Lean Design Management in an Infrastructure Project in UK

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Abstract. Lean Design Management (LDM) is a response from the lean community to overcome the chaotic design process in the AEC industry. Many tools, processes and methods were adapted to the context of design with limited success. This paper presents the use and adaptation of different lean design tools and processes in an infrastructure project in the UK. The lean design implementation occurred in a Joint-Venture (JV) that had been awarded contracts to deliver civil engineering and construction on the project. This paper also compares the results of combined use of adapted last planner and adapted design structure matrix, and identifies some of the practical challenges and benefits of the implementation of lean design management. The main contribution of this paper is the contextualisation of different project organisational structures and its influence on the success of the LDM tools implementation. Moreover, a common result for both phases is the enhancement of project communication, collaboration, and transparency of information for planning and control of the project activities.

Keywords: lean design management, last planner system, design structure matrix

Introduction

Lean construction had an initial focus on production aspects; nevertheless, design issues gradually started to receive more attention (Jørgensen and Emmitt 2009). The design management has been left to improvisation: poor communication among stakeholders, incomplete documentation for the subsequent process, unclear input information, poorly levelled resources, unbalanced workloads, lack of coordination between different disciplines and erratic decision making (Freire and Alarcon 2002).

Lean process, tools and methods have been developed for the design management to improve these deficiencies (Ballard and Koskela 1998). Although their relevance to the design process, if the lean processes were used integrated, more improvements could have been achieved (Freire et al. 2002). For instance, the work conducted by Koskela et al. (1997) applied Design Structure Matrix (DSM) with the Last Planner System (LPS) improving the design workflow reliability.

This paper presents a case study of lean design management implementation in an infrastructure project in the UK, in which a set of lean tools were deployed in the design stagem such as Collaborative Planning with LPS, and DSM incorporated into the Gives & Gets tool, supported by a control room. The integrated use of the lean tools enhanced the project communication, collaboration, and transparency of information for planning and control the project activities.

The results obtained in both phases were compared highlighting the context in which the lean tools were deployed. Next, the authors identified some of the main benefits of implementing lean design management into a major infrastructure project, its limitations and room for improvement.

Literature Review

Design Management

The design process in the AEC industry is known for being problematic (Emmitt et al. 2004), with high levels of rework, change orders, delays and un-constructible solutions for construction (Macomber et al. 2012). In an AEC project, design management is a challenging effort that must deal with increasing architectural complexity, a high number of interdependencies, uncertainty, and erratic decision-making by authorities and clients (Koskela et al. 1997). Likewise, design management in construction projects is often carried out under time pressure which requires a proper planning and control system, with a focus on information flow among participants (Tzortzopoulos et al. 2001).

Lean Design Management

Lean Design Management (LDM) is a response from the lean construction community to overcome the chaotic design process. It is rooted in the Transformation, Flow and Value (TFV) Theory (Koskela 2000), i.e., it considers the design as a production process (Ballard 2002; Ballard and Koskela 1998). Namely, the design transformation activities should deliver value for the client, while the information flow activities should be reduced and measured by some metrics (action rate, package size, work-in-progress, batch size, development velocity, bottlenecks and rework) (Tribelsky and Sacks 2011).

A set of tools and methods is recommended to facilitate design management and enhance transparency. For instance, the Design Structure Matrix (DSM) and the Last Planner System (LPS) have been deployed in lean design management with some success (Koskela et al. 1997).

Last Planner System

Last Planner System in design management is not as widely used as it is in construction. However, different sorts of projects have tried the LPS in design, such as office buildings (Koskela et al. 1997), small high-tech facilities (Miles 1998), residential condominiums (Tzortzopoulos et al. 2001), theatres (Ballard 1999), hospitals (Hamzeh et al. 2009), factories (Viana et al. 2015; Wesz et al. 2013), and so on (Bolviken et al. 2010; Hamzeh et al. 2009; Khan and Tzortzopoulos 2015).

With some limitations and peculiarities of design context itself, the LPS in design promotes process transparency, designers' collaboration and communication, and the use of project performance measurement (Biotto 2018). LPS limitations refer to the high amount of change orders or delays in the clients' decisions, plus difficulties in executing the lookahead plan, analysing the root causes of tasks non-compliance, and planning the design activities (Biotto 2018).

Due to these challenges, LPS requires more flexibility (Hamzeh et al. 2009). In the past few years, there have been some adaptations of the LPS to the project and design contexts (Bolviken et al. 2010; Tiwari and Sarathy 2012). In the UK, the partial use of LPS is known as Collaborative Planning (CP). The CP is limited to the implementation of a few elements of the LPS in the construction phase, for instance, the collaborative master planning, weekly planning meetings and PPC (Daniel et al. 2017), and its use in the design is still scarce.

Design Structure Matrix

Design Structure Matrix (DSM) to support the flow view in design management. It was presented as a lean design management tool by Koskela et al. (1997). The DSM is a network modelling tool for visually representing elements of a system and their interactions and supporting the decomposition and integration problems (Browning 2001; Eppinger and Browning 2012).

DSM can be applied in different contexts, for example, "product development, project planning, project management, systems engineering and organisation design", i.e., for the product, or process by aggregating individual interactions among components, people, activities, or parameters (Browning 2001; Eppinger and Browning 2012). To be able to define the relationship among elements, it is necessary to have the participation of experts in each activity to know the outputs of each activity; what activities use these outputs; what inputs are necessary; and, what activities produce these inputs (Browning 2001).

Although the DSM is an effective tool to achieve an optimal work sequence, it lacks production control mechanisms. For this reason, DSM has been combined with other lean methods, such as LPS (Hammond et al. 2000).

The success of lean tools for design management still requires further exploration regarding the organisational context. Managers should be able to recognise the potential results achieved by the different lean tools in order to overcome organisational limitations, such as the number of people involved in the design process, the teams composition, staff time availability for meetings, commitment

with planning and control, frequency of client's change orders, and so on.

Development

Lean concepts, tools and techniques, shown in Figure 1, had been implemented over the seven months in which the consultants were part of the project. The tools needed to be adapted to changes in the project organisational structure, characterising two different phases of LDM implementation activities.

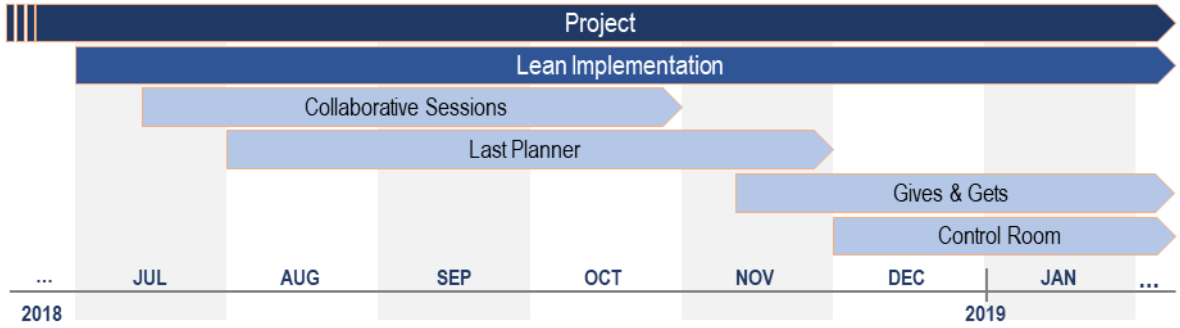


Figure 1: Lean implementation timeline.

Collaborative Planning (CP) Sessions

In order to establish a reliable process throughout the scheme design phase and programme development, the Collaborative Planning Sessions were used to set the design goals of the project, define the main phases, and pull the key activities. The sessions were led by the lean consultant who tried to optimise the workflow sequence.

There were two sessions of CP, which were attended by 32 functions leaders and coordinators from 19 different functions. Each swim-lane on the board was a function, and the participants were invited to mark with post-it's the main milestones from their schedules (developed in PrimaveraP6). These sessions promoted a shared understanding among the participants and enabled the teams to analyse the wastes and criticise the former planned programme together. The teams have also identified the interdependencies between functions, improved the sequence of activities, and created a unified and optimised plan based on the combined knowledge and requirements of the participants. Figure 2 and Figure 3 show one of the CP sessions.

The project owner and design teams were also invited to participate in the CP sessions, which encouraged the collaboration among all members in the project.

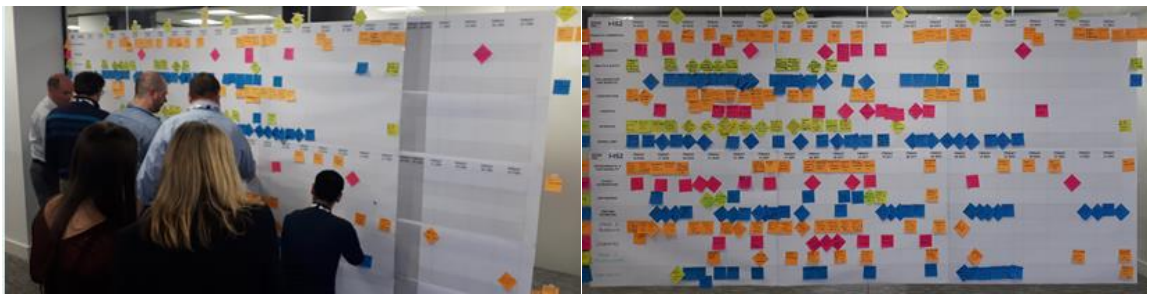


Figure 2 and Figure 3: Collaborative Planning Sessions.

Last Planner (LP) Meetings

The information from the Collaborative Planning Sessions was transferred to an MS Excel spreadsheet to enable the weekly meetings. Rather than gather the whole project participants, these meetings

occurred independently in each one of the 19 functions.

The Last Planner was adapted to the design stage of the project, i.e., instead of having two separate meetings for planning the make-ready constraints and the weekly production, the LP for the design management combined both in weekly meetings. It was possible due to the "last planner" being responsible for both planning and removing constraints, as well as for producing the deliverables.

In the LP meetings, the employees of each function gathered together independently to plan their weekly production, set the constraints and control the tasks progression using the spreadsheet (Figure 4).

FUNCTION

Task | Milestone	Start Date	Finish Date	Constraints	Owner	Due Date	Removed Date	Status	09 Th	10 F	13 M	14 Tu	15 W	16 Th	17 F	20 M	21 Tu	22 W	23 Th	24 F	27 M	28 Tu	29 W	30 Th	31 F
Works information ownership review	10-Aug	31-Aug						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
			Liaise with health and safety	-	10-Aug	10-Aug	Removed On Time																	
Close GW3 actions	24-Aug	24-Aug																	B					
Close GW3 actions	31-Aug	31-Aug																						Y
			Agree with owner with info still needed	-	31-Aug	31-Aug	Removed On Time																	
WI owners appointed	20-Sep	26-Oct																						
			SLT to agree WI owners strategy	-	05-Oct	20-Sep	Removed On Time																	

Figure 4: Production control spreadsheet.

Make-Ready Planning

The make-ready planning was a systematic process of identifying and removing constraints to ensure that the tasks forecasted in the Collaborative Planning Sessions were able to be executed. The MS Excel spreadsheet facilitated the visualisation of the constraint's deadlines, its owner, removed date and status. Due to the individual meetings per function, the focus of the constraints was exclusively regarding the function.

The constraints had their status updated weekly: it could indicate removed on-time, removed late or in-progress (open) – see Figure 5. It ensured a smooth production flow and the minimisation of rework and negative iterations.

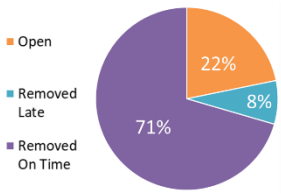
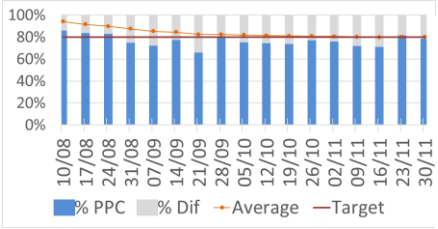


Figure 5: Constraints removal status.

Commitment Planning

Regarding the commitment planning, it was a process of collaboratively and systematically planning the weekly production, recording progress, looking ahead and adjusting the plan every week. The teams controlled the completion of planned tasks and committed to the next tasks on the following week. They had two metrics: The Percent Planned Complete (PPC) (Figure 6) and Reasons for Tasks Non-completion (Figure 7). The latter was analysed for continuous improvement.



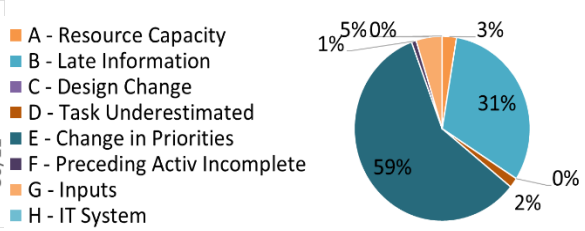


Figure 6: PPC of scheme design. Figure 7: Chart of causes for tasks non-completion.

Even though most of the constraints were removed on time, the PPC shows a decreasing average. Majority of the reasons for non-completion of the tasks were related to ‘change in priorities’, followed by ‘late information’, which means that the client used to change requirements and/or number and types of deliverables close to the deadline. This would affect the commitments made during the week and drop the PPC score. This information was taken by the function's leaders to the client every week, during the board meeting, to make the client aware of the effects of late changes.

Gives & Gets

The Gives & Gets Matrix is an adapted Design Structure Matrix. In the project, it was an effective way of getting teams to work together, recognising the information each other required, transitioning from “over the wall” approach between functions of different companies, to work groups composed by employees from the three companies (design office, JV and the owner) that shared the same deliverable and goal.

It worked similarly as the constraint analysis on the LP: responsibilities, deadlines and status were appointed between parties to keep track of what is required, forming a constructive way to ensure the needs are understood and met. This information was added to cards and posted on a board (Figure 8).

Figure 8: Gives & Gets cards and panel.

This was integrated into the programme to ensure that tasks could be tracked, allowing the teams to see in which manner their collaboration could positively influence activities. Furthermore, a heat map was produced to colour coordinate the more intense areas with greater Gives & Gets, to be focused on enhancing delivery between teams (Figure 9).

Total of Gives/Gets	OPT 1	OPT 2	OPT 3	OPT 4	OPT 5	OPT 6a	OPT 6b	IDT	IDT	IDT	IDT	IDT
58	Earthworks/ Drainage	Structures	Environment	Indirects	Stage 2 Delivery Model	EWC/L&P	Mob/Long lead items	VE/ Optimisation	Stage 1 close out	Schedule	Estimate	Risk
Earthworks/Drainage		1	1	0	0	0	0	0	0	0	0	0
Structures	1		2	0	0	0	0	6	3	0	0	0
Environment	2	0		0	0	1	0	0	0	0	0	0
Indirects	2	0	0		1	2	1	0	0	0	2	0
Stage 2 Delivery Model	1	1	1	1		0	0	0	0	1	0	0
EWC/L&P	0	0	0	0	0		0	0	0	0	0	0
Mob/Long lead items	0	0	0	0	0	0		0	0	1	0	0
VE/Optimisation	0	0	0	0	0	0	0		0	0	0	0
Stage 1 close out	0	0	0	0	0	0	0	0		0	0	0
Schedule	1	1	6	2	2	1	2	2	1		2	0
Estimate	0	1	3	0	0	0	0	0	0	1		1
Risk	0	0	0	0	0	0	0	0	0	0	1	

Figure 9: Gives & Gets heatmap.

Control Room (*Obeya*)

Based on the Japanese *Obeya*, the room was critical to develop the visual management. Relevant information was exposed to conducting fact-based decision making. It contained visually engaging charts and graphs depicting the programme, cost, milestones and progress-to-date information (Figure 10).

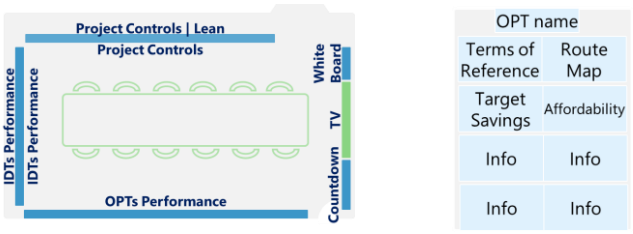


Figure 10: Control room details.

The control room accelerated decision making, encouraged collaboration, built leadership, made the organisation more agile to solve issues, increased the transparency and drove the project management toward a team level.

Discussions

The lean design implementation bridged the communication gap between stakeholders to significantly increase collaboration, boost project success, and reduce risk. It is important to highlight the following points which have been crucial to its progress:

- Creation of the collaboration culture among teams;
- Stakeholders involvement in the early stages of lean design implementation;
- Understanding and acceptance of project context: changes of requirements and deadlines by the client were constant, and the teams needed to adapt to it.

Regarding to the Last Planner, there was better control over the function's activities, mainly because of the weekly metrics, such as the PPC. The functions were more focused on their weekly activities, commitments and constraints. The CP sessions were the main opportunity for the participants to visualise the relationship and constraints between the functions.

Regarding to the DSM, it improved the collaboration and the visualisation of constraints between the working groups. It enhanced problem-solving and made the process more agile. The Gives & Gets had a great result regarding engagement and the number of constraints, and the teams were collaborating and exchanging more information. The control room was also a fundamental support for the visual management of the design phase.

Key Benefits

It was possible to uncover a wide range of factors related to the successful lean design implementation in the project:

- Organisational culture and structure: A key challenge during the early stages of lean implementation was to engage all staff in the process as quickly as possible. The adoption of these tools facilitated the planning of constraints and improved staff engagement.
- Effective communication: The high participation in the Collaborative Planning Sessions and the commitment to the weekly meetings showed engagement and a great sharing of knowledge between stakeholders. The Gives & Gets were also an essential contributor to collaboration because it increased transparency regarding the needs between working groups.
- Teamwork: Hierarchical boundaries were reduced, and it created a sense of collaborative work between the different stakeholders.

Limitations

Some limitations were found during the lean design implementation, such as: 1. The lack of lean knowledge of the stakeholders; 2. The several change orders from the client; and, 3. The rigidity and long lead-time of working in 'silos' without collaboration between project staff and other stakeholders.

What to Improve

For the continuity of the implementation at the project and the replication in others, some improvements need to be made, such as: Have a better requirements management to understand the client's needs and to improve the change management regarding the deliverables; Deploy lean training for all stakeholders at the beginning of the implementation; Feedback data from the weekly plans to the master plan to allow re-planning and data-driven improvement; Combine the Last Planner with the Gives & Gets and the Control Room; and, Deploy a proper lean maturity assessment to provide better support and direction to the lean implementation.

Conclusion

The dynamic, rapidly changing, and complex project environment continues to demand excellence in management. Improving efficiency in the delivery of major projects is a common demand of owners. The lean design management showed great potential for continued application in the project, which made impressive advances despite all the challenges of the design context of a major project.

The use of collaborative planning sessions is crucial to integrate different function schedules. However, it is difficult to visualise the constraints across the functions. The LPS was important to formalise the planning and control process, providing more metrics for continuous improvements, such as the PPC and chart for reasons of non-compliance. Both tools were applied in a rigid organisational structure, i.e., the "silos" teams. Collaboration in this context was difficult to achieve.

The visualisation of constraints among the teams was facilitated by the DSM matrix incorporated in the Gives & Gets tool. Collaboration increased and the using of the control room enhanced the visual management of the design process.

The improvements made in a short time frame indicate that the lean efforts are worth continuing moving forward. By tackling the barriers, lean design management is a suitable effort for improving performance and embedding a continuous improvement culture in the project. Thus, the project had effectively adapted lean to the design phase.

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