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HORIZON SCANNING 2020

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EXECUTIVE SUMMARY

This report serves to expose the reader to current research in Lean Construction related fields to identify areas of potential future research. The report does not purport to be exhaustive in this regard, instead curating and highlighting those areas that merit further attention. The methodology adopted for the report first involved the researcher attending the most recent International Group for Lean Construction (IGLC) conference in Oslo in 2014 to gain an overall view of the research currently being conducted. The researcher then reviewed the proceedings. The review was then extended to the three IGLC conferences held in 2011 through to 2013. This enabled the researcher to identify the categories of research topic and their popularity as a trend over time. This highlighted the topics that are well served by research and those topics that are less well served. The topic that was least popular in terms of research papers submitted was Health and Safety. The report follows this finding up with Ian Nowosielski, Senior Health and Safety Advisor, Highways England.

The next section of the report provides a more in depth review and commentary of the IGLC 2014 conference including the Industry Day and Academic Conference. The section is structured in alignment with the themes of IGLC 2014. The author consulted Professor Lauri Koskela for guidance with this section to gain his view on important emerging research themes. The section highlights Target Value Design, Takt Time Planning, Choosing by Advantages, Trust and Lean, Health and Safety as well as commenting on the difficulties of extending organization wide an understanding of the Lean philosophy, to this end Lean games are considered as a potential tool to enable this. Another consideration being that increased focus on applying Lean on downstream activities and processes could be explored more fully. The report concludes with a series of recommendations for further work.

ACKNOWLEDGEMENTS

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INTRODUCTION

The purpose of this report is to review current research in Lean Construction related fields to identify areas of potential interest over the next five years. The report does not purport to contain all of the areas that may exist but attempts to curate those that merit further exploration. This involved looking at what has gone before and what is going on currently in order to consider what may evolve in the future. To this end the author attended the 2014 annual meeting of the International Group for Lean Construction (IGLC) to speak to key individuals and to 'Go and See' current research being presented.

OVERVIEW - IGLC 2014

There were approximately 124 papers submitted by academics and practitioners to the conference and the themes and topics included theory (8 papers), sustainability (4 papers), contract and cost management (7 papers), IPD (7 papers), value (5 papers), design management (12 papers), production planning and control (21 papers), waste in construction (12 papers), BIM and Lean (4 papers), Industrialisation, prefabrication, assembly and open building (5 papers), supply chain management (5 papers), people culture and change (8 papers), safety and Lean (1 paper), teaching Lean construction (5 Papers) and industry papers (20 papers). Themes ranked in order of number of papers included in the proceedings:

- 1st Production Planning and Control
- 2nd Waste in Construction
- 2nd Design Management
- 4th People, Culture and Change

4th Theory
6th Contract and Cost Management
6th Integrated Project Delivery
8th Value in Construction
8th Teaching Lean Construction
8th Supply Chain Management
8th Industrialisation, Prefabrication, Assembly and Open Building
12th Sustainability, Green and Lean
12th Building Information Modelling (BIM) and Lean
14th Safety and Lean

The above ranking consists of the papers submitted to the conference and how they were allocated into the conference themes. It can be seen that production planning and control is the most populated of the themes, with waste and design management coming joint second. This is to be expected as these areas commonly focus on Lean tools. The themes in joint fourth position in the ranking are related to people, culture, change and theory that tackle the philosophical end of the Lean continuum. This is important, as one of the cornerstones to implementing Lean is a sound understanding of the philosophical issues prior to implementing the Lean tools (Liker, 2003). The other themes are represented in accordance with the author's expectations with the exception of the BIM theme, which the author expected to be more highly populated. The author's view on the lack of papers on safety is considered later in the report. The overall impression the author gained from the conference is that there is still a predominant research focus on Lean construction tools and software rather than the underlying philosophy of Lean which is a key implementation consideration.

OVERVIEW - IGLC 2011 TO 2014

This led the author to conduct a further review of the research topics at three IGLC conferences prior to Oslo 2014 to see if those presented in 2014 were representative of previous research trends. These conferences were IGLC 21 in Fortaleza, Brazil 2013, IGLC 20 in San Diego, USA 2012 and IGLC 19 in Lima, Peru in 2011. The author reviewed a combination of the conference proceedings and the papers listed for each conference on www.IGLC.Net. It became apparent that the conferences were all arranged into similar groups of themes with slight variations over the course of the 4 conferences. After reviewing the themes of all 4 conferences the author for purposes of comparison identified 7 main categories of theme:

1. Design and Production Management and Control. – This category includes papers relating to IPD, Production Planning and Control, Design Management, Waste Management and Production Design.
2. Theory – This category includes papers on the Theory of Lean and the teaching

- of Lean.
3. Supply Chain and Contract Management – This category includes papers on managing the Supply Chain, Cost Control, Contract Management and Prefabrication.
 4. Health and Safety.
 5. BIM and Lean.
 6. Sustainability – This category includes papers on environmental issues.
 7. People and Culture.

The total number of papers submitted to the 4 IGLC conferences from 2011-2014 was 397. The number of papers in each category submitted to these conferences is shown in Fig.1. The category themes across the four year period were ranked and found to be similar to the ranking of the paper themes from IGLC 2014. Thus indicating over time the themes have retained similar levels of popularity. Two notable exceptions being that the BIM and Lean theme and the Theory theme were less popular as topics in 2014. Also notably Health and Safety (10 papers out of 397) and Sustainability (22 Papers out of 397) are the two least represented categories of paper submissions over the period.

- 1st Design and Production Management and Control (180/397 Papers)
- 2nd Theory (60/397 Papers)
- 3rd Supply Chain and Contract Management (52/397 Papers)
- 4th People and Culture (49/397 Papers)
- 5th BIM and Lean (24/397 Papers)
- 6th Sustainability (22/397 Papers)
- 7th Health and Safety (10/397 Papers)

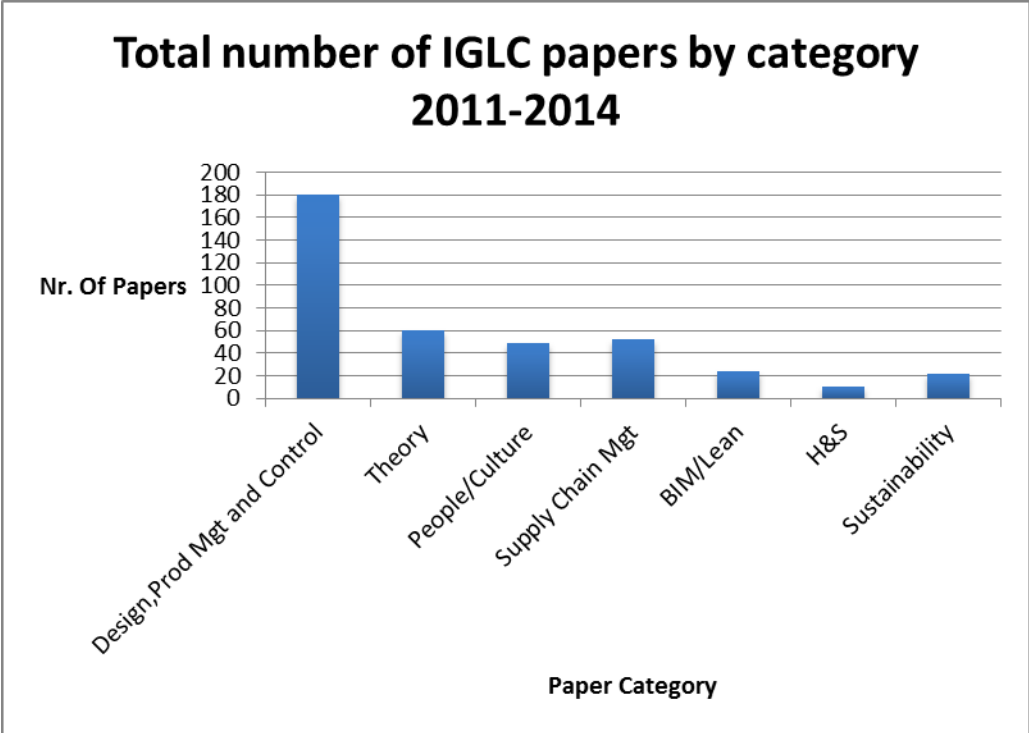


Figure 1. Number of IGLC Papers by Category 2011-2014

The number of IGLC Paper submissions by category and year are shown in Fig. 2. Health and Safety is again notable with regards to the low and declining number of papers on this topic submitted throughout the period.

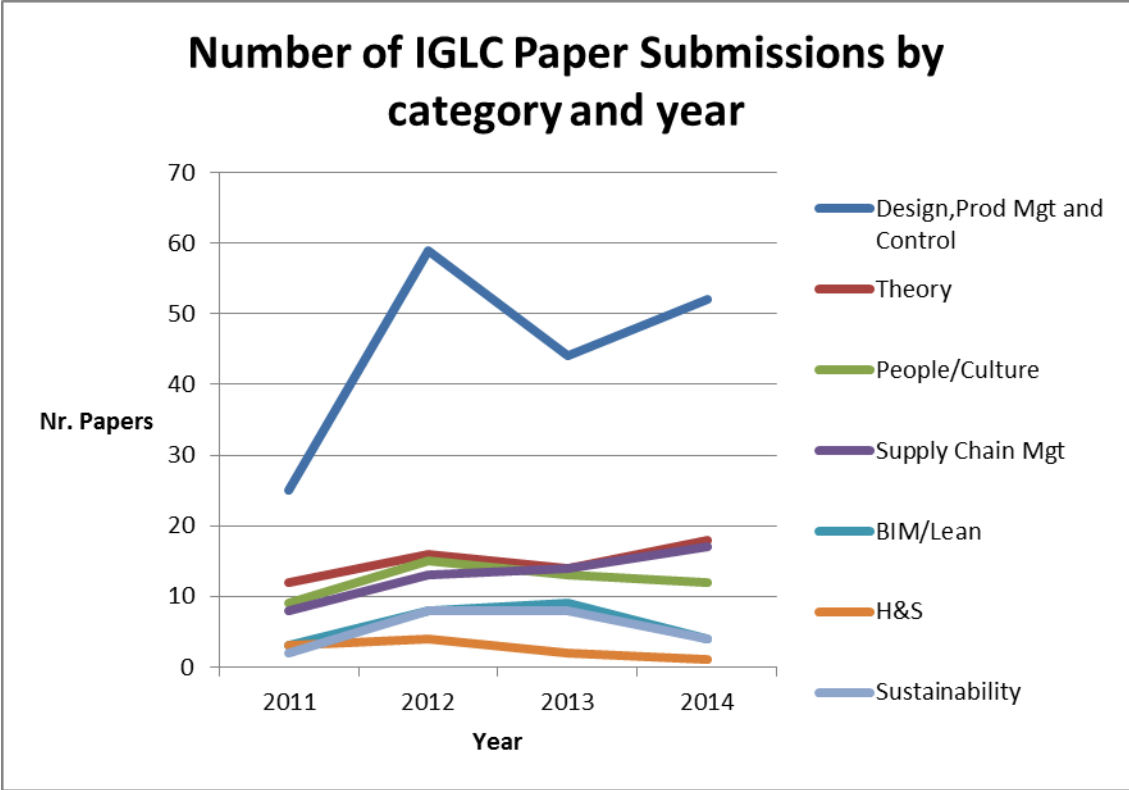


Figure 1. Number of IGLC Paper Submissions by category and year

CONFERENCE REVIEW - IGLC OSLO 2014 INDUSTRY SESSION

As mentioned above, in order to look forward it is also important to look back and the first session of the Industry day was entitled "how it all began" and Luis Alarcon, Sven Bertelsen, Glenn Ballard and Lauri Koskela were invited to tell their stories of how they became involved with working in the field of Lean Construction.

Glenn Ballard recounted his work background of industrial construction and how this informed his development of the Last Planner system. He was working at Stanford in the early 1990's when he met Lauri Koskela who was a visiting Scholar. Glenn recalls that they were both trying to understand how the construction industry could improve productivity as they were aware that improvements in performance could be made and waste could be reduced. From these discussions they coined the term 'Lean Construction'. Lauri Koskela recalled at the end of the 1980's he was working at VTT in Finland on high technology in construction which inspired him to research processes and how they could be streamlined. This research led him to the understanding that some people view process in an atemporal way as an input, transformation and output and others view processes in a temporal way focusing on the process as what happens over time. Koskela used this as the basis for further research into understanding how to relate the Toyota Production System to construction processes, the result of this work was the Transformation Flow and Value Theory. Sven Bertelsen recounted that in the early 1990's his work focused on redefining the role of the building material supplier. He was influenced by Last Planner and the TFV theory and he considers these two developments to be the basis of the implementation of Lean in Construction.

The panel were asked for their view on what Lean Construction is about? Glenn Ballard commented that in Lean construction *'Doers plan and when things go wrong we focus on the process rather than the person, lean leaders teach and coach and clients get value for money, designers and builders make more profit, and people actually want to come to work'*. Luis Alarcon continued that *'you need to give people the authority to continually improve, problem solve and make decisions'*. Koskela concluded by emphasising the importance of waste and about eliminating waste from the process. He asked *'what are we not doing if we are not eliminating waste, we are not optimising. There is always a gap between the optimum ideal and the real situation'*.

The session closed by Koskela commenting that he felt the International Group for Lean Construction is a network *'formed by content looking for structure, rather than structure looking for content'*.

The full discussion can be viewed here:

<https://www.youtube.com/watch?v=9ouHJ91CUy0>

The industry day continued with a presentation from Glenn Ballard and Alan Mossman on the Last Planner System. Ballard stated that Lean is all about how to understand construction. The eight wastes aren't necessarily wastes but places to start looking for where waste exists in your construction processes. He stated that the aim was to make it simpler and easier and less costly to build and to reduce the dramatic value loss through the value chain. He continued that *'we only do work well when the work is well-defined and we work to the correct quality, to the correct sequence of the work and it is sized to the capability of those performing the work'*. Alan Mossman commented it is to *'save lives, limbs and mental health'*.

Further Reading.

<http://www.leanconstruction.org/media/docs/Mossman-Last-Planner>

This was followed with a presentation on a Danish Case Study: 'Trust Based Lean' by Gunde Odgaard, Head of BAT-secretariat Federation of Building, Construction and Wood Workers' Unions (BAT) Denmark and Lars Scheibel, Production director NCC Construction, Denmark. Their presentation commented that there are common interests between employers and construction workers. From the trade union's perspective they are seeking improved well-being for building workers, a focus on training and lifelong learning, and combating the grey economy in the job market. The employers or clients are looking for shorter construction times, greater customer satisfaction and increased competitive strength. It is believed that the shared interests between these two groups such as increased job satisfaction, fewer conflicts, fewer defects, increased earnings, fewer accidents and continuous professional development could be aided by effective Lean Construction implementation. They presented a project on Trust Based Lean, which was a 9 month pilot study on a concreting unit in NCC Construction. The project focused on the collaboration between employers and construction workers and was supported by representatives from trade unions and the employers' organization. The overall aim of the project was to develop new methods of increasing productivity, efficiency, quality and job satisfaction, improvement of management and collaboration processes, strengthening competitiveness, ensuring diffusion and to develop a next practice standard.

The project drew on principles from Lean such as value for the customer, visibility of the value stream, flow, pull through the value chain, continuous improvement and elimination of waste. It also drew on principles of trust such as strong leadership and respect, a cooperation culture, involvement and motivation, delegation, visibility, transparency and openness. The work identified that trust based lean starts from the bottom up and is based on greater involvement of the construction workers by encouraging them to come up with ideas of improvement themselves and providing

them with on the job training and skills development. As a result the study found that job satisfaction increased, construction completion times improved, waste decreased and salaries rose. The project has developed a toolbox to enable the following; weekly board meetings, 5S, planning, value stream analysis, cooperation, job satisfaction and the work atmosphere on the site, competency management, waste identification and self-management.

The next presentation given by Pekka Petäjaniemi, Director, Finnish Transport Agency and Jaakko Kivi, Director, Lemminkäinen Oyj focused on a tunneling project in Tampere, Finland. They described that strategic decisions were taken early in the project to integrate owners, designers and contractors to consider risks and opportunities with every participant. The project used target value design and consisted of one joint agreement between all five parties where project success is shared. They found that unanimous decisionmaking, openness and trust were not a problem and that the commercial model must be understood clearly by all parties. There was a further presentation from Scandinavia, this time Norway on collaborative planning from Trond Bølviken of Veidekke who made a significant comment. He simply stated that his company has made a strategic decision to only take part in projects where they can be part of the design phase thus ensuring that they were able to influence customer value generation.

A later presentation by Steinar Krogstad, National Secretary, Norwegian Union for construction workers stated that implementing lean provides a good workplace environment for its members. He continued that the Union's objective is to ensure good wages and working conditions for our members and that members supply the union with the power to negotiate but this also depends on their value creation. He commented that productivity is important for the trade union movement and to enable this it is important that working people are well-managed by financially healthy companies that can provide them with a safe and constantly improving livelihood. Therefore, it is an important task for trade unions in every business and industry to contribute to raising productivity. They promote, skills at all levels, cooperation at all levels and permanent employment.

The final presentation of the day was given by Derek Drysdale who described the Lean Implementation work of the Highways Agency. He commented that a key issue is sustaining lean implementations and described the Highways Agency Lean Maturity Assessment Toolkit (HALMAT) as one approach to this. He also commented on the humanistic aspect of Lean.

CONFERENCE REVIEW IGLC 2014 CONFERENCE SESSIONS

THEORY

The theory stream of the conference contained eight papers focusing on how to implement Lean Construction. In the author's view this is one of the most important issues facing companies today as there is understanding and awareness of the Lean Tools and Techniques but less understanding of the actual philosophical perspective and cultural issues. In Liker's recent text *Toyota Under Fire* (Liker, 2011) he cites the key characteristic of Toyota that enabled them the resiliency to weather the recent recall crisis is their culture embedded within the TPS philosophy. The key question managers should ask is to how to impart this philosophy within their organization and within their teams. From teaching Lean construction at Masters Degree level the author is aware that the lean journey is a lifelong one that once started will enthrall and engage the learner, but how does one encourage the first steps of this journey to be taken? Soren Wandahl's presentation on the challenges of Implementing Lean Construction stated that insufficient knowledge of what Lean is to be a significant barrier. He commented that individuals often claimed to be using Lean and weren't and conversely he presented a survey which found that many of the respondents were using lean without knowing it (Wandahl, 2014). He also commented that throughout the world cultures are different which affects their absorptive capacity to adopt Lean (this echoes the work of Geert Hofstede's who has studied cross national cultures).

There was a paper discussing how Lean is applied on construction projects in Japan (Inokuma, 2014). Inokuma stated that many Japanese construction companies undertake lean practices as if its business as usual as they are embedded in their culture, even though they may not always be aware they are doing so. A consequence of this is that Inokuma felt that Lean construction networks were not well established in Japan. This was followed by a paper from Koskela (Koskela, 2014), analysing construction project management research which continued the theme of Koskela's earlier paper 'the theory of project management is obsolete' exploring the current deficiencies in CPM research and how it is to some degree ineffective. This was a challenge to the research community to continuously improve CPM research.

This was followed by a presentation from Laura Pekuri (Pekuri, 2014) applying the TFV (Transformation, Flow, Value) theory to analyzing the problem of procurement in construction. The issues relating to flow were viewed as the uncertainty faced by both parties as to what events will happen after contracts are signed. The Transformation element was related to the asymmetry of economic information and Value was clearly related to value loss throughout the procurement process.

A further paper from Aki Pekuri (Pekuri, 2014) presented another facet of Toyota other than the well researched Toyota Production System. This presentation focused on other

parts of the Toyota organization including its business model, organization structure and how other parts of the organization such as the HR department are vital parts of the overall Toyota Value creation system. Continuing this theme a presentation by Michael Schmidt (Schmidt, 2014) explored organization design towards lean. As the design of the structure of an organization or project has a direct impact on the wastes that are built into this structure it is important to consider this thoroughly. The author conducted a similar exercise at the University of Salford in 2006 analysing the committee structure of the University. The analysis found that there was significant potential to reduce the number of meetings that were held as many committees were duplicating each others work.

Rolf Simonsen's (Simonsen, 2014) presentation asked 'Is Lean Construction Another Fading Management Concept?' He encouraged the audience to consider how Lean management can be sustained over the long term as various new management approaches compete for attention. He described a cycle of discovery, acceptance, digestion and decline. The research comprised of a questionnaire to industry investigating how to sustain Lean Construction. The findings stated that there are several barriers to overcome. The first being value is sometimes a challenging concept to sell especially in times of recession as there is a danger of clients reverting back to lowest cost tendering. The second being that focusing on the front end of projects to ensure that the design is correct prior to construction and reducing the prevalence of making do is also a difficult concept to sell to some clients. The third being that sometimes it is difficult to find objective evidence of the benefits of lean especially in a quantitative environment when many of the benefits may be qualitative and hard to measure. This is partly linked to the fourth issue in that many quick wins have already been identified. The presentation suggested a number of ways to try and overcome these challenges, by identifying ways to increase value, develop mechanisms to accumulate knowledge and foster learning by linking international and national initiatives, networks and people.

SUSTAINABILITY, GREEN AND LEAN

The Sustainability, Green and Lean theme consisted of 4 papers including a green construction assessment model that applied the TFV theory to promote green building (Abduh, 2014). This was followed by a paper presenting a conceptual framework exploring the synergies between BIM and Lean as an enabler for green construction (Ahuja, 2014). The third paper presented the potential environmental benefits of implementing lean as construction is a major polluter and creator of environmental waste. If the wasteful activities are reduced then the environmental impact in theory could be minimised. A case study of two healthcare facilities in Arizona were presented to consider the impact of an IPD BIM Lean implementation (Ghosh, 2014). The final paper continued this theme of reducing environmental impact by considering the

philosophical and ethical issues of increasing the use of mechanization thus avoiding the need for human labour even though in general the amount of human labour is increasing (Salem, 2014). This caused the author of this report to recall a visit to South Africa in 2007 when he saw 7 construction workers in a row in the street digging holes with pick axes. At breakfast they had just started, by lunch they were down to their thighs and by the afternoon they were up to their shoulders, the holes almost completed. The author contemplated the ethics of this when mechanical diggers could save this hard labour and then realised that if a digger had been used these 7 men would be without work.

CONTRACT AND COST MANAGEMENT

In this stream 7 papers were presented on topics ranging from earned value management, target value design / target costing, contingency management, front-end concentration and PPP. Earned value management (EVM) is a technique that compares planned against actual physical, financial and time progress.

According to Savio Sampaio de Melo et al (Sampaio de Melo , 2014) in the paper 'Target Costing in Construction: A Comparative Study' Target costing is derived from the New Product Development (NPD) process in the manufacturing industry. It considers the whole lifecycle of a product in terms of the client requirements (in the form of targets) prior to the manufacturing phase. It is considered that during the pre manufacturing phase the potential for creating value for the client is at the maximum. The paper considers the challenge of adapting a new product development approach in the manufacturing context to the project based context of construction. Savio Sampaio de Melo et al presents Cooper and Slagmulder's (1997) generic structure for the Target Costing process *'which is comprised of market-driven costing, product-level target costing and component-level of target costing. The market-driven costing plays a key role in determining allowable costs. The product-level target costing disciplines and focuses the creativity of the product designers on achieving the cost aspect of this objective. The component-level of target costing helps discipline and focus the creativity of the suppliers in ways beneficial to the firms'*. When considering its application to construction Savio Sampaio de Melo et al comment from Nicolini et al. 2000 *'the main barrier to its adoption in construction derives from the UK commercial and cost management practice'*. Ballard 2004 reports on a successful implementation in Construction. The Savio Sampaio de Melo et al paper concludes that there is scope for applying target costing to construction and the attempts will continue. They point out the area of supplier base strategy that includes the factors of *'Degree of horizontal integration, Power over major suppliers and Nature of supplier relation'* as an area for further study and also the area of client requirements capture. They suggest the areas related to bidding and contractual issues may be more challenging due to the nature of contracts.

In the paper 'Target Value Design as a Method for Controlling Project Cost Overruns' by Do et al, the authors describe Target Value Design (TVD) as an adaption of Target Costing and show through analysis of the results from 47 case studies that implementing TVD reduces the likelihood of project cost overruns.

INTEGRATED PROJECT DELIVERY

The theme on Integrated Project Delivery included 7 Papers focussing on the impact of Non-Traditional Stakeholder Involvement on Project Quality, four phase project delivery, a hospital case study presenting lessons learned on the make ready process, a tool for optimising workflow, trust and a case study on IPD implementation in the Middle East.

VALUE IN CONSTRUCTION

The stream focussing on Value in Construction contained 5 papers focusing on perceived value, improving FM processes through standardisation, capturing value on low income housing, A case study on value generation in Columbia and on increasing the adoption of Lean Construction by Contractors.

DESIGN MANAGEMENT

The Design Management stream contained 12 papers focussing on choosing by advantages, multi criteria decision aids, lean briefing, value stream mapping related to house building, achieving predictability in engineering, early contractor involvement and Lean design processes.

Choosing by Advantages (CBA) is a decision making method developed by Jim Suhr and is described in his book "The Choosing by Advantages Decision Making System" (Suhr, 1999). Suhr focusses on advantages because he considers a disadvantage to be the same as an advantage, the only difference is with the perspective that you look at it with. He considers choosing by '*advantages and disadvantages*' to be double counting and therefore not a sound method of decision-making. Therefore Suhr developed the method of Choosing by Advantages based on the premise that decisions must be based on the importance of advantages.

The method was developed due to Suhr's observation that people make choices every day and that making 'sound' choices is very important. He states that often people do not make sound choices because they do not use correct data and they do not use data

correctly. He refers to this as '*not using sound methods*' which may include omitting key facts, multiple counting, distortion of facts, distortion of viewpoints. Suhr considers the role of decision-making an important discipline in its own right and one that is not naturally acquired but one that takes time to learn. He believes it is not "*what to decide but how to decide*". According to Suhr (1999), the benefits of sound decision-making and choosing by advantages are '*that sound decisions save time, they have better outcomes, they use resources in a more effective way, there are higher levels of job satisfaction resulting in less stress and happier people. Sound decisions are more likely to be implemented. Because decisions affect other people it is very important for our future that decisions are made soundly*'.

The CBA process starts at the point a decision is needed and ends when it has been implemented and evaluated. Suhr outlines four '*cornerstone principles*' of CBA. The first and what he refers to as the pivotal cornerstone principle is that "*to constantly make sound decisions decision makers must learn and skillfully use sound methods of decision making*". The second is that "*the fundamental role of sound decision making is that decisions must be based on the importance of advantages*". The third is the principle of anchoring: "*decisions must be anchored to the relevant facts*". The fourth is the methods principle: "*different types of decisions call for different sound methods of decision-making*".

Together with these four principles there are also four concepts that need to be understood in order to use the technique:

1. Factor: is an element of a decision and is also a container for criteria, attributes and advantages.
2. Criterion: is a decision rule, and a standard on which to base a judgment, decision which guides further decision-making.
3. Attribute: which is a characteristic or a consequence of one alternative.
4. Advantage: which is a difference between the attributes of two alternatives.

In Suhr's text he gives the example of choosing between two different canoes and the process involves initially identifying the significant differences between the two canoes, these were weight, smoothness, colour, stability and keel depth. These formed the factors and for each of these the attributes were identified. For example, the stability of canoe A was excellent and for canoe B was very good. The process then decides the advantages between the alternatives. For example the difference in advantage between the stability of the two canoes was 'slightly greater' as in reality the difference between excellent and very good is that excellent is 'slightly greater' than very good. The process then continues to look at all the advantages to identify the paramount advantage which is used to form an anchor point to weigh the other advantages against. By doing this it is possible to choose the alternative with the greatest total importance of advantages. This is followed by a reconsideration phase and an implementation phase. This example is summarized for explanation of the process and represents one of many methods in

Suhr's book. This method is called the 'tabular format for two alternatives'.

Glen Ballard and Paz Arroyo, presented a paper and workshop at the conference on applying CBA to the AEC Industry (Arroyo et al, 2014). This is a strand of work that has been ongoing for approximately 5 years and appears to be gaining traction hence its inclusion and in this report. Arroyo et al report that Parrish and Tommelein (2009) stated that CBA is a sound system to make decisions using well-defined vocabulary to ensure clarity and transparency in the decision-making process. Examples of CBA applications in the AEC industry are: for design and construction decision-making (Parrish and Tommelein 2009), for selecting a green roof (Grant 2007), for analyzing a viscous damping wall system (Nguyen et al. 2009). Arroyo et al (2014) report in their paper that *'decision-making lies at the heart of many human endeavors, including designing and constructing'* and according to Suhr (1999), *'decision making methods produce decisions, decisions trigger actions, and finally actions cause outcomes. Consequently, if the outcomes matter then the selection of the decision-making method also matters'*. Arroyo et al (2014) continue that *'decision making in the AEC industry appears to often use 'decide, present, and defend' approaches; resulting in decisions made without formal discussion, rigorous analysis, nor documentation'*. Arroyo et al recommend that CBA be incorporated in the lean construction body of knowledge relating to Set-Based Design (SBD), *'the design team should delay decisions in order to allow time to explore and evaluate as many feasible design solutions as possible, and also make sure that all factors and criteria are applied consistently to all alternatives'*.

PRODUCTION PLANNING AND CONTROL

This stream contained the most papers at slightly over 20. This indicates that this area is still the most fertile ground for researchers to study. The topics presented in this stream covered Last Planner and collaborative planning, Information flow and control, collaborative design management, digital kanban, visual control, line of balance and Takt-time planning.

A paper on Takt-time planning was presented by Frandson et al (2014) reporting on a case study on the Cathedral Hill Hospital Project in the United States to demonstrate how Takt-time planning (TTP) can be implemented with the Last Planner system. The paper refers to the work of Rooke et al (2012), in focussing on how *'how takt-time planning contributes to production theory by providing a method for work structuring around the principles of continuous flow and production leveling'*. Frandson et al, (2014) refer to Ballard (2000) when commenting that *'Takt-time planning is possible with the use of a production control system like the Last Planner System, which has proven to increase plan reliability and create the environment for continuous improvement to take place'* (Ballard 2000).

Takt-Time Planning - Takt is the German word for beat. The principle is to match the

rate of production to the rate that customers require products. In order to do this one piece flow and pull systems are designed and implemented to focus on leveling out the workload of production. In the context of Frandson et al (2014) when combined with the Last Planner system it serves to actively design continuous workflow for trade activities when possible. According to Frandson citing Liker in the context of The Toyota Production System (Liker, Meier, 2006), Last Planner performs the act of stabilising and Takt-time provides the means of creating the flow.

In Frandson et al's (2013) previous paper a Takt-time six step process was presented that consisted of: *'(1) Data gathering, (2) Zone definition, (3) Trade sequence, (4) Individual trade generation, (5) Workflow balancing, (6) Production schedule finalisation'*. This process is claimed to help answer the following questions identified by Ballard (1999):

1. *"In what chunks will work be assigned to specialists?"*
2. *"How will work chunks be sequenced?"*
3. *"How will work be released from one unit [one trade crew activity performing an activity] to the next?"*
4. *"Where will decoupling buffers be needed and how should they be sized?"*
5. *"When will the different chunks of work be done?"*
6. *"Will consecutive production units execute work in a continuous flow process or will their work be de-coupled?"*

According to Frandson et al (2014) when implementing Takt-time planning the first step is to establish the pace or "beat" of each work package with the aim of meeting the customer's minimum demand rate. If the client is flexible, the production team can set the demand rate for the phase. This enables activities to be planned to the correct size and sequence to the Last Planner and also relieves stress on the delivery team who know that as long as they get the work allocated finished they will be on target. It provides staff with focus and priority for their work on site. It serves to increase common understanding by engaging team members with a purpose. It helps to develop a daily goal for workers to achieve. As work is released at even intervals this improves the clarity for all involved as to current and future work. The approach increases the urgency for make ready analysis, to ensure trades are not idle. The approach considers tasks that are undertaken within a Takt-time sequence as 'schedule noise' and tasks that cross into other Takt-time sequences as "schedule variance" which would signal conflict resolution or re planning is required.

The Takt-time planning research project that Frandson et al (2014) are undertaking on the Cathedral Hill Hospital is initially focusing on the concrete floor assemblies by studying the concrete pouring and subsequent trade activities completing each floor. They set out to establish the production strategy for Takt-time (identifying trade sequence, phases, Takt-time duration, fabrication and spooling times and zones), the

completion criteria for trade activities, workable backlog outside the Takt time plan and identify current buffers in capacity. The main concept is that "*Takt-time planning is an attempt to perform work structuring and identify a feasible production strategy that can maximise the number of production activities performed with continuous use of resources*".

A further paper was presented by Seppänen (2014) comparing Takt-time planning (TTP) to Location Based Management Systems (LBMS). He commented that in the study he presented LBMS were used in a similar way to TTP and he outlined that depending on the project context both approaches could be suitable. LBMS in this context aims to avoid clashes between work teams thus aiding smooth work flow.

WASTE IN CONSTRUCTION

This theme consisted of 12 papers focussing on Waste in Construction. The majority of the papers focussed on various methods identify waste including studying the workflow and applying the Transformation Flow and Value (TFV) theory. Most of the papers focussed on the construction phase, although one paper focussed on a new interpretation of waste. Ahmed Stifi (Stifi, 2014) presented a paper on integrity management and introduced a new concept relating a lack of transparency and corruption as a form of waste.

BUILDING INFORMATION MODELING (BIM) AND LEAN

The BIM theme consisted of 4 papers. The author found this surprising as he thought there would have been more research activity focussed on this topic. The BIM related papers examined the interaction between Last Planner and BIM, Visual Management to aid Jidoka, Building in Quality, BIM as a visualisation tool to aid understanding of client constraints and there was a presentation looking at inter-team dynamics on the constructability of the BIM Model. This is an interesting topic because the nature of project information channels (intranets/Extranets) naturally changes the team dynamic. With a shift away from information 'push' to information 'pull' the traditional coordinators of the team are no longer the gate holders of information that they used to be and with this comes a shift in the team dynamic.

INDUSTRIALISATION, PREFABRICATION, ASSEMBLY AND OPEN BUILDING

This theme contained 5 papers ranging from the challenges of standardising products and processes in construction to presenting an enhanced scheduling technique for modular construction. Two case studies were presented, one on prefabrication

processes in the healthcare sector and the other on mass customisation and product architecture in the housing sector.

SUPPLY CHAIN MANAGEMENT

The supply chain management theme contained 5 papers focussing on supply relationships on Geothermal power projects in New Zealand, Supply and service of steel assembly structures, Off-Site Manufacturing Supply Chain Strategies for Australian Housing and a case study examining interfaces, Flows, and Problems of Construction Supply Chains in Brazil.

PEOPLE, CULTURE AND CHANGE

The people, culture and change stream contained 8 papers. As mentioned earlier in the report the author believes this to be one of the most important aspects of lean management. The papers in the stream reported on several case studies and research findings relating to Lean in South Africa, China and India. From the author's experience of teaching Lean Construction to international students the receptiveness to Lean Construction varies tremendously throughout the world and is affected by numerous issues such as regional cultures, cost of labour vs mechanization and statutory regulations. It is important to have an awareness of the barriers and drivers to implementing lean around the world. This issue is referred to by Liker in his text *Toyota Culture* (Liker, 2008) as he references the cross national culture work of Geert Hofstede (2004). Indeed this is a challenge that Toyota faced when expanding into the United States for the first time they decided to initially join forces with General Motors on the NUMMI joint venture. Another paper in the stream presented on barriers to continuous learning. This is an important issue as to achieve continuous learning employees and team members must be encouraged to problem solve, continuously improve and share in successes and failures and this requires the organizational environment to foster a culture of performance motivation as opposed to performance management. This is the subject of Mike Rother's *Toyota Kata* text (Rother, 2010) who suggests that a new management approach is needed "*one that incorporates constant improvement and adaptation*". Other papers in the stream focused on assessing Lean construction maturity in order to determine the level of an organisations' Lean capability.

SAFETY AND LEAN

The safety and Lean stream contained 1 paper on Implementation of Lean Tools on Safety in Construction Projects in Palestine. Initially the fact that there was just one

academic paper on safety was a surprise to the author, and indeed over the four conferences approximately 10 out of the 397 papers were categorized as relating to Health and Safety. On further reflection by the very definition of implementing lean it reduces transport, movement and other non value added activities that contribute to accidents and other occupational health issues such as stress. So in effect it is implicit that by implementing Lean, Health and Safety will be improved as a natural consequence. The author contacted Ian Nowosielski to consider some of the key Health and Safety issues that are facing Highways England and to gain a better understanding of how Lean thinking approaches can contribute an improved Health and Safety environment. Ian shared the view that Health and Safety should be embedded in an integrated way into all of Highway England's activities so that procedures and policies can integrate disciplines rather than being considered as separate isolated activities. This view appears to be reflected in the literature as although the number of papers specifically on Health and Safety is low it is likely that many of the papers would indirectly improve Health and Safety. Ian suggested a number of Lean approaches that could be applied to Improve Health and Safety including collaborative planning and 'big room' (Hub), employee empowerment, visual controls, waste eradication through process analysis and improvement.

Instead of taking a narrow view of risks, collaborative planning and the use of Hubs (Big Room) proactively enable teams to plan and communicate more effectively with each other thus enabling safer environments. Ian Nowosielski explained that the road working environment is a potentially complex hazard scenario with factors such as noise, vibration, fumes, pollution, heat, moving traffic all interacting together. By promoting collaborative planning all members of the project team should be more informed as to project plans, risks, each others activities to proactively identify and mitigate risks resulting in ideas such as contractors incorporating free motor vehicle recovery to aid safety.

There is a strong emphasis on empowering all project participants to adopt problem solving and continuous improvement approaches in order to act in a safe way. This philosophy also extends to empowering road users to act in a safe way by education of the potential hazards that exist and also by the use of Visual Controls. In an example of this interconnected thinking as a consequence of improving road worker safety a 50mph speed limit was introduced around road works. These signs were originally placed on the left and right of sides of motorway carriageways in order to provide road users with a form of visual control to lower their speed. However crossing the carriageway to install the right hand signs is hazardous and therefore after careful consideration the signs are now placed only on the left thus improving safety.

Ian Nowosielski recounted one lean inspired initiative that analysed Highway England's reporting of Health and Safety. Within the lean community reporting is often an activity that can be used as a starting point to identify non value adding activities that lead to

the waste of 'overproduction'. This initiative resulted in reducing waste in the reporting process by 50%.

TEACHING LEAN CONSTRUCTION

The teaching of Lean Construction stream consisted of 5 papers and this is a topic of interest to both academics and industry practitioners alike. In both arenas it is important to be able to convey the Lean philosophy, tools and approaches in clear and meaningful ways. All too often the tools are implemented without thorough understanding of the culture and philosophy. The texts by Liker especially the Toyota Way (Liker, 2004) are an excellent place to start for further reading on the culture and philosophy of Lean.

Another mechanism to successfully convey the lean principles is with the use of games. Several of the papers in this stream referred to games and simulations ranging from the very simple, such as making paper aeroplanes (sharing secrets of success), the 'magic stick' game (counterintuitive effects of teamwork) to more sophisticated simulations such as Villego (<http://www.villego.com>) which is a last planner simulation. There is an excellent book by John Bicheno called 'The Lean Games and Simulation Book' (Bicheno, 2014) that includes a wide range for games and simulations that can be used for educational and training purposes. A word of caution though, although some games may appear simple they often require well rehearsed and experienced facilitation. Further work could be carried out developing virtual lean games.

INDUSTRY PAPERS

The Industry Papers stream contained 20 papers focusing on a range of topics including partnering, implementation, IPD, Visual Management, Leadership, Planning and Design Management.

CONCLUSION

The report has attempted to provide an overview of current research in the field of Lean construction to identify and signpost areas that may be considered appropriate for further investigation and research. From the report it can be seen that there is an active research community throughout the world focusing on a wide range of topics associated with the lifecycle of design, construction and facility use. There appears to be a predominance of research focused on the construction phase of the lifecycle but less of a focus on the activities that form the pre project phases such as establishing the need for a project. It was to this end that the report reviewed the choosing by advantages approach first introduced by Jim Suhr and recently applied to the field of design and construction by Glenn Ballard and Paz Arroyo. This approach relates to the Liker (2003) principle of 'Make decisions slowly by consensus, thoroughly considering all options, implement decisions rapidly' and thus relates to set based design. This approach can be used throughout the project but it is of particular benefit during the early stages when decisions having the most impact are often made. Target costing also focuses on this part of the lifecycle where requirements are captured to aid value generation.

Another area of focus in the report is Takt-time planning which has potentially significant benefits when undertaking repeat work. It is not appropriate in all circumstances but again merits further investigation. As does Location Based Management Systems which again aid smooth work flow by avoiding clashes between teams. Again this may merit further investigation when considered in the context of the motorway construction environment that requires carefully sequenced safe staging of works. This could be developed further in the form of motion tracking tools for man and machine to enable safer working within defined perimeters. The author (A Fleming) visited a US Military training exercise in 2013 to observe a simulation of a nuclear accident and how the National Guard responded to this. It was notable how many lean approaches and techniques they were using including visual management and one piece flow. The author was informed they were trialing one device that enabled them to track the location of personnel and plant/ machinery. This technology may be available in the civilian environment and be used in conjunction with these techniques to aid flow and also safety.

In addition to these approaches there is also the question of how to sustain lean implementations and to ensure that the philosophy and culture pervade every level of the organization. How do you develop an environment where colleagues in all parts of an organization or project are empowered with lean ways of thinking to enable performance motivation, problem solving and continuous improvement? New mechanisms and approaches are called for to more effectively aid lean learning. Games and simulations and innovative learning technologies can play a valuable role to share knowledge. For example, traditional case studies could be converted to 2-3 minute learning videos and disseminated via social media to individual's accounts.

To conclude, the simple and advanced approaches described in this report are intended to contribute to the continuing conversation on the shape of lean construction in the future.

RECOMMENDATIONS

- To continue this reporting activity at annual or biennial intervals to serve as a mechanism to capture external factors that may impact Highways England.
- To review all IGLC conferences from inception to present day to identify longitudinal Lean Construction research trends to identify gaps in research knowledge.
- Develop a strategy for further research into the soft issues relating to Lean Construction such as culture and people, change management, academic theory and link this to research into ways to sustain lean implementations.
- Conduct further exploratory research into trust based lean with the aim of increasing employee empowerment and safety. Consider engaging with Unions on a trust based lean pilot project.
- Conduct further research focusing on how Lean principles could be further applied to downstream project activities and the potential benefits of this.
- Conduct further research focusing on applying Lean principles to the organizational structure as well as the project structure of Highways England.
- Conduct further investigation as to whether Health and Safety is really under represented in Lean research.
- Consider how Choosing by Advantages could be applied to Highways England to move away from traditional 'decide present and defend' decision making approaches towards a 'set based design' approach.
- To conduct further exploration into the application of Takt Time Planning and Location Based Management Systems.
- University of Salford to host a Futures Workshop to consider next steps.

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APPENDIX 1

All papers referred to from the IGLC 2014 conference can be found within the proceedings of the conference in the following three volumes.

IGLC 2014 Proceedings Volume 1:

<http://www.iglc2014.com/incoming/article88485.ece/BINARY/Volume+1+-+Proceedings+of+IGLC22.pdf>

IGLC 2014 Proceedings Volume 2:

<http://www.iglc2014.com/incoming/article88486.ece/BINARY/Volume+2+-+Proceedings+of+IGLC22.pdf>

IGLC 2014 Proceedings Volume 3:

<http://www.iglc2014.com/incoming/article88487.ece/BINARY/Volume+3+-+Proceedings+of+IGLC22.pdf>

APPENDIX 2

Full list of Papers IGLC 2014

THEORY

Implementing Lean Construction: A Practice Perspective Lena E. Bygballe and Anna Swärd

Absence in the Provenance? Lean Construction and Its Applicability in Japan Akira Inokuma, Mikiharu Aoki, Mitsuru Shimura, Daisuke Nagayama and Chikara Koizumi

If CPM Is So Bad, Why Have We Been Using It So Long? Lauri Koskela, Greg Howell, Ergo Pikas and Bhargav Dave

Analysing the Problem of Procurement in Construction Laura Pekuri, Aki Pekuri and Harri Haapasalo

Lean as a Business Model Aki Pekuri, Laura Pekuri and Harri Haapasalo

Lean Construction and Resilience Engineering: Complementary Perspectives of Variability Tarcisio A. Saurin and Rodrigo C. Sanches

Supporting Organizational Design Towards Lean with the Viable System Model Michael T. Schmidt, Fatos Elezi, Iris D. Tommelein, Klas Berghede and Udo Lindemann Rolf Simonsen, Mikael Hygum Thyssen and Dag Sander

Is Lean Construction Another Fading Management Concept Rolf Simonsen, Mikael Hygum Thyssen and Dag Sander

Lean Construction with or without Lean – Challenges of Implementing Lean Construction Søren Wandahl

SUSTAINABILITY, GREEN AND LEAN

Green Construction Assessment Model for Improving Sustainable Practices of the Indonesian Government Construction Projects Muhamad Abduh, Wulfram I. Ervianto, Dewi Chomistriana and Agus Rahardjo

BIM Based Conceptual Framework for Lean and Green Integration Ritu Ahuja, Anil Sawhney and Mohammed Arif

A Case Study to Examine Environmental Benefits of Lean Construction Somik Ghosh, Suchismita Bhattacharjee, Pardis Pishdad-Bozorgi and Ram Ganapathy

Reducing Environmental, Economic, and Social Impacts of Work-zones by Implementing Lean Construction Techniques Ossama Salem, Sharareh Pirzadeh, Sudipta Ghorai and Ahmed Abdel-Rahim

CONTRACT AND COST MANAGEMENT

Critical Analysis on Earned Value Management (EVM) Technique in Building Construction Luis Felipe Cândido, Luiz Fernando Mählmann Heineck José de Paula Barros Neto

Target Value Design as a Method for Controlling Project Cost Overruns Doanh Do, Chao Chen, Glenn Ballard and Iris D. Tommelein

Target Costing in Construction: A Comparative Study Reymard Savio Sampaio de Melo, Amit Kaushik, Lauri Koskela, Ariovaldo Denis Granja, Kaushal Keraminiyage and Patricia Tzortzopoulos

Contingency Management in Construction Projects: A Survey of Spanish Contractors José Ignacio Ortiz-González, Eugenio Pellicer and Gregory Howell

Front End Loading as an Integral Part of the Project Execution Model in Lean Shipbuilding Mikhail Shlopak, Jan Emblemståg and Oddmund Oterhals

The Effect of Economic Variation in Construction Projects on Contractor Firms Kajsa Simu and Helena Lidelöw

Characteristics of Public-Private Partnerships in Norway Espen Solheim-Kile, Ola Lædre, Jardar Lohne and Øystein Husefest Meland

INTEGRATED PROJECT DELIVERY

Quantifying the Impact of Non-Traditional Stakeholder Involvement on Project Quality Rizwan Assainar and Mounir El Asmar

Lessons Learned from the Make Ready Process in a Hospital Project Kevin Britt, Thais da C. L. Alves, Dean Reed and Brian Gracz

Four-Phase Project Delivery and the Pathway to Perfection Digby Christian, Jason Bredbury, Samir Emdanat, Frank Haase, Alex Kunz, Zigmund Rubel and Glenn Ballard

SimpLean: An Effective Tool for Optimizing Construction Workflow Mazen Faloughi, Wissam Bechara, Joy Chamoun and Farook Hamzeh

Implementation of IPD in the Middle East and its Challenges Farid Rached, Youssef Hraoui, Antoine Karam and Farook Hamzeh

Trust-Builder: a First-Run Study on Active Trust-Building James P. Smith, Zofia K. Rybkowski, Mindy Bergman and Mardelle Shepley

Developing a Production System on IPD: Considerations for a Pluralistic Environment Patricia Tillmann, Klas Berghede, Glenn Ballard and Iris D. Tommelein

VALUE IN CONSTRUCTION

Using the Means-End Approach to Understand Perceived Value by Users of Social Housing Projects Juliana Nunes de Sá Brito and Carlos Torres Formoso

Enhancing Facility Service Processes in Government Offices through Standardisation 343 Tuuli Jylhä and Auli Karjalainen

Improving Technique For Capturing Value in Low-Income Housing Mônica Veras Moraes, Thaís Marilane Carneiro and José de Paula Barros Neto

Value Generation in the Colombian AEC Sector by Adopting a PM Standard: A Case Study Laura Ramírez, Ana Paola Ozuna , Hernando Vargas and Raúl González

Increasing Adoption of Lean Construction by Contractors Matt Stevens

DESIGN MANAGEMENT

Choosing By Advantages and Rhetoric in Building Design: Relationship and Potential Synergies Paz Arroyo, Glenn Ballard and Iris D. Tommelein

Comparing Weighting Rating and Calculating vs. Choosing By Advantages to Make Design Choices Paz Arroyo, Iris D. Tommelein and Glenn Ballard

Exploring the Lean Briefing Process for Effective Design Management M. H. El-Reifi, S. Emmitt and K. Ruikar

Parametric Value Stream Mapping Framework: A Case Study of a Small Swedish Industrialized House-Building Supplier Jarkko Erikshammar, Erik Alestig and Weizhuo Lu

Increase Predictability in Complex Engineering and Fabrication Projects Knut Anders Lia, Henning Ringerike and Bo Terje Kalsaas

To Achieve Predictability in Engineering Bo Terje Kalsaas, Stian Finsådal and Kristian Hasle

Making Design Process Lean Chien-Ho Ko and Neng-Fu Chung

Creating, Sustaining and Optimising the Collaborative Realm for Participatory Design Zoya E. Kpamma, Theophilus Adjei-Kumi, Joshua Ayarkwa and Emmanuel Adinyira

Enhancing User-Involvement Through a Multi-Criteria Decision Aid: A Lean Design Research Agenda Zoya E. Kpamma, Theophilus Adjei-Kumi, Joshua Ayarkwa and Emmanuel Adinyira

Learning from Problem Analyses of Design Information Quality Data J. Lockert and O. Berard

Improving the Implementation of Modularization and Standardization of MEP Systems in Design Ahlam Mohamad, Fritz Gehbauer and Shervin Haghsheno

Early Contractor Involvement: Advantages and Disadvantages for the Design Team Andreas Heier Sødal, Ola Lædre, Fredrik Svalestuen and Jardar Lohne

PRODUCTION PLANNING AND CONTROL

Optimizing Joint Operation of Two Tower Cranes Through Look-Ahead Planning and Process Simulation Malak Al Hattab, Emile Zankoul and Farook Hamzeh

Using Last Planner Indicators to Identify Early Signs of Project Performance Luis F. Alarcón, José L. Salvatierra and José A. Letelier

Characterization of Flow in Multi Storied Residential Building Construction Thirumalai Rajan Arumugam and Koshy Varghese

Takt-Time Planning and the Last Planner Adam Frandson, Klas Berghede and Iris D. Tommelein

Addressing information flow in lean production management and control in construction Bhargav Dave, Sylvain Kubler, Kary Främling and Lauri Koskela

Evaluating the Impact of Lean Methodologies in Copper Mining Development Projects
Gustavo Castillo, Luis F. Alarcón and Vicente A. Gonzalez

The Magic of the Last Planner® System for Nigerian Construction Emmanuel Itodo
Daniel, Christine Pasquire and Oko John Ameh

Automatic Generation of a Daily Space Schedule Adam G. Frandson and Iris D.
Tommelein

Collaborative Design Management – A Case Study Ingvild S. Fundli and Frode Drevland

Integrated Planning vs. Last Planner System Bo Terje Kalsaas Ingvald Grindheim and
Nina Læknes

Understanding Production Management of Refurbishment Projects of a Housing
Association – An Exploratory Case Study Sergio Kemmer and Lauri Koskela

Digital Kanban for Earthwork Site Management Kim Kirchbach, Lauri Koskela and Fritz
Gehbauer

Literature Review on Planning Design and Engineering Activities in Shipbuilding Kristina
Kjersem and Jan Emblemståg

Visual Communication Panels for Production Control Using Gamification Techniques
Hugo Morêda Neto, Regina M. Leite, Dayana B. Costa and Frederico Durão

Line of balance – Is it a Synthesis of Lean Production Principles as Applied to Site
Programming of Works? Rafael de Sousa Leal Martins Moura, José Márcio Feitosa
Monteiro and Luiz Fernando Mählmann Heineck

A Lean Workflow Index for Construction Projects Vitaliy Priven, Rafael Sacks, Olli
Seppänen and Jonathan Savosnick

A Comparison of Takt Time and LBMS Planning Methods Olli Seppänen

Workflow Stabilization with Fine-Grained Work Packaging and Near Real- Time Progress
Monitoring Pingbo Tang, David Grau, Ram Ganapath, Jose Diosdad and Amin
Abbaszadegan

Learning to See Simplicity within a Complex Project Through the Lens of Pull Planning
Cynthia C.Y. Tsao and Glenn J. Hammons

Guidelines for Developing a Line of Balance for Non-Repetitive Areas (Common Areas)
at a Vertical Residential Building Caroline P. Valente, Germano A. Montenegro, Felipe L.
Brito, Clarissa N. Biotto and Bruno P. Mota

The Role of Visual Management in Collaborative Integrated Planning and Control for Engineer-to-Order Building System Daniela Viana, Carlos Formoso, Josana Wesz and Patrícia Tzortzopoulos

Implementing Takt-Time Planning in Construction to Improve Work Flow Tarek Yassine, Mohammad Bassel S. Bacha, Farah Fayek and Farook Hamzeh

WASTE IN CONSTRUCTION

Data Envelopment Analysis and the Quest for Targets – A Case Study in Connection to Waste Reduction on Site Aerson Moreira Barreto, Luiz Fernando Mählmann Heineck, Luiz Antonio Freire Pinto Silveira and Thais Moreira de Vasconcelos

The Wastes of Production in Construction – A TFV Based Taxonomy Trond Bølviken , John Rooke and Lauri Koskela

Construction Site Operations Made Leaner and Standardized: A Case Study

Roar Fosse, Bo Terje Kalsaas and Frode Drevland

To Measure Workflow and Waste. A Concept for Continuous Improvement Bo Terje Kalsaas, Mariann Gundersen and Truls Olav Berge

Integrating Production and Quality Control with the Support of Information Technology Cibeli F. Leão, Carlos T. Formoso and Eduardo L. Isatto

Exploring the Australian House Completion Time to Improve Housing Supply Sherif Mostafa and Jantanee Dumrak

Concepts and Methods for Measuring Flows and Associated Wastes Cristina Pérez, Dayana Costa and Jardel Gonçalves

A Lean-TRIZ Approach for Improving the Performance of Construction Projects Brahian Román Cabrera and Guillermo Juárez Li

Institutional Waste within the Construction Industry: An Outline Saad Sarhan, Christine Pasquire and Andrew King³

The Picture of Integrity from lean Management's Point of View and the Relationship Between Integrity Management System and Last Planner System Ahmed Stifi, Fritz Gehbauer and Sascha Gentes

Recommendations for Practical Application of Transparency in Construction Site Rafael Cardoso Valente and Dayana Bastos Costa

BUILDING INFORMATION MODELING (BIM) AND LEAN

Effects of the Interactions Between LPS and BIM on Workflow in two Building Design Projects Sheriz Khan and Patricia Tzortzopoulos

Improving Built-In Quality by BIM Based Visual Management Enni Laine, Otto Alhava and Arto Kiviniemi

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