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CHALLENGES IN THE DIGITAL TRANSFORMATION OF LEAN DESIGN METHODS: A CASE STUDY

Dimosthenis Kifokeris[1], Janni Tjell[2], Mikael Viklund-Tallgren[3], Linda Nygren Farah[4] and Mattias Roupé[5]

[1, 3&5] *Division of Construction Management, Department of Architecture and Civil Engineering, Chalmers University of Technology, Chalmersplatsen 4, Gothenburg, 41296, Sweden*

[2&4] *NCC Sverige, Gullbergs Strandgata 2, Gothenburg, 41104, Sweden*

Lean design, a major lean construction focus, entails a number of various methods which are practically implemented. Among them, the lean design-inspired concept Project Studio (PS) has been utilized since 2011 by a major Swedish contractor, to facilitate and standardize the design process in conjunction with collaborative planning. PS promotes the face-to-face communication and collaboration of designers within the same physical project space, by using visual analogue tools, fostering creativity, and facilitating mutual learning. Following the digitalization paradigm shift in the construction industry, the aforementioned contractor sought to digitally transform existing flows, processes and tools, as part of its operational strategy. This course of action included PS, which was digitalized in 2017 via cloud applications seeking to optimize its performance, increase scheduling availability, and facilitate the question-answer handling outside of the PS physical project space. In the current paper, the digital transformation of PS is critically analysed. Methodologically, the abductive reasoning of qualitative analysis is adopted, by working iteratively between a preliminary targeted literature review performed through the concept-centric framework, and the qualitative field data obtained in a case study that was conducted by observing an in-company competence course. While it was noted that through the digitalization of PS some benefits were indeed brought about (e.g. higher detail of deliverables and remote access capabilities), the major results of this analysis were rather alarming. The critical observations showed a large variation on the understanding and utilization of the cloud tools (which in themselves could not adequately replace any of the PS existing working methodologies), more time-consuming meetings, frequent misinterpretation of digitally exchanged information, mobility reduction in the PS physical project space, and stakeholder dislocation. These results can be tied with the general discussion of the possibly negligent way of introducing and utilizing digitalization within construction (following the current hype), the largely unfounded perception that digital tools make processes self-propelled, and the still existent unavoidable discrepancies emanating from the disassociation between developers and implementers.

Keywords: Lean Design, Project Studio, digitalisation, cloud-based tools, challenges

[1] dimkif@chalmers.se

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INTRODUCTION

Lean design (LD) is a major focus of lean construction (LC) and aims at optimizing the management of the design phase of a construction project (London 2008). Such an optimization can entail that LD is integrated with frameworks, concepts and tools of collaborative planning (Herrera *et al.,* 2020), such as visual management (Tjell 2016).

There are evidently construction firms implementing an integration of LD and collaborative planning to attain the aforementioned optimization (Tzortzopoulos *et al.,* 2020a). Among them, a major Swedish contractor has utilized Project Studio (PS) since 2011. PS is a LD-inspired methodological concept to collaboratively plan, facilitate and standardize the design process. By using visual analogue tools, PS promotes face-to-face communication and collaboration of designers within the same working space, thus fostering creativity and facilitating mutual learning. Interestingly, PS was digitalized in 2017 via cloud applications, in an effort to optimize its performance, increase schedule availability, and facilitate the question-answer handling outside of the PS physical project space. This was decided by the contractor as part of its operational strategy, which sought to digitally transform existing flows, processes and tools - a decision that is not particularly surprising, as it follows a major current paradigm shift of digitalization within the industry (Elshafey *et al.,* 2020).

However, the full effect of this paradigm shift has not yet been adequately evaluated and can be subject to scenarios (Lavikka *et al.,* 2018). This inconclusive evaluation can also concern the digitalization of LC (including LD), especially in contexts where the results of implementing lean are, in many cases, still tentative - such as in relation to construction productivity in Sweden (Koch *et al.,* 2020). Therefore, it would be useful to document practical cases of such a digital transformation, in order to understand the potential disruption that has been possibly brought about in the corresponding specific context. The insights derived from such context-specific cases can then be juxtaposed and help form a bigger picture tied to wider discussions on the way digitalization is introduced, facilitated, and implemented within construction.

THEORY

LC emerged as a particularization of lean manufacturing for construction (Koskela 1992). It aims at waste elimination (namely, the elimination of unnecessary tasks), efficient resource usage, workflow optimization, on-time delivery of information and materials to construction sites, cost minimization, and customer value maximization (Tzortzopoulos *et al.,* 2020b).

LD is one of the five major foci of LC, along with lean project management, lean supply, lean partnering, and cooperative supply chain management (London 2008). Specifically, LD introduces several LC tenets that can be fundamentally applicable in the design phase of a construction project; these can include, among others, active and systematic early client involvement, value maximization, identification of stakeholder needs, simultaneous realization of product and process design, and just-in-time decision-making in order to reduce waste (Gambatese *et al.,* 2017). While several of these tenets have also been proposed in a scattered manner by a number of managerial frameworks pertaining to the design phase, lean design can group them into a single framework of best practices (Herrera *et al.,* 2020).

In order to optimize the management of the design phase, LD can utilize several lean concepts and tools, such as the Last Planner system (LPS) (Fosse and Ballard 2016),

target value design and set-based design (Alves *et al.,* 2017), design structure matrix (Tzortzopoulos *et al.,* 2020b), and choosing by advantages (Tzortzopoulos *et al.,* 2020b). It can also be integrated with other frameworks, such as Virtual Design and Construction (VDC) (Kunz and Fischer 2012), Building Information Modelling (BIM) (Dave and Sacks 2020), location-based planning (Seppänen 2020), and collaborative planning methods like visual management (Tjell 2016). Collaborative planning can be especially suitable for integration with LD, since it fosters cooperative and collocated social processes that are at the core of the lean concept and have proved to be particularly beneficial in the framing of tools like, for example, LPS (Fosse and Ballard 2016). More specifically, collaborative planning builds upon the same ground as LPS; it ensures that the tacit knowledge of participants is being used and embedded in the planning, thus improving its quality, accuracy, and adherence to the decided-upon plans (Seppänen *et al.,* 2010, Friblick and Nordlund 2013).

Over the last two decades, the utilization of VDC and especially BIM, has furthered the possibilities of a wider digitalization in the construction sector by enabling new tools and forms of collaboration (Alaloul *et al.,* 2018). With the increased digital transformation of the construction industry, aspects of LD are also in the process of being digitalized (Tezel *et al.,* 2020). This emerges in good agreement with practice, since the design process today is mostly digital; the deliverables are in CAD format, and there has been a gradual shift from delivering paper drawings to digital ones (Harty and Whyte 2010). At the same time, the use of the underlying data existing in the structures of the aforementioned digital frameworks, enables a more integrated information and communication flow through design and construction (Alaloul *et al.,* 2018) - a central LD goal (Gambatese *et al.,* 2017).

METHOD

In this section, there will be an elaboration on the research method regarding the literature review capturing the fundamentals of the current study (featured in Theory), the conduct of the case study, the synthesis of the review findings and case study outcomes, and the critical analysis of the synthesized results (featured in Case Study, Analysis, and Results).

For the literature review, the concept-centric framework augmented by units of analysis (Webster and Watson 2002) was used. This framework was supported by the references-of-references and "snowballing" techniques (Greenhalgh and Peacock 2005). The main concepts of the review were "lean design", "collaborative planning", and "digitalization". The emerged units of analysis included, indicatively, "virtual design and construction", "visual management", and "collocation". The conducted search was aimed to be targeted but still comprehensive (MacLure 2005); therefore, a wide collection of search engines featuring engineering and/or managerial content, was utilized. There was an application of operators to seek the terms of the searched concepts and units of analysis everywhere in each of the relative publications found in the search engines: title, abstract, keywords, text, author affiliations, and references. This process initially resulted in a large number of aggregated hits per research engine and per year. Refining the initial results by specifying incrementally more targeted units of analysis, led to finding the studies that were finally included in the paper.

The case study itself was approached with a qualitative lens, as the research was about understanding and depicting a present situation involving socio-technical phenomena and interrelations between humans (Yin 2009, Easterby-Smith *et al.,* 2014). Data in such case studies can be collected in a number of ways (e.g. observations, interviews,

informal communication, collection of written documentation) (Yin 2009). For the current paper, a mix of such methods was used, and most prominently internal analyses, observations, informal communication, secondary obtainment, and collection of written documentation. Such mixing can enable the triangulation and validation of the collected data (Easterby-Smith *et al.,* 2014). This was deemed important for the validity of the paper's critical results and was also something of special relevance for the current study, since two of the co-authors have been and still are employed by the company where the case study was conducted. Throughout the case study, one of the co-authors that have been employed by the firm used their well-established company network to fully access new and ongoing information, while the rest of the co-authors were allowed a typically partial and ordained company access.

The synthesis and critical analysis of the literature review results and the case study outcomes, followed the abductive reasoning of qualitative analysis, where observations and explanations of phenomena are developed by working iteratively between theory (i.e. the literature review results) and data (i.e. the empirical findings of the case study) (Bell *et al.,* 2019).

Case study, analysis and results

As mentioned in the Introduction, a major Swedish contractor introduced and has been utilizing the LD- and collaborative planning-inspired concept Project Studio (PS) since 2011. PS integrates LD and collaborative planning tenets to plan, facilitate and standardize the design process. This introduction also followed the (then) rising demands that both VDC application and the corresponding internal strategy should be able to handle megaprojects. The aim of introducing PS was to enable all involved design team members to contribute with their full knowledge and creativity (by encouraging a shared responsibility among them) for the development and delivery of the design documentation with the right quality and at the right time.

The approach of PS consisted of three aspects: structured work methods of visual management, collocation, and VDC. The first aspect (structured work methods) engaged the involved design members through analogue visual management tools such as pull planning (e.g. with Post-It stickers on a whiteboard), A3 sheets, and to-and-from matrices. The objective was to increase collaboration and enable the design team members to stay focused on the project goals throughout the design phase. The second aspect (collocation) was about creating trust and understanding among all the involved design team members, who shared a common physical project space which was called the PS room.

Its goal was to create an environment where knowledge embedded in action could be shared among the team members, as it was believed that a lot of knowhow could be disseminated by observing the actions of others. Furthermore, informal communication was facilitated, as it was considered that a lot of cooperative solutions can increase quality, provided that they are well worked through during the creative part of the design phase. The third aspect (VDC) enabled continuous data and information streams throughout the entire life-cycle (and especially the design phase) of the respective projects.

Through the implementation of PS, it was observed that changes and optimization were easily implemented during the design phase, leading to higher-value and less expensive solutions in comparison to cases where obstacles were discovered late during construction. However, there were material and procedural difficulties in the implementation of PS as it was; these included post-it stickers not being "sticky"

enough and thus making the pull planning process cumbersome for the designers, long notes that had to be taken manually, knowledge facilitation mainly for people in the PS room and seldomly for external colleagues, the PS rooms requiring large spaces that were sometimes difficult to provide within the respective office premises, design managers consuming too much time digitalizing the notes after the PS meetings, and information connected solely to the physical space occupied by the PS room.

These difficulties led to a gradual process of digitalizing PS. Sometime before 2016, the design team members began using an application to take and share photos of the post-it notes on the visual timetable. Finally, the contractor decided to start testing a fully digitalized version of PS in 2017 via cloud applications (e.g. Apricon, Yolean, or online "whiteboards" where "stick notes" in the form of written text could be uploaded). The aim was to optimize the performance of PS by increasing scheduling availability and facilitating the question-answer handling outside of the PS room. However, as will be shown below, this digitalization was impaired by a loss of focus on understanding and implementing the essential aspects of PS itself and was coupled with relative challenges.

The observation and analysis of such challenges was conducted through a case study in the calendar year 2019, embedded in an in-company competence course. Four internal design managers (two men and two women) from two different Swedish regions where the contactor operates, were coached by an internal lean specialist in a number of sessions, in order to make root cause analyses about their respective challenges and outcomes regarding the digitalization of PS. The coaching was conducted in a way that the design managers were handing in their assignments on a regular basis, and afterwards received feedback to gradually enrich their analyses. The authors of the current paper participated in various degrees and with different roles (e.g. observers, facilitators, note-takers) through this year-long case study, and had a series of meetings for the juxtaposition, processing and analysis of their accumulated data and observations after the in-company competence course sessions.

Initial observations entailed that while the first introduction of PS back in 2011 followed, among others, a demand of optimizing the handling of megaprojects (as was mentioned before), the digitalized PS was respectively applied for middle-sized projects in each of the regions. Middle-sized projects are ones with a budget of 50-500 MSEK (ca £4.2-42 million). Such projects are often considered challenging, because they are given little time for the design phase, even though they can hold a high degree of complexity. Consequently, less ideal collaborative constellations of designers can be formed during the design phase, often leading to suboptimal results regarding the design solutions and documentation. Accordingly, while it was assumed that the digitalized PS would make the design phase more effective and would help resolve the issues leading to the aforementioned suboptimality, the outcome was actually the opposite. The digitalization of PS actually impeded the concept from being used in the intended way - as described in the following.

In one of the observed regions, digitalized PS was extensively applied. It was noted that some benefits were indeed brought about; these included a higher detail of deliverables, remote access capabilities, better progress documentation, and better allocation of documentation responsibilities. However, and despite these benefits, the application was found to not yield the expected leverage. The digitalization, while initially conceived as a way to optimize PS without losing the focus on the actual method, ended up being considered as the driving force for PS, in the hopes that it

would automatically save time and provide increased accessibility for the design team members. However, the case study findings led to the realization that by applying the digital tools, the focus on the actual work method was lost and a number of setbacks were apparent. It was found that there existed a large variation on the understanding and utilization of the cloud tools (which in themselves could not adequately replace any of the PS existing working methodologies).

The meetings ended up being more time-consuming, and sometimes derailed in a situation where the participants were just trying to interpret the digital information previously exchanged. Notes stemming from the digitally exchanged information had to be prepared between meetings - while in the case of the "analogue" PS, the notes would have been directly shared in the PS room. The actual visual aspect of co-handling information was largely lost, and the digitally exchanged information was frequently misinterpreted. There was mobility reduction and stakeholder dislocation in the PS room, which could mean that material that could be previously communicated face-to-face and elaborated on right there and then, ended up needing further elaboration after it was exchanged digitally. The digitalization actually increased the time the designer managers needed to tune in to the schedule, which proportionally decreased the time for actual productive collaboration. In the effort to reduce the design manager's manual handling of information in the design phase, the digitalization of PS actually prolonged the time that the designers had to spend on this phase. Moreover, the design managers themselves faced the risk of losing out on the project overview, since the digitalization of PS meant, in some cases, that the incorporation of solutions was done solely by the designers themselves due to their dislocation.

In the other region, the implementation of digital PS was in its early stages. That region initially reached out for more digitalization, as they believed that by applying digital tools, they would improve the regional offices' potential of working with the collocated design approach which was required by the company. This reaching-out was also driven by material and spatial limitations in the regional office, as the premises were not considered ideal for implementing the "analogue" version of PS. Furthermore, some clients perceived that the demands of PS for collocated physical participation unnecessarily increased the design cost. However, while some benefits (like remote access capabilities) were realized to some extent, it was found that the resources applied during the digitalization of PS were not utilized in their full capacity for being properly implemented in the respective projects. An initial lack of fully understanding the PS method was accentuated by introducing the digitalization of the respective tools and processes, as a lot of focus was directed on learning to use the digital systems rather than the LD and collaborative planning tenets that are essential to PS. There existed, again, a large variation on the understanding and utilization of the cloud tools, followed by inertia in certain standard digital processes (e.g. logging in and out). The visual co-handling of information was impaired, resulting in time being consumed in the interpretation of information that was previously exchanged digitally. The designers were dislocated, and they somehow continued to face material problems, as the lack of space for the implementation of PS, was now replaced by a lack of sufficient access to monitors for the implementation of digital PS.

The work carried out by the two groups led to an internal company workshop, which took place in the end of 2019 and was also attended by the authors of this paper, concluding the data gathering for the currently delineated case study. In this

workshop, more than 80% of the whole company's design managers participated. Its purpose was to discuss the drivers and challenges related to implementing digital tools in the company's current design approach. During the workshop, the challenges and outcomes of digitalizing PS were discussed and showcased by the internal lean specialist; during this process, the results of the analysis of the current case study were confirmed and validated.

DISCUSSION

While belonging to the same company and sharing similar motivations for implementing both the initial PS and its digitalized version afterwards, the two regional offices varied in their material, digital and human resources, their relationship with the respective project clients, their initial understanding of PS itself, and the level of digitalization they implemented at the time this case study was conducted. However, the observations from the gradually enrichened root cause analyses conducted by the design managers of both offices, were largely consistent in their identification of challenges and outcomes (both positive and negative) of digitalizing PS. It can be understood that the negative outcomes outweighed the positive ones - a result that is rather alarming and leads to a number of critical reflections.

While not having this intention, the digitalization of PS violated central LD and collaborative planning tenets, upon which the method of PS was collectively based. Major violated LD tenets included, among others, the systematic stakeholder (mainly, the designers and design managers) involvement during the design phase, and the just-in-time decision-making in order to increase value. Major violated collaborative planning tenets included, among others, the direct exchange and embedding of the designers' tacit knowledge, and the taking place of social processes (like e.g. collocation and visual management) that in turn facilitate visual planning.

These violations and negative outcomes are due, in part, to a largely unfounded perception that digital tools could make processes self-propelled. In the observed cases, the professionals seemed to rely (at least, initially) on the digital tools as the drivers rather than facilitators of the PS method. This led to situations where instead of tailoring the tools to fit the method, the method started being inconsistent to fit the structure of the tools. A stark example is the one regarding the solutions supposed to be visually communicated through pull planning during the PS sessions; while the physical dimensions of the material post-it notes in the "analogue" PS entailed that all noted information should be short and on-point, the digital notes uploaded on the cloud tools could fit whole paragraphs of text, making them very similar to actual e-mail exchanges and beating the point of being laconic and precise.

Moreover, there are still existent discrepancies emanating from the disassociation between developers and implementers of the digital and/or cloud systems. While developing such tools can necessarily entail a mechanistic and more static understanding of the concepts, methods, and principles for which the tools are developed in the first place, their actual implementation can follow an unpredictable and out-of-the-box path. It is largely impossible to envision all different implementation scenarios when developing the respective tools, which may entail that a level of disassociation is unavoidable. However, it may be suboptimal to justify the negative outcomes and major challenges in the digitalization of PS on the grounds of this "unavoidable" disassociation, by accepting it on an "it what it is" basis. Indeed, the disassociation between the tools' development and implementation could be mitigated by more active collaboration between the developers and the implementers.

In that sense, it would be beneficial to establish a platform where the users of PS and other LD and collaborative planning methods, processes and tools (who are, at the same time, implementers of the digitalized and/or cloud systems), can form a continuous feedback and experience exchange platform with the developers. Such a platform could include collaborative workshops and information-exchange fora.

The identified challenges in digitalizing PS can also be tied to a wider discussion of the possibly negligent and in some cases hype- rather than requirements-driven way of introducing and utilizing digitalization within several contexts of the construction sector. This can also apply to general-purpose technologies, like machine learning anf blockchain. A number of recent studies have drawn attention on similar and related considerations, like e.g., Moscati and Engström (2019), and Elshafey *et al. (*2020).

However, we do not claim that digitalizing LD and collaborative planning, as it was reflected in the digitalization of PS, should be avoided. Indeed, we believe that it can be valuable and useful, provided that the optimization of the respective core methods and flows is given attention. Our study has shown that a number of benefits were indeed realized in the first place, and any negative outcomes were almost exclusively connected to a lack of understanding of the way the new digital tools can be coupled with the underlying concepts, methods and processes without violating them. Therefore, resolving such challenges should not be translated into avoiding digitalization itself, but rather carefully and knowledgably embedding it in the respective context. The situation of having to work with different and unavoidably long-distance processes that were disruptively brought about by the recent coronavirus pandemic, has also shown that digitalization and cloud communication and collaboration might be the principal ways to conduct business in certain contexts. This entails that approaching these processes optimally is even more crucial.

CONCLUSION

Lean design can be centrally integrated in conjunction with collaborative planning, in order to better facilitate, standardize, streamline and optimize the design phase of a construction project. In practice, a major Swedish contractor has attempted to reap the benefits of such an integration, by utilizing the lean design- and collaborative planning-inspired concept Project Studio since 2011; this concept promotes face-to-face communication and the collaboration of designers within the same physical project space, by using visual analogue tools, fostering creativity, and facilitating mutual learning. In 2017, after years of successful implementation, the firm opted for digitalizing Project Studio via cloud applications, seeking to furtherly optimize its performance, increase scheduling availability, and facilitate the question-answer handling outside of the Project Studio physical space. In this paper, we tried to critically analyse this process of digital transformation, by conducting a qualitative case study that was preceded by a targeted literature review.

The results show that while some benefits were indeed brought about by this digital transformation (e.g. higher detail of deliverables and remote access capabilities), the digitalization of Project Studio was rather problematic. There has been a large variation on the understanding and utilization of the cloud tools (which in themselves could not adequately replace any of the Project Studio existing working methodologies), more time-consuming meetings, frequent misinterpretation of digitally exchanged information, mobility reduction in the Project Studio physical space, and design team members' dislocation. These results can be tied with the general discussion on potential problems emanating from the possibly negligent way

of introducing and utilizing digitalization, not only within lean design, but within the construction sector in general. Moreover, there is a largely unfounded perception that digital tools can make processes self-propelled, resulting in a loss of focus and/or competence in understanding and utilizing the underlying methodologies which are being digitally transformed. Finally, there still exist discrepancies emanating from the disassociation between the developers and the implementers of digital solutions.

This work is delimited by focusing on a case study conducted within a specific contractor company and in a specific context (that of the Swedish construction sector). While the derived insights can be a starting point for a relevant problematization, this study cannot solely and by itself lead to generalized conclusions pertaining to the full Swedish context, let alone the construction industry *en large*. Therefore, the conduct of a series of progressively wider observational case studies is recommended as future work; this can take place first in more companies within the same context, and then in more contexts (the construction sectors of other regions or countries).

Despite any setbacks, the digital transformation of lean design and collaborative planning, as well as numerous other aspects of construction, is a train that cannot (and, largely, should not) be stopped. Therefore, going through with it in the most informed way is important for the actual attainment of the respective envisioned benefits. We hope that our study can offer a step towards the right direction.

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