A LEAN WAY OF DESIGN AND PRODUCTION FOR HEALTHCARE CONSTRUCTION PROJECTS

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ABSTRACT

As a consequence of the lack of solid conceptual foundation, the project management concepts and techniques usually applied within the construction sector are fragmented and have proved to be incapable of solving the complex problems of design management. As a result, healthcare providers have become frustrated with the outcomes such as cost and schedule overruns, accidents, less than expected quality and inadequate functionality. However, an investigation of successful healthcare projects reveals that new approaches have been developed to tackle such problems. This study uses recent data based on six construction projects. The idea is demonstrate how successful projects are dealing with the integration between design, production, and operations, through an appropriate approach to the management of production systems. The paper aims to assist the different parties of the AEC industry to better understand how practices applied into design phase could support the efficiency in the management of production systems.

KEYWORDS

Design management, implementation, lean philosophy.

INTRODUCTION

It is largely acknowledged that it is within the design phase that the best opportunities for improving production efficiency, customer value as well as sustainability occur. It is within the design phase that product, service specifications are determined, the execution process established, and consequently costs are set. However, as argued by Ballard and Koskela (1998), architectural, engineering and construction (AEC) developments present complex management problems. For instance, there are conflicting needs and requirements that lead to complex trade-offs and an inherent high degree of uncertainty. In the specific context of healthcare projects, Reed (2008) states that owners, mainly large healthcare providers, have become frustrated with the outcomes provided by the conventional project delivery, such as cost and schedule overruns, accidents, less than expected quality and inadequate functionality.

The problems of managing the design and production are well investigated and myriad ideas have been developed as a way to solve such problems. However, many of these ideas fail due to the fragmentation of the AEC industry as stated by Mauck et al. (2009). For these authors, the fragmentation has been a cause of a considerable negative impact on the productivity of the sector over the last 40 years. These issues were evidenced by Feng and Tommelein (2009) whilst carrying out research in healthcare projects. These authors analyzed the causes of rework in the design and permitting phases and identified over 150 instances of relevant process waste. They argue that these wastes are on its vast majority related to design and can be reduced by improving its management. Researchers have been investigating how lean production principles can minimize these problems (Koskela et al, 1997, Ballard and Koskela, 1998; Howell and Ballard, 1999, Ballard et al., 2001,

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Koskela et al., 2002, Ballard, 2008). For these authors, Lean provides the foundation for project managing complex projects.

Successful cases exist and lessons can be learnt in order to improve the management of large and complex projects (Khemlani, 2009; AIA, 2010a; AIA, 2011). Project management initiatives such as changes in commercial relationships and the use of managerial tools for managing production systems are being fruitfully used (Tiwari et al, 2009; AIA, 2010b; Lichtig, 2010). In this article, successful cases of healthcare projects are investigated with the aim of amalgamating the existing and fragmented knowledge and better understanding commonalities and differences amongst the identified initiatives that have supported the increase of efficiency of design and construction processes.

The investigation was based on the thorough analysis of rich secondary data of six cases. Given that lean construction provides the appropriate basis for managing complex projects, this study sought to identify practical examples that follow this line of thought in order to investigate the initiatives implemented and also the outcomes achieved. Thus, the criterion used to select the case studies was the relation between the initiatives implemented in those cases and the lean construction approach to the management and execution of design advocated in the literature review (Ballard and Zabelle, 2000b; Ballard, 2008). The unit of analysis of this study was the implications of having an integrated process from a systemic point of view. The theoretical foundation of this research is based on lean construction principles. The limitation in terms of reliability, accuracy generated by the use of secondary data is here acknowledged.

ON INTEGRATED DESIGN AND PRODUCTION

In construction projects the management of design and engineering is one of the most ignored areas (Koskela et al, 1997). According Ballard and Koskela (1998) the separation of design and construction has long been presented as the root problem of construction. The same authors also reveal that the project management concepts and techniques have demonstrated incapable for solving the complex problems of design management. They argue that the primary reason for the poor level of design management has been the absence of solid conceptual foundation. That the traditional conceptualization of engineering looks the engineering just as a conversion. And, that it is necessary to move from a conception of production solely based on the transformation of inputs into outputs to the TFV (Transformation / Flow / Value) model of production (Koskela, 2000).

Following that line of thought, Ballard and Zabelle (2000) argue that it was in order to structure the work in pursuit of the lean ideals that the Lean Project Delivery System (LPDS) was conceived. The LPDS is described as “a new and better way to design and build capital facilities” (Ballard, 2000). Ballard et al (2001) considers that the production system design tackles the three main goals of lean production systems: do the job, maximize value, and minimize waste. Figure 1 presents the LPDS model.

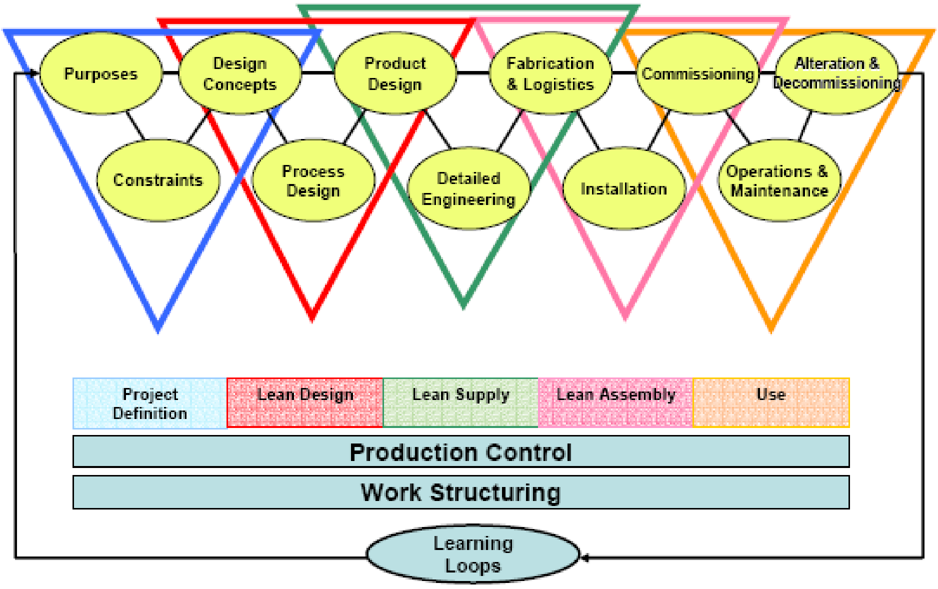

Figure 1 - Lean Project Delivery System (Ballard, 2008).

The lean approach to the management and execution of design embedded in the LPDS model include steps such as: a) cross-functional teams organization; b) the pursue of a set-based strategy; c) the structuring of the design around a lean processes; d) the minimization of negative iteration; e) the use the Last Planner System™ for design and production planning and control; and f) the use IT that facilitate lean design (Ballard and Zabelle, 2000b). Two aspects come into view from this model that represents relevant contemporary additions (Ballard, 2008). First, the importance of managing the production systems from a life cycle perspective is evident. Within the model, management starts at the beginning of the project and follow throughout the product developed been in use. Second, the project definition and design phases, which are more often explored than the other triads, have their scope of work expanded. Particularly to the design phase, the early engagement of key members along with the implementation of practices such as target costing and set-based design are practices that have been explored with successful results. Moreover, the collaborative work between project participants, ranging from designers to subcontractors, in conjunction with the use of technologies that enables this integrated work efficiently have been tested.

There are many initiatives for managing design and production processes. Examples of these include the adoption of the Last Planner System™, Integrated Project Delivery, Target Costing, Set-Based Design, Building Information Modelling, Value Stream Mapping, Cross-functional teaming, Co-location ("Big Room"), and Early Involvement of Participants. The literature on these methods and tools is abundant and assumed to be well known and for this reason not covered within this section. Less known and relevant are the issues related to the design of production systems in construction.

Production system design in construction is a topic that uses concepts and ideas that emerged in manufacturing. Slack et al. (2007) argues that, in general, the design of product and services and the design of the processes, which make them, are considered as separate activities. Despite product and process design are clearly interrelated and should be treated together, practitioners from downstream phases are not involved in early phases and do not participate in making key decisions that impact positively on efficiency. Gaither and Frazier (2001) emphasize that decisions regarding technological process, connections among its parts, equipment's choice, installation layout, and human resources are made. Askin and Goldberg (2002) argue that it within the design of the production system that a manner to manage the resources and information to produce the products is defined. In addition, Meredith and Shafer (2002) contend that alternatives for production organization and strategy that influence target results are set. Figure 2 illustrates the interconnection between product and process design.

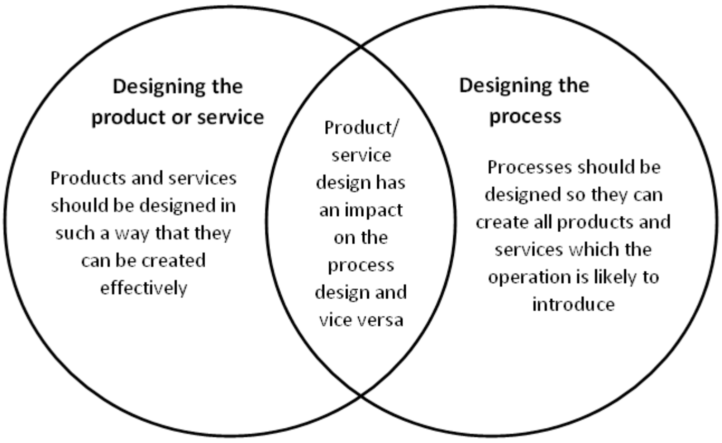

Figure 2 - The relation between products and processes design (Slack et al., 2007).

It is evident from the manufacturing and construction literature that better integration of design and production have been sought and achieved through the adoption of the tools and methods above mentioned. However, less discussed are the implications of having an integrated process from a systemic viewpoint. Also the impact that adopting lean principles have on the project environment. Therefore, the cases presented in the next sections illustrate how successful projects have been considering the lean philosophy in the design phase through the implementation of managerial practices.

CASE ANALYSIS

Six reported success cases (Table 1**Error! Reference source not found.**) have been included in the analysis of the implications of having an integrated process within construction projects. In spite of the fact that six cases were used, only three cases are presented in detail due to space constraints. However the source of information is given. Table 2 lists the practices implemented throughout the investigated cases.

Table 1 - Case projects

	Case Projects	***Location***	***Construction Type***
1	*Sutter Health Farfield Medical Office Building (AIA, 2010a)*	*Fairfield, California, US*	*New building*
2	*Sutter Medical Centre (Khemlani, 2009; Tiwari et al., 2009; Lichtig, 2010 and AIA, 2010b)*	*Castro Valley, California, US*	*New building*
3	*The California Pacific Medical Centre's (CPMC) Cathedral Hill (Parrish et al., 2008; Yoders, 2010 and AIA, 2011)*	*San Francisco, California, US*	*New building*
4	*Cardinal Glennon Children's Hospital (AIA, 2010a)*	*St. Louis, Missouri, US*	*Expansion*
5	*St. Clare Health Centre (AIA, 2010a)*	*St. Louis, Missouri, US*	*Replacement*
6	*Encircle Health Ambulatory Care Centre (AIA, 2010a)*	*Appleton, Wisconsin, US*	*New building*

Table 2 - Practices presented in the cases

Practices implemented	*Cases*					
	1	*2*	*3*	*4*	*5*	*6*
Last Planner System™	*X*	*X*	*X*		*X*	
Integrated Project Delivery	*X*	*X*	*X*	*X*	*X*	*X*
Relational Contracting	*X*	*X*	*X*	*X*	*X*	*X*
Target Costing		*X*	*X*			*X*
Set-based Design			*X*			
Building Information Modelling	*X*	*X*	*X*		*X*	*X*
Value Stream Mapping		*X*				
Co-location ("Big Room")	*X*	*X*	*X*		*X*	

Case 1 – Sutter Health Fairfield Medical Office Building

All the information about this project was gathered from AIA (2010a). This project was the first of a series of building projects to be developed by Sutter Health (SH), a healthcare organization in California. In order to comply with the legislative framework for seismic safety in California as well as to support the growing healthcare needs of the communities Sutter Health has set a $6.5 billion building program. The hospital seismic safety law from California came up as the main driver for Sutter Health improves its hospitals. According to that, healthcare facilities must be upgraded to meet the safety requirements in order to enable those hospitals to continue in service after an earthquake. In addition to this major requirement, Sutter Health has also taken this opportunity to experiment an innovative way to design and build its hospitals as well as the delivery of healthcare through innovative ways.

The Sutter Health Fairfield Medical Office Building comprises a three-story, 70.000sf medical office building housing primary care medical practices and laboratories, with pediatrics, oncology, rheumatology, and cardiology departments and administrative offices. The construction project has achieved positive results according to project managers. Despite a considerable amount of owner scope additions ($836,528), the final construction cost remained below the contracted cost. Furthermore, the completion date was achieved even though there was three months delay for reprogramming and the extra services caused for the scope additions.

In order to promote conceptual alignment among team members, participants were made aware of the project vision and its practical implications through their involvement in a three-day event. This event aimed at promoting transparency in terms of project goals and aspirations and it was delivered through a partnership between Sutter Health and the Lean Construction Institute (LCI). Whilst SH provided project context, the LCI provided the theoretical guidance for project management.

Integrate Project Delivery (IPD) was used the project method delivery. Consequently, an intensive up-front work was needed and collaborative work ranged from strategic to operational areas. Collaborative practices included the **early involvement of project participants**. For instance, client representatives were engaged from the fuzzy front-end of design to the end of the construction in order to speed up the decisions and foremen participated in up-front group scheduling meetings. This up-front attitude led to reduction of the rework in the building site. The subcontractors were responsible for the main sub-systems (mechanical, electrical and plumbing/fire protection) and their participation was vital in the pre-construction design phase. According to the builder, further improvements could have been achieved if other specialties (e.g. exterior glazing and skin) were also involved earlier in the design process. Besides, at the end of this project the builder concluded that foremen from all subcontractors must participate in group scheduling meetings. Collaboration was also observed through **cross-functional teamwork**. For example, the project team did the management of contingency funds jointly. Architect and builder adjusted their contingencies as per demand. They were also equally responsible for construction errors and design omissions.

The work environment for project development, management and delivery was considered as a key for integration. In this regards, a space named "Big Room" (BR) was created to facilitate integration. The BR consisted of a common space configured to allow meetings with more than 30 people to work. Within this space, facilities such as a big wall for planning the process, a space for planning the design (wall sized maker board) used for both planning and sketching design ideas, smartboards to project 3D models, plans, schedule and to make possible the remote communication among team members, planning tables to the teams refine plans and small meeting rooms were provided.

IT was perceived as an enabler of better integration between design and production. The use of Building Information Modelling (BIM) in conjunction with Big Room (BR) assisted the project team to achieve better efficiency outcomes. In this respect, more than 400 systems clashes were identified prior construction. According to builder representatives the combination of BIM and BR "provided significant cost savings due to increased field productivity, tighter schedule, more prefabricated work, and less redesign". Additionally, the use of BIM as a GPS (Global Positioning System) allowed a shorter time to accomplish the placement of hangers (from 2-3 weeks to 2-3 days). It created conditions for much larger sections of shop pre-fabricated ductwork and less field labour.

Key project participants, when interviewed, expressed their opinion about features of this project that had positive, negative, or neutral impacts on better integration. For the builder representative the cost of the work should be disconnected from the profit - "*the key is the alignment of commercial interests*". For the architect, the incentive pool did not necessarily led to a collaboratively environment. He argued that to keep control of his own is a better approach - "*a lump-sum fee is a leaner approach*". Finally, according the project participants the IPD was considered suitable for complex and large-scale projects whereas not so much for smaller and simpler projects.

Case 2 – Sutter Medical Centre

The information for this case was gathered from Khemlani (2009), Tiwari et al. (2009), Lichtig (2010) and AIA (2010b). The project comprised of a new 130-bed, US$320 million hospital project for Sutter Health. Project aims included the development of a facility that supports the recognition of this corporation as a state-of-the art advanced technology and quality medical centre. Requirements included hard goals, such as design and deliver a facility of the highest quality, at least 30% faster, and far no more than the target cost.

According Lichtig (2010) Sutter Health used an Integrated Form of Agreement (IFOA) model that combine 'Lean Project Delivery' and a new contractual model. This new contractual model sought to balance the commercial interests of the major project participants and govern the delivery process as a collective enterprise. For Lichtig (2010), the adoption of the IFOA had a significant influence in the implementation of management practices on reasonable terms. The feature of the IFOA contract that was key to incentive collaborative work was the definition of rules for sharing gains and pains amongst all project participants. Tiwari et al. (2009) stress that the IFOA contract was the major incentive for the architects and structural engineers getting involved in the model-based cost estimating process.

The effort and money invested to plan and coordinate the design process by using those innovative practices had significant impact on carrying out a design process that resulted in higher quality outputs, at a faster design and construction pace, and with no relevant additional costs An illustration of that is the reduction of the expected time for structural design from fifteen to eight months with substantial improvement in the design quality (Khemlani, 2009).

Better integration was perceived as the result of many initiatives been used concomitantly. Primary to this was the **early involvement of a cross-functional** team approach along with the use of **incentives** (financial) for motivating project participants to collaborate and optimize the whole project rather than the parts. The Big Room concept was essential to create conditions for people, geographically distant, working together (AIA, 2010b).

The use of Value Stream Mapping (VSM) was instrumental in the provision of a better understanding of the improved design process as well as for streamlining workflows. The implementation of Last Planner System™ (LPS) was perceived as equally important in dealing with uncertainty in the course of design development. Team members understood the flow of value by the use of VSM and made commitments to each other applying the LPS principles (AIA, 2010b).

BIM was used as a support to design coordination and sharing of information. Cross-functional teams periodically reviewed 3D models in order to get better solutions. Design issues were identified and corrected earlier through the use of fully integrated BIM models. Moreover, BIM increased the reliability of the design information allowing it to be directly used for fabrication and pre-assembly. Gains in terms of reduced changes and schedule delays were perceived (Khemlani, 2009).

Case 3 – California Pacific Medical Centre's Cathedral Hill

Information for this case was gathered from Parrish et al. (2008), Yoders (2010) and AIA (2011). The California Pacific Medical Centre's (CPMC) Cathedral Hill comprises a new 555 beds, 858.000sf, US$ 1,028 billion hospital development for Sutter Health in San Francisco, California (AIA, 2011). Design and construction schedule were planned for 55 and 48 months respectively and it is an ongoing project to be completed in 2015. Moreover, the project is aiming a LEED-Gold rating from the U.S. Green Building Council and is expected to be completed below the target cost (Yoders, 2010).

According to Yoders (2010), Sutter Health project team adopted a traditional design process initially that led to a considerable cost overrun as a result of the 1.2 million sf design. Consequently, the entire process of design and delivery of CPMC Cathedral Hill had to be re-thought. For the program manager of the Cathedral Hill Project and the senior program manager at Sutter Health "*it was 400.000sf too big and the finishes were out of step with the needs. We had a recognition that we had to do something different. We needed an approach that streamlines the entire planning and design process by applying lean management techniques and focusing on drastically reducing waste while increasing value*" (Yoders, 2010).

This project is arguably remarkable in terms of innovations implemented to the management of production system. Besides the adoption of Integrated Project Delivery (IPD) as project delivery method, the CPMC has used several practices to improve the efficiency of design and construction, such as Target Costing, Set-based design, Last Planner System™, Building Information Modeling, among others.

Yoders (2010) argues that better integration (though collaboration) is an inherent feature of IPD and Lean Construction that leads to improved efficiency outcomes. In terms of architectural layout, for instance, the current proposal delivers 90% of the original's briefing in 70% of the space. The LPS has been fundamental in promoting stability within the design process. The statistical approach of the planning process reliability enabled by the LPS facilitated the improvement of project participants own efficiency (AIA, 2011). Moreover, the learning curve of the project participants is high as they can assess the root cause of the tasks non-accomplished.

It is worth mentioning that as long as IPD and lean construction has become fundamental to project outcomes, training and study are required to enable team members to deal with this innovative way of work. In this sense, the involvement of the client and the general contractor (GC) with research should be pointed out. For instance, both companies have a strong relationship with the Lean Construction Institute, who is partnering with UC Berkeley. According to AIA (2011) the client and the GC have been studying lean construction and IPD over seven years. Experience in IPD and lean construction as well as the motivation to collaborate and learning were considered as characteristics highly desirable in the selection process of project stakeholders.

Early involvement of a cross-functional team has been crucial in terms of financial savings. Return on investment (ROI) has been already made up-front. According AIA (2011), "the initial target cost developed by the team early in the project was approximately 14% (i.e. $80 million) below market average. At the time of this report, the team estimated that an additional $22 million dollars will be saved under the national market average. The team is continuing to track ROI throughout the development process. These significant savings have been primarily attributed to the Target Cost process".

The financial scheme agreed in the Integrated Form of Agreement (IFOA) is believe to support integration. According Parrish et al. (2008) "*this pay structure supports collaboration and innovation, as there is an incentive for the entire team, not just one team member. The IFOA mandated that all project participants collaborate and use set-based design as soon as they are brought onto the team*". The set-based design was used as a way to consider multiple design alternatives jointly, avoiding rework due to early commitment to a specific design, and to develop a more satisfactory design decision.

BIM has been used to support design coordination and production planning. In respect to production planning, the proposed construction process was simulated as well as optimal production method alternatives assessed. The use of BIM was required of all IPD team members, including trade partners. A BIM cluster group was created consisted of a BIM champion from each company of the IPD team. A management protocol was set in order to promote transparency in terms of the procedures that should be adopted as well as roles and responsibilities.

DISCUSSION AND FINAL CONSIDERATIONS

It has been argued throughout this article that AEC developments present complex management problems that lead to low levels of satisfaction with project performance and delivery from clients and professionals within this industry. Lean, it has been claimed, provides the appropriate foundation to cope with those complex management problems inherent to construction projects. In this respect, initiatives based on the lean approach to the management and execution of design (Ballard and Zabelle, 2000b; Ballard, 2008) that have been developed and implemented to mitigate these problems were identified. These include the Last Planner System™, Integrated Project Delivery, Target Costing, Set-Based Design, Building Information Modeling, Value Stream Mapping, Cross-functional teaming, Co-location ("Big Room"), and Early Involvement of Participants.

This research aimed at investigating the implications of adopting such practices from a holistic point of view. This was done through the thorough analysis of rich secondary data of healthcare project developments. The unit of analysis was the investigation of the implications of having an integrated process from a systemic point of view. Six cases were selected for the analysis and three are described in detail. The key principles identified throughout this research as well as their similarities with the lean features embedded in the LPDS model are presented below.

- **Early involvement of the cross-functional team:** all the studies stressed the importance of recognising the necessary movement of people from downstream to upstream in the project process as a way to increase value as well as reduce waste. Although it sounds simple, it implies the generation of a considerable amount of extra information at an early stage that must have contractual support. In the investigated cases, IPD provided such support by a) establishing the agreement of purposes between stakeholders; b) by providing incentives to achieve better performance, c) by fostering a learning environment that leads to innovations, hence higher performance levels; and d) by setting clear rules for shared pains and gains. Optimizing the whole rather than the part was the primary message for IPD projects members. Six out of six projects analyzed have implemented this principle, thus supporting the lean approach featured in the LPDS.

- **Transparency of goals, process, rules and responsibilities**: transparency is a principle that emerged in varied ways throughout the case studies presented. For instance, the clear definition of customers' values and expectations, the open budgets to enable designers to understand the impact of their changes in the overall budget, the 3D models used for design coordination, the maps created to make people aware of the design process and its constraints, and also the meetings to share performance indicators. In this respect, the identified practices that embed this principle include Target Costing, Building Information Modelling, Value Stream Mapping, and Last Planner System. For example, the use of Last Planner System has a specific objective, which is deal with the uncertainty and complexity inherent to building projects by managing commitments in order to achieve a stable and smooth process. This stability means a project running with less variability, which is considered into the lean systems a type of waste. Therefore, it is possible to identify a coherent relationship between theory and practice. In other words, it is the adoption of the right practice for the correct purpose. Corroborating with Santos (1999), Liker (2004), and Tezel (2011) arguments, transparency plays a key role in the management of production systems, therefore its consideration within design phase must be more explicit and systematic.

- **Supportive collaborative environment:** collaboration amongst the involved parts is essential for the integration of design and production. This principle, it was observed, is intrinsically related to all the management practices identified. This result corroborates with what is suggested in the literature of lean production. A collaborative environment relates to the physical and virtual environment where the project team develops their work as well as the psychological environment created. In respect to the later, the transparency regarding the goals to be achieved, the rules and responsibilities of each member, the clarity of the status of the development as is evolves and the level of commitment of each team member are fundamental for a supportive environment.

- **Investment up-front:** the "extra" and necessary effort and investment made up-front to plan and coordinate design ad production is arguably worthwhile. Perceived positive impacts of up-front investments included the increase of predictability in terms of cost and schedule, the promotion of a stable and smoother design and production process with less rework, the incorporation of innovations and improvements, and increased clients' satisfaction. To this end, two factors should be noted as facilitators. At first, the willingness to change. Based on the case studies, it is clear that the best way to assess the efficacy of this approach is experimenting. It is by practicing and experimenting that the necessary awareness to achieve a continuous improvement is developed. However, there are risks of experimenting new practices that can be managed by, for instance, integrating industry and academy. The cases have presented this connection as a starting point for a solid journey towards excellence in performance and innovation. As long as new ways to manage the production systems have been brought to the project environment, support are required to enable people to deal with this innovative way of work.

From the research, lessons could be learnt that are indicative of success in project management. For example, any path to improve the way that healthcare facilities are designed, built and operated must consider the integration of design, construction and operations as a relevant factor. This integrated approach constitutes a change in the way that projects have been developed and delivered. In order to embrace this change, AEC project members must base their practices in appropriate theory for managing production systems. In this respect, Lean philosophy has been proved as a strong conceptual foundation to guide the implementation of the practices for the management of production systems purposes. Each construction project is characteristically different from each other, thus the main idea is developing a prescriptive way that help users to understand and decide what is suitable for their specific purposes in relation to managing production systems, rather than creating a solution that fit all projects. Continuous learning is intrinsic to all projects and the most important outcome of this is developing a continuous capacity to learn and improve. The whole picture is more important than the isolated results, and the opportunity to create a better project environment that improves the construction sector as well as the healthcare infrastructure must be taken into account.

Due to the limitations of using secondary data in this research, it is recommended as further research an extended and through testing of the identified principles with a basis on empirical and direct observation. Such research is also necessary to clarify the intrinsic interconnection that was perceived amongst the proposed principles.

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