construction Industry is relatively scarce. Very often, the implementation of Lean concepts and principles in production management is simply monitored by Last Planner related indicators (España et. al, 2012; Sacks et.al, 2017). There seem to be opportunities for extending PMS in companies that have adopted the Lean Production Philosophy, especially by using some leading indicators related to core Lean principles, such as pull production, reduce work-in-progress, and continuous flow, for instance. In fact, despite the large number of Lean implementations reported in the literature, very little has been reported on the development of PMS that are effective for assessing changes that occur in lean implementation (Sánchez and Peréz, 2001). Besides, there is a lack of studies on how Lean companies (or projects) use indicators and to what extent these reflect the result of actions that have been undertaken (Bititci et al., 2011; Bellisario and Pavlov, 2018).

Therefore, the **aim of this research work is to propose a set of requirements for PMS from a lean production perspective and a taxonomy of metrics for lean production systems.** This investigation also intends to contribute to the development of a conceptual framework to support the design and implementation of PMS in lean production systems.

Research method:

Design Science Research is the methodological approach adopted in this investigation. This approach has a prescriptive character, seeking to devise solution concepts, named artefacts, to solve classes of problems (Holmstrom et al. 2009; Van Aken 2004). In this research study, the proposed artefact is a set of requirements that can contribute to the design and implementation of PMS in Lean Production Systems in the construction industry.

Based on the phases suggested by Lukka (2003) for Design Science Research, Figure 1 presents an overview of the research design.

The work started with a literature review on performance measurement both in operations and construction management. Most papers found are concerned with PM in general, and only a few of them are related to PMS in Lean Production Systems.

In parallel, a survey with a sample of construction companies from the South of Brazil that have implemented some lean construction practices has been undertaken, The aim of this survey is to analyze PM good practices that are somewhat related to Lean implementation, and also to identify some barriers to measure performance in that context. The results of this survey will contribute to the proposal of a taxonomy of metrics for lean production systems.

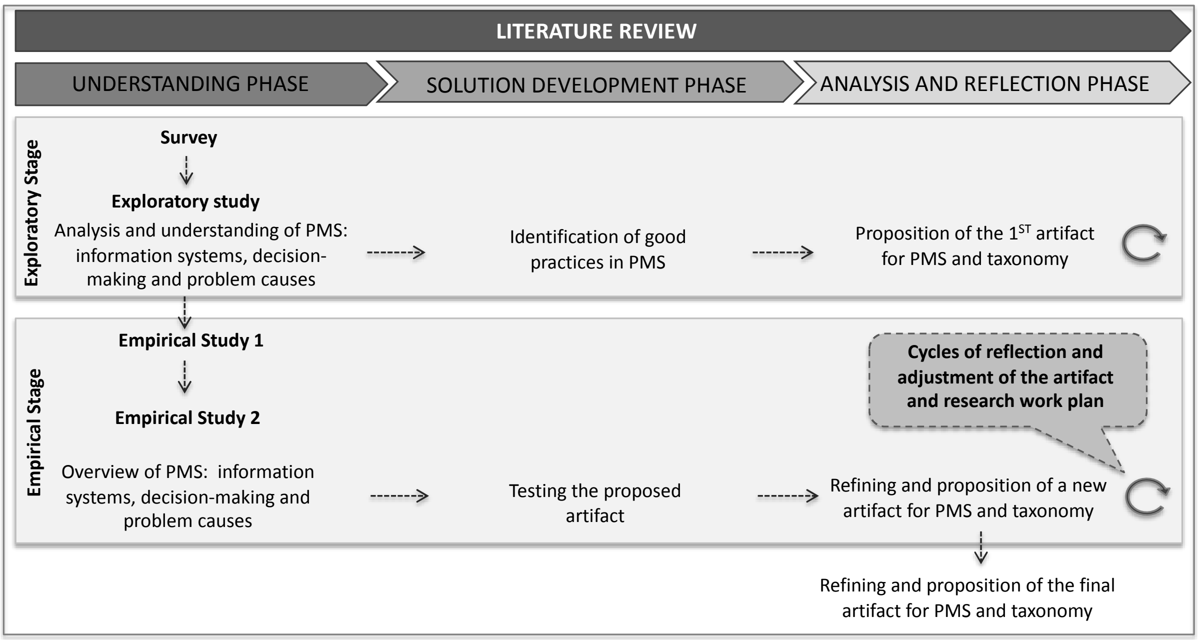

Figure 1: Research Design

The first empirical study of this research work started in November 2018, in the project management department of a fashion retail company that has carried out a program for implementing Lean and Agile project management principles and concepts. This is a leading retail company from South America and has a portfolio of around 60 projects a year. Many of those are refurbishment projects, that have a short duration, and a high level of complexity. In this company a critical analysis of the existing PMS has been made, in which some improvement opportunities have been identified. The next step will be to propose and implement some changes in the PMS, by adopting a research strategy similar to action research. Based on this empirical study an initial set of requirements for PMS from a Lean Perspective will be proposed.

A brief descriptive case study in a manufacturing company that is very advanced on the implementation of the Lean Production will be carried out, with the aim to get some more innovative contributions for the set of requirements to be proposed. Finally, a second empirical study in a construction company will be undertaken with the aim of refining and testing the proposed set of requirements, by also adopting an action research strategy.

The main sources of evidences that has been used in the first empirical study are: semi-structured interviews with project managers, design managers, representatives of construction companies, and other technical staff; analysis of documents, such as plans, procedures, and design documents; participant observation in planning and control meetings; analysis of data used in existing digital control systems; direct observation in construction sites. As in any action research project, there will be learning cycles in which the changes are planned, implemented and evaluated.

Preliminary findings

Some preliminary findings will be reported at the Summer School, based on the results of the first exploratory study that will be obtained in the next few months.

Research Scope and Limitations

The scope of this investigation is limited to construction projects as production systems, rather than at the level of construction organizations.

Expectations from the Summer School

This research is in its early stages. Therefore, my expectations are related to the opportunity to obtain feedback for the definition of the scope of the investigation, as well as to get some insights on the role of performance measurement in lean production systems.

References

Bassioni, H.A., Price, A.D.F., and Hassan, T. M. (2004). Performance measurement in construction. ASCE J. of Manage.in Eng., 20(2), pp. 42-50

Beatham, S., Anumba, C., Thorpe, T., & Hedges, I. (2004). KPIs: A critical appraisal of their use in construction. Benchmarking, 11(1), 93–117.

BELISSARIO, A., & PAVLOV, A. (2018). Performance management practices in lean manufacturing organizations: a systematic review of research evidence. Production Planning & Control, 7287, 1–19.

BOURNE, M.; MILLS, J.; WILCOX, M.; NEELY, A.; PLATTS, K. Designing, implementing and updating performance measurement systems. International Journal of Operation & Production Management, Bradford, v.20, n.7, p.754-771, 2000.

Costa, D. B., & Formoso, C. T. (2004). A set of evaluation criteria for performance measurement systems in the construction industry, 9(2).

Costa, D.B., Formoso, C.T., Kagioglou, M., Alarcon, L.F. and Caldas, C.H. (2006). "Benchmarking Initiatives in the Construction Industry: Lessons Learned and ImprovementOpportunities."J. Mgmt. inEng., 22(4),158-167.

ESPAÑA, F., TSAO, C., & HOUSER. (2012). Driving Continuous Improvement By Developing and Leveraging Lean Key Performance Indicators. 20th Conference of the International Group for Lean Construction.

Holmstrom, J., & Ketokivi, M. (2009). Bridging Practice and Theory: A Design Science Approach. Decision Sciences, 40(4), 65–87.

KAGIOGLOU, M.; COOPER, R.; AOUAD, G. Performance management in construction: a conceptual framework. Construction Management and Economics, London, v.19 n.1, p. 85-95, 2001.

Kennerley, M., & Neely, A. (2003). Measuring performance in a changing business environment. International Journal of Operations and Production Management, 23(2), 213–229.

Koskela, L. (2000), An Exploration towards a Production Theory and Its Application to Construction, VTT Technical Research Centre of Finland.

LANTELME, E. M. V., FORMOSO, C. T. Improving performance though measurement: the application of lean production and organisational learning principles. In: INTERNATIONAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 8, 2000, Brighton. Proceedings... Brighton, University of Sussex, 2000.

LUKKA, K. The constructive research approach. In Ojala, L. & Hilmola, O-P. (eds.) Case study research in logistics. Publications of the Turku School of Economics and Business Administration: Series B1, p.83- 101. 2003.

Neely, A., Richards, H., Mills, J., Platts, K., & Bourne, M. (1997). Designing performance measures: a structured approach. International Journal of Operations & Production Management, 17(11), 1131–1152.

PAVLOV, A., & BOURNE, M. (2011). Explaining the effects of performance measurement on performance: An organizational routines perspective. International Journal of Operations and Production Management, 31(1), 101–122.

Peter, E. D. L., & Gary, D. H. (2000). Construction business performance measurement: the SPM alternative. Business Process Management Journal, 6(5), 408.

Sanchez, A. M., & Pérez, M. P. (2001). Lean indicators and manufacturing strategies. International Journal of Operations & Production Management, 21(11), 1433–1451.

SARHAN, S and FOX, A (2013) 'Performance measurement in the UK construction industry and its role in supporting the application of lean construction concepts', Australasian Journal of Construction Economics and Building, 13 (1) 23-35

VAN AKEN, J. E. Management Research Based on the Paradigm of the Design Sciences: The Quest for Field- Tested and Grounded Technological Rules. Journal of Management Studies, v. 41, n. 2, p. 219-246, 2004

WAGGONER, D.B.; NEELY, A.D; KENNERLEY, M.P. The forces that shape organisational performance measurement system: an interdisciplinary review. International Journal Production Economics, Amsterdam, v. 60-61, p. 53-60, Apr. 1999.

Wegelius-Lehtonen, T. (2001) Performance Measurement in Construction Logistics. International Journal of Production Economics, 69, 107-116.

Yu, L., Kim, K., Jung, Y. and Chin, S. (2007), "Comparable performance measurement system for construction companies", Journal of Management in Engineering, Vol. 23 No. 3, pp. 131-9.

Identification and Assessment of Stakeholder Value/s in the Design of the Built Environment

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Purpose of research

Built facilities not only meet the functional and pragmatic needs of the users, but also create strong emotional and value building experiences among users based on its design. Building design is a combination of art, material and technology, tradition and spirit of the time culminating into artefacts which yield social and economic values (Saunders, W. S. 2007). The design of any facility reflects the values of the users or the stakeholders of the facility and can in-turn influence the values of the stakeholders.

In the present times, these values go beyond the conventional cost, schedule, construction quality, safety and environmental values. The investment in a good design generates economic and social value and it does not always imply increase in cost when measured across the entire life-cycle of the facility (CABE 2001). However, defining design values for a built facility is challenging owing to the extended time taken for the completion of projects, the presence of multiple stakeholders and the lack of a common understanding on design values.

The overall aim of this research is to study the characteristics of design values and their influence on design requirements and to subsequently provide a framework for its identification and assessment in the context of AEC projects.

Research Gaps:

Based on the literature review, the following research gaps were identified.

1. Value/s provide a broader range, long term and motivational objectives for any design (Saunders, W. S. 2007). A value-based approach is therefore warranted for the AEC design process. Most of the tools and techniques reported in literature lack the value/s perspective in the context of AEC design.
2. Although, there are anecdotal evidences depicting the influence of value/s on the design requirements, very less research has been focused on developing a value-based methodology for systematic identification of design value/s let alone its quantification. There is a lack of empirical studies on how value/s influence design requirements.
3. Although studies have suggested certain design value/s for a built facility (Emmitt et al. 2004; Saxon 2005), there is a lack of sufficient empirical evidence that provides a basis for these values. Further, there is no commonly accepted definition and classification of design values in the case of AEC

design.
4. There is extant literature on how value/s act as criteria which influence decision making among individuals (Lera 1981; Simon 1987; Lindberg 1987). However, very less scholarly study has focused on how the characteristics of value/s can be utilized in design decision making. Further, the application of individual value/s and its characteristics to group decision making needs to be explored.

Research Questions:

1. Can a value-based approach be applied in the design process of a built facility? How can we identify a set of design values for a built facility and evaluate the methodology for its effectiveness?
2. How do design values influence design requirements of a particular built facility?
3. How can the identified values / criteria and sub-criteria (design requirements) be prioritized and subsequently utilized for decision making?

Research Objectives:

1. To propose a methodology to arrive at a set of identifiable values for a built facility based on an empirical study
2. To map various levels of design criteria to the corresponding design values
3. To propose a framework for design assessment based on the identified set of values and investigate its effectiveness in design decision making

Research method

Design requirements are elicited in the architectural brief and design conceptualization phase of a construction project. Architectural brief consists of tacit information which are many times not explicitly stated in the design brief. Further, design requirements evolve through iterative and unstructured dialogues between different stakeholders. The descriptive nature of design values entails the need for research methods used in social sciences. This work uses ethnographic study as the research method. Figure 1 illustrates the overall research methodology adopted for the work.

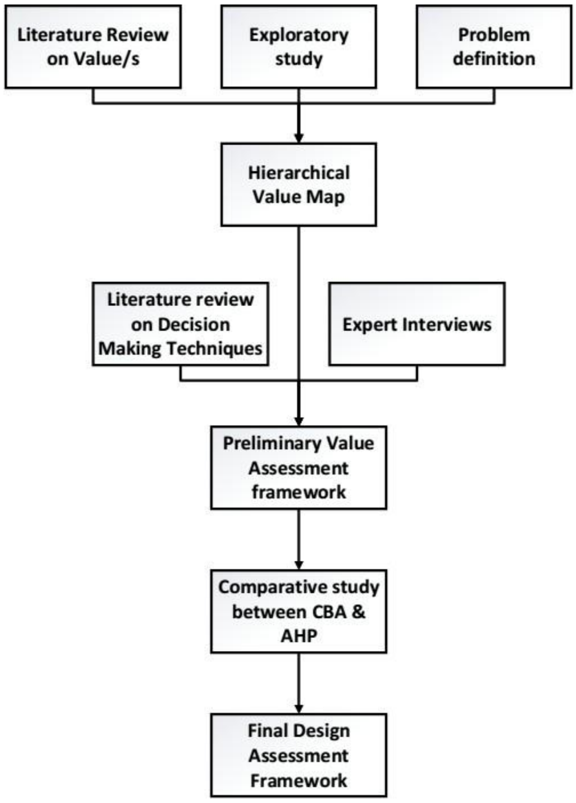

Figure 1: Overall Research Methodology

Preliminary findings:

1.1 VALUE BASED METHODOLOGY

Based on the study we propose a step by step approach for capturing of values as summarized in Figure 2.

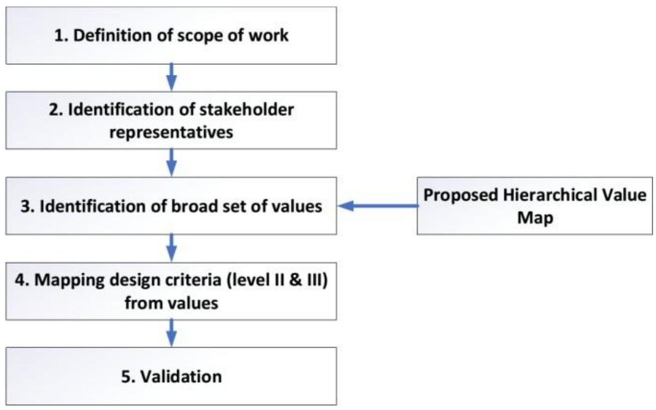

Figure 2: Methodology for value capture in design process

The steps involved in the methodology for value capture are as explained below.

Step 1: In this step, the overall scope of the project is defined which essentially includes the overall budget, broad design requirements, the site details and other preliminary investigation related details, the scale of the project, etc.

Step 2: This step involves identification of stakeholder representatives including representatives from the user group.

Step 3: This study provides a Hierarchical Value Map and a hierarchical framework as a set of values which can be utilized for guiding the value capturing process. The framework can be refined to suit a particular project by including only the relevant values and adding any values which are not already present but relevant to the case.

Step 4: The value framework provides level II and III design criteria which can be assessed for the suitability of the case and refined accordingly. In case of any new values, the stakeholders need to arrive at level II and III design criteria through methods such as focus group discussions with the stakeholders.

Step 5: The refined value framework needs to be validated through expert interview to avoid the bias of the stakeholder group.

1.2 MAPPING OF THE DESIGN VALUES TO DESIGN REQUIREMENTS

The current work utilizes the means-ends chain model developed by Gutman (1982) for mapping design requirements to design values. The means-ends chain model has been studied for its application in the construction management research by Coolen and Hoekstra (2001) to understand housing preferences through the technique of laddering. Henteschke et al. (2014) further proposed a framework for defining value adding attributes using the means-ends chain model for mass housing customization projects.

The data from the ethnographic study was used to arrive at themes which were used to arrive at criteria and their influence at various levels of the Hierarchical Value

Map. The model represented by a tree diagram (Figure 3) illustrates how product attributes (in this case a built facility) lead to value generation. The map signifies the importance of considering user values in design decision making. The map also serves as a visual aid for design decision making.

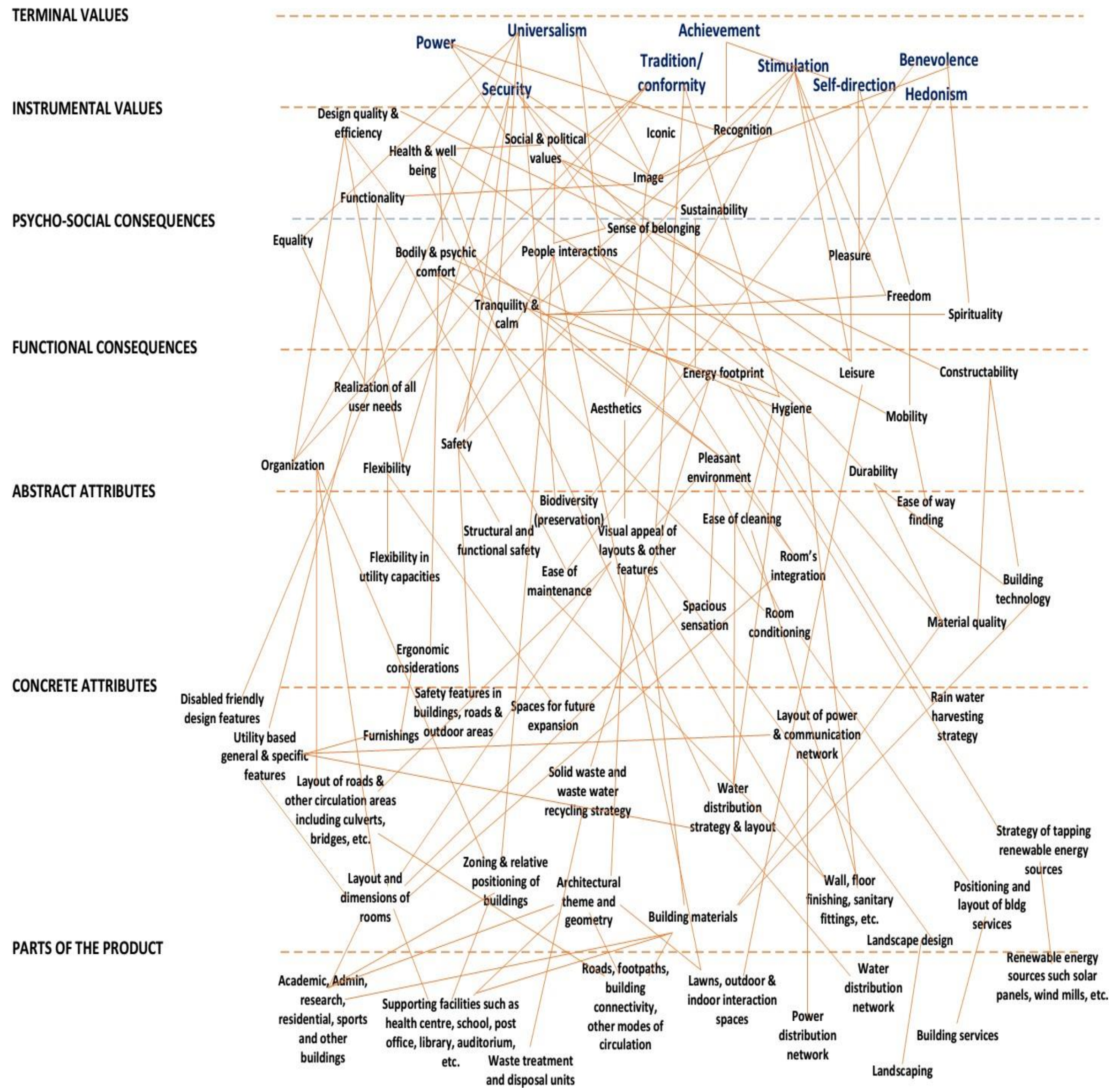

Figure 3: Hierarchical Value Map

The means-end chain model relates product attributes to emotional and personal values through six levels of abstractions: concrete attributes, abstract attributes, functional consequences, psychological consequences, instrumental values and terminal values (Reynold and Olson 2008). The concrete and abstract attributes (Zeithaml 1988) refer to the tangible and intangible product attributes respectively. The functional consequences are concerned with the situation-based utility of the product. The psychosocial consequences are a result of satisfaction of intrinsic objectives of individuals (Overby et al. 2004). And finally, the instrumental values are modes to attain terminal values. The terminal values are desired end-states. The laddering technique does not always lead to terminal values (van Rekom and Wierenga, 2007).

Therefore, in the current study we are using a modified HVM wherein the ten motivational types of values studied by Schwartz (1992) form the terminal values. Figure 4 illustrates a set of design values that were chosen for the decision-making framework from the hierarchical value map.

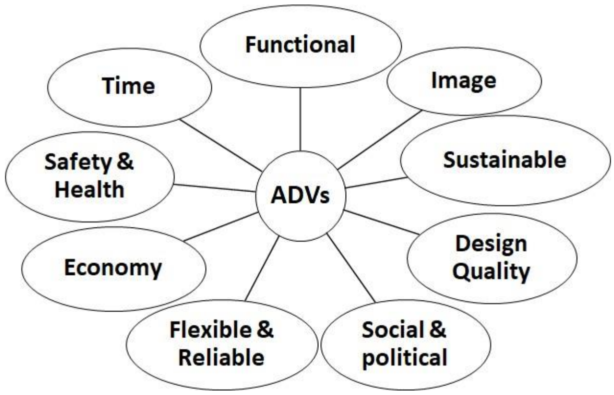

Figure 4: Architectural Design Values

In the current study, it was observed that there are ambiguities with respect to the awareness and alignment of the stakeholders to a particular or set of terminal values. Further, there are significant overlaps in the lower level design attributes pertaining to certain terminal values. Therefore, the terminal values were excluded when deciding the design values and their corresponding design requirements as criteria and sub criteria for the MCDM framework. Further, while choosing the design criteria and sub-criteria we have tried to keep the design requirements as much exclusive as possible.

Research Scope and Limitations

The study is limited to the design conceptualization and design brief/ requirement specification stage.

Likely contribution:

1. Hierarchical Value Map illustrating link between building components and design values
2. Methodology for value capture in the design for a built facility
3. Framework for evaluation of design alternatives for a built facility
4. Architecture for automated Set Based Design

Expectations from the Summer School

Look forward to feedback on methodology adopted in the study.

References:

5. CABE (2001) “The value of good design: how buildings and spaces create economic and social value”, London: CABE
6. Coolen, H. and Hoekstra, J. (2001). “Values as determinant of preferences for housing attributes”, *Journal of Housing and the Built Environment* 16: 285-306, 2001.
7. Emmitt, S., Sander, D., & K., C. a. (2004). “Implementing Value through Lean Design Management.” *In Proceedings of the 12th International Conference*, 361–374.
8. Gutman, J. (1982). “A Means-End Chain Model Based on Consumer Categorization Processes.” *Journal of Marketing*, Vol. 46, No. 2 (Spring 1982), pp. 60-72
9. Hentschke, C. S., Formoso, C. T., Rocha, C. G., & Echeveste, M. E. S. (2014). “A method for proposing valued-adding attributes in customized housing.” *Sustainability (Switzerland)*, 6(12), 9244–9267.
10. Lera, S. G. (1981). “Architectural designers’ values and the evaluation of their designs” Design Studies, volume 2, issue 3, July 1981, pp. 131-137
11. Lindberg, E., Gärling, T., Montgomery, H. and Waara, R. (1987). “People’s Evaluation of Housing Attributes. A Study of Underlying Beliefs and Values.” Scandinavian Housing and Planning Research, 4, 81–103
12. Overby, J. W., Gardial, S., Woodruff, R. B. (2004). “French versus American Consumers. Attachment of Value to a Product in a Common Consumption Context: A Cross-National Comparison.” J. Acad. Mark. Sci., 32, 437-460.
13. Saunders, W. S. (2007). “Judging Architectural Value”, *Harvard Design Magazine Reader,* Vol. 4
14. Saxon, R. (2005). “Be Valuable: A guide to creating value in the built environment” Commission for Architecture and the Built Environment.
15. Schwartz, S. H. (1992). “Universals in the Content and Structure of Values: Theoretical Advances and Empirical Tests in 20 countries” *Advances in Experimental Social Psychology*, Vol. 25.
16. Simon, H. A., Dantzig, G. B., Hogarth, R., Plott, C. R., Raiffa, H., Schelling, T. C., Shepsle, K. A., Thaler, R., Tversky, S. and Winter, S. (1987). “Decision Making and Problem Solving, Interfaces,” 17, 11-31.

Takt production in construction: An empirical study

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Purpose of research

Production planning and control are key contributors to successful and flow-efficient construction projects (e.g., Koskela 1992, Ballard, 2000). Activity-based planning and control methods, especially Critical Path Method (CPM) have been widely used in construction for several decades (Plotnick & O'Brien 2009). Although CPM is a powerful tool for managing construction projects, it has been critisized for its lack of workflow and lack of continuity in resource usage, while resulting in lengthy and complex schedules which are difficult to control (e.g. Olivieri & Seppänen 2018). Linear scheduling methods, such as Line of Balance (LOB, Lumsden, 1968) and the latest-generation method Location-Based Management System (LBMS, Kenley & Seppänen 2010) have attempted to tackle the shortcomings of the activity-based methods, and indeed have shown their potential in improving flow efficiency and reducing waste in several occasions (e.g. Seppänen et al. 2014)

In addition of the potential of LBMS, location-based production planning and control methods Takt Time Planning (TTP) and Takt Planning and Control (TPTC) have received attention within the Lean Construction community. TTP and TPTC have shown great potential in increasing flow and radically decreasing production durations, and for example, Frandson et al. (2013) and Binninger et al. (2018) have documented 55% and 70% reductions, respectively, in durations by implementing takt production.

Takt is a concept originated from lean manufacturing, which refers to a constant production time in different work tasks. According to by Hopp & Spearman (2008,

p. 495), “*takt time is the unit of time within which a product must be produced in order to match the rate at which that product is needed*”. In construction, takt practically means balancing the work tasks in order for them to proceed in the same beat, around the same unit of time. Takt in construction has been explored especially in California by Frandson & Tommelein (e.g. 2016, defined as TTP, takt time production), and in Germany, by Dlouhy & Binninger (e.g. 2016, defined as TPTC, takt planning and takt control). Although there are differences between the approaches, the basic principle of working around the balanced beat exists in both systems. Takt planning is based on identifying repetitive processes and sub-processes, after which production is optimized from the process perspective, and not from the product perspective which leads to sub-optimization (Dlouhy et al. 2016). Thus, the benefit of takt surfaces from its structured and methodological way of planning as well as daily control of the production, and therefore, achieving stability and continuous flow (Tommelein, 2017).

However, the critical analysis and comparison of different takt production approaches in construction has remained scarce. Research of takt planning and control has been focusing on developing the methods in certain unique situations, such as in hospital projects in California or in factory construction in Germany. In addition, the documented cases have been primarily focusing on the potential and benefits of the method. Although takt production has been implemented in various instances for example in Germany, California, Norway and Finland, little comparison of different takt methods and holistic documentation of actual implementations yet exists.

Therefore, research is needed on comparing different takt production approaches, as well as critically reviewing the benefits and shortcomings in order to understand how takt production could be the most effectively used. While generating unified theory for takt production is perhaps not desirable, understanding the concept of takt production in construction in general could enable more efficient development of successful and flow-efficient construction.

The scope of the study is to create an overview of different takt production methods and implementation cases to understand the current development of takt production in more holistic manner. **The aim of the study** is to distinguish how takt differs from other planning and control methods, to develop understanding on what enablers but also barriers emerge while implementing takt production, and how to properly address the found enablers and barriers in order to improve production flow. The aim is pursued by answering the following research questions:

RQ1: How the implementation of takt production differs from the implementation of other widely used planning and control methods, CPM and LBMS?

RQ2: What differences and similarities can be found between different takt planning and control methods, as well as between different takt implementation cases?

RQ3: What are the most significant enablers and barriers for effective takt production, and how found enablers can be implemented and barriers be tackled in order to improve takt production, and production flow in general?

Research method

The study is conducted as a qualitative multiple-case study, by investigating the implementation of takt production in six different cases, in Finland, California, and Germany. The data collection strategy and case selection is affected by the propositions formulated from the basis of the literature review, to match the theoretical and practical conditions. Data is collected through triangulation, including several semi-structured interviews, supported by an observation of project documentation, data created by digital production control tools, production meetings, several site visits as well as workshops with the project stakeholders. Furthermore, acquired data is clustered and analyzed first by cases individually, and then cross-analyzed. At last, results are discussed between the literature and conclusions are drawn. The flow of research activities is presented in figure 1.

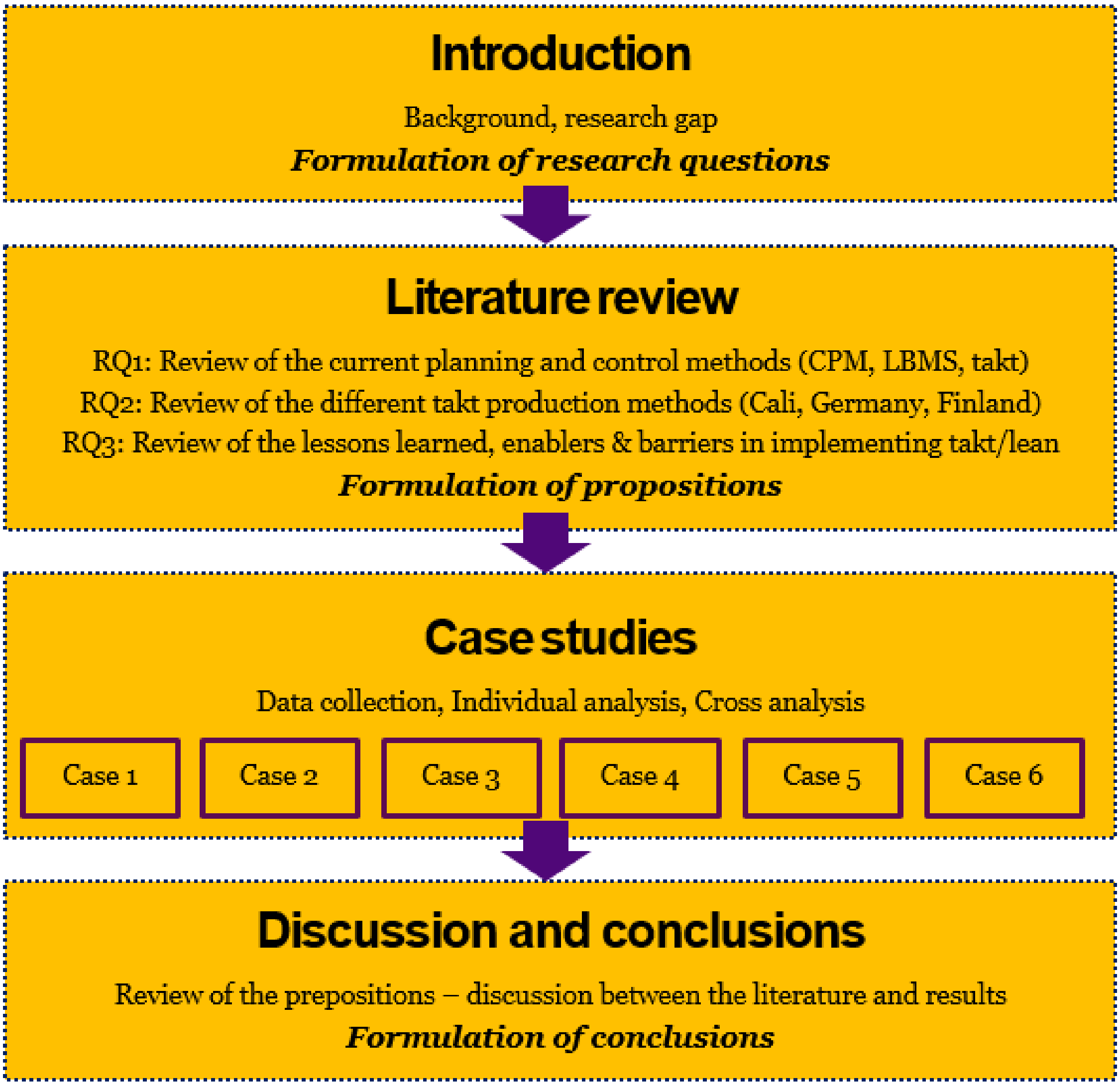

Figure1: Flow of the research

Preliminary findings

Preliminary findings indicate that even though several barriers are discovered while implementing takt production, the overall flow and transparency of the production is significantly increased in all cases. The trust and collaboration between the parties play a central role in the control, but also in the planning phase. Means and methods of takt production should be addressed well before the production in order to increase trust and mutual understanding, while adopting completely new methods of working. The analysis is not yet complete, the preliminary results indicate that differences in working cultures, maturity level of takt implementation as well as previous usage of different planning and control methods generate several differences between the implementation cases.

Research Limitations

Multiple case study approach was selected to cover different theoretical conditions, to gain robustness and an ability to generalize the results, as well as wider exploration of the propositions (Eisenhardt & Graebner 2007). Moreover, the approach was selected to increase reliability that can occur due the variation caused by cultural differences, differences between levels of takt implementation maturity as well as between different project types. The case were selected in a way that at least two cases represent each the mentioned categories to further increase the reliability. However, the study inspects only a limited amount of cases, and the observation is limited to three countries (USA, Germany, Finland) and three different project types (hospital, manufacturing and residential). In addition, the study is limited to a qualitative analysis, while the results are suspect to biases of the viewpoints and deductions of the researchers.

Implications and avenues for future research

The study has implications for achieving the full potential of takt production methods widely. As the critical and thorough documentation of takt implementation cases has remained scarce, the study encourages the industry players to implement takt production methods more widely, while better understanding the shortcomings and ways in which the barriers could be effectively tackled. In addition, the study has implications to construction production planning and control theory, as in 2019, no peer-reviewed articles yet exist on the subject.

Future research topics could include 1) the validation of the results in further case studies, 2) quantitative analysis on how takt implementation affects the production flow and 3) the examination of the long-terms benefits of takt production implementation

Expectations from the Summer School

As the presented paper will be my very first peer-reviewed journal paper, I would like to get feedback wide from several angles. However, the most beneficial areas of feedback could include the research design and analysis of the multiple-case study findings. I am very excited to see you in Dublin!

References

Ballard, H. G. (2000). The last planner system of production control. Doctoral dissertation, University of Birmingham.

Binninger, M., Dlouhy, J., Müller, M., Schattmann, M., & Haghsheno, S. (2018). Short Takt Time in Construction – a Practical Study. In 26th Annual Conference of the International Group for Lean Construction.

Dlouhy, J., Binninger, M., Oprach, S., & Haghsheno, S. (2016). Three-level method of Takt planning and Takt control–A new approach for designing production systems in construction. In 24th Annual Confenrence of the International Group for Lean Construction.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. Academy of management journal, 50(1), 25-32.

Frandson, A., Berghede, K., & Tommelein, I. D. (2013). Takt time planning for construction of exterior cladding. In 21th Annual Conference of the International Group for Lean Construction.

Frandson, A. G., & Tommelein, I. D. (2016). Takt time planning of interiors on a Pre-Cast hospital project. In 24th Annual Conference of the International Group for Lean Construction.

Hopp, W. J., & Spearman M. L. (2008) Factory Physics. Waveland Press.

Kenley, R., & Seppänen, O. (2010). Location-based management for construction: Planning, scheduling and control. Routledge.

Koskela, L. (1992). Application of the new production philosophy to construction (Vol. 72). Stanford: Stanford university.

Lumsden, P. (1968). The line-of-balance method. Pergamon Press Limited.

Olivieri, H., Seppänen, O., & Denis Granja, A. (2018). Improving workflow and resource usage in construction schedules through location-based management system (LBMS). Construction Management and Economics, *36*(2), 109–124.

Plotnick, F., & O'Brien, J. (2009). CPM in construction management. McGraw-Hill Education.

Seppänen, O., Evinger, J., & Mouflard, C. (2014). Effects of the location-based management system on production rates and productivity. Construction Management and Economics, 32(6), 608–624.

Tommelein, I. D. (2017). Collaborative Takt Time Planning of Non-Repetitive Work. In 25th Annual Conference of the International Group for Lean Construction

Influence of behaviors and psychological safety in improving quality management in construction projects.

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Purpose of research

Researchers have suggested that quality is a major concern worldwide in the construction industry and it is therefore a potential area for improvement (Rumane 2011; Arditi and Gunaydin 1997). Flynn (2001) introduced the concept of behavior-based quality (BBQ) for organizations whose quality has reached a plateau and aim to keep improving by managing upstream behaviors rather than downstream defects. Flynn suggested that behaviors are reinforced by consequences; therefore, in an industry where quality is a concern such as construction, project teams are motivated to behave differently by the desire to obtain different results, by the desire to please their clients, by the desire to achieve some goals or to act in accordance with certain principles. Such understanding was strengthened by Spencley et al. (2018) who introduced the BBQ concept to shift the traditional quality management in construction and increase the likelihood of meeting project participants' expectations with a team that is motivated to think and behave differently.

The study seeks to understand why and how a behavior-based quality (BBQ) approach works in construction projects and how the process looks like in detail. One on-going construction projects are part of the study. The researcher will observe the implementation process of BBQ for different scopes of work to understand the concept, how it is currently being apply and how we can refine the process itself. Construction projects tend to move fast, and information constantly changes. Achieving quality is not a one-time conversation but rather a series of conversations to make sure all project participants involved in a specific scope of work are aligned around the same expectations, and processes are set in place accordingly to steer towards successfully meeting these expectations.

As the BBQ approach implies people being able to uncover their expectations and be transparent, there is a strong correlation between BBQ and people feeling free to speak up their minds in a psychologically safe work environment. Edmondson (1999, p.350) defined psychological safety as "a shared belief that the team is safe for interpersonal risk taking" with the expectation that individuals will mutually respect each other, not get embarrassed, rejected or punished for speaking up. Nembhard and Edmondson (2006) suggested that when individuals feel psychologically safe, they speak up freely and are not constraint by others disapproval or negative personal consequences. In the context of behavior-based quality, quality involves identifying distinguishing features of work, developing methods for delivering those features, and having agreement on how to measure whether the features have indeed been delivered.

Research question: What are the characteristics of a sustainable quality management process based on behaviors that facilitates the understanding of project participants' expectations in early phases of construction projects and therefore increases the likelihood that a quality product is being delivered?

Hypothesis: A behavior-based approach to quality help project participants to have a higher predictability of results.

Research method

The researcher will use design science as main methodology as it is well suited when new methodologies including processes are designed, tested and refined (Hevner et al. 2004). Design science involves the creation of new knowledge through design of artifacts (processes or products). The artifact I will develop is a detailed process to apply a behavior-based quality (BBQ) approach in construction projects. Figure 1 summarizes the research timeline.

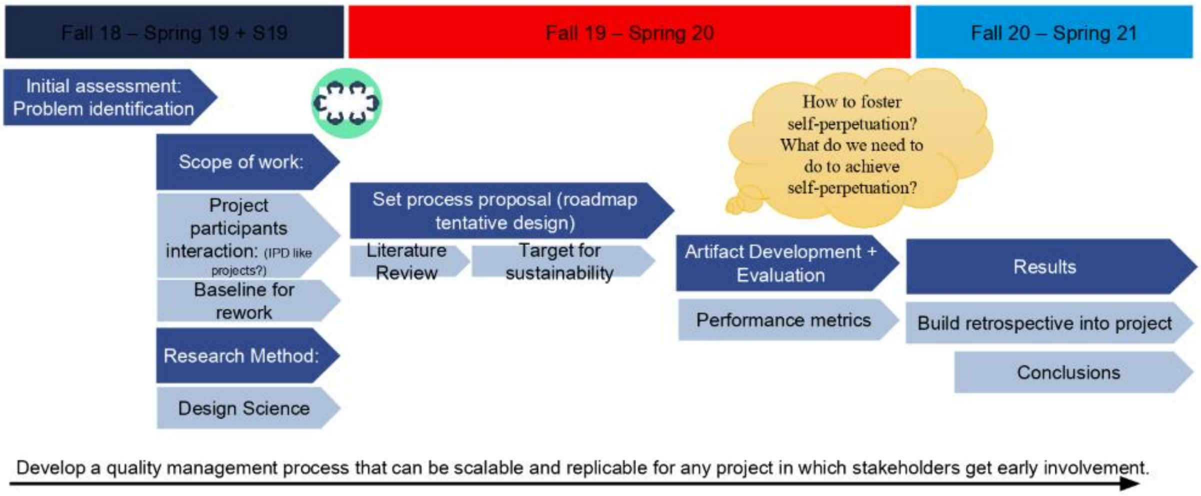

Fig 1. Research Timeline

Also, a qualitative interview methodology is suitable for developing the study because of its capacity to generate detailed explanations as to why and how certain people' behaviors in a psychologically safe environment develop and influences work outcomes. By interviewing the project team, the researcher plans to capture the weaknesses and strengths of the BBQ implementation process and help to refine it. As the same time, as the BBQ concept relies on people being able to freely speak up about their expectations, psychological safety will be studied since it is important to first understand what factors on site might be impacting people's comfort to speak up. To achieve that, a survey measuring psychological safety parameters on site will be distributed.

Preliminary findings:

I started the study by analyzing the awareness of the project team members in regard of BBQ. I found that even some of the team members from the general contractor were not aware of the approach and the activities they were expected to do to lead the approach. I collaborated with the team to set some short term plans and long terms plans. Sort term plans included training sessions with the general contractor team and setting expectations for each member.

I have also captured one cycle of BBQ implementation process for the scope of work of "architectural exposed concrete shear walls." I plan to conduct an in-depth interview round with the project team members to get their insides about the process. Later I will define a second cycle of BBQ implementation and what changes will be tested then.

Research Scope and Limitations

As I am trying to develop, test and refine a concept (BBQ), my main limitation is that the case studies available would only come from one project, which makes generalizability hard. However, I plan to offer a very detailed and in-depth study of the process, so it can be applied everywhere if the culture needed is created.

Implications:

I want to prove that better projects wan be built if we plan construction projects first for quality to fully understand expectations of what the team should build, then for safety to identify any potential risks associated with the processes to build the agreed work and define how tasks will be built in a safe manner, and then for production to secure flow and an adequate use of resources. This is a contrast to what we have seen in traditional construction industry where production, safety, and quality are planned fragmented or in isolation one from another.

We have seen that the largest claims in construction companies come up for issues involved with quality on projects. In quality as well as in risk management, companies should pursue not having surprises and rather having a common understanding on expectations. Both require a discipline to be sustainable and both require people able to speak up, people feeling free in a psychological safe work environment.

For future research, it would add value to prove that that the highest impacts of BBQ implementation can be achieve on projects where project participants get involved early in the projects (such as IPDs).

Expectations

My objectives include but are not limited to:

- Get feedback on my research method and generalizability of the study.
- Learn from another attendees' research and identify potential new themes for research or potential areas in common that can be used for joint research.

References:

Arditi, D., and Gunaydin, H. M. (1997). Total Quality Management in the Construction Process. International Journal of Project Management, 15(4), 235-243.

Edmondson, A. (1999). Psychological Safety and Learning Behavior in Work Teams. Administrative Science Quarterly, 44(2), pp.350-383.

Flynn, K., (2001). "Behavior-Based Quality–Connecting People to the Systems."Behavioral Science Technology Annual SpringConference Proceeding, Chicago,IL.

Hevner, A., March, S., Park, J., and Ram, S. (2004). "Design Science in Information Systems Research." MIS Q, 28(1), pp. 75–105.

Nembhard, I. M., and Edmondson, A. C. (2006). Making it Safe: The Effects of Leader Inclusiveness and Professional Status on Psychological Safety and Improvement Efforts in Health Care Teams. Jrnl. of Organizational Behavior: The Int'l. Jrnl. Of Industrial, Occupational and Organizational Psych. and Behavior,27(7),941-966.

Rumane, A.R. (2011). Quality Management in Construction Projects. Construction Research Congress Press, Boca Raton, FL.

Spencley, R., Pfeffer, G., Gordon, E., Hain, F., Reed, D., and Marosszeky, M. (2018)."Behavior-Based Quality Closing the Knowing Doing Gap." Proc. 26th AnnualConference of the International. Group for Lean Construction (IGLC), Chennai,India, pp. 1170–1181.

Lean practices for Forcibly Displaced Populations in Slums

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Purpose of research

The need to develop resilient shelters for forcibly displaced populations has been a long-standing concern in urban areas in developing countries. Poor construction planning, ad-hoc decision-making, poor quality, material wastage, environmental damage, and cost and time overruns are common problems in building shelters for the forcibly displaced, especially in temporary housing, a largely adopted response to housing provision (Zetter, 2012, Johnson, 2006, Félix, Branco and Feio, 2013 and Mojtahedi and Oo, 2012).

Regardless of the well-known problems enumerated above, temporary shelters continue to be implemented all around the world and are supported by donations and agencies and by the current political management of the forcibly displaced (Zetter, 2012). This scenario of social, economic and environmental unsustainability could be avoided by the application of lean principles which have been applied successfully in other industries to improve processes efficiency and effectiveness (Mojtahedi and Oo, 2012, Almeida and Picchi, 2018 and Babalola, Ibem and Ezema, 2019).

Finding the confluence between Temporary Housing and Lean Thinking also lies on the theory that lean production can be applied to the housing sector where volumes are high enough to allow its economic viability (Winch, 2003) as it avoids craft production high cost and mass production strictness (Womack et al., 2007).

The aim of this research is to propose an integration of lean construction practices in temporary housing for displaced people living in slums in Latin American developing countries. The application of lean principles in temporary housing is explored in order to improve construction processes and efficiency regarding cost saving, time reduction, quality improvement and waste reduction and thus create a resilient sustainable solution.

Despite the fact the majority of the forcibly displaced do not live in camps (Zetter, 2012), there has been considerable research into temporary housing provision in the context of refugee camps and disaster reconstruction, but there has been little research into temporary housing in slums.

In the context of disaster reconstruction and based on some of Davis (2013) approaches, Johnson (2006) and Félix, Branco and Feio (2013) suggest a systemic view for temporary housing after disasters arguing that there is a need to look at the problem in a holistic way through an understanding of all the relationships in the system. Johnson (2006) proposes a strategic planning framework that incorporates organizational and technical design and project processes guidelines and Félix, Branco and Feio (2013) state that temporary housing should be studied from the point of view of the dwellers.

In relation to the Lean Approach, Hofmann and Powell's study (2012) combine Systems Thinking with Lean Thinking as an interdisciplinary method to improve the design of manufacturing systems. And, when it comes to Lean Principles and Housing, Martinez (2016) explores the potential of the implementation of the Lean Principles described by Liker (2004) relating user satisfaction to mass production and cost in affordable housing provision in Latin America. Other studies also attempt to view the provision of affordable housing (Arcila and Vanegas, 2005) post-disaster reconstruction (Mojtahedi and Oo, 2012) and refugee camps (Eljazzar et al., 2013) through the lens of the Lean Approach, applying lean principles, tools and implementation frameworks to the problem.

Finally, Almeida and Picchi (2018) and Babalola, Ibem and Ezema (2019), conducted a systematic review of literature, identifying and categorizing the different lean practices implemented in the construction industry and the benefits derivable from them, linking economic, social and environmental benefits to the implementation of lean practices in the construction industry.

As described above, studies have identified problems and presented the implementation of strategies and application of lean practices in temporary housing after disasters or in affordable housing and have related lean practices to the construction industry in general, but no studies have related the issues above to temporary housing in slums. In order to address this important gap in knowledge, this case study research will examine the incorporation of the principles of lean construction into temporary buildings programmes such as the Latin American NGO Techo, an organisation that provides temporary shelters in slums tackling the worst conditions in slums being able to build more than 120,000 units in 20 years.

Research method:

In order to address the exposed above, this research addresses three key research questions:

1- How is the program implementation of temporary housing organisations in terms of eligibility, funding, management, design, construction and community participation?

2- Why are the implementation of programmes often criticized for their environmental, social and economic unsustainability?
3- How could lean practices address these sustainability problems in temporary housing programmes?

Based on these research questions, theoretical propositions are established to guide the research design:

1. Post-disaster temporary housing programmes are unsustainable because they often incorporate imported technologies, designs and prefabricated buildings, the approach misunderstands dwellers needs and fails to deal with environmental issues and local resources (Félix, Branco and Feio, 2013; Johnson, 2006 and Zetter, 2012). The same issues can be found in temporary housing for slums as identified in a preliminary documental review of the NGO Techo for the purpose of this research as mentioned below.
2. Lean practices can be applied to organisational and technical systems for temporary housing programmes in order to integrate community participation, local conditions and the dwellers real needs affecting their perception in relation to the solution delivered.

These theoretical propositions are informed by the preliminary literature review cited above and the researcher experience working for NGOs such as Architecture for Humanity and Voluntary Architects Network, with the architect Shigeru Ban in disaster relief buildings. Both the literature review and the researcher's experience will form the basis of the research and are used to define the specific subjects for research.

This research is expected to use the mixed method approach, an exploratory sequential mixed method design which is characterized by an initial qualitative phase of data collection and analysis, followed by a phase of quantitative data collection and analysis based on the initial qualitative phase (Creswell, 2014).

The study will be based on the Case Study Methodology, which allows the development of an empirical approach to complex social and human phenomena within their own context (Yin, 2015). The main case study – Techo´s Emergency Housing other cases not specifically related to slums will be used to perform a cross case analysis in other to identify the major issues in temporary housing programs building a better understanding of temporary housing programs in slums. The researcher will also engage in Action Research, a "process the researcher enters a real-world situation and aims both to improve it and to acquire knowledge" (Checkland and Holwell, 1998, p.9) by volunteering in the construction of temporary shelters in slums in Latin America.

Main research question	How could lean practices address environmental, social and economic sustainability in temporary housing programmes in slums in Latin American Countries?

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Literature Review	Stablish the theoretical framework	Design research method and select data analysis methods	Analyse data	Summarize and conclude the study
• Temporary Housing after disasters • Temporary Housing in Slums • Sustainability in Temporary Housing • Lean Principles, Lean Construction and Lean Practices	• Reviewing past theories • Developing theoretical framework • Definition of variables • Formulating Hypothesis	• Action research • Questionnaire Design • Sampling frame: which slums/ which type of housing model • Data collection: technical, minutes of project meetings, contractual documents and agreements, construction documents, and narrative reports obtained from Techo • Data Analysis Methods	• Analysis of Techo's Housing program • Cross-case analysis	• Summary of results • Contribution to theory • Implications • Limitations to the study • Future implications

Figure 1: Flow of research activities

The qualitative phase of the study will include interviews with actors in temporary housing organizations, examination of records, databases, photographs, architectural drawings, reports and literature to determine the impacts, benefits and barriers of the programme.

The action component of the research will be both qualitative and quantitative, as the researcher will volunteer in the NGO and, besides participating in the design and construction of the shelter, the investigator will take part in interviews with the dwellers organised by the NGO and in a survey of a researcher of Fundação Getúlio Vargas which will study the impact of the program on the users´ life. The final phase of the study will integrate both of phases in the results and conclusions of the research.

Preliminary findings:

The preliminary documental review of the NGO Techo found out that the temporary shelters provided by the NGO are as environmental, social and economic unsustainable as temporary shelters after disasters. Moreover, Techo's prefabricated model redesigns fail to resolve the identified issues, calling for a need for new approaches in organizational, technical design and project processes.

Research Scope and Limitations

The scope of the proposed work is Latin American Slums where Techo provides housing, but time and resource constraints limit not only the number and types of slums and populations to be studied but also not focusing on all possible applications of Lean Construction practices in Temporary Housing in Slums.

Implications

This research will contribute to an understanding of lean practices and its integration into temporary shelters in slums in order to improve their sustainability, and it will represent a further step in the research on temporary housing. It will also contribute to the formulation of temporary housing programmes, as well as to the research on provision of shelter in slums. Furthermore, it may encourage a change in the industry´s resistance to accepting the use of lean construction principles in mainstream construction. Suggestions for future research may include the application of lean practices to other types of affordable housing, aspects, countries or communities.

Expectations from the Summer School

As the research is at its early stages, it needs feedback in the development of the theoretical framework and the definition of variables for the quantitative part of the study. Especially it needs feedback on how to narrow the scope of the research in relation to lean practices to be studied for the research.

References

Almeida, E. and Picchi, F. (2018). Relação entre construção enxuta e sustentabilidade. *Ambiente Construído*, (18), pp.91-109.

Babalola, O., Ibem, E. and Ezema, I. (2019). Implementation of lean practices in the construction industry: A systematic review. *Building and Environment*, 148, pp.34-43.

Checkland, P. and Holwell, S. (1998). Action Research: Its Nature and Validity. *Systemic Practice and Action Research*, 11(1), pp.9-21.

Creswell, J. (2014). *Research design: qualitative, quantitative, and mixed methods approaches*. 4th ed. Thousand Oaks: Sage Publications.

Davis, I. (2013). What have we learned from 40 years´ experience of Disaster Shelter? In: D. Sanderson and J. Burnell, ed., *Beyond Shelter after disaster: Practice, process and possibilities*. Oxford: Taylor and Francis, pp.5-24.

Félix, D., Branco, J. and Feio, A. (2013). Temporary housing after disasters: A state of the art survey. *Habitat International*, 40, pp.136-141.

Eljazzar, M., Beydoun, A. and Hamzeh, F. (2013). Optimizing Workflow for Shelter Rehabilitation Projects in Refugee Camps. In: *The 21st Annual Conference of the International Group for Lean Construction*. Fortaleza: IGLC, pp.491-501.

Hofmann, P. and Powell, D. (2012). The Combination of Lean Thinking and Systems Thinking in the Design of Manufacturing Systems. In: *International Conference on Industrial Engineering and Engineering Management*. Hong Kong: IEEE, pp.50-60.

Johnson, C. (2006). *Strategic planning for temporary housing: 1999 earthquakes in Turkey*. Ph.D. Université de Montréal.

Liker, J. (2004). *The Toyota way: 14 management principles from the world's greatest manufacturer*. New York: McGraw-Hill.

Loría-Arcilla, J. and Vanegas, J. (2005). Issues affecting the flow of information during the design phase of affordable housing developments. In: *The 13th Annual Conference of the International Group for Lean Construction.* Sydney: IGLC, pp.161-169.

Martinez, E. (2016). *Exploring the use of the Lean Principles to Deliver Affordable Housing in Latin America*. Doctor of Philosophy in Engineering. University of California, Berkeley.

Mojtahedi, M. and Oo, B. (2012). Possibility of Applying Lean in Post-Disaster Reconstruction: An Evaluation Study. In: *The 20th Annual Conference of the International Group for Lean Construction*. San Diego: IGLC.

Winch, G. (2003). Models of manufacturing and the construction process: the genesis of re-engineering construction. *Building Research & Information*, 31(2), pp.107-118.

Womack, J., Jones, D. and Roos, D. (2007). *The Machine That Changed the World: The Story of Lean Production-- Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry*. New York: Free Press.

Yin, R. (2015). *Estudo de caso*. Porto Alegre: Bookman.

Zetter, R. (2012). Shelter and Settlement for Forcibly Displaced People. *International Encyclopedia of Housing and Home*, pp.330-335.

Timber Industry meets BIM and Lean – Increasing the efficiency in design and construction process in multi-storey timber buildings

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Purpose of research

Construction sector is the largest consumer of raw materials on the world and responsible for about 1/3 of the global waste annually in the European Union (EC, 2018). Besides, its activities account for circa 1/3 of energy-related carbon dioxide emissions (UN, 2017). There is an environmental need to reformulate construction avoiding carbon intensive materials and wasteful practices, while increasing the well-known low productivity of the sector. Timber is proposed as the most suitable material to build with, since its production is less carbon intensive, it is renewable and stores carbon for the long term (Green and Taggart, 2017). Besides, and trying to avoid wasteful practices, a leaner approach should be implemented, eliminating waste, minimizing material use, avoiding errors and increasing accuracy and efficiency.

Off-site construction is implicit to timber construction, and should be understood as a systematic work methodology where sub-pieces are combined forming an end-product with bare constrictions. Such an approach, where a project is subdivided into similar elements produced in a factory, brings several positive aspects such as higher productivity, speed of execution, fewer errors, higher quality and reliable cost and time plans (Smith, Griffin and Rice, 2015). However, it needs an accurate construction management to achieve an optimized supply chain of off-site construction and to a precise aligned scheduled on-site assembly.

Following this discourse, a Lean Management is proposed throughout the entire process, from design along production to execution, starting with a Lean Design based on an Integrated Planning (IP), continuing with a Lean Production in a factory within Just In Time (JIT) and Pull Planning and getting to Lean Construction Management through Last Planner® System (LPS) and Takt Time Planning (TTP). All in a smooth workflow digitally supported with a BIM-Model which implements resource and flow efficiency.

Few LC principles applied to timber constructions were highlighted within an international research project developed under the name “LeanWOOD” and coordinated by the Chair of Design and Timber Construction at Technical University of Munich (TUM, 2017). Nevertheless, its focus stood in the design phase and in collaborative ways to perform when designing timber buildings, but no performances on site, nor a holistic approach were investigated. The potential of technology, especially BIM, to support a lean approach in the design phase and in the construction management was also not included.

Research method:

With the purpose to explore the weaknesses and potential improvements in timber industry towards industrialization, extended literature review and expert surveys in form of interviews and workshops are proposed around two main topics: the constraints and possibilities of implementing timber or timber-based materials in multi-storey buildings and the potential benefits of applying Lean Construction in industrially manufactured building systems supported by BIM.

Holistic approach about how to efficiently behave when planning and constructing multi-storey buildings with timber or timber-based materials will be proposed and

a framework will be formulated where deviations and constraints are minimized.

Preliminary findings:

A round of workshops within three months were already conducted, where different stakeholders from the timber industry actively highlighted weaknesses, potential improvements and possible strategies to investigate aiming to implement the use of timber as main material for multi-storey buildings based on prefabrication. 41 participants in a brainstorming oriented round table discussed an amount of decisive factors regarding to increase efficiency and productivity.

Besides, a workshop about Lean based on off-site construction was also performed, consisting in three rounds simulations of a production line, where elements and prefab components were delivered from different sub-producers in a semi-structured timeline, being together assembled, further delivered to quality control management and finally to the client under a given TTP. Within cooperative meetings between the simulations, analyzing the results and proposing improvements, the production line was optimized in a way that errors were minimized, workers stress was reduced and all products were delivered on time, even though some deviations appeared.

Although the utilization of timber on multi-storey buildings, and the application of lean construction strategies supported by BIM have been barely implemented together in the sector, two case studies were detected whereas IP, LPS and TTP were implemented in high-rise timber buildings and are being analyzed within extended literature review.

For four month the interviews with experts started and are planned to be conducted for the following two months. An exchange review of all interviews will be performed and compared to the discussions within the workshops and the literature review in order to draw conclusions. Thereafter, a conceptual framework will be suggested and within a collaborative workshop, the experts taking part on the interviews and workshops can suggest improvements and validate the model.

Research Scope and Limitations

The main scope of the research is to develop an accurate digitally supported TTP to visually draw and level all on-site activities, optimizing its duration and identifying parallel processes. Since the activities would be linked to its element on a BIM-Model with an ID and subdivided into daily tasks, a permanent monitoring of on-site activities is eased by printing those in *Kanban* cards and being their bare code scanned after being accomplished.

In order to achieve the desired workflow above exposed, it is assumed that the proposed holistic framework should be based on an IP conformed of construction elements from a catalogue with high definition and the possibility of getting the CAM (Computer Aided Manufacturing) plans directly from the BIM model. Besides and based on LPS, each on-site activity should be defined, upfront planned and aligned enhancing transparency, identifying problems, requirements and preconditions, unlocking constraints and avoiding deviations, while uncovering optimization potentials.

As a conceptual framework, this approach is limited to theory and its implementation within a pilot project should be enhanced. Throughout its benefits, deficits and deviations could be measured and analyzed, and some application principles could be stated for further projects.

Implications:

Aiming to create more sustainable building environments regarding material selection, timber should be implemented as main material to build with in urban areas. Since planning and building with timber require specific expertise (Kaufmann, Krötsch and Winter 2017), architects and construction companies use to refuse to work with this CO_2 neutral material. In order to enforce its use, all deviations and constraints through the whole process need to be minimized, and achieve a semi-automated digital based framework of a smooth and fluent workflow from design to erection. Such an approach implies the active and thigh collaboration not only between timber experts, construction companies and workers, but also between lean and BIM experts with the common goal to enhance low-carbon intensive materials within the frame of just value-adding activities.

Expectations from the Summer School

IGLC-Summer School can bring to the researcher the opportunity to deeply understand how TTP and LP can be efficiently performed within a construction management, and how to effectively conduct or moderate their inherent collaborative meetings.

The purpose is to build the conceptual framework within a hypothetical project together with the experts taking part in the surveys, and throughout optimize the tasks, the resources and the flow, being thereafter validated from those experts.

REFERENCES

European Commission Environment Directorate-General (2018): *Construction and Demolition Waste (CDW) [Online]. Available at:* *h*ttp://ec.europa.eu/environment/waste/construction_demolition.htm (Accessed: 23 April 2019)

Green, M. and Taggart, T. (2017): *Hoch Bauen mit Holz, Technologie, Material, Anwendung*. Basel, Switzerland: Birkhäuser Verlag GmbH

Kaufmann, H., Krötsch, S. and Winter, S. (2017): *Atlas Mehrgeschossiger Holzbau. DETAIL Atlas.* München*: Detail*

Smith, R. E., Griffin, G. and Rice, T. (2015): *Off-site Studies, Solid Timber Construction, Process, Practice, Performance. [Online]. Available at: https://cdn.ymaws.com/www.nibs.org/resource/resmgr/OSCC/OffSite_Studies_STC.pdf* (Accessed: 23 April 2019)

TUM, Technische Universität München (2017): *LeanWOOD, innovative lean processes and cooperation models for planning, production and maintenance of urban timber buildings. [Online]. Available at: http://www.holz.ar.tum.de/fileadmin/w00bne/www/leanWood/leanWood_FinalReport.pdf* (Accessed: 23 April 2019)

UN, United Nations Environment and International Energy Agency (2017): *Towards a zero-emission, efficient, and resilient buildings and construction sector. Global Status Report 2017. [Online]. Available at:* https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf (Accessed: 23 April 2019)

BIM as the Key Interface for Situational Awareness in Construction Projects

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Purpose of research

Technology development is increasing the possibility to collect data automatically in the architecture, engineering and construction industry (AEC) through 3D laser scanning and photogrammetry, indoor positioning systems (IPS) and other applications of Internet of Things (IoT). These developments are increasing the volume and quality of data collected, but the different data streams have been used individually so far. This maintains the information silos which have been commonly identified in the construction industry (Dave et al. 2008).

Building Information Modelling (BIM) tools are increasingly used in the AEC industry to manage the design and construction phases of projects. Studies of the synergies between lean construction and BIM revealed that high quality information provided by information models can improve the flow of work on site (Sacks et al. 2010) and that building model-based interfaces for visual representations of the construction project status can be applied effectively (Sacks et al. 2010).

BIM is "a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, planning, construction, and later operation" (Eastman et al. 2011). Therefore, it has the potential to be the tool to cluster and integrate the information about the construction project generated from different data streams and become the interface to visualize this information.

Previous research on the integration of activities' status information and BIM for visual representation of the construction flow have been conducted with the test and implementation of the system called 'KANBIM' (Sacks et al. 2012) and with the creation and implementation of the commercial system VisiLean® (Dave 2013). Both systems were able to measure benefits of utilizing BIM as the interface to visualize activities' status.

However, both of the systems were developed counting on manual input of status information, focusing on the available technologies at the time. The technologies now available, such as sensors, 3D laser scanning and IoT applications, enable automated data collection. In addition, integrating these data with BIM, using the model as interface to visualization, can increase the information reliability and accessibility, resulting in work flow identification and increased situational awareness about the construction project.

A particularly interesting new technical tool from the perspective of lean construction are Indoor Positioning Systems (IPS). IPSs automate data collection on production resources and status using sensor technologies, and different types of sensors are being explored as Radio-frequency Identification (RFID) (Costin et al. 2012), Magnetic Field (Park et al. 2016), ZigBee (Lin et al. 2013), and BLE (Olivieri et al. 2017; Dror et al. 2018). These technologies can enable real-time tracking and positioning of labour, material and equipment, and the information can be used to evaluate and visualize the flows of construction projects, improving the decision-making process at the operational, tactical, and strategic levels (Vasenev et al. 2014).

Visualised real time data collected from IPS have potential to increase the situational awareness in construction projects and enable pro-active management regarding resources placement. The development and research of systems to enable such visualization is ongoing (Dror 2018).However, so far, they have been implemented independently of BIM.

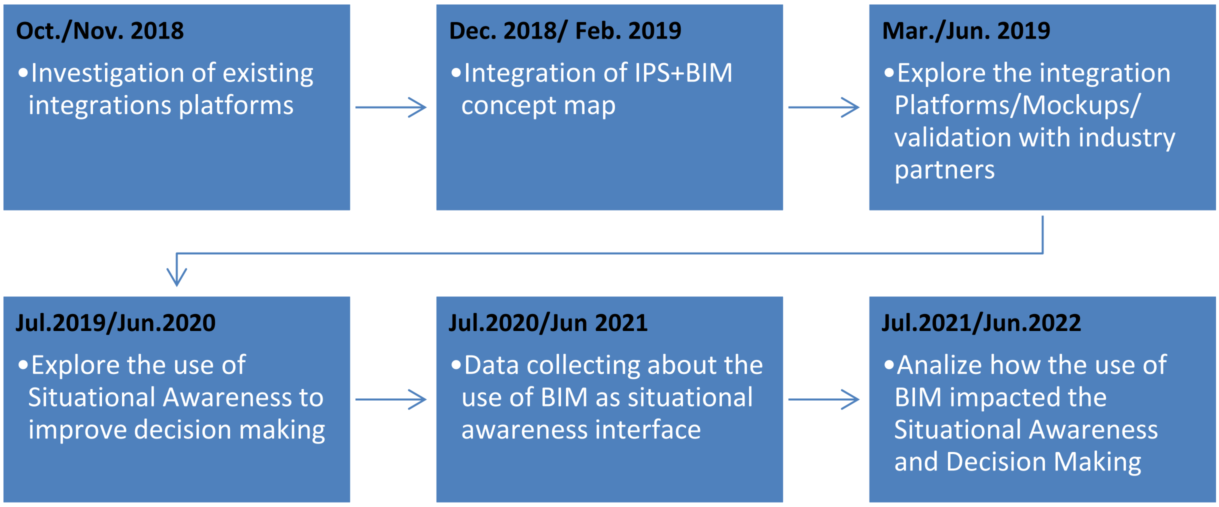
The research goal is to explore how BIM models can be used as the key interface for situational awareness in construction projects. With the development of technologies, like Internet of Things (IoT), indoor and outdoor positioning systems to track materials and workers, the data streams about the construction are able to collect an extensive amount of information. Having this information linked to BIM models can enable a better understanding of their meaning through 3D, resulting in a more accurate situation awareness and improving Lean Management in construction projects. Related to that goal the following research questions are presented:

1. How can indoor positioning and environmental sensor be linked to BIM models?
2. How can BIM with situational awareness data be used for visual management?
3. How can visualized situational awareness be used for decision making?
4. Which technology should be used to disseminate the information? What is the role of Virtual / Augmented / Mixed Reality in situational awareness?

To explore the usage of BIM models as the key interface for situational awareness in construction projects it is necessary to integrate the different information streams with the models. The research questions were elaborated with the intent of exploring how the information can be combined in one model, enabling a centralized data cluster and sharing. The research then continues with using the data to enable visual management. Visual management only works if the resulting information can be used to make better decisions. Decision making based on the model and how to disseminate the information optimally to achieve shared situational awareness using latest visualization technologies is the ultimate contribution of the research.

Research method

The research approach is mainly based on the constructive research method and is action-oriented, which aims at the development of an artifact to solve a real problem (Kasanen et al. 1993). A problem is investigated in context by observing and interviewing on project and company level both in Finland and internationally, solution concepts and use cases are innovated and validated in construction projects. Situation awareness data is collected from case projects, with industry partners, and integrated with BIM models.



Preliminary findings:

Not applicable.

Research Scope and Limitations

This research scope is to investigate the use of BIM as the key interface for situational awareness in construction projects. We hypothesize that the integration of different data streams about the construction project with BIM models can increase the situational awareness about the project and due to this provide information for the decision making, improving the processes. Also that possible identification of waste during the flow of resources can be facilitated.

Limitations regard technologies, knowledge about BIM models and 3D models navigation are expected.

Implications:

This research is expected to result on a process to integrate situational awareness data with BIM models, resulting in effective information sharing through available technologies (laptops, hand handle devices, Virtual/Augmented/Mixed Reality). The results will be tested during the research phase with field cases, and the reported feedback will be used to improve the data collection and storage and the information sharing among stakeholders.

The research contributes to visual management using BIM. The research results include how situational awareness can change construction management from reactive problem solving to data-driven, real time and proactive management.

It aims contributes to the area of Visual Management and Production Management in construction. The expected contributions to the area of Visual Management and Production Management include 1) investigate how Visual Management can improve construction projects situational awareness and 2) demonstrating how visual tools can be applied to visualize resources flow and tasks in progress.

Expectations from the Summer School

I would like to receive feedback regard the research methodology, the research limitations and how to minimize them. Also suggestions on how to conduct validation of models with interviews.

References

Costin, A, Pradhananga, N., and Teizer, J. (2012). Leveraging passive RFID technology for construction resource field mobility and status monitoring in a high-rise renovation project. Automation in Construction, 24, 1-15.

Dave, B. (2013). “Developing a Construction Management System Based on Lean Construction and Building Information Modelling” PhD Diss., Univ. of Salford.

Dave, B., Koskela, L., Kagioglou, M. and Bertelsen, S., (2008). A critical look at integrating people, process and information systems within the construction sector. In: Annual Conference of The International Group for Lean Construction, IGLC-16, Manchester,UK.

Dror, E. (2018). “Improving information flow in construction projects using real-time monitoring and information visualization”, MSc Thesis, Technion IIT.

Eastman, C. M., Teicholz, P., Sacks, R., and Liston, K., (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors, 2nd Ed. Hoboken, NJ: John Wiley & Sons, Inc.

Kasanen, E., Lukka, K., & Siitonen, A. (1993). The constructive approach in management accounting research. Journal of Management Accounting Research, 5, 242-264.

Lin, P., Li, Q., Fan, Q., and Gao X. (2013). “Real-time monitoring system for workers' behavior analysis on a large-dam construction site”. International Journal of Distributed Sensor Networks, 9(10), 509423.

Olivieri, H., Seppänen, O. and Peltokorpi, A. (2017). ”Real-Time Tracking of Production Control: Requirements and Solutions” In: 25th Annual Conference of the International Group for Lean Construction. Heraklion, Greece, 9-12 Jul 2017. pp 671-678.

Park, J., Marks, E., Cho, Y. K., and Suryanto W. (2016). “Performance test of wireless technologies for personnel and equipment proximity sensing in work zones”. Journal of Construction Engineering 654 and Management, 142(1), 04015049.

Sacks, R., Barak, R., Belaciano, B., Gurevich, U. and Pikas, E.(2012) " KanBIM Workflow Management System: Prototype implementation and field testing". Lean Construction Journal 2013 pp 19-35

Sacks, R., Koskela, L., Dave, B. A. and Owen, R., (2010). Interaction of lean and building information modeling in construction. Journal of Construction. Engineering and Management, 136(9), pp.968-980.

Vasenev, A., Hartmann, T., and Doree, A. G. (2014). A distributed data collection and management 665 framework for tracking construction operations. Advanced Engineering Informatics, 28(2), 127-137.

Effectiveness of Collaborative Project Delivery Methods Utilizing Predictive Game Theory

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The purpose of proposed research is to assess the effectiveness of collaborative project delivery methods compared to traditional construction contracting methods utilizing predictive game theory, focusing on effort and associated behaviours. This research is important to the building industry because collaborative project delivery (CPD) methods, including Integrated Project Delivery (IPD), Lean Construction, Construction Manager at Risk, and Design-Build methods, are becoming common delivery methods. To date, research findings have been mixed with some research indicating positive impacts of CPD methods compared to traditional delivery methods in terms of project schedule and cost control (Asmar, Hanna, & Loh, 2013, 2016; Kahvandi, Saghatforoush, Alinezhad, & Noghli, 2017; Kulkarni, Rybkowski, & Smith, 2012) and other research indicating less successful outcomes in terms of total cost savings compared to less collaborative methods (Bilbo, Bigelow, Escamilla, & Lockwood, 2015; Kahvandi et al., 2017; Rojas & Kell, 2008).

Game theory provides an opportunity to evaluate common contracting methods in conjunction with risks, behaviours (Baiden & Price, 2011) and contractor strategies to gain an understanding of the value of CPD. Past research has primarily used game theory to evaluate contracts in the context of risk, decision management, and resource allocation for fields such as logistics, transportation, labour negotiation, international affairs, and engineering to name a few. This research will provide an analytical framework to assist building owners, designers, and contractors in choice and/or acceptance of procurement/contracting terms based on a firm's acceptance of perceived risks versus effort involved. To accomplish this objective, the research will address the following questions:

Research questions:

1. To what extent does one construction contracting method provide more value and a higher likelihood of success?
2. How can level of effort be assessed in construction projects relative to project outcome?

This research builds upon a well-established body of literature documenting the utilization of game theory in engineering and construction disciplines. Such research is summarized in the following section.

Research method:

The research is proposed in three phases, with each phase intended to culminate in a conference or journal submission. Phase details are as follows:

Phase I: Application of Game Theory Models to Construction Contracting and Delivery Process

This phase will establish the applicability of select game theory concepts to construction contracting and delivery processes. This will be accomplished by modeling construction contract relationships relative to delivery method via the Principal-Agent method, and in conjunction with associated 2x2 matrix games of the Prisoners-Dilemma and Stag-Hunt. The model will account for variability in cost, schedule, and quality, and work to define "effort" in the context of the design and construction industry.

Research Tasks:

1) Review game theory literature
2) Identify 2x2 matrix and theory of agency models that align with adversarial and collaborative contracting methods
3) Iterate and adapt chosen model(s) to structurally align to adversarial/collaborative contracting methods
4) Validate structure of model based on project specific data

The intended outcome of this phase of research is a journal paper documenting the game model as developed and validating its applicability to construction contract methods.

Phase 2: Utilize Model to Analyze Construction Effort

Use the game model developed in Phase I and game theory simulation to further explore the relationships between risk tolerance and bonus structure (for cost, schedule, and quality) in comparison to effort (as the dependent variable). Modeling techniques may include use of a Monte Carlo simulation (Madani & Lund, 2011) and/or by utilizing a reinforcement learning algorithm (Fang, Kimbrough, Valluri, Zhiqiang, & Pace, 2002), and/or the use of software specific to economic experiments, such as z-Tree (Javed, Lam, & Chan, 2017)to predict outcomes based on the mix of variables.

Research Tasks:

1) Develop working simulation engine(s) for the game model as developed in Phase 1
2) Iteratively calibrate and validate the model's simulations using available real-world project data
3) Use the game model and simulation system to perform robust sensitivity analyses for various contracting variables

The intended outcome of this phase of research is a journal paper describing the use of game model to test the sensitivity of project outcome to construction contract inputs.

Phase 3: Analysis of Effects from behaviors of Principal and Agents on effort

Based on an expanded literature review as well as research findings generated during Phase 1 and 2, analyze effects of behaviors on effort (Fulford &

Standing, 2014; Pinto, Slevin, & English, 2009; Podsakoff, Mackenzie, Paine, & Bachrach, 2000). This phase of research will define attributes of effort and associated behaviors aggregating literature, sensitivity analysis results, and empirical case study results. After generating such a definition, the research will explore how to (i) drive high effort from both agents to meet project success criteria (the incentive, or bonus) in a CPD project and (ii) identify which delivery methods drive behaviors which lead to high or low effort from either agent when using CPDs. Research will collect empirical and qualitative data and compare these findings to simulated results.

Research Tasks:

1) Generate new and precise definition of effort which incorporates associated behaviors in construction
2) Use game model simulation system to test and explore "effort" as newly defined
3) Create guidance as to how to promote high effort situations with successful outcomes using CPD
4) Test guidance through case study implementation or lessons learned
5) Demonstrate generality and applicability of guidance developed across construction projects, contracting methods and principal-agents.

The intended outcome of this phase of research is a journal paper which defines effort in the context of construction projects and their outcomes, and explores the drivers of success using real-world case studies.

Preliminary findings:

Limited findings at time of this application, but will give updates on Phase I and Phase II findings during Summer School.

Research Scope and Limitations

Research results will be limited based on the following:

i. Small sample size of CPD projects and participants, may not be generalizable to every CPD-type project.
ii. As understanding of collaboration project delivery advances and sophistication of participants increases, findings may have limited applicability.

Implications:

The contribution of the research will be to use game theory to establish to what extent:

(i) CPD is an effective delivery model when used with appropriate
(ii) team members that elicit effective behaviors that can maximize effort. Currently a gap in the literature exists around these issues regarding construction. Furthermore, such information would be of critical

importance to industry. Findings will be used to inform the team onboarding process in building delivery to best address the transactional nature of the process. The resulting effort incentive structure and behavioral influences could be used to analyze and inform the public contracting processes, and will incorporate additional project metrics than cost and schedule alone. This research will ultimately assist the decision-making process of the construction and design community by utilizing economic gaming theory to evaluate associated contracting methods and their needed behaviors in order to optimize collaboration during design and construction.

8. Expectations from the Summer School

It would be helpful to get feedback on the following:

i) Phased deliverables
ii) Research methodologies
iii) Industry implications and application

Reference

Asmar, M. El, Hanna, A. S., & Loh, W.-Y. (2013). Quantifying Performance for the Integrated Project Delivery System as Compared to Established Delivery Systems. *Journal of Construction Engineering and Management*, *139*(11). https://doi.org/10.1061/(ASCE)

Asmar, M. El, Hanna, A. S., & Loh, W.-Y. (2016). Evaluating Integrated Project Delivery Using the Project Quarterback Rating. *Ournal of Construction Engineering and Management*, *142*(1). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001015

Baiden, B. K., & Price, A. D. F. (2011). The effect of integration on project delivery team effectiveness. *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2010.01.016

Bilbo, D., Bigelow, B., Escamilla, E., & Lockwood, C. (2015). Comparison of Construction Manager at Risk and Integrated Project Delivery Performance on Healthcare Projects: A Comparative Case Study. *International Journal of Construction Education and Research*, *11*(1), 40–53. https://doi.org/10.1080/15578771.2013.872734

Fang, C., Kimbrough, S. O., Valluri, A., Zhiqiang, A., & Pace, S. (2002). On Adaptive Emergence of Trust Behavior in the Game of Stag Hunt. *Group Decision and Negotiation*, *11*, 449–467. Retrieved from https://link-springer-com.aurarialibrary.idm.oclc.org/content/pdf/10.1023%2FA%3A1020639132471.pdf

Fulford, R., & Standing, C. (2014). Construction industry productivity and the potential for collaborative practice. *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2013.05.007

Javed, A. A., Lam, P. T., & Chan, A. P. (2017). Construction Management and Economics Change negotiation in public-private partnership projects through output specifications: an experimental approach based on game theory Change negotiation in public-private partnership projects through output specifica. https://doi.org/10.1080/01446193.2014.895846

Kahvandi, Z., Saghatforoush, E., Alinezhad, M., & Noghli, F. (2017). Integrated Project Delivery (IPD) Research Trends. *Journal of Engineering, Project, and Production Management*, *7*(2), 99–114. Retrieved from http://www.ppml.url.tw/EPPM_Journal/volumns/07_02_July_2017/05_ID_163_7_2_99_114.pdf

Kulkarni, A., Rybkowski, Z. K., & Smith, J. (2012). Cost Comparison of Collaborative and IPD-Like Project Delivery Methods Versus Competetive Non-collaborative Project Delivery Methods. In *20th Annual Conference of the International Group for Lean Construction*. Retrieved from http://iglc.net/Papers/Details/797/pdf%0Ahttp://iglc.net/Papers/Details/797

Madani, K., & Lund, J. R. (2011). A Monte-Carlo game theoretic approach for Multi-Criteria Decision Making under uncertainty. *Advances in Water Resources*. https://doi.org/10.1016/j.advwatres.2011.02.009

Pinto, J. K., Slevin, D. P., & English, B. (2009). Trust in projects: An empirical assessment of owner/contractor relationships. *International Journal of Project Management*, *27*, 638–648. https://doi.org/10.1016/j.ijproman.2008.09.010

Podsakoff, P. M., Mackenzie, S. B., Paine, J. B., & Bachrach, D. G. (2000). Organizational Citizenship Behaviors: A Critical Review of the Theoretical and Empirical Literature and Suggestions for Future Research. *Journal of Management*, *26*(3), 513–563. Retrieved from http://journals.sagepub.com.aurarialibrary.idm.oclc.org/doi/pdf/10.1177/014920630002600307

Rojas, E. M., & Kell, I. (2008). Comparative Analysis of Project Delivery Systems Cost Performance in Pacific Northwest Public Schools. *Journal of Construction Engineering and Management*, *134*(6). https://doi.org/10.1061/(ASCE)0733-9364(2008)134:6(387)

The Last Planner System in Design Management for Lead Consultant Companies

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Purpose of research

The Last Planner System (LPS) was created by Glenn Ballard and Gregg Howell (Ballard, 1994; Ballard, 2000; Ballard and Howell, 1998) to improve the predictability and reliability of construction production (Mossman, 2013), which improves the chances of delivering projects on time (Ballard, 2000). It was developed by construction people for construction people (Mossman, 2013).

With adaptations, the LPS works in design too (Mossman, 2013). There are cases where the LPS has been implemented to construction design management (Milles, 1998; Tzortzopoulos et al., 2001; Codinhoto and Formoso, 2005; Hamzeh, Ballard and Tommelein, 2009).

However, the reported applications of the LPS during the design stage of building projects (e.g., by Hamzeh, Ballard and Tommelein, 2009; Bhatla and Leite, 2012; Wesz et al., 2013) have been somewhat general in nature and limited in scope (Khan and Tzortzopoulos, 2015). Therefore, this research aims to find a holistic approach for the LPS implementation in a design phase.

The research question is:

Can the LPS be a holistic tool to manage and coordinate the interfaces between the external design trades and the internal departments in a design process in AEC industry especially for integrating different design disciplines and different project stages?

The aim of the research is:

To determine the conditions under which the LPS can successfully be implemented in a Lead consultant company.

The legal contractual framework in German AEC industry is complemented by federal contracting rules, such as the Standard Rules of Contracting and Execution of Construction Works (Vergabe und Vertragsordnung für Bauleistungen – VOB) which are compulsory for the procurement of public works but are also frequently used in private construction projects (Country profile: Germany, 2017). It means that most of the contracts are design-bid-build. Inefficiencies during construction result from lack of interaction between contractors and designers (Tommelein and Ballard, 1997). Design-bid-build approach does not account for specialty-contractor involvement in design (Gil et al., 2001). The interface problems between designers and contractors therefore may arise due to this type of contracting. However, the Lead consultant companies, e.g. the Lead designer companies which also have departments which are responsible for production design (logistics, pharma, biotech, catering, healthcare planning, factory design, IT) are able to overcome this shortcoming, because they manage the whole development of a construction project from the beginning (as a designer during the design phase) to the end (as a supervisor during the execution phase). However, the holistic approach of using the LPS in a design phase, where different stakeholders, such as architects, structural engineers, MEP engineers, other engineers and consultants (including production planners) are involved, is missing. This research is conducted to fill this gap.

The objectives of this research are:

- to identify the current status in a design process in a design-bid-build environment;

- to find out, whether the LPS brings the designers the same benefits as it brings contractors;

- to identify what steps should be done to implement the LPS in the design phase with regards to a design-bid-build approach;

- to identify the key success factors and the challenges of LPS implementation;

- to create a route map for the LPS implementation for a Lead consultant company.

Possible directions for the PhD have been outlined but no choices are yet made:

1) Capability of LPS to

- develop common ground, awareness, situational understanding

- improve collaboration of people who normally do not collaborate, including client representatives

2) Involvement of clients in the LPS process

3) Bringing agility into LPS in design (combination of weekly work planning and look-ahead planning with scrum)

4) LPS implementation in design-bid-build environment:

- How to get the constructability knowledge into design in DBB environment (contracting the contractor's specialist during the design; combining the functions of lead design and construction management in one hands)

- To justify, why construction input is needed (reducing the problems on site, change requests)

5) Effective use of BIM in LPS projects (using LODs as milestones etc.)

Research method

Research methods are plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation (Creswell, 2013). Certain types of social research problems call for specific methods (ibid.).

Hamzeh, Ballard and Tommelein (2009) used the action research for the implementation process of the LPS in a design project. Khan and Tzortzopoulos (2016) proposed this method too. Hamzeh, Ballard and Tommelein (2009) underlined the reasons for the action research to be adopted in a design environment:

- it is an appropriate strategy for answering questions pertaining to 'how' and 'why' when no control for behavioral events is required and when research focuses on contemporary affairs;
- it uses both quantitative and qualitative methods to explain phenomena;
- it uses real-life evidence and observational richness to describe relationships;
- it utilizes multiple sources of evidence in a natural setting that encompasses temporal and contextual facets of the variables monitored;
- it uncovers the dynamics of events explaining the phenomenon under study;
- it can employ rigorous evidence collection, description, observation and triangulation;
- it provides qualitative understanding when arriving at conclusions and analyzing results (Meredith, 1998; Stuart et al., 2002; Yin, 2003).

During the action research process, a researcher is able to gather empirical data, analyze and evaluate the data with the team, search for useful patterns or variations, develop various improvement alternatives, and test these improvements empirically (Hamzeh, Ballard and Tommelein, 2009).

The author, as a member of a project management team, has already started to implement some parts of the LPS, e.g. phase planning and weekly work planning, to coordinate the external and internal design trades in a basic design phase of a pharmaceutical project. In another production project a client asked a Lead consultant company, the author is working in, to implement the LPS in a design phase from the very beginning of a project. It will give an opportunity for the author to start gathering data and implementing plan-do-check-act action research circle right after the beginning of his research. Moreover, the author has got an allowance from the company to use all the available data and to take part in designer meetings of the project he is not involved in, to gather the data about existing procedures during the designer meetings and coordination actions from the project management side.

Implications:

The implementation of LPS in multy-party procurement environment (design and build; engineering to order; integrated project delivery; engineering, procurement and construction) has been widely reported by numerous researchers. However, little attention has been paid to the LPS implementation in design-bid-build environment. The experience of implementation of LPS in design-bid-build environment should help the practitioners to promote the Last Planner System further to the industry even if there are contractual boundaries.

Expectations from the Summer School

To get a feedback on the novelty of topic, to get an opportunity to present the ongoing work, to get advices about the research methods, to fill the gaps in the knowledge regarding design management in construction, to find new contacts with the state-of-the-art researchers in the field of implementing LPS.

REFERENCES

BALLARD, G. (1994). The last planner. Northern California Construction Institute, Monterey.

BALLARD, G. (2000). The last planner system of production control. PhD. The University of Birmingham.

BALLARD, G. and HOWELL, G. (1998). Shielding production: essential step in production control. Journal of Construction Engineering and management, 124(1), pp. 11-17.

BHATLA, A. and LEITE, F. (2012). Integration Framework of BIM with the Last Planner System. In: Proc. 20th Ann. Conf. of the Int'l. Group for Lean Construction, San Diego, California, USA, July 17-22.

CODINHOTO, R. and FORMOSO, C. T. (2005). Contributions for the integration of design and production management in construction. In: International Conference on Design Management in the Architectural and Engineering Office (pp. 321-330). University of Bath.

CRESWELL, J. (2013). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. 4th ed. Thousand Oaks: Sage publications.

EUROPEAN CONSTRUCTION SECTOR OBSERVATORY. COUNTRY PROFILE: GERMANY (2017).

GIL, N., TOMMELEIN, I. D., KIRKENDALL, R. L. and Ballard, G. (2001). Leveraging specialty-contractor knowledge in design-build organizations. Engineering Construction and Architectural Management, 8(5-6), 355-367.

HAMZEH, F. R., BALLARD, G. and TOMMELEIN, I. D. (2009). Is the Last Planner System applicable to design? – A case study. In: Proceedings of the 17th Annual Conference of the International Group for Lean Construction, IGLC (Vol. 17, pp. 13-19).

KHAN, S. and TZORTZOPOULOS, P. (2015). Improving design workflow with the Last Planner System: two action research studies. In: 23rd Annual Conference of the International Group for Lean Construction, 29-31 July 2015, Perth, Australia

KHAN, S. and TZORTZOPOULOS, P. (2016). A framework for evaluating an action research study on lean design management. In: Proc. 24th Ann. Conf. of the International. Group for Lean Construction. Boston, USA, July 20-22. pp. 113-122

MEREDITH, J. (1998). Building Operations Management Theory through Case and Field Research. Journal of Operations Management, 16, pp. 441-454.

MILES, R.S. (1998) Alliance lean design: construct on a small high tech project. IGLC conference 6th., Guaruja, Brazil

MOSSMAN, A. (2013). Last Planner®: 5 + 1 crucial & collaborative conversations for predictable design & construction delivery.

STUART, I., MCCUTCHEON, D., HANDFIELD, R., MCLACHLIN, R., SAMSON, D. (2002) Effective Case Research in Operations Management: A Process Perspective. Journal of Operations Management, 20, pp. 419-433.

TOMMELEIN, I.D. and BALLARD, G. (1997). Coordinating specialists (Vol. 8). Technical Report No. 97.

TZORTZOPOULOS, P., FORMOSO, C.T. and BETTS, M. (2001). Planning the Product Development Process in Construction: an Exploratory Case Study. In: Proc. 9th Annual Conference of the International Group for Lean Construction (IGLC-9), Singapore, Singapore

YIN, R.K. (2003). Case Study Research- Design and Methods. Third edition, Sage Publications, Thousand Oaks, CA, 181 pp.

WESZ, J., FORMOSO, C. and TZORTZOPOULOS, P. (2013). Design Process Planning and Control: Last Planner System Adaptation. In: Proc. 21st Ann. Conf. of the International. Group for Lean Construction, Fortaleza, Brazil, July 31- August 2.

Conception of a predictive planning model for frame schedules of construction projects

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Purpose of research

Frame schedules are important, as they are the basis for the following project success. A successful project planning depends on numerous influences and their characteristics (Magnussen et al., 2006; Walker, 1995; Flyvbjerg et al., 2002; Potts et al., 2005). The planning of project milestones often takes place months or years before the actual realization of the respective project phase and must therefore consider many uncertainties. The consideration of all these uncertainties at project start often leads to unreliable schedules (Magnussen et al., 2006; Potts et al., 2005). Incorrect schedule planning can influence costs, quality and work safety, especially when deadlines are exceeded. As a result, customers are dissatisfied with the lack of target achievement.

In spite of the low information density at the beginning of a project and the high complexity in an early planning phase, the goal for clients and their contractors is to make as valid statements as possible about milestones and potential process contents. For this reason, there are already numerous studies with the aim of pre-scription. Often used research methods are surveys with the Relative Importance Index (RII) and multivariate regression models. One of the first models for estimating construction times was developed in 1960 by the Australian researcher Bromilow (Kaka 1991). This model uses as a data basis the costs paid by the client, a country-specifically project performance, and a factor indicating the dependence of time on costs. Based on Bromilow's model, further multi-factor models were developed (Chan et al. 1995, Hoffmann et al. 2007, Ifran et al. 2011). Time estimation models with the cost factor as a basis are the most widespread.

However, many case studies show by their miscalculations that costs have only a small share in the forecast accuracy of time (Magnussen et al. 2006, Potts 2005, Walker 1995, Flyvberg et al. 2002). In order to include the large number of influencing factors, soft computing methods are required. Soft computing (frequently used synonym "computational intelligence") refers to models that attempt to solve problems that are difficult to calculate approximately. The models covered here can "learn" to a certain extent and consider a variety of influencing factors. “Fuzzy systems", "data mining", "artificial neural networks", "evolutionary algorithms" and "genetic algorithms" are some of the areas of soft computing.

The aim of the work is to design a predictive model with soft computing methods for the creation of valid frame schedules.

4. Research method:

In the context of the objective three essential research questions arise with different research methods.

1.) How are frame schedules for construction projects in Germany currently drawn up? (Question type: Description)

Secondary study - Literature study (WP1): For the first research question a literature search on the definition and objective of frame schedules will be done.

Primary Study - Expert Interview (WP2): To get further on practical knowledge in creating frame schedules, expert interviews with the regional restriction to Germany are conducted on the procedure for frame scheduling.

From the secondary and primary study generalizable statements are derived. Based on this, the limits of the existing procedures and models can be shown.

2.) How can the frame dates be forecasted? (Question type: Design)

Secondary study - Literature study (WP3): In a literature search, systematics and their characteristics are summarized in a holistic view of different project phases. Methods for comparing processes and their required durations are detected and examined for their applicability in construction projects. Within the frame of a multivariate preliminary study, possible influencing factors on the construction time are clustered. Finally, the relevant impact factors are assigned to the phases of a project.

Own development (WP4) – model formulation: On the basis of the identified analytical methods, a model will be created that enables the predictive ability of frame schedules. This also includes the conception of a possible process database as a basis for the model to be created. Algorithms support the extraction of project-relevant information. This model is created on a project database of already completed construction projects in order to expand and balance the low information density in early planning phases. Statistical statements on the frame dates support decisions and cross-phase statements. The model can be used universally and is independent of the type of customer.

3.) <u>How can the prediction accuracy of frame dates of a construction project in an early planning phase be improved and optimized with the developed model</u>? (Question type: Forecast)

<u>Secondary study – model validation (WP5):</u> In an empirical investigation of case studies in construction projects, the prognostic ability is examined on the basis of the created model. Here, the prognosis of the time schedule is examined on the basis of the identified influencing and result factors along the project phases (research question one). Furthermore, levers for additional optimization potentials can be uncovered. Quantitative and qualitative effects by applying the created model are queried and summarized.

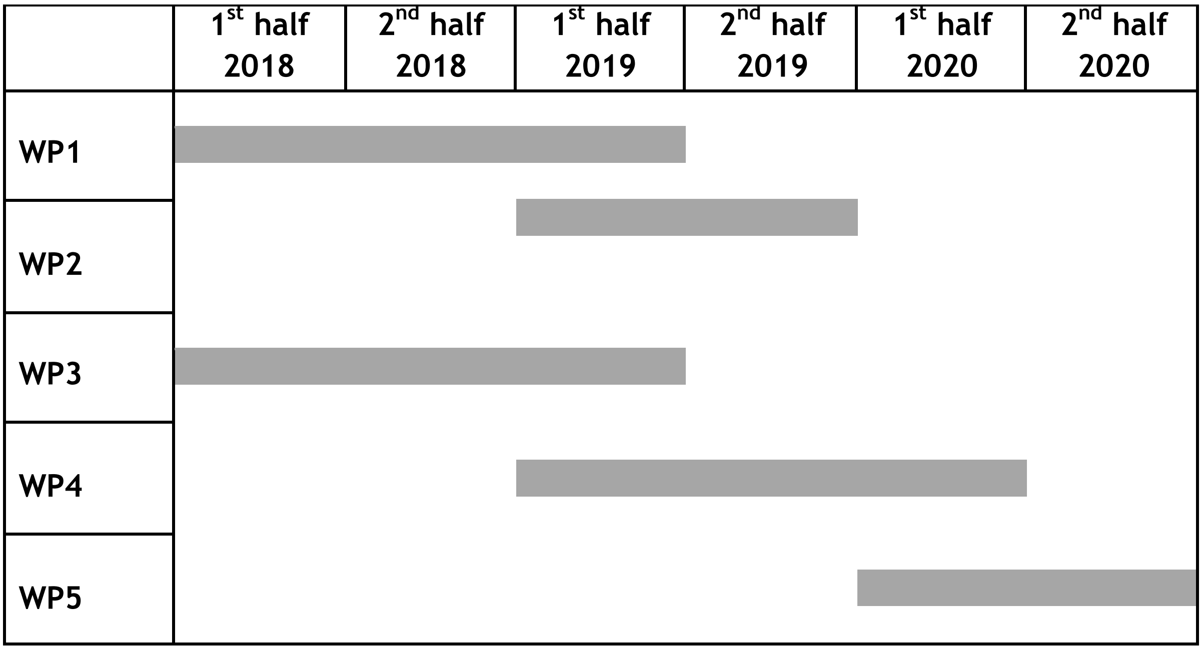

Figure 1: Time table for the identified work packages (WP) of the phd

Preliminary findings:

Result 1: In an international study, the diversity of influencing factors on construction projects was recorded and categorized. Based on the 4P model of the Toyota production system (Liker, 2004) seven layers can be identified to create a taxonomy for construction time influencing factors. These are (1) the prioritization of different customer groups; (2) pricing factors; (3) the place of the construction influenced by national laws and market economy; (4) product features like project type, gross floor area (GFA), number of storeys, complexity or compactness; (5) the involved persons behavior and skills; (6) the project-individual implemented processes (e.g. number of feedback loops, information flow, communication, available resources) and (7) the problem solving (speed of decisions, rework, conflict prevention).

Result 2: A conducted empirical study in around 50 German companies shows a general lack of knowledge management practices. Further on, analyzing the existing project information shows a lack of data and low-quality data. Due to the high complexity of construction projects the naming of information and the degree of detail is project-individual. The existing data structures leads in general, to challenges in data-based predictions.

Result 3: A database of around 2.700 projects from an international client were analyzed with stochastic methods in order to get a first data understanding. With ANOVA and t-test documented factors were analyzed regarding their influence on each phase from project definition, over planning and realization to handover (part of sensitivity analysis). The results in figure 2 show when individual influencing factors have no influence on the project time.

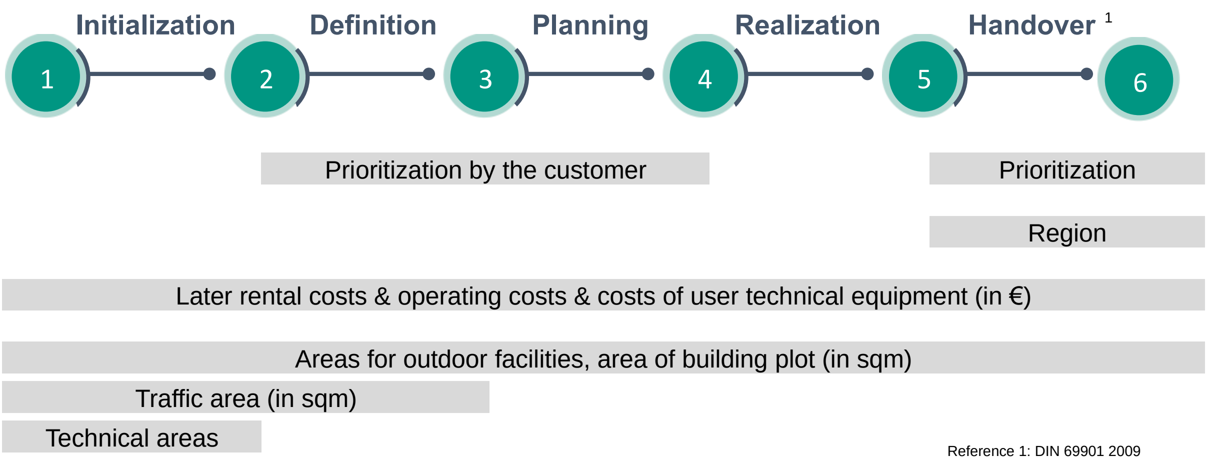

Figure 2: Results of ANOVA and t-tests

Result 4: Sensitivity analysis

If a data set has many columns, a good way to quickly check correlations among columns is by visualizing the correlation matrix as a heatmap.

The correlation coefficient is bound between -1 and 1 and shows the linear relationship between these two variables. A coefficient close to 1 means a strong and positive association between the two variables; A coefficient close to -1 means strong negative association between the two variables; A coefficient close to 0 means no linear relation between the two variables. If the coefficient is close to 0, it means that there is nor linear relationship, but there might be another type of functional relationship (for example, quadratic or exponential). As the heatmap in figure 3 for the realization phase shows, the most of features have a weak linear relationship with the target variable time. This confirms that a multitude of influencing factors must be considered for successful modelling and that methods of machine learning can be seen as a potential solution.

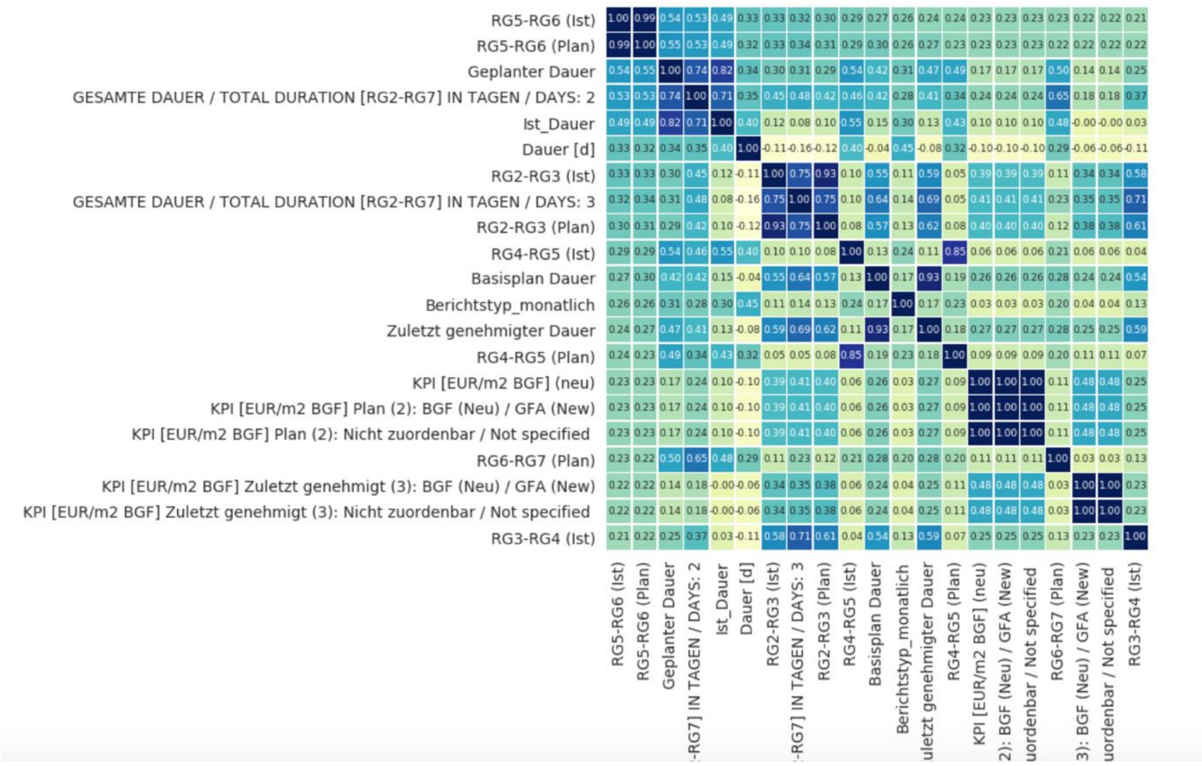

Figure 3: Heatmap for the realization phase

Based on these possible influencing factors in a next step with machine learning (ML) methods like random forest, support vector machines (SVM) or gradient boost trees the predictability for each phase will be analyzed.

Research Scope and Limitations

The developed model is a first draft creating a learning structure for frame schedule planning. Depending on the number of project and their documented features, the predictability of the outcomes will increase.

Implications

The aim is to support a comparability of construction projects and thus setting up scenarios to point out relevant decision points for the client and his contractors. In future research, Internet of Things (IoT) applications need to be added to get a more valid high-quality database. Further on, detailing the project information on product component level and pattern detection in building plans will support the quality of predictability.

By applying data-based analytics, the planning fallacy (Kahneman & Tversky 1979) will be reduced. Therefore the research is relevant for the clients in getting valid frame schedules. Also planning engineers, construction companies and consultancies are getting a transparent database to analyze influences of their decisions.

Expectations from the Summer School

- Related research areas / studies for scenario planning, machine learning and deep learning methods for time prediction
- Measures for low-data quality challenges
- General feedback for the relevance and planned methods

9. References

Chan, D.W.M.; Kumaraswamy, M.M. (1995): A study offactors affecting construction durations in Hong Kong, Construction Management and Economics 13, S. 319–333.

Flyvbjerg, B.; Holm, M.S.; Buhl, S. (2002): Underestimating cost in public works projects:error or lie?, Journal of the American Planning Association 68(3) S. 279–295.

Hoffman, G.J; Thal, A.E.; Webb, T.S.; Weir, J.D. (2007): Estimating performance time for construction projects, Journal of Management in Engineering, ASCE23(4), S. 193–199.

Ifran, M.; Khursid, M.B.; Anastasopoulos, P. ;Labi, S.; Moavenzadeh, F. (2011): Planning-stage estimation of highway project duration on the basis of anticipated project cost, project type, and contract type, International Journal of Project Management 29(1), S. 78-92.

Kahnemann & Tversky (1979): Intuitive Prediction: Biases and corrective procedures, Defense Advanced Research Projekts Agency Contract, Technolcal Report Ptr 1042-77-6

Kaka, A. (1991): Price, Relationship between value and duration of construction projects, Construction Management and Economics 9 pp. 383–400.

Magnussen, O.M.; Olsson, N.O.E. (2006): Comparative analysis of cost estimates of major public investmentprojects, International Journal ofProjectManagement24, S. 281–288.

Potts, K. (2005): The New Scottish Parliament Building—a critical examination of the lessons to be learned, in: Proceedings of the Third International Conference on Construction in the 21st Century (CITC-III)Advancing Engineering, Management and Technology,Athens,15–17 September, S. 534–539.

Walker, D.H.T. (1995): An investigation into construction time performance, ConstructionManagementandEconomics13, S. 263–274.

PROPOSAL OF A MODEL TO SUPPORT VALUE GENERATION IN MASS CUSTOMIZED HOUSING PROJECTS

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Purpose of research

The understanding of customers' desires, needs and preferences in housing is complex due to a diversity of requirements. In order to respond to this diversity, housing companies should be able to offer a higher product variety while achieving cost effectiveness. The application of Mass Customization (MC) has been suggested as an alternative for balance fulfilling clients' specific needs and maintaining controlled costs in housing (Formoso et al., 2011; Hentschke, 2014; Noguchi & Hernández-Velasco, 2005; Rocha, 2011; Schoenwitz et al., 2012; Shin et al., 2008; Tillmann & Formoso, 2008). MC is an strategy for companies with the main goal of offering products that fulfill customers' specific requirements, potentially adding value, through flexible processes, with costs and delivery time similar to mass production (Hart, 1995; Jiao, Ma, & Tseng, 2003; Pine, 1993; Fogliatto et al., 2012). Within the housing context, a major challenges for its application is capturing customers' requirements (Barlow; Ozaki, 2003; Formoso, 2015; Martinez; Tommelein; Alvear, 2017) and keeping a balance between variety and housing affordability (Martinez, Tommelein and Alvear, 2017).

According to Piller et al. (2004), MC is only applicable through practices that enable customer integration, which can potential reduce transactional cost, achieve cost savings, and improve cost-effectiveness along the value chain. Therefore, there are many opportunities for improving value generation by understanding customers' willingness to pay. Therefore, understand and consider customers' requirements in the product development process of customized products is essential for the success of MC strategy (Ferguson et al., 2014; Fettermann, 2013; Hart, 1995; Ogawa & Piller, 2006; Piller et al., 2004) as well as in housing (Barlow & Ozaki, 2003; Formoso et al., 2011; Hentschke et al., 2014).

Customer integration is often achieved during the configuration and design phases, but its extent depends on the level of customization offered, varying from a simple configuration of predefined options, to effective co-design (Piller, Moeslein and Stotko, 2004). Initially, customer integration depends on companies´ abilities to identify market segments and explore customers' demands to translate these trends into requirements and product specifications that support the development of customized goods (Fogliatto et al., 2012; Piller et al., 2004). This information about customers' demand, confronted to customization costs and customers' willingness to pay, can be used for the definition of the solution space (Piller, Moeslein and Stotko, 2004; Salvador, Holan and Piller, 2009). The solution space is a set of customization units[1] and rules for combining them to be offered to customers, which is crucial to define product variants (Rocha, 2011; Salvador et al., 2009).

Much about defining MC strategy remains unexplored Fogliatto et al., 2012; Rocha, 2011), including the identification of consumers´ preferences and its impacts in the production process (Schoenwitz et al., 2017). Thus, the aim of this research work is to **propose a model for customer integration in the development of mass customized housing projects by construction companies**. The potential impact of this model is to keep the additional costs of product variety under acceptable limits, improve value generation for house-building companies.

Although several authors recognize the relevance of the characterization of the demand for customization and inclusion of customers' requirement in customized products, few studies have been developed with that goal (Fogliatto et al., 2012; Hentschke et al., 2014). Some authors have indicated conjoint analysis technique because of its potential to identifying customers' preferences and supporting the development of MC strategies (Ferguson et al., 2014; Fogliatto and da Silveira, 2008; Schoenwitz et al., 2017). In this sense, an specific aim of this research is **to propose a method for identifying customers' demands, anticipating their preferences and defining a solution space for mass customized housing projects**.

Research method

The methodological approach adopted in this research is Design Science Research (DSR), which aims to build an innovative solution for a real world problem and, at the same time, make a scientific contribution (Kasanen et al, 1993; Lukka, 2003). This approach was used to address the practical problem of how construction companies can integrate the customer in the development of mass customized housing projects and mitigate the effects of offering product variety, improve cost-effectiveness and value generation. The alignment of the DSR outputs with the aims of the research and stages is illustrated in Table 1.

Table 1: alignment of DSR outcomes with research aims and stages

1. DSR OUTPUTS	2. RESEARCH OBJECTIVES	3. RESEARCH STAGE
4. METHOD 5.	6. Propose a method for identifying customers' demands, anticipating their preferences and defining a solution space for mass customized	7. Stage 1

[1] The customization units are the customizable attributes of the product and their range of options to be choose by the customers (ROCHA,2011)

	housing projects;	
8. **CONSTRUCTS**	9. Propose and refine mass customization constructs (local concepts) for customer integration and their relationship to support the development of the model.	10. Stage 2
11. MODEL	**12. “Propose a model for customer integration in the development of customized housing projects”**	13. **Stage 3**

The three main steps of this research study are depicted in **Error! Not a valid bookmark self-reference.**. The dot line contour represents all the activities that will be developed in the future, and the continuous line represents those that are already completed.

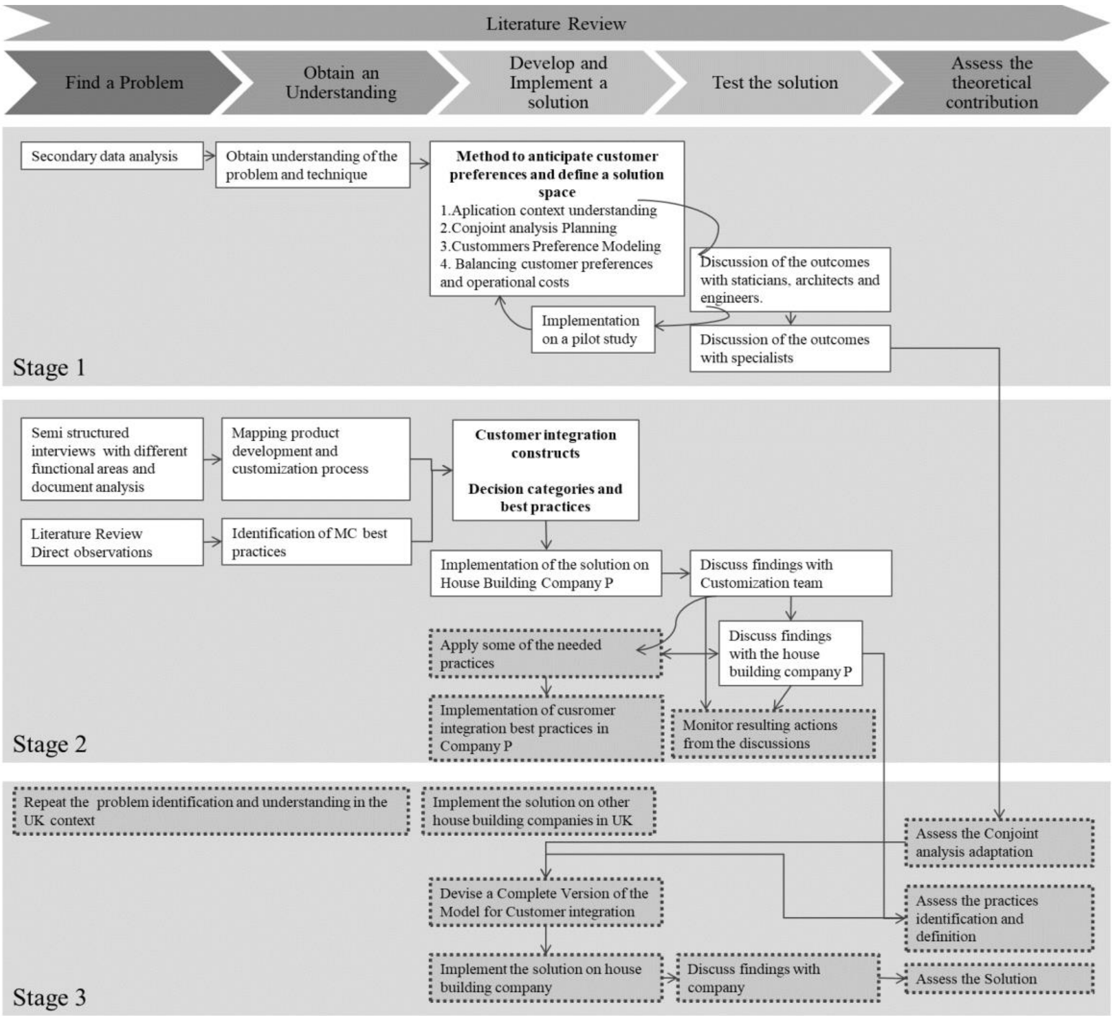

Figure 2 - Research Design

The first stage of the investigation was developed from August 2016 to March 2018, in which the method for identifying customers' demands, anticipating their preferences and defining a solution space was proposed. The development of that method was based on the following sources of evidence: (i) survey about changes in social housing after occupancy, to obtain an understanding about the demand for mass customization and how it can be identified; and (ii) a survey with 80 potential customers of housing projects, to adapt conjoint analysis to this specific context; (iii) development of a customers' preference model.

Stage 2 started in December 2017 with the development of the empirical study B. The focus of stage 2 is on understanding how house building companies can consider customers' requirements and reduce the impacts of product variation in the product development process.

Thus, an empirical study was developed with the collaboration of Company P, that has over 20 years of experience in the house-building market. The provision of customized housing projects as part of the competitive advantage of the company was one of the key elements for its selection for the development of this company. This empirical study addresses a relatively new product line in which the company provides a limited offer to customers' choice, which fits the MC approach. The sources of evidence used in this case study were: (i) eleven semi structured interviews with architects, civil engineers and other company P staff, aiming to understand the customization process, find improvement opportunities and identify existing good practices; (ii) two open interviews, one with customers manager, one with operations manager, for understand the process and find improvement opportunities; (iii) analysis of documents related to the customization process, mostly concerned with the solution space definition; (iv) three meetings, 2 with the customization team about the process map, improvement opportunities and recommendation of best practices, and 1 meeting with the departments involved in the customization process to discuss the overall findings of the study.

Stage 3 will occur from November 2018 until April 2020. A complete version of the solution will be proposed at the end of this stage, integrating solutions developed in previous stages. With the aim of acquiring a theoretical refinement of the solution, previous research outcomes (i.e. constructs and method) will be accessed, supporting the proposition of the final solution. Afterwards, this solution may be applied on a practical context, tested by external partners and have its theoretical contribution assessed.

5. Preliminary findings and Implications:

The method for identifying customers' demands, anticipate their preferences and defining a solution space for mass customized housing projects combines conjoint analysis technique to understand demands for mass customization, a model to estimate willingness to pay for these products. Then, to support the solution space definition, it is necessary to counterbalance the preference model findings with operational costs.

Subsequently, a pilot study was done to implement the developed solution. The main results were: i) the most relevant attributes to offer customization for the market segment, which are finishing and dimensions and layout; ii) demonstration that customers are willing to pay a premium price for obtaining customized housing units; iii) anticipation of customers' preferences as a result of the application of the customer preference model, which can support the decision-making related to the solution space. The main theoretical contributions are related to how the willingness to pay for customized housing is portrayed.

The second research stage resulted in two new decision categories proposed and the adaptation of other 3, and the description and understanding of 50 MC best practices related to customer integration and mass customization strategy definition. The decision categories proposed were: i) assessment and feedback, i.e. approaches to assess customers demand for customization and delivered product after occupancy to capture and understand requirements; ii) customer interaction and relationship along the product configuration process. Those contributions emerged during the development of the empirical study, during the identification of improvement opportunities in Company P and based on literature review. Additionally. The first version of the artifact of these research was developed in this stage, based mainly in the literature review and insights from the empirical study.

Research Scope and Limitations

The scope of this research study is limited to the development of mass customized housing projects, where there is a particular concern about offering a limited solution space to maintain cost –effectiveness and reduce the flexibility-productivity trade-offs. This means that, the level of customer integration in the design process is limited, as well as, the level of customization of the product, excluding approaches such as co-design and pure customization. Another limitation of this investigation is the focus on the customer integration in the MC strategy, so that the solution is not concerned with operations and product design, although these areas will be addressed to some extent due to interfaces with customer integration.

Expectations from the Summer School

My expectations from the summer school are related to the discussion about the connections between the research outcomes, the development of the first version of the artifact and how can this be assessed. Hopefully, this discussion will provide insights for improving the final version of the artifact of this Ph.D. research.

References

Barlow, J. and Ozaki, R. (2003) 'Achieving "customer focus" in private housebuilding: Current practice and lessons from other industries', Housing Studies, 18(1), pp. 87–101. doi: 10.1080/0267303032000076858.

Ferguson, S. M., Olewnik, A. T. and Cormier, P. (2014) ‘A review of mass customization across marketing, engineering and distribution domains toward development of a process framework’, Research in Engineering Design, 25(1), pp. 11–30. doi: 10.1007/s00163-013-0162-4.

Fettermann, D. de C. (2013) Desenvolvimento de produto orientado à customização em massa.

Fogliatto, F. S. and da Silveira, G. J. C. (2008a) ‘Mass customization: A method for market segmentation and choice menu design’, International Journal of Production Economics, 111(2), pp. 606–622. doi: 10.1016/j.ijpe.2007.02.034.

Fogliatto, F. S. and da Silveira, G. J. C. (2008b) ‘Mass customization: A method for market segmentation and choice menu design’, International Journal of Production Economics, 111(2), pp. 606–622. doi: 10.1016/j.ijpe.2007.02.034.

Fogliatto, F. S., da Silveira, G. J. C. and Borenstein, D. (2012) ‘The mass customization decade: An updated review of the literature’, International Journal of Production Economics. Elsevier, 138(1), pp. 14–25. doi: 10.1016/j.ijpe.2012.03.002.

Formoso, C., Leite, F. and Miron, L. (2011) ‘Client requirements management in social housing: A case study on the residential leasing program in brazil’, Journal of Construction in Developing Countries, 16(2), pp. 47–67.

Frutos, J. D. and Borenstein, D. (2004) ‘A framework to support customer-company interaction in mass customization environments’, Computers in Industry, 54(2), pp. 115–135. doi: 10.1016/j.compind.2003.09.004.

Hart, C. W. L. (1995) ‘Mass customization: conceptual underpinnings, opportunities andlimits’, International Journal of Service Industry Management, 6(2), pp. 36–45. doi: 10.1108/09564239510084932.

Hentschke, C. dos S. (2014) ‘Método para identificar atributos customizáveis na habitação baseado no modelo conceitual Cadeia Meios-Fim’, pp. 1–181.

Hentschke, C. S. et al. (2014) ‘A method for proposing valued-adding attributes in customized housing’, Sustainability (Switzerland), 6(12), pp. 9244–9267. doi: 10.3390/su6129244.

Jiao, J., Ma, Q. and Tseng, M. M. (2003) ‘Towards high value-added products and services: mass customization and beyond’, Technovation, 23(10), pp. 809–821. doi: 10.1016/S0166-4972(02)00023-8.

Kasanen, E., Lukka, K. and Siitonen, A. (1993) ‘The Constructive Approach in Management Accounting Research’, Journal of Management Accounting Research, 5(June 1991), pp. 243–264.

Lukka, K. (2003) 'The constructive research aproach', in Ojala, L. & Himola, O-P.(eds) Case study research in logistics. Turku School of Economics and Business Administration, Series B1, pp. 83-101.

Martinez, E., Tommelein, I. D. and Alvear, A. (2017) 'Integration of Lean and Information Technology to Enable a Customization Strategy in Affordable Housing', II(July), pp. 95–102. doi: 10.24928/2017/0136.

Noguchi, M. and Hernández-Velasco, C. R. (2005) 'A "mass custom design" approach to upgrading conventional housing development in Mexico', Habitat International, 29(2), pp. 325–336. doi: 10.1016/j.habitatint.2003.11.005.

Ogawa, S. and Piller, F. T. (2006) 'Reducing the Risks of New Product Development', 47(2).

Piller, F. T., Moeslein, K. and Stotko, C. M. (2004) 'Does mass customization pay? An economic approach to evaluate customer integration', Production Planning & Control, 15(4), pp. 435–444. doi: 10.1080/0953728042000238773.

Rocha, C. G. da (2011) A conceptual framework for defining customisation strategies in the house- building sector.

Salvador, F., Holan, P. M. De and Piller, F. (2009) 'Cracking the Code of Mass Customization Cracking the Code of Mass Customization', MIT Sloan Management Review, 50(50315), pp. 70–78.

Schoenwitz, M. et al. (2017) 'Product, process and customer preference alignment in prefabricated house building', International Journal of Production Economics. Elsevier, 183(September 2015), pp. 79–90. doi: 10.1016/j.ijpe.2016.10.015.

Schoenwitz, M., Naim, M. and Potter, A. (2012) 'The nature of choice in mass customized house building', Construction Management and Economics, 30(April), pp. 203–219.

Shin, Y. et al. (2008) 'Application of information technology for mass customization in the housing construction industry in Korea', Automation in Construction, 17(7), pp. 831–838. doi: 10.1016/j.autcon.2008.02.010.

Tillmann, P. A. and Formoso, C. T. (2008) 'Opportunities to adopt mass customisation – a case study in the brazilian house building sector', Proceedings for the 16 Annual Conference of the International Group for Lean Construction, pp. 447–458.

An Exploration towards integrated Healthcare Design and Assessment

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PURPOSE OF RESEARCH

Design assessment is a fundamental step in the design process. During its development, both design strategy, approaches and propositions of solutions should be verified based on the basic premises related to the project scope and expected outcomes. These cycles of analysis-modification-evaluation (Lawson 2005) are responsible for improving the overall design quality by ensuring that (a) clients' needs related to the built environment are fulfilled (Kamara et al. 2000) and (b) the design solutions are compliant to the associated regulatory code documents and standards (Nawari 2013). Therefore, the design assessment process presents an opportunity to improve design value (Fiksel and Hayes-Roth 1993; Miron and Formoso 2003).

Within the healthcare context, this is even more important because of different factors: (i) the iteration amongst requirements and the design solution is fundamental due to the large number of stakeholders involved in this type of project (Passman 2010); (ii) there is a large amount of information involved in the design (Kiviniemi and Fischer 2004; Tzortzopoulos et al. 2009; Yu et al. 2010), much of it originated from regulatory documents (Marchant 2016; Macit İlal and Günaydın 2017), which usually are subjective and open to different interpretations and individual perceptions; (iii) requirements for healthcare design tend to be more specific because of the medical domain and the associated technologies (Chellappa 2009) and they can evolve during the design process (Kiviniemi and Fischer 2004); and (iv) the relation between requirements and the built environment impact directly the quality of services delivered within healthcare facilities (Tzortzopoulos et al. 2005), and thus important share of the value perceived by clients, such as patients, staff and support teams.

The aim of this research is to explore how assessment can be better incorporated to the design process, so different types of requirements can be properly considered, in order to improve value generation for healthcare projects. This will be done by exploring three different approaches for design assessment: (i) manual-based; (ii) automated-based; (iii) semi-automated based. Therefore, a method to support assessment during the design process for healthcare projects will be proposed. This will be developed based on semantics and supported by Building Information Modelling (BIM). Specific objectives are not properly defined by this date, but this research shall also contribute towards shifting design assessment to a more iterative, simultaneous and continuous design-checking process by exploring Lean principles applied to the design process.

RESEARCH METHOD

Design Science Research (DSR) is the methodological approach adopted in this investigation. This research is currently at the first stage of DSR (Holmström et al. 2009; Lukka 2003), related to understanding the research context and the associated problem to be solved. This approach supports addressing and solving practical problems in a more effective and innovative way (Hevner et al. 2004) at the same time it enables advancements in the associated fields of theoretical knowledge (Kasanen et al. 1993; Lukka 2003). Moreover, DSR has been pointed to solve classes of problems related to design, production and operation within the built environment (Voordijk 2009).

Therefore, DSR appears to be a relevant methodological approach for this research, since the issue regarding design assessment for healthcare projects represents a situation which has both theoretical and practical relevance. For this research, two empirical studies shall be conducted within the healthcare design context. Besides that, literature review will occur during all stages of the research process.

The artefact to be constructed is a method to support assessment during the design process for healthcare projects by identifying the best approach to verify different types of requirements. Initially, this will provide support to: (i) architects and other professionals involved in the design process; (ii) governmental institutions (such as the National Health System – NHS) responsible for creating and updating regulations; and (iii) IT developers, who could support creating and updating software tools. Following, Figure 1 presents a schema of the DSR approach applied to this research. This was developed based on the research of Hevner et al. (2004).

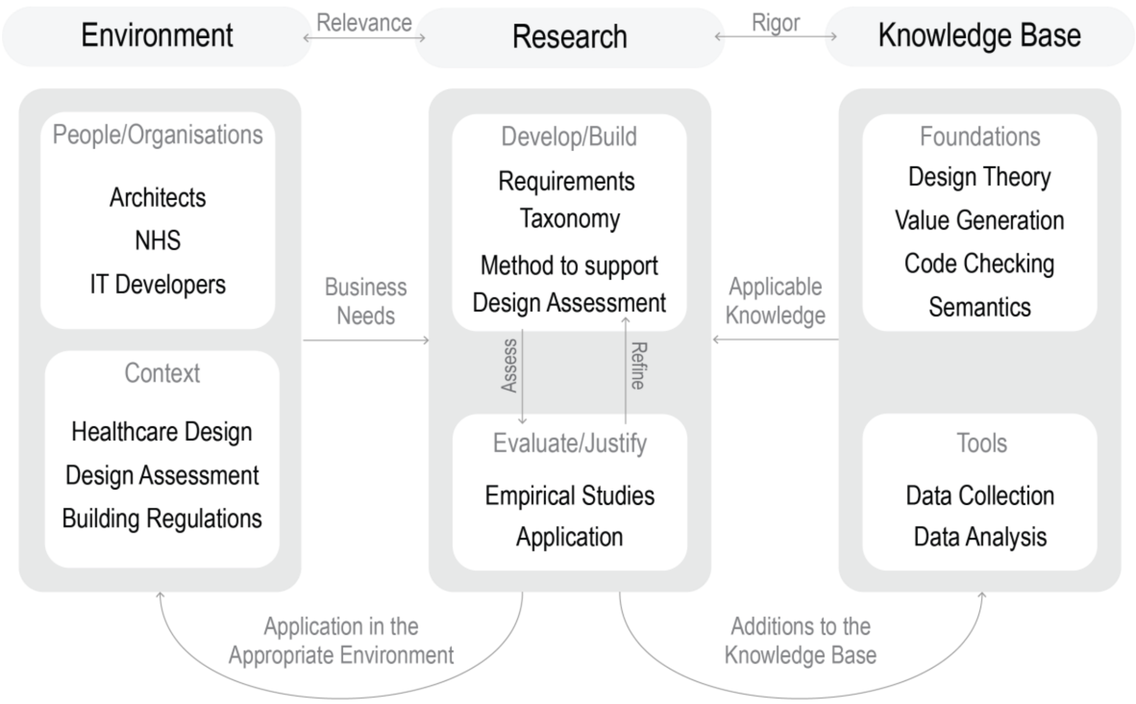

Figure 1. DSR approach applied to the research (Based on Hevner et al., 2004)

The first empirical study is an ongoing activity and is being conducted in close collaboration with a Primary Health Centre (PHC) project development in the UK. From the DSR perspective, this study involves understanding the research problem and start developing the artefact. The main activities related to this study are associated to: (i) the PHC development itself and how design is being assessed; (ii) healthcare design regulations analysis and classification (Health Building Notes – HBN and Health Technical Memoranda – HTM); and (iii) the interaction between requirements management and design compliance to regulations. Thus, the following sources of evidence (mostly based in qualitative data) shall be used: (a) meetings and semi-structured interviews with those involved in the project, such as project managers, architects and clients' representatives; (b) analysis and classification of healthcare regulations (HBNs and HTMs, provided by the UK Government and the NHS) which will be determined according to their relevance for the study); (c) analysis of the PHC design documents (2D floorplans, 3D building models, operational process descriptions); and (d) direct observations of existing Primary Health Centres.

At the end of the first empirical study, there will be possible to devise the first version of the research artefact, from the local understanding of (i) healthcare requirements and (ii) the design assessment process of the PHC project. In the following table (Table 1) the sources of evidence (meetings, interviews and direct observations) collected up to this moment are presented:

Table 1. Sources of evidence collected up to date

Number / Date	**Source of Evidence**	**Approx. Duration**	**Profile of the Participant(s) Involved**	**Understanding**	
				Research Problem	**Specific Context E1**
01 25/10/2018	Meeting	180 min	02 Client Design Advisors / Enablers		X
02 08/11/2018	Meeting	180 min	Multiple PHC Project Stakeholders	X	X
03 15/01/2019	Project Meeting	135 min	Client, Project Manager, Contractor, Architects, Consultants		X
04 21/01/2019	Meeting	60 min	Architect (Healthcare Design)	X	
05 24/01/2019	Meeting	150 min	02 Client Design Advisors / Enablers		X
06 13/02/2019	Direct Observation	45 min	Primary Health Centre		X
07 13/02/2019	Project Meeting	120 min	Client, Project Manager, Contractor, Architects, Consultants		X
08 13/02/2019	Interview	30 min	Client Design Advisor / Enabler	X	X
09 13/02/2019	Interview	60 min	Architect (Concept Design)	X	X
10 14/02/2019	Interview	45 min	02 Architects (Healthcare Design)	X	

11 01/03/2019	Interview	30 min	Professional Healthcare Estate, Management and Facilities Services	X	

A second empirical study is planned to be conducted after the first version of the artefact is devised. This will also be based within the healthcare design context with the aim of implementing and refining the artefact. Thus, during this development, multiple cycles of application-evaluation-refinement shall be conducted, which is a fundamental element of DSR approach.

During the analysis and reflection phase, both theoretical and practical contributions shall be proposed from refining the artefact to its final version. To propose better contributions and trying to overcome the limitations of DSR evaluation is a fundamental step in the research methodology. This will be made based on the criteria of utility and applicability (March and Smith 1995) by conducting a series of interviews and applications of the proposed approach for design assessment in healthcare projects. This process is presented in Figure 2, which is a schema of the research design, built according to the DSR steps, proposed by Holmström et al. (2009).

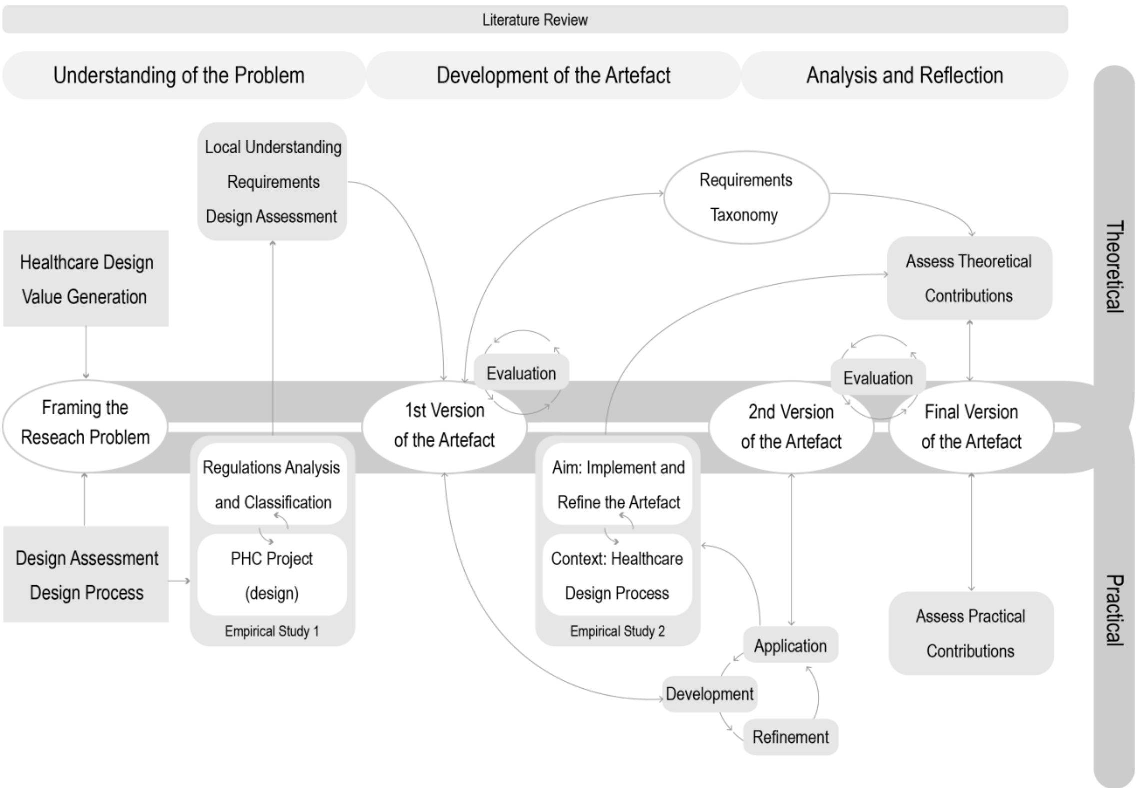

Figure 2. Research design and process

PRELIMINARY FINDINGS

Preliminary findings relate to the first phase of DSR, in which the research problem is still being understood. Therefore, this will contribute towards better understanding and defining the research problem. Literature review indicates that manual approaches for design assessment in terms of compliance may lead to inconsistent and prone to error outputs (Eastman et al. 2009; Bhatt et al. 2012; Zhong et al. 2012; Nawari 2013; Hardin and McCool 2015; Pauwels and Zhang 2015; Preidel and Borrmann 2015, 2016; Jiang and Leicht 2016; Lee et al. 2016; Macit İlal and Günaydın 2017; Zhang and El-Gohary 2017).

On the other hand, automated-based compliance checking has been subject of research for a number of years, aiming to alleviate the above described issues. Despite these efforts, fully automated approaches developed so far also appear to fail in assessing the building design in terms of compliance checking. This is because they usually are developed based on hard-coded premises and thus they might lack of consistent information throughout the design process (Eastman et al. 2009; Lee et al. 2016; Soliman Junior et al. 2018). Additionally, automated approaches struggle in dealing with requirements subjectivity. Within this context, embedding personal knowledge and creativity, with the aim of addressing the wide range of healthcare requirements in the design solution is fundamental for successful outcomes.

The preliminary results from the empirical study 1 relate well with the findings from literature review so far. It is noted from practice that healthcare regulations usually are dependent on interpretation to be properly considered in the design assessment. Specific to the set of regulations analysed so far, multiple times this interpretation relies on the understanding of textual elements associated with sketches, photography and diagrams (example in Figure 3). Besides, their content tends to be reduced to simpler understandings from both designers and clients' perspectives, such as by only considering requirements related to spatial adjacencies and dimension criteria.

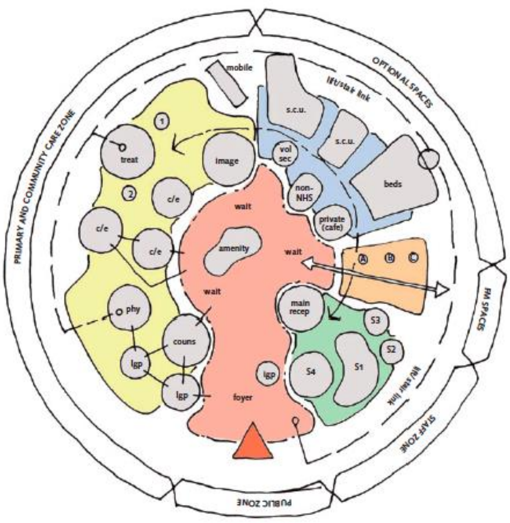

Figure 3. Adjacencies diagram – Example from HBN 11-01 –Facilities for primary and community care services

These factors represent an issue that compromise not only the design and compliance process, but in a deeper perspective, might affect the value generation process. This is because the design outcome might not meet the different clients' needs, and also it might be non-compliant to the associated regulations and standards. Therefore, a different approach for design assessment appears to be necessary and within this context a hybrid approach, based on semi-automated tasks could overcome some of the limitations from both manual and automated checking.

RESEARCH SCOPE AND LIMITATIONS

This research is defined for the healthcare design process and assessment. Therefore, the scope of the research corresponds to this typology of project. Moreover, as the empirical study 1 is based within the Primary Care context, this presents a current and more specific limitation. This will probably be alleviated during the research process, while defining the scope of empirical study 2 into a different context within healthcare. Additionally, other limitation observed so far is related to analysing and classifying just a specific set of healthcare regulations. As the research process evolve, different regulations will be included in this analysis.

IMPLICATIONS

The use of a research approach grounded within the socio-technical environment, such as DSR, supports the constant iteration between theory and practice, thus, providing benefit for the healthcare design context. This is why the Lean Philosophy could offer some support to this research. It could be achieved by providing a well-established flow of information and making data available to support design decision-making along all phases of its development. It also would support how autonomation could be better explored in the design process. Preliminary results indicate that coordinated and improved design assessment approaches can facilitate the value generation process. This should be explored in such a way as to understanding which typologies of requirements can be better assessed according to different approaches. Additionally, it is expected to explore how assessment can be less routine check-based and move towards an iterative and simultaneous approach for the entire design process.

EXPECATATIONS FROM THE SUMMER SCHOOL

The main expectations from the IGLC Summer School are associated with discussing the way forward of this PhD research. As this is the summary of the first six-months development, this opportunity might enable a rich discussion of the research problem, as well as indicating the best ways to continue the research process throughout the next years.

1.1. REFERENCES

Bhatt, M., Hois, J., and Kutz, O. (2012). "Ontological modelling of form and function for architectural design." *Applied Ontology*, 7(3), 233–267.

Chellappa, J. R. (2009). "BIM + healthcare: utilization of BIM in the design of a primary healthcare project." University of Hawaiʻi.

Eastman, C., Lee, J., Jeong, Y., and Lee, J. (2009). "Automatic rule-based checking of building designs." *Automation in Construction*, 18(8), 1011–1033.

Fiksel, J., and Hayes-Roth, F. (1993). "Computer-aided Requirements Management." *Concurrent Engineering*, 1(2), 83–92.

Hardin, B., and McCool, D. (2015). *Bim and construction management: proven tools, methods, and workflows, second edition*. John Wiley and Sons, Indianapolis, IN.
Hevner, March, Park, and Ram. (2004). "Design Science in Information Systems Research." *MIS Quarterly*, 28(1), 75.
Holmström, J., Ketokivi, M., and Hameri, A.-P. (2009). "Bridging Practice and Theory : A Design Science Approach." *Decision Science*, 40(1), 65–87.
Jiang, L., and Leicht, R. M. (2016). "Supporting automated Constructability checking for formwork construction: An ontology." *Journal of Information Technology in Construction*, 21(October), 456–478.
Kamara, J. M., Anumba, C. J., and Evbuomwan, N. F. O. (2000). "Establishing and processing client requirements: a key aspect of concurrent engineering in construction." *Engineering, Construction and Architectural Management*, 7(1), 15–28.
Kasanen, E., Lukka, K., and Siitonen, A. (1993). "The Constructive Approach in Management Accounting Research." *Journal of Management Accounting Research*, 5, 243–264.
Kiviniemi, A., and Fischer, M. (2004). "Requirements Management Interface to Building Product Models." 1–12.
Lawson, B. (2005). "Route maps of the design process." *How Designers Think: The Design Process Demystified*, Routledge, New York, 31–53.
Lee, H., Lee, J. K., Park, S., and Kim, I. (2016). "Translating building legislation into a computer-executable format for evaluating building permit requirements." *Automation in Construction*, Elsevier B.V., 71, 49–61.
Lukka, K. (2003). "The constructive research approach." *Case study research in logistics. Publications of the Turku School of Economics and Business Administration, Series B*, 1(2003), 83–101.
Macit İlal, S., and Günaydın, H. M. (2017). "Computer representation of building codes for automated compliance checking." *Automation in Construction*, 82(June), 43–58.
March, S. T., and Smith, G. F. (1995). "Design and natural science research on information technology." *Decision Support Systems*, 15(4), 251–266.
Marchant, D. (2016). "The design brief: Requirements and compliance." *Journal of Information Technology in Construction*, 21(November), 337–353.
Miron, L. I. G., and Formoso, C. T. (2003). "CLIENT REQUIREMENT MANAGEMENT IN BUILDING PROJECTS." *11th Annual Conference of the International Group for Lean Construction*, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.
Nawari, N. (2013). "SmartCodes and BIM." *Structures Congress 2013*, 928–937.
Passman, D. (2010). "Planning Healthcare Environments." *Improving Healthcare through Built Environment Infrastructure*, M. Kagioglou and P. Tzortzopoulos, eds., Wiley-Blackwell, Salford, UK.
Pauwels, P., and Zhang, S. (2015). "Semantic Rule-checking for Regulation Compliance Checking: An Overview of Strategies and Approaches." *Proceedings of the 32nd CIB W78 Conference*, (2009), 619–628.
Preidel, C., and Borrmann, A. (2015). "Automated Code Compliance Checking Based on a Visual Language and Building Information Modeling." *Proceedings of the 32nd International Symposium of Automation and Robotics in Construction, 15-18 June*, 256–263.

Preidel, C., and Borrmann, A. (2016). "Towards code compliance checking on the basis of a visual programming language." *Journal of Information Technology in Construction*, 21(July), 402–421.
Soliman Junior, J., Baldauf, J. P., Formoso, C. T., and Tzortzopoulos, P. (2018). "Using BIM and Lean for Modelling Requirements in the Design of Healthcare Projects." *26th Annual Conference of the International Group for Lean Construction*, Chennai, 571–581.
Tzortzopoulos, P., Chan, P., and Cooper, R. (2005). "Requirements management in the design of primary healthcare facilities." *SIBRAGEC*.
Tzortzopoulos, P., Codinhoto, R., Kagioglou, M., Rooke, J., and Koskela, L. (2009). "The gaps between healthcare service and building design: a state of the art review." *Ambiente Construído*, 9(2), 47–55.
Voordijk, H. (2009). "Construction management and economics: the epistemology of a multidisciplinary design science." *Construction management and economics*, Taylor & Francis, 27(8), 713–720.
Yu, A. T. W., Shen, G. Q. P., and Chan, E. H. W. (2010). "Managing employers' requirements in construction industry." *Facilities*, 28(7/8), 371–382.
Zhang, J., and El-Gohary, N. M. (2017). "Semantic-Based Logic Representation and Reasoning for Automated Regulatory Compliance Checking." *Journal of Computing in Civil Engineering*, 31(1), 04016037.
Zhong, B. T., Ding, L. Y., Luo, H. B., Zhou, Y., Hu, Y. Z., and Hu, H. M. (2012). "Ontology-based semantic modeling of regulation constraint for automated construction quality compliance checking." *Automation in Construction*, 28, 58–70.

A framework for developing primary healthcare facilities based on a modular service concept to allow flexibility in use and maintenance

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Purpose of research

The amount of knowledge about the concept of modularization, based on results of previous studies, points to the need for clarification about its effective application in the construction industry. Modularity can be defined as the degree to which a system can be divided into subunits (modules) that can be joined and recombined in different ways (Simon 1991; Schilling 2000). A module is understood as an independent unit, which has its own functionality and standardized interfaces that interact according to the definition of the systems (Miller and Elgard 1998).

Since the 2000s, the topic of modularization applied specifically to the construction industry has been the subject of numerous researches, mainly in developed countries such as the United States, United Kingdom, Australia and Canada. In Brazil, the amount of research in the area is small, which may reflect the low level of industrialization of construction in the country.

Although some characteristics of the construction industry make it difficult for the adoption of modularity in some construction projects, there are potential benefits for its implementation (Doran and Giannakis 2011). Modularization in the construction industry has been pointed out in the literature as a strategy for: (a) meeting customer requirements, through mass customization, for example; (b) development of innovative products; (c) improvement of quality performance, safety performance, schedule and costs of projects and (d) flexibility in use and maintenance.

Some empirical studies in the construction industry point out that there are different types of modularity: product, process, and supply chain modularities (Voordijk et al. 2006; Lessing 2006, Viana et al. 2016, Peltokorpi et al. 2018). Recently some researchers have focused attention on service modularity (Luoma-Halkola 2017), arguing that modularization might not be always related to industrialization or preassembly but applied to a specific part of the building or focused on developing flexible products for later modifications (Peltokorpi et al. 2018).

"Modular services" is a concept based on modularization theories that is pointed to create value to healthcare facilities which often have project specifics demands through allowing the composition of customized service modules from standardized components (Luoma-Halkola 2017).

The health-care context comes from a project under the proposal, involving partner institutions. Although, in fact, the thematic of modularization applied to health-care facilities has been approached by recent studies such as Fifield et al. (2018), Lahtinen et al. (2018) and Peltokorpi et al. (2018).

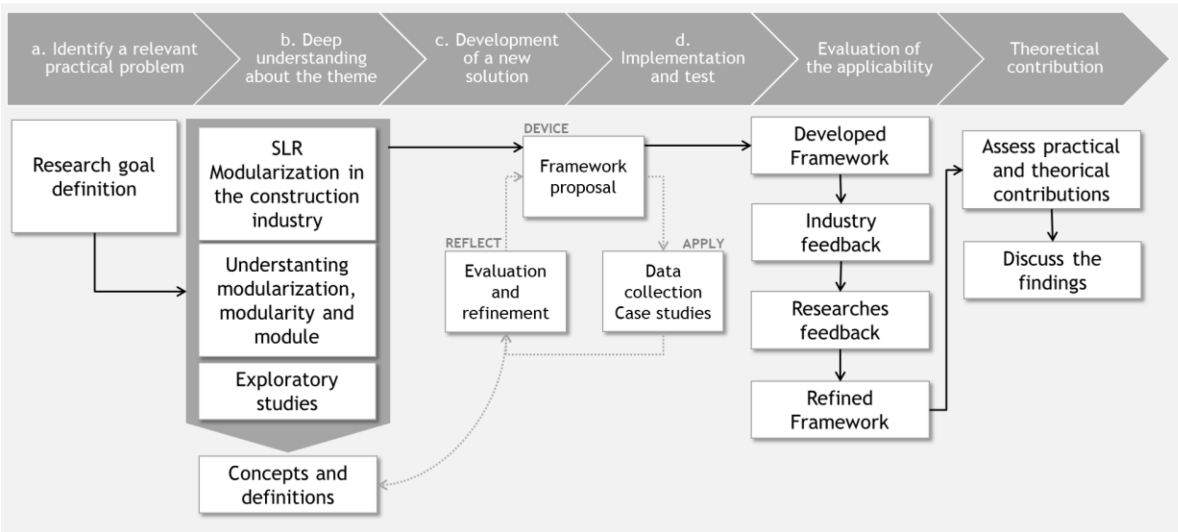
The use of modular services in healthcare facilities may meet the need of this sector to offer flexible solutions that adapt to the rapid changes that the industry has been going through. Due to the fast advances in medicine in terms of technologies and innovations, it demands the possibility of efficiently and adequately renovating and adapting to the needs of the client, in an environment that supports patient recovery, at the same time it should consider the wellbeing of the workers and the work processes involved (Lahtinen et al. 2018).

In this sense, the research question of our effort is: how to use modularization as a management strategy for the development of innovative products in the construction industry and, moreover, how to ensure its benefits in the flexibility in use and maintenance of healthcare projects?

The thesis aims to propose a framework to support the development of public and small primary healthcare facilities with high value-added and allowing upgrading during its life cycle through service modularity.

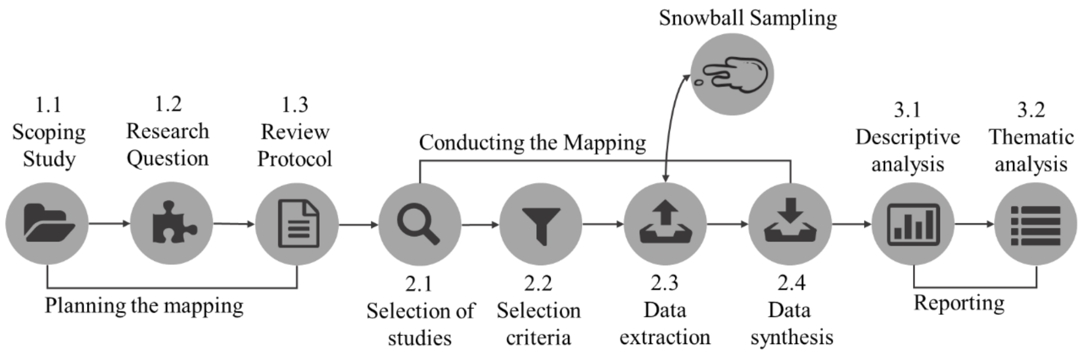
Research method

The research method is proposed on a constructive and prescriptive approach, based on Design Science Research (DSR). DSR aim to solve real-world problems by devising solutions or artifacts, test and assess their applicability, and provide theoretical advances. Figure 1 summarizes the main steps of the research:



Preliminary findings:

The preliminary results comprise a systematic mapping study on modularity applied to the construction industry, whose steps are presented in figure 2.



Through the initial reading of 8 seminal articles, search strings (modular * AND construction industry) were applied to 5 databases. The selection and filtering process were performed through the screening steps (table 1), including the reading of the articles available for extracting the data.

Table 1: Screening steps

Papers founded	ENG / PT Only	NOT duplicated	After Title/abstract/Keywords analysis	Available for download	Snowball Sampling	Final selection
2149	1742	843	236	142	14	113

In order to analyze the main topic areas covered in the literature on modularity, the following classification was proposed, based on the IGLC 2019 proposed themes (Table 2).

Table 2: Description of the proposed topic areas

Topic Area	Description
Product Development and Design Management	Papers related to the development of modular products, components, or to the management of the design process.
Contract and Cost Management	Papers related to the decision-making process, including risk analysis, real estate market and stakeholders.
Production Planning and Control	Papers related to the process of planning and control of modular projects.
Theory	Theoretical or literature review about modularity, including authors who have identified best practices in the construction industry.
Sustainability	Papers related to the environmental impact of modular buildings and green technologies.
Production System Design	Papers related to the design and execution of modular building systems, including assembly techniques and automation.
Off-Site Construction	Papers related to the manufacturing process of modules or modular component and transportation.
Supply Chain Management	Papers related to the modular construction supply chain.
Safety, Quality, and Health	Papers that investigated the relationship between the use of modularity and safety performance.
Lean and BIM	Papers that specifically addressed the use of BIM and/or Lean in modular construction.

A total of 10 categories were proposed in order to group the diversity of topics addressed by the selected papers. This classification is still propositional. The aim of this division into categories was to identify future trends and knowledge gaps (scarce evidences). Figure 3 shows the distribution of the topics covered by previous studies. The category "Product Development and Design Management" had around 40% of the papers.

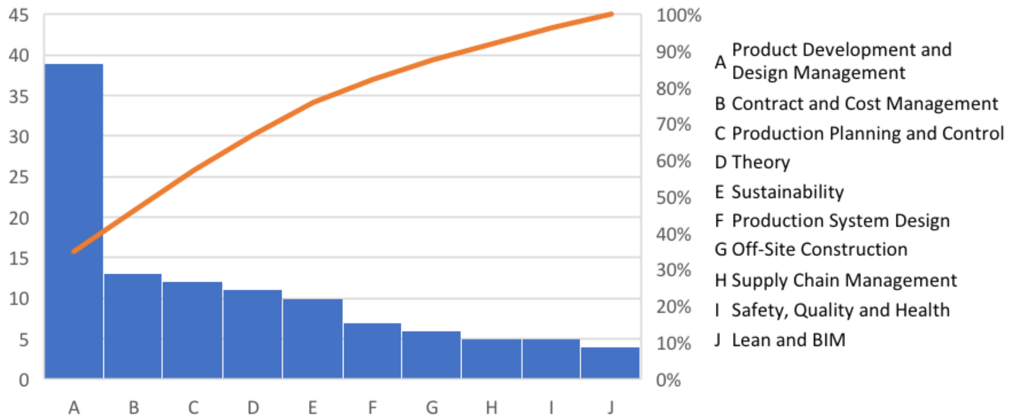


Figure 3: Distribution of papers according to topic area

In conclusion, most of the papers selected were related to the development of modular products. However, this category involves a great diversity of aspects, since it encompassed both the design process and the development of modules or modular components. Further Systematic Literature Review aims to understand how modularity concepts are applied to the construction sector as well to distinguish types of modularity such as service modularity.

Research Scope and Limitations

Our scope focus on primary care facilities, specifically the Basic Health Units (BHU), which is considered the preferential path of access of the population to the Unified Health System (*SUS – Sistema Único de Saúde*) services in Brazil (Carvalho et al. 2014). Public services and Healthcare environmental are particular complex topics and will demand high efforts to obtain cooperation between researchers and stakeholders as well as the intrinsically ethical implications in this field. Additionally, is expected some difficulties in the DSR validation process through testing the framework in real project development.

Implications:

It is expected that the theoretical discussion of this study will contribute to the technological advance of the industry, through the dissemination of service modularization and upgrading strategies applied to primary healthcare facilities projects. The development of the artifact will necessarily involve the various stakeholders involved in project development, as well as the clients and users of this type of facility, which reinforces the importance of the intended practical and theoretical orientation.

Expectations from the Summer School

As this is an initial proposal, contributions are expected mainly in the sense of defining and adjusting the focus of this study.

9. References

Carvalho, B.G.*et al.* (2014), 'Management of basic health units in municipalities of different size: profile and management instruments', Revista Da Escola de Enfermagem Da USP, Vol. 48 No. 5, pp. 907–914.

Doran, D. and Giannakis, M. (2011) 'An examination of a modular supply chain: A construction sector perspective', *Supply Chain Management*, 16(4), pp. 260–270. doi: 10.1108/13598541111139071.

Fifield, L. J. *et al.* (2018). 'Hospital wards and modular construction: Summertime overheating and energy efficiency.' *Building and Environment*, 141, 28–44.

Lahtinen, M. *et al.* (2018). "Possibilities for user-centric and participatory design in modular health care facilities." *Intelligent Buildings International*, 1–15.

Luoma-Halkola, L. (2017). 'Modular service concept for hospital retrofits.' Master thesis. Science in Technology. Aalto University. 94 p.

Miller, T. D. and Elgård, P. (1998). 'Defining Modules, Modularity and Modularization.' *Proceedings* of the ASME Design Engineering Technical Conference.

Peltokorpi, A. *et al.* (2018) 'Categorizing modularization strategies to achieve various objectives of building investments', *Construction Management and Economics*. Routledge, 36(1), pp. 32–48. doi: 10.1080/01446193.2017.1353119.

Schilling, M. A. (2000) 'Toward a general modular systems theory and its application to interfirm product modularity'. *Academy of management review*, v. 25, n. 2, p. 312-334.

Simon, H. A. (1991) 'The architecture of complexity. In: Facets of systems science.' *Springer*, Boston, MA. p. 457-476.

Exploratory Study on Collaborative Costing in the UK Construction Industry.

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Introduction

Successive reports of Latham, Egan and now Farmer have all challenged the UK construction industry for lack of collaborative culture and innovation. Accordingly, they recommended the adoption of lean and manufacturing advances to enhance efficiency in the industry. Recent evidence from other industries have shown that lean concepts like integrated project delivery (IPD), target value design (TVD) among others are gaining prominence in the global construction landscape and their influence on collaborative practices is rapid and significant. Despite these advances, collaborative practices in the UK construction industry is still sporadic.

In the UK collaborative working (CW) is fading due to certain commercial behaviours, which are reinforced by the prevailing procurement protocols and the 'institutionalised' factors that surrounds project delivery approach in construction. Consequently, this continue to hinder the industry from realising the full benefits of collaboration in practice. For instance, costing approach in the industry is still marred with irregularities, uncertainties, lack of shared understanding amongst stakeholders. Partly, because the customary approach is still based on RIBA plan of work, which is discrete, sequential and favours competitive tendering. Herein, stakeholders still maintain the narrow view and considers costing and design activities as separate functions, instead of integrated and part of production to intensify collaboration. This view is subtly inspired by how fragmented the construction model is. Accordingly, this point out the need to shift the prevailing mind-set to support industry-wide collaborative practices in construction.

Purpose

In view of these problems, this study focus on exploring 'collaborative costing' (CC) using TVD as a guiding lens across the major sectors in the UK construction. The purpose is to understand the perceptions and development of CC in the UK construction industry. In addition, the aim of the study is to develop CC framework, which has the potential to engender early collaboration in costing practices within the UK. Based on the forgoing discussions, the following research questions have been developed: What is collaborative costing? How would the integration of commercial practices improve CW in the UK construction industry?

Methodology

This research adopted an exploratory qualitative approach using multiple case study technique. Accordingly, this provides an opportunity to investigate real-life perspective (Pratt 2009; Yin 2009). Also, it covers the 'what and how' questions and the influence of the social context (e.g., what/how CC are viewed in multidisciplinary settings) on practices within human dimensions (Maxwell 2005).The primary research gathered data from interviews utilized open-ended questions, which provides insights from the views of participants and allowed the author to understand the concept of CC. An ascribed definition was produced, which was further examined in the cases studied to substantiate its progress, using semi-structured interviews and the analysis of costing & estimating manuals; financial business plans and supply chain policy documents from the cases studied, to improve the quality of findings and conclusion (Yin, 2009). The study adopts purposive sampling method in selecting the cases. Bryman (2012) maintained that this allow researchers to choose case(s) that can answer particular question(s). For example, some criteria for the case study selection were: (a) the companies must have adopted target costing or any integrated approach during early costing phase (b) encourage collaborative values that cut across project teams and supply-chain groups and (c) to be domiciled in the UK. Thus, 45 participants participated in the interviews that lasted for 60 minutes comprising of: client, directors (commercial, alliance & procurement), designers, contractors, cost consultants, estimators, lean practitioners, and suppliers.

Findings

The summary of the study findings are as follows

- ✓ The study found that the current costing practice adopted in UK construction industry aligns partially with some of the generally advocated lean principles of TVD.
- ✓ Analysis of the results revealed that the current approach has not explored all components of the TVD and other wider attributes to underpins 'collaborative costing' strategies in construction.
- ✓ It also found that the depth and understanding of CC among the relevant teams is still weak.
- ✓ Although, the current costing approach in multidisciplinary setting appears to be progressing, which has shown client focus, design centred and somewhat involves cross-functional teams, yet, the approach is still driven by price consideration.
- ✓ The study concludes that 'collaborative costing' is practicable, but would be better if the wider teams are involved early (including traditional cost

consultants and tier-2) to compensate the lack of trade-specific and constructability input to inform the limited options that aren't available during costing development.

Implications

The study investigate CC practices. It shows that collaboration is still significant in achieving construction industry reforms. The results showed that 'collaborative costing' approach is progressing within the cases examined, although for it to work successfully, commercial teams and the tier-2 members need to be on-board with a complete mind-set shift subscribing to the collaborative ideologies.

Whilst comparing, the TVD principles exploited on the three case studies, the findings showed that an ideal CC is required in practice to improve on the existing approach currently in use. This is because, the depth of all-inclusive collaboration and dialogue with relevant parties is weak/lacking, and risk/reward strategies are not properly understood, especially among the tier-2 groups. For example, the case 2 & 3 showed that TC are set in isolation from the project teams using data from 'cost capture system', and these drive the client database. It was also found that CC approach in case 3 is alternating from cost negotiation to competition. Although, case 1 seem to be steps ahead in terms of collaborative practices, but they could also improve on from the missing TVD principles identified like the set-based design & choosing by advantage methods, last planner system.

Interestingly, the study showed that all the cases seem to have integrated governance and cross-functional teams, however, they could also benefit from using project modification and innovation (PMI) process along with these principles to enable them achieve their TC. This is because the PMI allow anyone with potential cost-saving ideas to bring it up for review, and is successful in steering design to TC. Although, this would be better if the wider teams are involved early during costing and design conversations (including the tier-2) to compensate the lack of trade-specific and constructability input to inform the limited options that aren't available during costing and design. Indeed, establishing this would further strengthen CW, as testament to the definition of CC, upstream & downstream players need to have a sense of ownership and starts from a position of transparency and sustainability to eliminate any transactional characteristics in practice.

Expectation

I would like to have a feedback from the IGLC committee on my proposed framework for collaborative costing process in construction. Although, the framework is not completed now but would be by the time of the conference.

REFERENCES

Ballard, G., & Pennanen, A. (2013). Conceptual Estimating and target costing. *Iglc-21*, 217–226.

Bresnen, M., & Marshall, N. (2000b). Partnering in construction: a critical review of issues, problems and dilemmas. *Construction Management and Economics*, *18*(2), 229–237. http://doi.org/10.1080/014461900370852

CabinetOffice. (2014). Cost Led Procurement Guidance. Retrieved from https://www.gov.uk/government/publications/cost-led-procurement

Challender, J., Farrell, P., & Sherratt, F. (2015). Exploration of Factors Which Affect Trust Within the Context of Construction Partnering. *In: Raidén, A B and Aboagye-Nimo, E (Eds) Procs 31st Annual ARCOM Conference, 7-9 September 2015, Lincoln, UK, Association of Researchers in Construction Management, 1189-1198.*, (September),

Eriksson, P. E., & Laan, A. (2007). Procurement effects on trust and control in client-contractor relationships. *Engineering, Construction and Architectural Management*, *14*(4), 387–399. http://doi.org/10.1108/09699980710760694

Hanid, M. (2014). Design Science Research as an Approach to Develop Conceptual Solutions for Improving Cost Management in Construction, 192.

ICE (2018). Insittute of Civil Engineers: P13 Commercial Hnadbook. *Published May 2018.*

Jung, W. et al. (2012) 'Understanding of target value design for integrated project delivery with the context of game theory', Construction Research Congress 2012: Construction Challenges in a Flat World, pp. 556–563. doi: 10.1061/9780784412329.056.

Laryea, S., & Watermeyer, R. (2016). Early contractor involvement in framework contracts. *Proceedings of the Institution of Civil Engineers: Management, Procurement and Law*, *169*(MP1), 4-16. http://doi.org/10.1680/jmapl.15.00012

Love, P. E. D., Zhou, J., Edwards, D. J., Irani, Z., & Sing, C. P. (2017). Off the rails: The cost performance of infrastructure rail projects. *Transportation Research Part A: Policy and Practice*, *99*, 14–29. http://doi.org/10.1016/j.tra.2017.02.008

Mark Farmer (2016). The Farmer Review of the UK Construction Labour Model: Modernise or Die. Mark Farmer, Founding Director and CEO, Cast Consultancy. Published by the Construction Leadership Council (CLC).www.constructionleadershipcouncil.co.uk

Marchesan, & Formoso. (2001). Cost Management and Production Control for Construction Companies. *9th Annual Conference of the International Group for Lean Construction*, 1–12.

Namadi., Pasquire C., and Manu E (2018). 'Evaluating Why Quantity Surveyors Conflict with Collaborative Project Delivery System.' In: Proc. 26th Ann. Conf. of the Int'l. Group for Lean Construction, Chennai, India, 18-20 Jul 2018. pp 1272-1282.

Pasquire, C., Sarhan, S. and King, A. (2015) 'A Critical Review of the Safeguarding Problem in Construction Procurement: Unpicking the Coherent Current

Model', 23rd Annual Conference of the International Group for Lean Construction, 44(0), pp. 309–318. Available at: http://www.iglc.net/papers/details/1163.

Sarhan, S. (2018). Institutional Waste Within The Uk Construction Industry : An Exploratory Study of Nottingham Trent University.

Shalpegin, T., Sommer, S. and Wan, Z. (2018) 'Collaborative Prototyping of Alternative Designs Under a Target Costing Scheme', Production and Operations Management, 27(3), pp. 496–515. doi: 10.1111/poms.12811.

Simonson, J. (2016) 'Rethinking GMP on collaborative projects', Georgetown Law Journal, 104(6), pp. 1559–1579. doi: 10.1525/sp.2007.54.1.23.

Zimina, D., Ballard, G., & Pasquire, C. (2012). Target value design: using collaboration and a lean approach to reduce construction cost. *Construction Management and Economics*, *30*(5), 383–398. http://doi.org/10.1080/01446193.2012.676658

Design of a new lean BIM-based production system in construction

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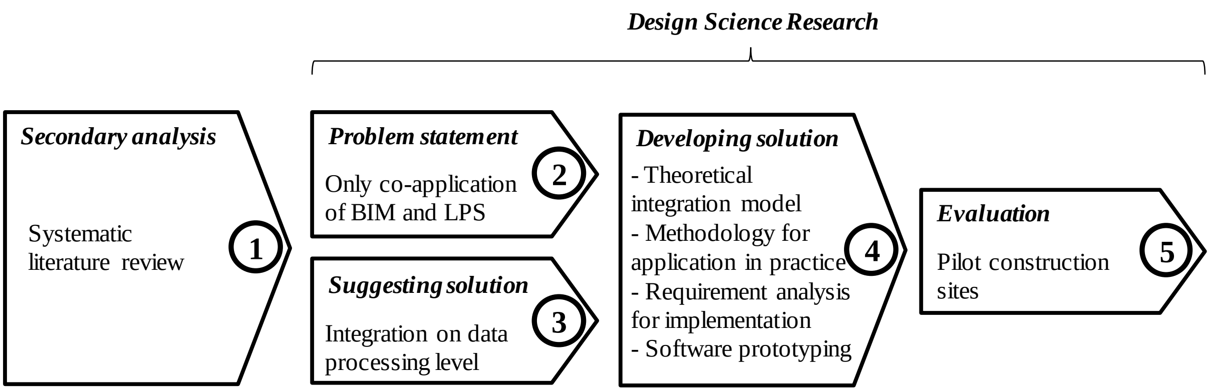
Purpose of research

My research aims at developing a new lean BIM-based production system in construction. To prove whether productivity in construction execution processes can be improved, the aforesaid production system is designed to assess the hypothesis that a true integration of BIM functionalities with the Last Planner System (LPS) will contribute to a more efficient project delivery in the phase of construction execution. Although beneficial synergies of BIM and Lean have been widely described and acknowledged in research (Sacks *et al.*, 2010; Sacks, Radosavljevic and Barak, 2010; Dave, Boddy and Koskela, 2013; Khan and Tzortzopoulos, 2014), previous work has not fully addressed the stated hypothesis, since it has only provided frameworks on how to use BIM and the LPS in parallel. The core of my proposed lean BIM-based production system is the linkage of BIM objects at data processing level with the LPS routines making use of digital Kanban boards. The production system will also be extended by cost control aspects of the Earned Value Management (EVM) approach and thus represents the basis for a complete construction management system with respect to quality, schedule and costs. My study plan foresees to develop the theoretical concept of this new production system, to derive requirements for implementation of this concept into software, to develop prototypes as well as validating them on-site and thereby testing the above formulated hypothesis.

As a consequence of these integration endeavors, a research question to be answered within this PhD studies arises as: What is the effect of a true integration of BIM and LPS on data processing level on the project performance in terms of LPS metrics? This should be evaluated with respect to no or only partial integration of the two. In addition, the impacts of EVM functionalities in this regard should be analyzed too.

Research method

A combined research approach is followed which is composed of a systematic literature review addressing the co-applications of BIM and LPS in previous studies and a Design Science Research (DSR) approach to develop new artefacts for system integration of BIM and LPS allowing for a joint application. The starting point of the DSR approach is a specific problem, which is followed by elaborating hypotheses for a possible solution of that problem based on previous knowledge and the literature review. In this case the problem is, that parallel co-application of BIM and LPS does not exploit synergy potentials to the maximum extent, whilst the suggestion for solving this problem is true integration on data processing level and deriving a new production system. Subsequently, in the development phase there will be created concrete artefacts, which will be a theoretical integration model, a methodology for application in practice which will follow the proposal for method development by Highsmith (2002) as well as software prototypes. The evaluation foreseen in DSR will be conducted through pilot construction sites where the developed artefacts will be tested under real conditions in case study scenarios.



Preliminary findings

The design of the new production system technically represents a system integration on data processing level of the two sub-systems BIM and LPS to deliver new functionalities and exploit synergies. Eventually, both sub-systems should work together, where their conjunction will be expressed through an integration model, which has been already elaborated theoretically. This integration model takes up the five steps of the LPS routines and describes the possible linkage to a BIM model by association on data processing level with respect to the Industry-Foundation-Classes (IFC) file format and will serve as the basis for the requirement analysis for later prototypical software implementations.

Regarding new functionalities, literature review has revealed three major aspects for potential improvement, which consequently will be added into the integration model in the future. These three aspects are (1) elements of the Scrum method, which amongst others is reasoned in the work of Owen and Koskela (2006), since they have investigated the applicability of agile project management ideas in construction execution. More in detail, they suggest beneficial applications in process planning of execution but not for the site-management itself. Contradictorily Fernandes and Ribeiro (2010) state that agile techniques were suitable for steering all project phases in the context of medium and small sized enterprises (SMEs). Based on these prospects, I want to discover the potential of AGM aspects for the proposed production system. Particularly, I see value in adopting Scrum's clearly defined roles. Since literature showed that main barriers of successful LPS implementation amongst others are comprised of poor methodological correctness and partial implementation (Alarcón *et al.*, 2005; Bortolazza and Formoso, 2006), I think that precisely formulated roles with distinct responsibilities in the single process steps will improve the production system.

The other two aspects are (2) implementation of a digital Kanban board to make use of both the Kanban method itself and enhanced visualization capabilities of digital whiteboards as alluded in (Modrich and Cousins, 2017) and (3) adding features of the Earned Value Management (EVM) project control system since LPS lacks in controlling cost performance (Novinsky *et al.*, 2018; Zhang, Li and Tang, 2018).

Research Scope and Limitations

The research scope covers on the methodologically side in the first run in principal every kind of construction execution process independent of the project size. Nonetheless the applicability of the suggested production system in different project settings is also matter of investigation within this PhD study. The concept for the proposed production system foresees as a domain of application a General Contractor + Multi-Subcontractor-Trade environment, whereat local cooperation with regular physical meeting participation is a prerequisite.

On the other hand, technical implementations of the proposed production system into software prototypes will be presumably limited to groups of construction tasks such as e.g. shell works and not cover all possibly occurring processes on-site in the first run.

Implications

This design of the proposed production system aggregated different existing and well-proven techniques: EVM provides methods to compare planned and earned value for determining whether a project is running well or not. LPS offers the instruments to define when and whether value has been earned. Additionally and primarily, it provides a framework for enhanced process stability and workflow reliability which in turn increases the probability of “earning” as much as planned. The missing piece in this puzzle here is BIM, which provides quantities and information to estimate durations and costs of construction processes and serves as a better basis for decision-making in phase and look-ahead-planning session as well as a medium for intuitive visualization of the project’s status by coloring the BIM objects with respect to their progress. These features will be unified making use of digital Kanban boards. Innovative aspect here is, that not only frameworks or guidelines are given how to apply these techniques in parallel, but an integration model for system integration on data processing level is developed.

So far, no changes to practice can be derived from this ongoing research project. Nonetheless, it is hoped that this research project will contribute to the understanding of practitioners that a BIM model is an excellent basis for controlling construction processes and not a pure planning instrument. This is demonstrated on the methodological side by the seamless linkage to proven lean construction techniques for execution and on the technological side by the provision of software systems that support the vendor-neutral IFC files and thus also contributes to the general misbelief that BIM - especially in the context of execution - can only benefit the big players on the market, but also small and medium-sized companies directly whenever a BIM model is available.

In addition, the proposed production system, in its digital implementation at data processing level, opens up possibilities for future research activities, such as an expansion towards Internet of Things (IoT) applications. It is conceivable that allocated LPS assignments via digital Kanban cards on the mobile phone could also be reported back by sensors and played back into the BIM model, resulting in a BIM-based Last Planner System 4.0 in the future.

Expectations from the Summer School

I hope to receive feedback on the methodological side as to whether a linking of BIM, LPS, Scrum, Digital Kanban-Boards and EVM in the envisaged form is worth pursuing and whether the planned research methodology is adequate. I am also interested in advice on how and to what extent to validate the production system to be developed under real site conditions. Furthermore, I would like to exchange ideas with other PhD students working on similar topics. Since a PhD topic is highly specialized, it is difficult to exchange details on one's own research topics with other students locally. Therefore, I consider the IGLC summer school as a perfect platform for such an exchange to understand whether other students dealing with related issues are pursuing similar solution strategies.

References

Alarcón, L. F., Diethelm, S., Rojo, O. and Calderon, R. (2005) 'Assessing the impacts of implementing lean construction', in *Proc. 13h Ann. Conf. of the Int'l. Group for Lean Construction*. Sydney: International Group for Lean Construction, pp. 387–393. doi: 10.4067/S0718-50732008000100003.

Bortolazza, R. and Formoso, C. T. (2006) 'A quantitative analysis of data collected from the last planner system in brazil', in *Proc. 14th Ann. Conf. of the Int'l. Group for Lean Construction*. Santiago de Chile: International Group for Lean Construction, pp. 625–635.

Dave, B., Boddy, S. and Koskela, L. (2013) 'Challenges and opportunities in implementing lean and BIM on an infrastructure project', in *21st Annual Conference of the International Group for Lean Construction 2013, IGLC 2013*, pp. 60–69. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903291737&partnerID=tZOtx3y1.

Fernandes, M. T. and Ribeiro, F. L. (2010) 'Exploring agile methods in construction small and medium enterprises: a case study', *Journal of Enterprise Information Management*, 23(2), pp. 161–180. doi: 10.1108/17410391011019750.

Highsmith, J. (2002) *Agile Software Development Ecosystems*. Bosten: Pearson Education.

Khan, S. and Tzortzopoulos, P. (2014) 'Effects of the interactions between lps and bim on workflow in two building design projects', in *22nd Annual Conference of the International Group for Lean Construction, IGLC 2014*, pp. 933–944. doi: 10.1016/j.autcon.2010.09.013.

Modrich, R.-U. and Cousins, B. C. (2017) 'Digital kanban boards used in desing and 3D coordination', in *Proc. 25th Ann. Conf. of the Int'l. Group for Lean Construction*, pp. 663–670.

Novinsky, M., Nesensohn, C., Ihwas, N. and Haghsheno, S. (2018) 'Combined Application of Earned Value Management and Last Planner System in Construction Projects', in *26th Annual Conference of the International Group for Lean Construction*, pp. 775–785. doi: 10.24928/2018/0491.

Owen, R. L. and Koskela, L. (2006) 'An Agile step forward in project management', in *Proc., 2nd Specialty Conference on Leadership and Management in Construction*, pp. 216–224. doi: ISBN 0-9707869-1-3.

Sacks, R., Koskela, L., Dave, B. A. and Owen, R. (2010) 'Interaction of Lean and Building Information Modeling in Construction', *Journal of Construction Engineering and Management*, 136(9), pp. 968–980. doi: 10.1061/(ASCE)CO.1943-7862.0000203.

Sacks, R., Radosavljevic, M. and Barak, R. (2010) 'Requirements for building information modeling based lean production management systems for construction', *Automation in Construction*. Elsevier B.V., 19(5), pp. 641–655. doi: 10.1016/j.autcon.2010.02.010.

Zhang, L., Li, Y. and Tang, J. (2018) 'The Application of the Earned Value

Management in the Last Planner System for Project Performance Control', in *Proceedings of the 17th International Symposium on Advancement of Construction Management and Real Estate*, pp. 1–12.

Management of design processes and the impact of Project delivery Models (PDM) on Civil construction projects

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Purpose of research

The design process represents around 10%, a relatively small share of construction costs (Evans, Haryott, Haste, & Jones, 1998) however early decisions have an impact on influencing project value, see figure 1. Value can be measured in design and value creation corresponds to the differences in the different phases of design (Gilbertson, 2006). The effect of value is greater in the earlier stages of design, and the ability to influence value creation is lower the closer, value is actually realised, in the construction being taken in use. As a result, knowledge about design and management of design are all vital aspects in order to achieve a smooth and efficient workflow. In addition, knowledge of value and its creation in different phases of design are important in fulfilling the needs but also strategic goals of construction projects.

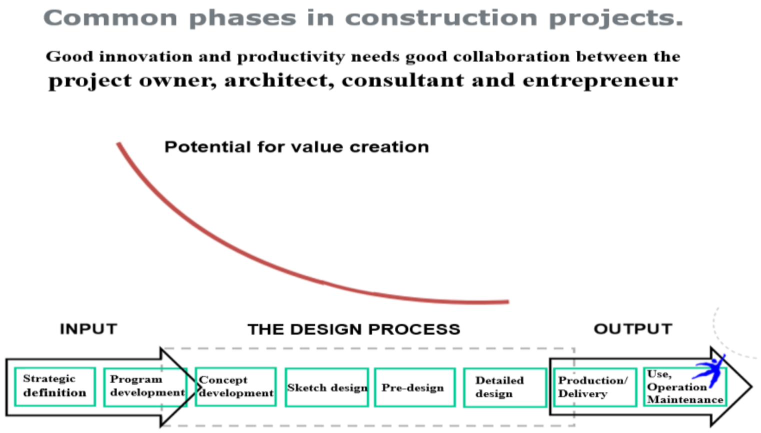

Figure 1 Shows the value creation's effect in the common phases in construction projects. Adapted from: Multiconsult illustration in Arge, Moe, and Westgaard (2010).

Activities performed in projects are of interest to numerous stakeholders, both outside and within the project due to capital investment and a large number of individuals involved from the various organisations. Civil construction projects, in particular, are of interest due to society's contribution to public resources. The way activities are organised is essential in creating value in civil construction projects to stakeholders both outside and within the project.

However Civil construction projects are often complex due to their extensive timeframes, uncertainties, risks, technicalities and interaction with a large number of individuals and organisations. Klagkegg (2017) argues that long-term value plays an important role in achieving sustainable solutions and reducing waste. Value is dependent on decision making and early decision making can influence and help decide how value is created in a project. One has to see the bigger picture whereby the best results are often achieved based on the early decisions taken within a Project's Delivery Model (PDM). However, literature on project delivery models should not be confused with project delivery method or a project's execution model.

Klagkegg defines a project's delivery model as containing four main aspects - Organizational Form (Communication hierarchy), Specification Form (Description of projects deliverables), Structural Form consisting of a Work Break Down Structure (Task breakdown) and a Contractual structure (Explanation of project execution), and Finally The form of Agreement consisting of; a Contracting Strategy (Procurement of services for the project), Contract Format (Type), Conflict Handling, Risk Sharing and Payment (Remuneration).

A similar view is also shared by Toolan (2005) who argues that different contracting models (a grouping for execution models) have an impact, based on the other parts of the PDM, in optimising the design process. Many critical decisions made during the early phases in design have a considerable impact on later stages (Miller, Garvin, Ibbs, & Mahoney, 2000). As a result, good project execution requires good collaboration, coordination and implementation for project success.

Evidence also shows that different aspects of a PDM impact the design process in a project. For example, the BVP process shows that value is created not just through early contractor involvement (ECI) in public projects (Wondimu, Klakegg, Lædre, & Ballard, 2018) but through the identification and mitigation of risk, within the pre-awarding phase (Storteboom, Wondimu, Lohne, & Lædre, 2017), all of which have an effect on the decision making within the design phase in public projects. Bremdal, Haddadi, Bj, Lohne, and Lædre (2017) investigated how designers contribute to creating value in design-build (DB) projects, in other words an execution model highlighting the barriers and requirements necessary in order to maximize value creation in the design process.

In addition, other conditions surrounding the project, like rules and regulations, also have an influence on the project in terms of collaboration and coordination. For example, Public procurement regulation in Norway is governed by a set of rules to ensure fair competition, in the procurement process[2]. This means that previous work experiences gathered through working with other firms or in other words re-hiring of familiar contractors is less likely on public projects as it does not ensure fair competition.

There exists a considerable array of previous literature on value (Drevland & Lohne, 2015). Many authors discuss have subjective definitions on value suggesting that it depends on human interest which changes over time (Thomson, Austin, Devine-Wright, Mills, & Information, 2003)) whereas the term value can be seen as core beliefs, morals and ideals (Kelly, Male, & Graham, 2014; Thomson et al., 2003). However, there are a number of authors that define value more objectively and suggest that value is in the relationships represented by positive and negative consequences and should be seen in the assessment of an object (Thomson et al., 2003) or that value should be defined as having a monetary value through the exchange value or opportunity cost (Moran & Ghoshal, 1996) or alternatively value is defined as an item which can be measured by its valuation compared with another item (Thomson et al., 2003). However, Best and De Valence (1999) define three types of value: Exchange value (monetary), Use value (fit for purpose & beneficial to the user); and Esteem Value (prestige).

[2] https://www.anskaffelser.no/

Yet from the Transformation, Flow, Value (TFV) theory in production value generation is seen as fulfilling the customers' requirements (Lauri Koskela, 2000). Similarly, Womack, Jones, and Roos (1990) from the book, The Machine That Changed The World which shaped Lean thinking in many of today's construction companies, define value, as only being determined by ultimately the customer.

However, LJ Koskela, Bølviken, and Rooke (2013) describe value creation as a potential in design which is captured in production and only realized when the product is taken in use. A similar deduction is also arrived at by Haddadi, Johansen, and Andersen (2016) in that value creation, is clearly linked in building design to the businesses and users of the building. In that value is created only when needs are fulfilled, and strategic goals are achieved. However (Eikeland, 2001) describes creating value in building projects, as using two convergent expressions, Inner Effectivity where minimal time, cost and resources are used to produce a result, in other words, efficiency, and Outer effectivity, in the building processes ability to meet the requirements.

From the 'value creation perspective' there are tools that are important to unpack customer value in the design process. Tools such as;

- Target Value Design (TVD), adapted from target costing in the early 2000, can help in focusing on setting design and cost targets towards the owners intended business plans (Ballard & Morris, 2010; Zimina, Ballard, & Pasquire, 2012);
- Choosing By Advantages (CBA), developed by Suhr (1999), is a decision making tool that can inform the customer of the importance of the advantages between the alternatives (Arroyo, Tommelein, & Ballard, 2012).
- Building Information modelling, introduced into the construction industry in the 1980's to improve efficiency, can help the owner benefit from identifying preconstruction challenges and allowing for early collaboration from multiple design disciplines to help shorten design time, reduce errors and omissions (Eastman, Eastman, Teicholz, & Sacks, 2011; Mejlænder-Larsen, 2019).

However, when addressing value creation in design this is difficult to find, and as a result, this research will fill the gap in not just management of the design process, but the impact project Delivery Models (PDM) have in creating value for the customer (in this case society)

Based on the above mentioned in state of the art this research proposal will explore and investigate complex project-based production in civil engineering projects (see figure 2).

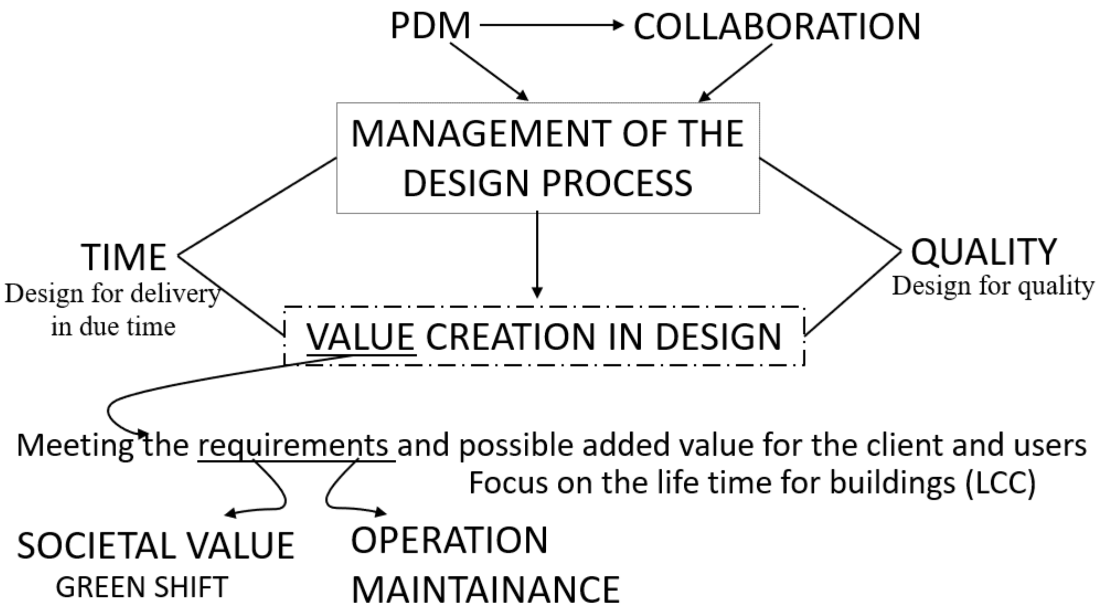

Figure 2 shows a cause and effect diagram showing the focus area of the PhD thesis in achieving Customer value in Civil Engineering projects

This research will be focused on one central research question:

- How are, the methods of managing the design process, fruitful in creating value under different conditions?

Research method:

The proposed dissemination of the PhD will be in the form of 6 publication articles and end an article-based dissertation known as the Kappe event (the joining of the articles)

In order to tackle the research, question the methodology, at the highest level, in other words, the ontology will be based on critical realism. This lies within epistemology between the realms of positivism and constructionism. Where the natural inference (reasoning/logic) is based on Abstraction. Figure 3 shows a V-model graphically representing the PhD project management. The methodology of this PhD will focus on case study research from Yin (1994) by investigating using critical realism (Sayer, 1992), in order to examine the facts and understand the underlying mechanisms which exist but cannot always be seen. The method and techniques for data collection will involve a mix of methods involving the use of in-depth semi-structured interviews and observations, will be conducted on those within the supply chain, to include the owner, project manager, contractors, designer's etcetera, all of which will be analyzed using Nvivo software.

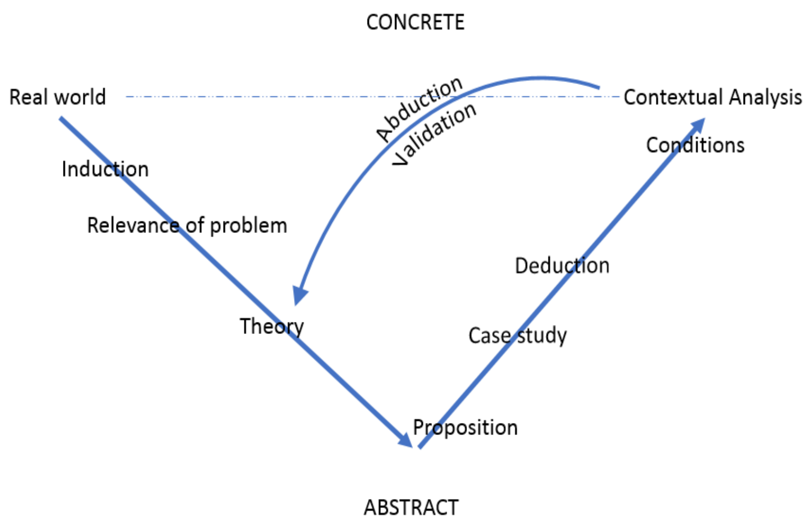

Figure 3 The thesis research design (Based on personal communication *Kalsaas, 2018*)

Survey's will be analyzed using SPSS software. Other documentary material and participatory observation will also be gathered. This will include for example, public presentations, on site visits, documents, including the project contract and guide book, company PowerPoint presentations, government reports, project audits, newspaper articles, and the trade press magazines all of which will be used to understand other mechanisms that might be in force, which might be unobservable under site conditions. Other documentation such as networking in conferences will also be an ongoing form of data collection.

Research Scope and Limitations

The scope of the proposed work is to focus on the individuals and groups that work in civil construction projects.

What are the limitations of the research?

A limitation of the research is the limited number of interviews given time and resources.

Implications:

The fruits of this inquiry will increase insight in the research and academic community but also contribute to creating a greater understanding and persuading firms, management and civil construction projects, of how the arrangement of projects has an impact in maximizing different aspects of value creation in the design process. Effectively this research hopes to influence governmental projects, in increasing efficient arrangement of its construction projects thus creating more value for the customer, government and society.

Expectations from the Summer School

Areas I want feedback is on the viability of this topic (interesting or not interesting) and any literature that could help me with my literature review. I am also interested in people's views on what is value creation, and the impact design has on creating value (if any).

References

Arge, K., Moe, K., & Westgaard, H. (2010). *Prosjekteringsplanlegging og prosjekteringsledelse*. Retrieved from https://www.sintef.no/globalassets/upload/prosjekteringsplanlegging-og--ledelse.pdf

Arroyo, P., Tommelein, I., & Ballard, G. (2012). *Deciding a sustainable alternative by 'choosing by advantages' in the AEC industry*. Paper presented at the

Proc. 20th Conf. of the International Group for Lean Construction (IGLC), San Diego, CA.
Ballard, H., & Morris, P. H. (2010). Maximizing owner value through target value design. *AACE International Transactions, 2010*, 1-16.
Best, R., & De Valence, G. (1999). Value in Building. In R. Best & G. De Valence (Eds.), *Building in value: pre-design issues* (pp. 13-22): Routledge.
Bremdal, J. H., Haddadi, A., Bj, S., Lohne, J., & Lædre, O. (2017). *Value creation in design-build projects: The role of the designers.* Paper presented at the Computer Sciences and Information Technologies (CSIT), 2017 12th International Scientific and Technical Conference on.
Drevland, F., & Lohne, J. (2015). *Nine Tenets on the Nature of Value.* Paper presented at the 23rd Annual Conference of the International Group for Lean Construction. , Perth, Australia.
Eastman, C. M., Eastman, C., Teicholz, P., & Sacks, R. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*: Wiley.
Eikeland, P. T. (2001). *Teoretisk analyse av byggeprosesser. Samspill i byggeprosessen.* Retrieved from
Evans, R., Haryott, R., Haste, N., & Jones, A. (1998). *The long term costs of owning and using buildings*: Royal Academy of Engineering London.
Gilbertson, A. L. (2006). *Briefing: measuring the value of design.* Paper presented at the Proceedings of the Institution of Civil Engineers-Municipal Engineer.
Haddadi, A., Johansen, A., & Andersen, B. (2016). A Conceptual Framework to Enhance Value Creation in Construction Projects. *Procedia Computer Science, 100*, 565-573.
Kelly, J., Male, S., & Graham, D. (2014). *Value management of construction projects*: John Wiley & Sons.
Klagkegg, O. J. (2017). Building arena and project delivery models - framework for value creation. In *Lean construction : forstå og forbedre prosjektbasert produksjon* (pp. 453). Bergen: Fagbokforlaget.
Koskela, L. (2000). *An exploration towards a production theory and its application to construction*: VTT Technical Research Centre of Finland.
Koskela, L., Bølviken, T., & Rooke, J. (2013). *Which are the Wastes of Construction?* Paper presented at the Proceedings for the 21st Annual Conference of the International Group for Lean Construction.
Mejlænder-Larsen, Ø. (2019). *Use of project execution models and BIM in oil and gas projects: searching for relevant improvements for construction.* (PhD), NTNU,
Miller, J. B., Garvin, M. J., Ibbs, C. W., & Mahoney, S. (2000). Toward a new paradigm: Simultaneous use of multiple project delivery methods. *Journal of Management in Engineering, 16*(3), 58-67.
Moran, P., & Ghoshal, S. (1996). *VALUE CREATION BY FIRMS.* Paper presented at the Academy of Management Proceedings.
Sayer, A. (1992). *Method in social science: a realist approach* (2nd ed.). London: Routledge.
Storteboom, A., Wondimu, P., Lohne, J., & Lædre, O. (2017). Best Value Procurement-The Practical Approach In The Netherlands. *Procedia Computer Science, 121*, 398-406.
Suhr, J. (1999). *The Choosing by Advantages Decision making System.* Westport CT: Quorum Books.

Thomson, D. S., Austin, S. A., Devine-Wright, H., Mills, G. R., & Information. (2003). Managing value and quality in design. *Building Research, 31*(5), 334-345.
Womack, J. P., Jones, D. T., & Roos, D. (1990). *Machine that changed the world*: Simon and Schuster.
Wondimu, P. A., Klakegg, O. J., Lædre, O., & Ballard, G. (2018, 2018/07/18). *A comparison of competitive dialogue and best value procurement*. Paper presented at the 26th Annual Conference of the International Group for Lean Construction, Chennai, India.
Yin, R. K. (1994). *Case study research: design and methods*: Sage Publications.
Zimina, D., Ballard, G., & Pasquire, C. (2012). Target value design: using collaboration and a lean approach to reduce construction cost. *Construction Management and Economics, 30*(5), 383-398.

Formalities and human behavior

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Purpose of research

The contextual of this PhD-thesis is the paradoxical situation of the Norwegian construction industry; we have the *know-how* knowledge of construction issues and the digital tools to assist, but productivity does not increase (Knotten, 2015). This phenomenon is described as the productivity paradox; as more is invested in information technology, worker productivity goes down instead of up (Barbosa, 2017; Harris, 1994; Rotman, 2018).

Transformation construction from the current state into a state of being digital updated and thereby effective and sustainable, has proven to be challenging (Barbosa, 2017). The construction industry is of great importance for society, and the general perception is that society will struggle to maintain the current level and function if the industry does not unravel the productivity paradox (Javed et al., 2018).

Although considerable research has been devoted to measurable factors of design management (cost, quality, time), significantly less attention has been paid to the soft factors (trust, psychological safety, collaboration), which exist as a result of the presence of people. A question that needs to be addressed is if construction moves slowly in the digital transformation because humans are not yet on-board this journey. Thus, Figure 1 is an illustration of the high-level proposition the PhD research work from: *"There is a knowledge-gap on the understanding of people's response when digital information and communication technology is fundamentally changing the nature of work."*

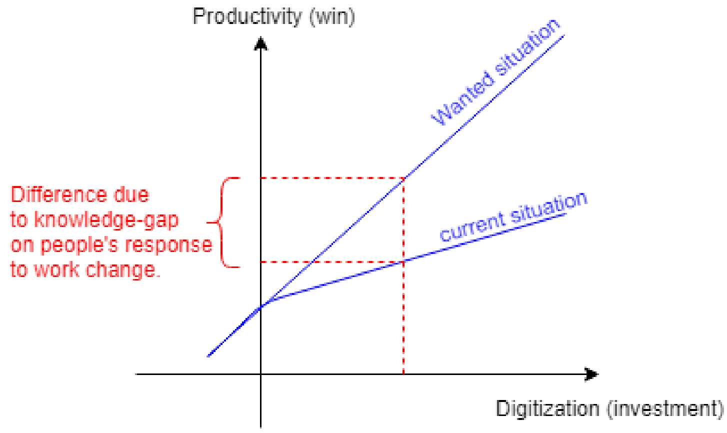

Figure 1: Illustration of the research proposition foundational for the thesis.

If the proposition is found to be true, there is a need to understand why and how to improve the situation. Thus, the two high-level objectives of the thesis are: (*1) understand how formalities influence human behavior* and (2) *understand why people are not utilizing the potential of digital tools*.

To address the described paradoxical situation, the research area of this PhD-thesis is the design phase of the construction project. The design phase is the stage of the project where key decisions regarding technology and formal frameworks are made (Knotten, 2015), and changes have the most influence to the lowest cost for the overall project (Ballard, 2018; Eikeland, 2001).

Hence, the unit of analyses is the design team and the design manager. The connection between the research area, the research topic and the unit of analysis is shown in Figure 2. The light grey symbolizes variables outside my research focus. The red markup illustrates the research area, and the blue is the unit of analysis. More specifically, the unit of analysis is the individuals working within the design phase (ref. target population in Figure 2) and the relationship between the design manager and the design team.

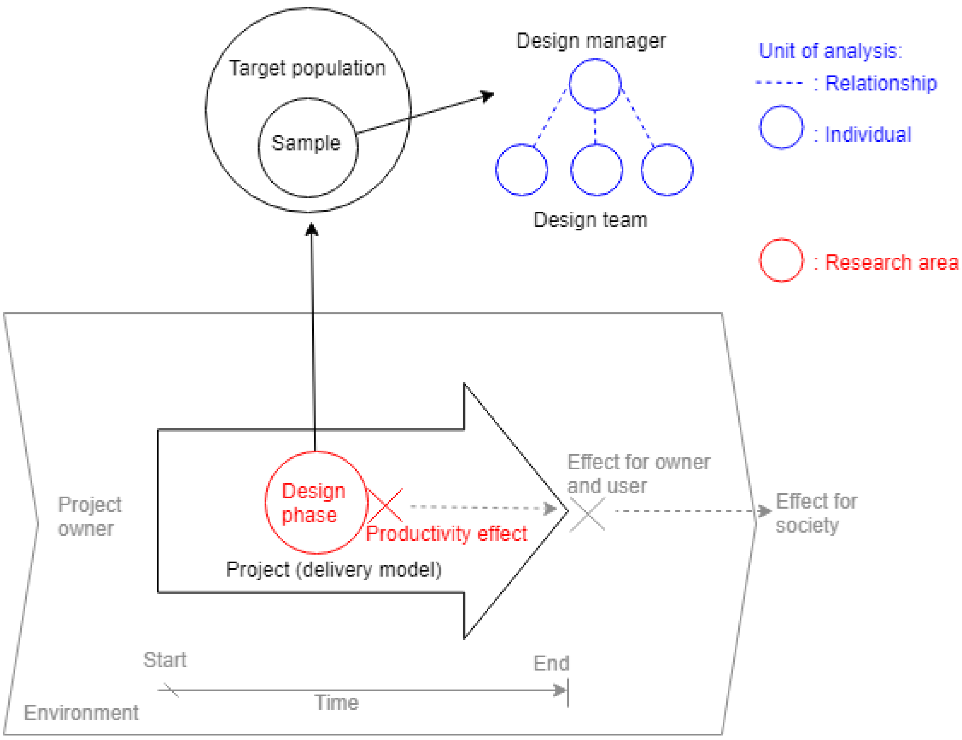

Figure 2: Project model showing the research area and unit of analysis.

To answer the objectives, this thesis studies the relation between three paradoxes, as shown in Figure 3. To measure and understand the level of the paradoxes in case studies, a focused proposition and 11 research questions are listed below.

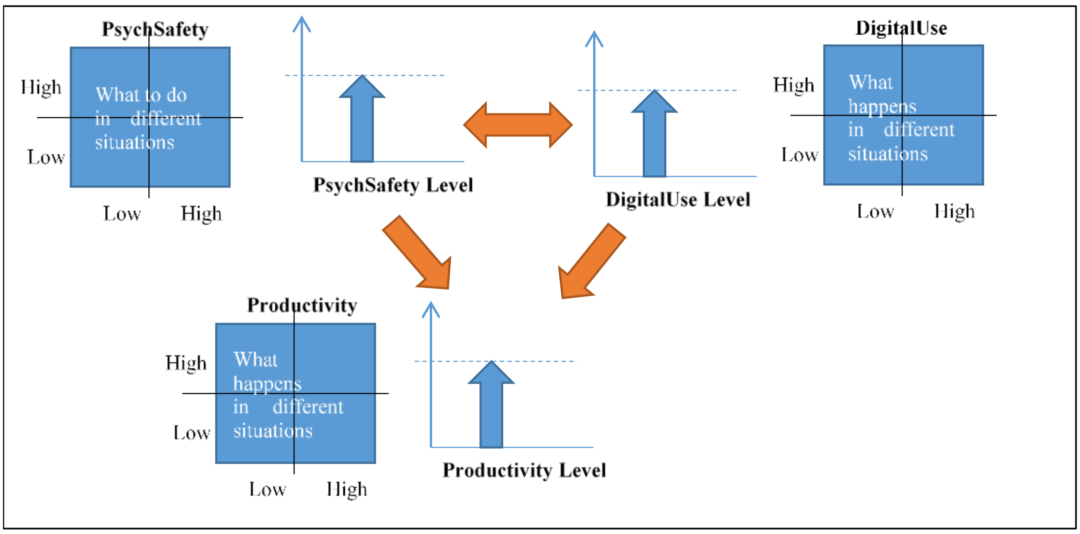

Figure 3: The paradox(s) of the thesis.

Proposistion from high-level industry problem: "There is a knowledge-gap on the understandingof people's response when digital information and communication technology isfundamentally changing the nature of work."

↓

Two objectives: (1) Understand how formalities influence human behavior and the consequences

(2) Understand why people are not utilizing the potential of digital tools

↓

Proposition from contextual setting: "A cooperative project structure emphasizes psychological safety in the design phase, which could contribute to the utilization of digital tools and increased productivity."

↓

Research questions:

RQ1: How do cultural differences (norms and workplaces practices) alter the extent to which different variables matter to psychological safety?

- RQ1a: How do norms and workplace practices influence people's experiences of psychological safety at work?
- RQ1b: To what extent does the team size/diversity alter the level of psychological safety?

Research questions:

RQ2: What are the needed boundary conditions (structure) for the development of a high level of psychological safety?

- RQ2a: How do project structure influence people's experiences of psychological safety at work?

RQ3: What kind of psychological mechanisms contributes to productivity in design teams?

- RQ3a: To what extent do high-level of psychological safety and high productivity occur together?
- RQ3b: To what extent does the team size/diversity alter the need for a high level of psychological safety?
- RQ3c: Is psychological safety sufficient for increasing productivity?

RQ4: Which psychological safety mechanism(s)cultivate the utilization of digital tools?

- RQ4a: To what extent do a high level of psychological safety and a high level of digitalization occur together?

Research method

To answer the research questions, the research anticipated for this PhD-thesis will entail empirical and descriptive work matched with theory, illustrated in Figure 4. Thus, the approach is qualitative research through case studies (Richards, 2009). The theoretical contribution will be to the project management discipline, to the conversation on digital transformation and team safety. To address both the subjective and objective complexity of the research paradox, the researcher is positioned within critical realism (Klakegg, 2016). Thus, the research strategy is explaining within a context, and that observable phenomena provide credible data (Klakegg, 2016; Starbuck, 2005; Vincent and O'Mahoney, 2018).

Secondly, the researcher is perusing relational knowledge, and if needed descriptive knowledge in the presented research questions (Klakegg, 2016). Also, the thesis contributes with know-that knowledge, meaning that the aim is not solutions but increased understanding of the paradox. Thus, the connection between theory and research will be both inductive and abductive. Based on the stated philosophical positioning, the research approach graphically presented in Figure 4.

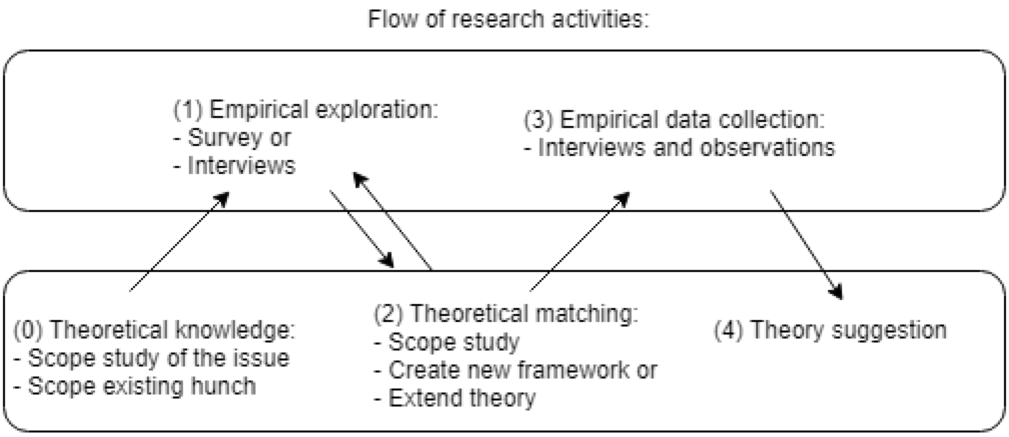

Figure 4: Flow of research activities at an early stage of the PhD-process.

As the figure shows, the research has started with an exploration of theory to identify existing literature. The next step will be to explore the proposition and the research questions through empirical exploration in stage (1). The exploration is planned to be a Norwegian case-study, consisting of interviews, observations, and document analysis. In step (2), a further theoretical study will be conducted to identify theories explaining the findings of the case study. Further, in step (3) an additional data collection will be conducted in California, USA. Thus, the aim is a cross-case analysis (Eisenhardt, 1989) for the final stage of theory suggestion.

For empirical resources, a Norwegian company has opened a project for research and agreed to provide informants. Hence, the first case study will be conducted in June 2019. For the second project, a research exchange to UC Berkeley and the P2SL under Professor Tommeleine is under consideration, where the aim is to do a similar case study as in Norway, as a basis for cross-case analysis.

Research Scope and Limitations

To achieve the objectives stated above, the scope of this PhD-thesis is as follows:

- Investigate designer's and design managers' use of digital communication.
- Investigate what effect management of digital communication has on productivity in the design phase of the project.
- Compare finding across cultures through research exchange.

The success of the research depends on knowledge from disciplines outside an engineer's usual area of work. This could limit the in-depth understanding of the research paradox.

Also, the research will be limited to projects carried out with collaboration-based processes. The contextual setting to identify cases for the research is design as a set of project variables, inspired by the psychological safety literature. The reason for this is that collaborative structures with relational values focus on soft-factors and the use of digital communication (Edmondson, 2004).

Implications:

The theoretical contribution of the Ph.D. thesis is to the ongoing conversation in the project management research-discipline on the effect of new technology on the work process within interdisciplinary teams.

The practical aim of the research is to identify the effect of collaboration in the design phase in the use of digital communication in the design phase of the project. The effect will be a measure of the success of the phase, helping actors to learn and develop.

Expectations from the Summer School

Firstly, I would find it interesting to get feedback on my research topic; formalities and human behavior in the digital transformation. What is being done in the field of Lean construction?

Secondly, I would appreciate getting feedback on how my positioning within critical realism will benefit/ limit my understanding of the research paradox that I am addressing. Also, as I have not started to gather data, feedback on my draft of research activities would be much appreciated. How can I best proceed methodologically to provide practical contributions to my research? As explained, I aim to identify an effect that can be measured and thereby increase the productivity of the design phase.

Also, I would benefit from a conversation regarding how one can best compare the level of digital use, the level of psychological safety, and the level of productivity, which is my research paradigm.

References

Ballard, G., 2018. Positive vs negative iteration in design.

Barbosa, F., 2017. Reinventing construction through a productivity revolution | McKinsey.

Edmondson, A.C., 2004. Psychological Safety, Trust, and Learning in Organizations: A Group-Level Lens, in: Trust and Distrust in Organizations: Dilemmas and Approaches, The Russell Sage Foundation Series on Trust. Russell Sage Foundation, New York, NY, US, pp. 239–272.

Eikeland, P.T., 2001. Teoretisk analyse av byggeprosesser. SiB, Trondheim.

Eisenhardt, K.M., 1989. Building Theories from Case Study Research. Acad. Manage. Rev. 14, 532–550. https://doi.org/10.5465/amr.1989.4308385

Harris, D.H. (Ed.), 1994. Organizational Linkages: Understanding the Productivity Paradox, 1st Edition edition. ed. National Academies Press, Washington, D.C.

Javed, A.A., Pan, W., Chen, L., Zhan, W., 2018. A systemic exploration of drivers for and constraints on construction productivity enhancement. Built Environ. Proj. Asset Manag. 8, 239–252. https://doi.org/10.1108/BEPAM-10-2017-0099

Klakegg, O.J., 2016. Ontology and Epistemology, in: Designs, Methods and Practices for Research of Project Management. Routledge, England, pp. 57-66.

Knotten, V., 2015. Prosjekteringsledelse og BIM - den kloke tegning.

Richards, L., 2009. Handling Qualitative Data: A Practical Guide, Second edition. ed. SAGE Publications Ltd, London.

Rotman, D., 2018. The productivity paradox. MIT Technol. Rev.

Starbuck, W.H., 2005. The Origins of Organization Theory. Oxf. Handb. Organ. Theory. https://doi.org/10.1093/oxfordhb/9780199275250.003.0006

Vincent, S., O'Mahoney, J., 2018. Critical Realism and Qualitative Research: An Introductory Overview, in: The SAGE Handbook of Qualitative Business and Management Research Methods: History and Traditions. SAGE Publications Ltd, 1 Oliver's Yard, 55 City Road London EC1Y 1SP, pp. 201–216. https://doi.org/10.4135/9781526430212.n13

Making Projects Ready: A Model for Integrating Project Production Risk Management with Collaborative Planning & Control

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Main Research Question

"How can project production risk management be integrated with a collaborative planning and control system?"

Help Request

Input and thoughts on the gap identified and the proposed journal papers and approach to complete this research as a PhD.

Background

The integration of "known known" "unknown but known" and "unknown unknown" project production risks and collaborative planning control is absent from prevailing Architectural, Engineering, and Construction (AEC) lean project production management theory and practice. Risks become clearer when reciprocal understanding emerges between all the actors invested in the output of an activity. In collaborative planning, these risks typically emerge from the conversations during pull planning sessions. This is an indication of effective collaboration. Pull planning requires the input of all relevant stakeholders to identify the right sequence of work, understand the handoff criteria of activities and create a shared understanding and sense of ownership of the plan. However, empirical evidence gathered through this research shows that not all stakeholders are engaged at the right time during these sessions and production risks are not identified from 360° perspectives. Furthermore, "unknown known" risks subsequently emerge. These often stop production. While many risks that stop the flow of production are often identified during pull planning, risk identification is not the purpose of the pull planning. If production risks are not identified and treated, production will be interrupted when the risk (constraint) emerges. In collaborative planning theory, the reasons for plan failures are logged, trended, investigated for root causes and counter measured through a Plan-Do-Check-Act/Adjust (PDCA) cycle to remove the blockage from other activities. However, this is a fundamentally a reactive approach and a countermeasure to ineffective make-ready planning. This research has developed a proactive collaborative approach to production risk management that elevates the make-ready process as a pre-requisite to planning and expands current collaborative project production planning and control theory and practice. This approach is called IRMA (Integrated Risk Management Approach).

The Problem

The Last Planner® System (LPS) was developed predominately as a social tool by Ballard and Howell in the 1990's. It is the original collaborative project production planning and control system used in the UK (Egan, 1998) and is effective anywhere humans must coordinate action (Ballard & Tommelein, 2016). While the LPS is the foundation of this study the specific emphasis is on make-ready planning and expanding make-ready theory and practice. Much has been written about the benefits of LPS (e.g. (Skinnarland 2012) (Skinnarland and Yndesdal 2012) (Gehbauer 2008) (Barbosa, et al. 2013) (Fuemana and Puolitaival 2013) (Drysdale 2013) (Fauchier and Alves, Thaís da C. L. 2013)), but less about implementation challenges (Ebbs and Pasquire, 2018a) or underpinning theories that support the system. Indeed, Fauchier and Alves (2013) stress that practice has outpaced the theoretical development of the LPS. The LPS schematic in Figure 1 illustrates the LPS. However, while the LPS is recognised as a system of interconnected parts (Ballard & Tommelein, 2016), partial implementations are increasingly being reported (e.g. (Salvatierra, et al. 2015) (Dave, et al. 2015) (Alarcón, Salvatierra and Letelier 2014) (Alarcón, Salvatierra and Letelier 2014) (Hamzeh 2011b) (Brady, Tzortopoulos and Rooke 2011) (Fireman and Formoso 2013)). Other schematics like Figure 1 appear to show the LPS as a linear process. Figure 1 was developed through this research and is more reflective more of a system approach like Ballard's Lean Project Delivery System (Ballard 2000, 2008). This research has significantly advanced the LPS schematic to emphasize some important elements of the LPS such as learning and action and make-ready planning that are often not practiced (Daniel et al, 2017) or are misapplied and misunderstood.

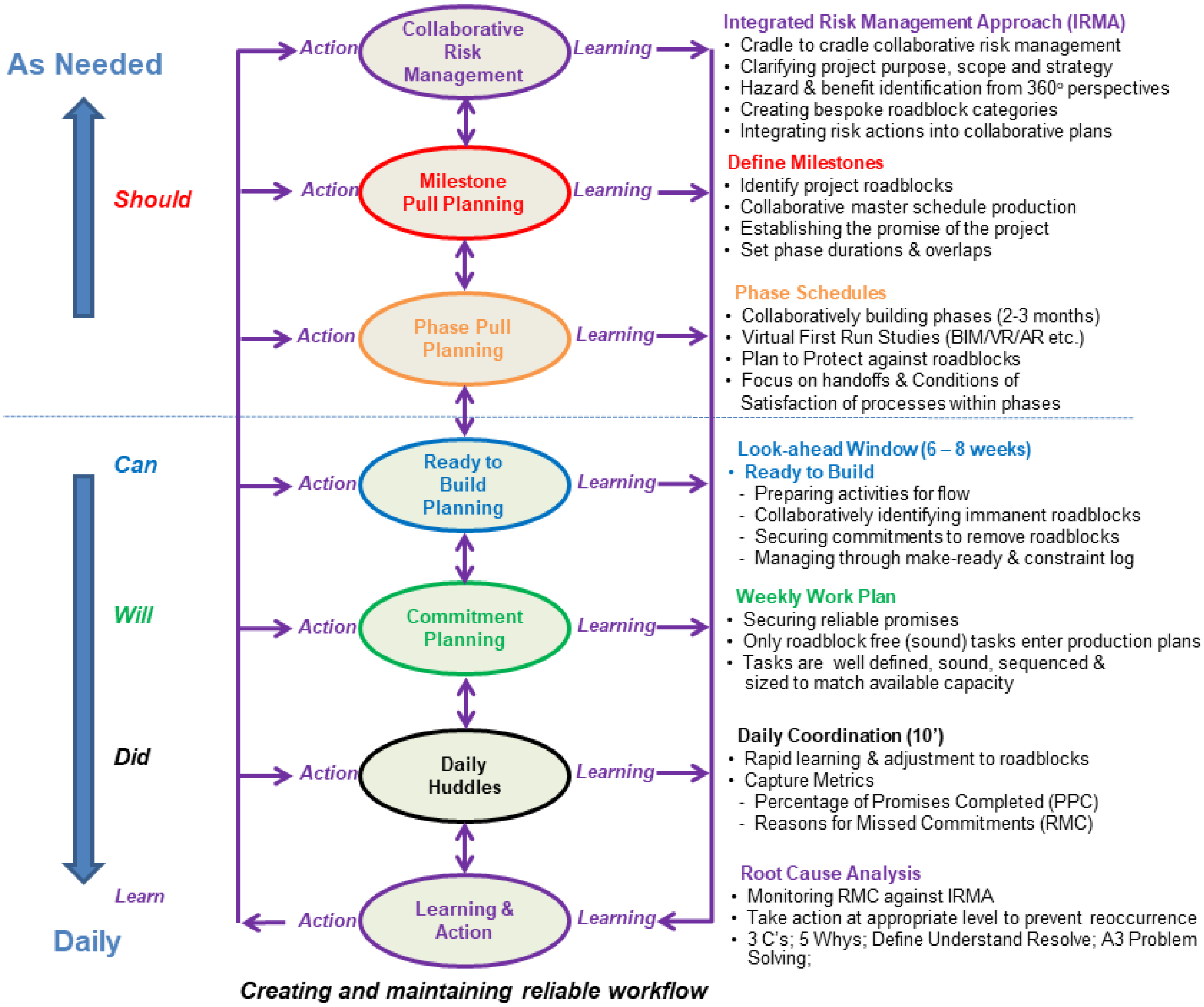

Figure 3: The Last Planner® System Schematic after Ballard, Howell, Macomber and others (adapted from Ebbs & Pasquire, 2019)

For example, the literature states that Make-Ready Planning (originally called Lookahead Planning) is when activities are screened for constraints (production risks). Current theory states that constraints are then removed to prepare for flow (e.g. (Hamzeh 2011a) (Hamzeh, Ballard and Tommelein 2008) (Jang and Kim 2008) (Kim, Y. and Jang 2006) (Lindhard and Wandahl 2012b) (Lindhard and Wandahl 2012a) (Rizk, Hamzeh and Emdanat 2017) (Wehbe and Hamzeh 2013) (Jang and Kim

2007) (LPS workbook, 2007). However, other studies such as Fireman et al. (2013) and Ebbs and Pasquire (2018a; 2018b), along with anecdotal evidence from experienced LPS practitioners shows that the struggle with LPS often begins with make-ready as it is often misunderstood, misapplied and narrowly defined (i.e. identify constraints and act). This study has expanded the current theory of collaborative production planning and control and the make-ready process from an organisational and project level perspective. The research has taken take a deeper look at the social system required to share and treat risks from this project first perspective to produce reliable workflow that ultimately creates reliable project delivery. Current more traditional project delivery methods pass risk (at a cost) through Work Breakdown Structures (WBS), Risk Breakdown Structures (RBS), CPM schedules, and contractual documents.

Relationship of this Research to Current Theory and Practice

Much of the current AEC thinking on traditional and lean theory and practice favours a reductionist view to maximise the efficiency of resources (e.g. labour, materials, equipment). Many scholars and practitioners view the purpose of lean through the reductionist lens which is to eliminate waste from every activity (Ebbs et al 2015, Pasquire and Ebbs, 2018a). These reductionist views do not support a flow-based or system view of projects because spare capacity (e.g. people, equipment, locations etc) act as buffers to variability. Projects implicitly function as multiple but interdependent production and social systems that are typically managed through multiple individual contracts that seek to optimise each piece to reduce overall cost. Risks are identified by each contractor but often without sufficient knowledge or understanding of interdependent work packages. Risk is often passed down the supply chain through contractual arrangements rather than being embraced.

The longitudinal case study with Organisation X highlighted how collaboration and creating a shared understanding of risk was discouraged without explicit contractual arrangements in place. This prevented many production risks from being identified until performance metrics had been agreed and after collaborative planning took place. Multiple versions of the schedule existed and misunderstanding of "next" customer and supplier requirements surfaced during collaborative planning and Flow Walk workshops.

Traditionally, risk sits on risk registers and gets passed through the supply chain using Work Breakdown Structures (WBS), Risk Breakdown Structures (RBS) and CPM schedules (refs). Constraints affecting production are usually dealt with reactively and production is typically managed and controlled through the CPM schedule. Promises to act (or not) on risks, constraints and production activities depend on the conversations and moods of project actors. Furthermore, a pre-requisite to action is a promise which requires either a request or an offer that is made following a grounded or un-grounded assessment (Flores, 2013). Projects can be mapped out as a network of these promises. Reliable promises lead to reliable project delivery, however, reliable promises can only be made once activities are made-ready to execute i.e. free of any risks/constraints known by any project actors (Ebbs and Pasquire, 2018a).

The Countermeasure

Figure 2 proposes a complimentary model to the LPS schematic but specifically for make-ready planning.

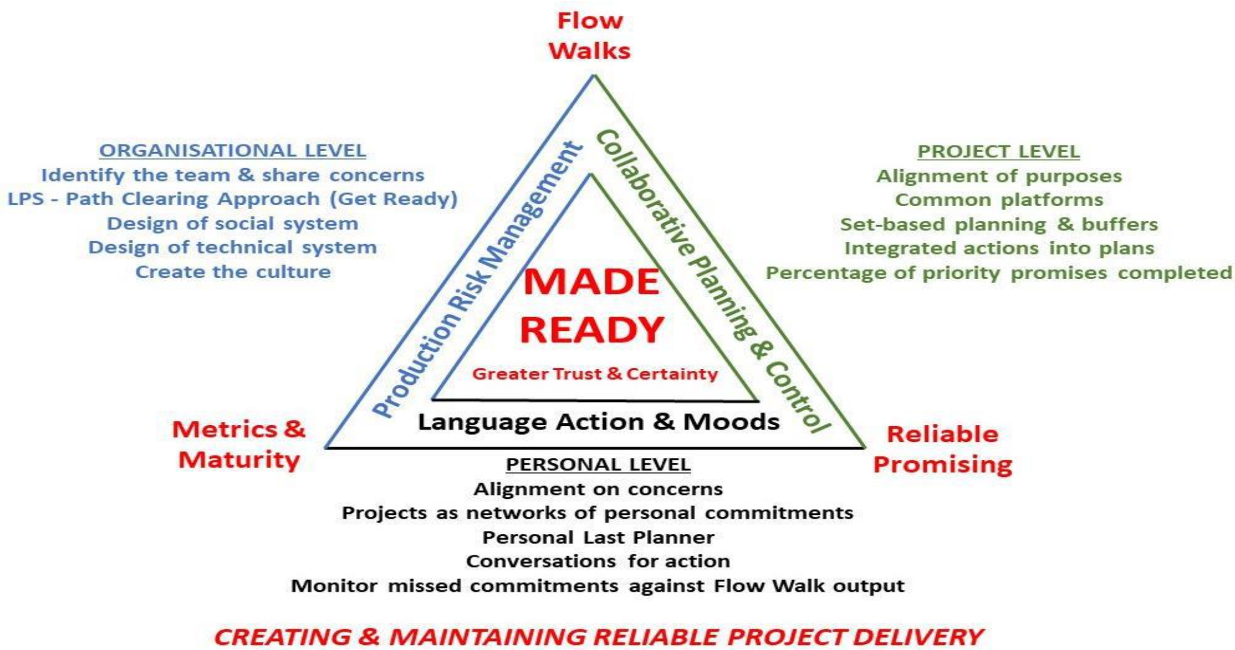

Figure 4: Integrated Model of Production Risk Management with Collaborative Planning & Control (Flow Walks now IRMA)

The model incorporates current make-ready theory and other theories from risk management, supply chain management, software development and other domains. The theories that support the integrated model in Figure 2 include agency, contingency, uncertainty (unknown unknowns), theory of constraints, TFV, and language action perspective theories. The proposed integrated model places make-ready at the heart of the LPS rather than as a step within the system. The study also proposes that new theory is required to support make-ready at organisational, project and personal levels, and has already identified areas for future research and development such as "Personal Last Planner". Furthermore, the model proposes that all actions to treat risks are integrated into production plans and missed commitments are monitored against the output of make-ready as a measure of effectiveness of using the LPS in full. This approach does not form part of current theory and practice.

Contribution to Knowledge and Practice

This research is addressing a gap in knowledge and practice to integrate project production risk management with collaborative production planning and control. The model (Figure 2) requires production risk to be pulled into collaborative project production planning. It also requires missed commitments being monitored (controlled) against the output of collaborative risk identification workshops and subsequent actions taken to treat risk. This is a new approach. In summary, the contribution to knowledge and practice is a cradle to cradle project approach to production risks that places make-ready planning and learning with action at the heart of collaborative production planning to improve production flow.

Publications to date

Four research conference papers have been published in IGLC proceedings since 2015. These are:

- Ebbs at al. (2015). Lean Construction Theory and Practice: An Irish Perspective
- Pasquire & Ebbs (2017). Shared Understanding: The Machine Code in a Socio-Technical System

- Ebbs & Pasquire (2018). The Last Planner® System Path Clearing Approach in Action: A Case Study
- Ebbs & Pasquire (2018). Make-Ready Planning using Flow Walks: A New Approach to Collaboratively Identify Constraints
- Ebbs & Pasquire (2019). A Facilitators' Guide to the Last Planner® System: A Repository of Facilitation Tips for Practitioners

Methods and Techniques

This research is at an advanced stage of development. To date, the research has included mixed methods including focus groups, interviews, online surveys, observational research, action-research, thematic analysis and a systematic literature review to identify the gap in knowledge. Furthermore, the applicant was embedded in a UK Organisation (X) over a 27-month period where the bulk of data gathering and artefact testing took place. The researcher currently works as a consultant with WSP and is incorporating collaborative risk management techniques into practice.

Proposed Journal Publications

- The Theory of Making Projects Ready: A Systematic Literature Review of Risk & Collaborative Planning
- Language Action Perspective & Moods: The Key to Overcoming Resistance to Innovation & New Initiatives?
- Projects Made-Ready: Integrated Risk Management Approach with Collaborative Planning & Control

Proposed IGLC 2020 Publications

- Getting Ready for Make-Ready

- The Facilitators’ Role in the LPS

Proposed Practitioner Guide

- A Facilitators’ Guide to Integrated Risk Management Approach (IRMA)

Reference

Alarcón, L.F., Salvatierra, J.L., and Letelier, J.A., 2014. Using Last Planner Indicators to Identify Early Signs of Project Performance. In: 06/25. Oslo, Norway: pp. 547-558 Available at: http://iglc.net/Papers/Details/1086/pdf http://iglc.net/Papers/Details/1086 .

Ballard, G. 2000a. *The Last Planner System of Production Control*. University of Birmingham, UK.

Ballard, G. 2000b. *Lean Project Delivery System*. Ketchum, ID, US: Lean Construction Institute.

Ballard, G., and Tommelein, I. 2016. *Current Process Benchmark for the Last Planner System*. UC Berkeley: P2SL.[Accessed on: 7 February 2017].

Ballard, G., Kim, Y., Azari, R., & Cho, S., 2012. *Starting from Scratch: A New Project Delivery Paradigm*. Austin, Texas: .

Barbosa, G., Andrade, F., Biotto, C., et al., 2013. Implementing Lean Construction Effectively in a Year in a Construction Project. In: 07/31. Fortaleza, Brazil: pp. 1017-1026 Available at: http://iglc.net/Papers/Details/874/pdf http://iglc.net/Papers/Details/874 .

Brady, D., Tzortopoulos, P., and Rooke, J., 2011. An Examination of the Barriers to Last Planner Implementation. In: 07/13. Lima, Peru: Available at: http://iglc.net/Papers/Details/1109/pdf http://iglc.net/Papers/Details/1109 .

Daniel, E. I., and Pasquire, C. 2017. *Last Planner System Path Clearing Approach (LPS-PCA): An approach to guide clients, main contractors and subcontractors of the LPS*. Nottingham Trent Publications.

Dave, B., Hämäläinen, J., Kemmer, S., et al., 2015. Suggestions to Improve Lean Construction Planning. In: 07/29. Perth, Australia: pp. 193-202 Available at: http://iglc.net/Papers/Details/1225/pdf http://iglc.net/Papers/Details/1225 .

Drysdale, D., 2013. Introducing Lean Improvement into the UK Highways Agency Supply Chain. In: 07/31. Fortaleza, Brazil: pp. 1067-1074 Available at: http://iglc.net/Papers/Details/891/pdf http://iglc.net/Papers/Details/891 .

Ebbs, P., and Pasquire, C. 2019. *A Facilitators Guide to the Last Planner System*. Nottingham Trent Publications

Ebbs, P.J. and and Pasquire, C.L., 2018. Make Ready Planning Using Flow Walks: A New Approach to Collaboratively Identifying Project Constraints. In: 07/18. Chennai, India: pp. 734-743 Available at: http://iglc.net/Papers/Details/1598/pdf http://iglc.net/Papers/Details/1598 .

Ebbs, P.J., Pasquire, C.L., and Daniel, E.I., 2018. The Last Planner® System Path Clearing Approach in Action: A Case Study. In: 07/18. Chennai, India: pp. 724-733 Available at: http://iglc.net/Papers/Details/1597/pdf http://iglc.net/Papers/Details/1597 .

Ebbs, P.J., Sexton, P., Greensmith, D.G., et al., 2015. Lean Construction Theory and Practice: An Irish Perspective. In: 07/29. Perth, Australia: pp. 496-506 Available at: http://iglc.net/Papers/Details/1206/pdf http://iglc.net/Papers/Details/1206 .

Fauchier, D. and Alves, Thaís da C. L., 2013. Last Planner® System Is the Gateway to Lean Behaviors. In: 07/31. Fortaleza, Brazil: pp. 559-568 Available at: http://iglc.net/Papers/Details/898/pdf http://iglc.net/Papers/Details/898 .

Fireman, M.C.T. and Formoso, C.T., 2013. Integrating Production and Quality Control: Monitoring Making-Do and Unfinished Work. In: 07/31. Fortaleza, Brazil: pp. 515-525 Available at: http://iglc.net/Papers/Details/899/pdf http://iglc.net/Papers/Details/899 .

Flores, F. 2013. *Conversations for action and collected essays : Instilling a culture of commitment in working relationships*. US: Createspace.

Flores, G, 2016. *Learning to Learn and the Navigation of Moods: The Meta-Skill for the Acquisition of Skills*. US: Self Published.

Fuemana, J. and Puolitaival, T., 2013. Last Planner System – a Step Towards Improving the Productivity of New Zealand Construction. In: 07/31. Fortaleza, Brazil: pp. 679-688 Available at: http://iglc.net/Papers/Details/903/pdf http://iglc.net/Papers/Details/903 .

Gehbauer, F., 2008. Lean Organization: Exploring Extended Potentials of the Last Planner System. In: 07/16. Manchester, UK: pp. 3-13 Available at: http://iglc.net/Papers/Details/569/pdf http://iglc.net/Papers/Details/569 .

Hamzeh, F.R., 2011a. The Lean Journey: Implementing the Last Planner ® System in Construction. In: 07/13. Lima, Peru: Available at: http://iglc.net/Papers/Details/1105/pdf http://iglc.net/Papers/Details/1105 .

Hamzeh, F.R., Ballard, G., and Tommelein, I.D., 2008. Improving Construction Work Flow – The Connective Role of Lookahead Planning. In: 07/16. Manchester, UK: pp. 635-646 Available at: http://iglc.net/Papers/Details/572/pdf http://iglc.net/Papers/Details/572 .

Jang, J.W. and Kim, Y.W., 2008. The Relationship Between the Make-Ready Process and Project Schedule Performance. In: 07/16. Manchester, UK: pp. 647-656 Available at: http://iglc.net/Papers/Details/577/pdf http://iglc.net/Papers/Details/577 .

Jang, J.W. and Kim, Y., 2007. Use of Percent of Constraint Removal to Measure the Make Ready Process. In: 07/18. East Lansing, Michigan, USA: pp. 529-538 Available at: http://iglc.net/Papers/Details/497/pdf http://iglc.net/Papers/Details/497 .

Jun, L., Qiuzhen, W., and Qingguo, M., 2011. *The effects of project uncertainty and risk management on IS development project performance: A vendor perspective*. Available at: http://www.sciencedirect.com/science/article/pii/S0263786310001468.

Kim, Y. and Jang, J., 2006. Applying Organizational Hierarchical Constraint Analysis to Production Planning. In: 01/01. Santiago, Chile: pp. 371-382 Available at: http://iglc.net/Papers/Details/432/pdf http://iglc.net/Papers/Details/432 .

Lindhard, S. and Wandahl, S., 2012a. Improving the Making Ready Process - Exploring the Preconditions To Work Tasks in Construction. In: 07/18. San Diego, USA: Available at: http://iglc.net/Papers/Details/801/pdf http://iglc.net/Papers/Details/801 .

Lindhard, S. and Wandahl, S., 2012b. The Robust Schedule - A Link to Improved Workflow. In: 07/18. San Diego, USA: Available at: http://iglc.net/Papers/Details/802/pdf http://iglc.net/Papers/Details/802 .

Pasquire, C. and Ebbs, P., 2017. Shared Understanding: The Machine Code of the Social in a Socio-Technical System. In: 07/09. Heraklion, Greece: pp. 365-372 Available at: http://iglc.net/Papers/Details/1409/pdf http://iglc.net/Papers/Details/1409 .

Rizk, L., Hamzeh, F., and Emdanat, S., 2017. Introducing New Capacity Planning Metrics in Production Planning. In: 07/09. Heraklion, Greece: pp. 679-686 Available at: http://iglc.net/Papers/Details/1458/pdf http://iglc.net/Papers/Details/1458 .

Salvatierra1, J.L., Alarcón, L.F., López, A., et al., 2015. Lean Diagnosis for Chilean Construction Industry: Towards More Sustainable Lean Practices and Tools. In: 07/29. Perth, Australia: pp. 642-651 Available at: http://iglc.net/Papers/Details/1208/pdf http://iglc.net/Papers/Details/1208 .

Samad, G.E., Hamzeh, F.R., and Emdanat, S., 2017. Last Planner System – the Need for New Metrics. In: 07/09. Heraklion, Greece: pp. 637-644 Available at: http://iglc.net/Papers/Details/1368/pdf http://iglc.net/Papers/Details/1368 .

Skinnarland, S., 2012. Norwegian Project Managers and Foremen's Experiences of Collaborative Planning. In: 07/18. San Diego, USA: Available at: http://iglc.net/Papers/Details/843/pdf http://iglc.net/Papers/Details/843 .

Skinnarland, S. and Yndesdal, S., 2012. The Last Planner System as a Driver for Knowledge Creation. In: 07/18. San Diego, USA: Available at: http://iglc.net/Papers/Details/844/pdf http://iglc.net/Papers/Details/844 .

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Reference