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Published in:
Engineering, Construction and Architectural Management

DOI:
10.1108/ECAM-03-2018-0135

Published: 19/08/2019

Document Version
Peer reviewed version

Please cite the original version:
Uusitalo, P., Seppänen, O., Peltokorpi, A., & Olivieri, H. (2019). Solving design management problems using lean design management : the role of trust. *Engineering, Construction and Architectural Management*, *26*(7), 1387-1405. https://doi.org/10.1108/ECAM-03-2018-0135

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Solving design management problems using lean design management: the role of trust

Abstract

Purpose: Although prior studies have noted the importance of trust for project performance, research remains scant on describing the role of trust when using lean design management (LDM) in projects. This study explores the connection between LDM and interpersonal trust in solving construction projects' design management problems.

Design: A qualitative study was conducted that included 29 trust- and LDM-themed semi-structured interviews in the United States (California), Brazil and Finland; 11 focus group discussions were also organized to validate the interview findings.

Findings: The study reveals how LDM contributes to solving design management problems through two distinct but interconnected mechanisms: 1) improved information flow and 2) improved trust among project team members. A conceptual framework was crafted to illustrate the mechanisms in building trust by means of the social domain of LDM concepts.

Research limitations: The conceptual framework requires testing through an international survey or through multiple case studies.

Practical implications: The results indicate that design management would benefit from trustful environments and that trust may be the catalyst for actors' engagement with LDM. Managers in charge of design within projects can use the conceptual framework when selecting the appropriate LDM tools, which should include both the social and technical domains.

Originality: The study emphasizes the importance of the social domain of LDM concepts. Previous studies have focussed on information flow aspects of LDM but have overlooked the value of interpersonal trust in solving design management problems.

Keywords: trust, lean design management (LDM), collaboration, information flow, construction project, communication, design management

Paper type: Research paper

Introduction

Design management problems are major contributors to the failure of construction projects (Busby, 2001; Tilley, 2005a). From the main contractor's perspective, designers often lack competence in cost awareness, while the designs themselves often contain errors and inconsistencies (Kärnä and Junnonen, 2017), thus decreasing productivity during construction. Designers often feel that contractors fail to make decisions when needed and that the managerial systems contractors use are onerous (Emmitt *et al.,* 2011); they often feel that the time reserved for actual design work is too limited (Tilley, 2005a). In addition to the problems caused by this optimism bias, many projects fail because of problems in sharing design information and in underestimating project complexity (Tilley, 2005b; Flyvbjerg, 2011). Sharing common ground and meeting project targets both require fluent social interactions between all project parties, since most project success factors are human-related (Nguyen *et al*., 2004; Kärnä and Junnonen, 2017).

Developing strong mutual trust between the project parties involved can yield many positive impacts, such as 1) enhancing information exchange (Wong *et al*., 2008), 2) discouraging opportunistic behaviour (Zaheer *et al*., 1998), 3) improving team well-being and performance (Wong *et al*., 2008; Cheung *et al*., 2013) and 4) establishing long-term trading partnerships (Dominic *et al*., 2013). Trust plays a significant role as a social lubricant that helps to reduce conflicts in organizations: when interacting with others whom they trust, people often experience lower levels of conflict (Lindskold, 1978). In contrast, a lack of trust, which often triggers negative project impacts, is a leading factor in project failure (Akintoye and Main, 2007). This lack of trust undermines innovation, jeopardizes confidence in decision-making (Boukendour and Hughes, 2014) and contributes to partnership failure (Chen *et al*., 2008). Additionally, judging a colleague untrustworthy may lead to poor collaboration (Flores, 2016). Trust plays a central role in improving the effects of several organizational attributes, thus promoting project performance (McEvily *et al*., 2003).

Despite the role of trust in improving project outcomes, very little research has been conducted to describe how managers create mutual trust in design and construction teams, or what the actual impacts of trust are in the design management context. Various authors have explored the subjects of lean construction (Koskela, 1996; Ballard, 2008) and lean thinking in design management over the past few decades (Koskela *et al*., 1997; Tilley, 2005b) as solutions to related managerial challenges. The application of lean principles to the design management context creates a structured approach that enhances the entire design system, reduces waste and improves both value and information flow (El Reifi and Emmitt, 2013). This approach is known as lean design management (LDM). Finding an unambiguous definition of LDM, however, is still a matter of debate (El Reifi and Emmitt, 2013).

LDM provides several problem-solving methods and processes, the principal attributes of which include information flow (e.g. Tilley, 2005a; Tribelsky and Sacks, 2011; Aasrum *et al*., 2016; Al Hattab and Hamzeh, 2017), process transparency (e.g. Aasrum *et al*., 2016; Tauriainen *et al*., 2016), project commitment (e.g. Tauriainen *et al*., 2016) and collaboration (e.g. Tribelsky and Sacks, 2011; Zimina *et al.*, 2012; Fosse and Ballard, 2016). While an investigation of the connection between LDM methods and trust would be fruitful for identifying concrete methods and mechanisms for improving trust and, ultimately, more efficient design management, research appears to be lacking on the role of trust in solving design management problems using LDM concepts. In addition, because the literature on trust underlines the role of social interactions, whereas the LDM literature focusses primarily on improved information flow, construction practitioners would benefit from an identification of LDM concepts based on the mechanisms these concepts influence in solving design problems, whether in improved information flow, improved trust, or both.

This study aims to describe the connection between LDM concepts and trust when solving design management problems in construction projects. More specifically, the study examines the different mechanisms through which LDM concepts improve design management during the detailed design phase (i.e. when design overlaps with production), as well as the role of improved trust as a mediator. This study's contributions are twofold. First, it contributes to the literature on LDM by identifying the mechanisms behind different LDM concepts when solving design management problems. Second, the study elaborates on previous research on trust in construction by identifying managerial tools and methods that develop trust between the different actors involved in design teams.

The remainder of this paper is structured as follows. The next section presents typical design management problems and their sources. The paper then provides a review of various LDM concepts and their primary mechanisms in solving design management problems. The next part focusses on trust and its role in solving design management problems; the paper then describes a theoretical framework for solving design management problems through LDM and trust. Specific research questions are presented to guide the empirical study into a more in-depth analysis of the connections between LDM and trust in solving design management problems. The paper then presents the methods that were adopted in this research, describes the sources of the data and presents the results. Finally, the paper ends with discussions of the findings in general and of the revised conceptual framework, followed by conclusions and possibilities for future work.

Literature review and theoretical framework

Design management problems

Design is often inadequately managed during construction projects (Koskela *et al*., 2002). The overlapping of design and production during the detailed design phase leads to coordination challenges and poor information flow (Hossain and Chua, 2014). During this phase, it is critical that information flows between different stakeholders. In the current process, however, information flow is hampered by unclear task definitions, deficient specifications of responsibilities and delayed client decision-making (Koskela *et al*., 2002; Cheung *et al*., 2013).

Prior studies have indicated multiple reasons for design management problems. Uden and Naaranoja (2007), for example, argue that lack of *assessment strategies*, *time for planning* and *trust* are the main reasons for project problems and failure; the same holds true for design management. Tauriainen *et al*. (2016) categorize design management problems into six types:

1) *project management*, which may be reflected as overly tight design schedules that are set without knowing enough about the process of design work;

2) *communication*, which may be related to email overuse and abuse (for example) or from not conducting enough daily face-to-face communication;

3) *instruction*, such as the client or the owner not agreeing with design disciplines on guidelines related to building information modelling output;

4) *competence*, which may occur if project managers are unfamiliar with either the contents of design contracts or the fields they are evaluating;

5) *technology*, which is often referred to as problems with software compatibility between different parties as well as information and communication technology glitches;

6) and finally *general miscellaneous problems*.

Problems related purely to technology (number five) lack the human factor, whereas the other five types of design management problems underline the role of human behaviour.

Most prior work has tended to focus on information flow aspects when discussing design management problems. Tzortzopoulos and Formoso (1999), for example, found that poorly balanced and allocated resources, uncoordinated disciplines and inconsistent decision-making contribute significantly to poor design management processes. The problem in traditional design management is often that, due to project complexity, insufficient thought is given to the importance of the interdependent information needs of other project parties in order to complete design tasks (Busby, 2001). In cases such as this, problems stem from the poor information-flow and people management (Tilley, 2005a). Irrelevant information flow inhibits project parties from aligning their expectations and project objectives (Cheung *et al*., 2013).

Problems with information flow often cause designs to be delayed or incorrect when they are delivered to the contractor (Tilley, 2005b). Design issues cause poor productivity in construction work (Koskela *et al*., 2002; Tilley, 2005b) and delays to project schedules. A certain number of delays are assumed in standard schedules, but excessive delays may lead to claims and litigation, especially within standard design-bid-build contracts (Marzouk *et al.*, 2008). Ballard and Koskela (1998) stress that the root problem of these issues is the separation of design and construction. Unutilized organizational integration leads to insufficient control of design processes. Through the construction project lens, design is often seen as value generation that happens through a learning process conceived of as an effective dialogue between ends and means. Even in more modern and collaborative contract types, such as integrated project delivery (IPD) or alliancing, improvements to design management are crucial to project success (Aapaoja *et al*., 2013). In addition to problems within the interface of design, procurement, prefabrication and construction, problems related to value may occur if the designers are unable to capture an owner's requirements adequately within the design (Thyssen *et al.*, 2010). If the design solution or the construction documents contain errors, these errors will decrease value through defects in the constructed artefact.

To summarize the prior research on design management problems, the focus has been on complexity and the management of information flows; researchers have paid limited attention to social aspects such as interpersonal trust in the design management context.

Lean design management

LDM offers several methods and tools to facilitate design management. Uusitalo *et al*. (2017) reviewed and categorized the current LDM concepts that are generally considered to support lean thinking into 1) social processes, 2) methods and 3) technologies. In Seppänen *et al*.'s (2010) discussion of production control systems for construction, the authors distinguished between social and technical systems. For example, they considered the widely implemented Last Planner System, or LPS (e.g. Ballard, 2000a), to be primarily a social system with a technical component. (LPS is a trademark of the Lean Construction Institute.) The two ways of categorizing concepts are aligned, but the technical system was further subdivided into methods and technologies in Uusitalo *et al*.'s (2017) system.

The present study uses Seppänen *et al*.'s (2010) simpler classification and sorts each LDM concept (based on its key domains) as social and/or technical. The further subdivision of the "technical" factor into methods and technologies is not required for the purposes of this paper, because the study's

focus is to identify the relative importance of social and technical domains. Table 1 presents a collection of LDM concepts and their related categories, as well as their key domains, that help to solve design management problems. The key domain of a concept is said to be purely technical if that particular concept could be primarily applied without requiring any social interaction within the project team; if social participation is required to effectively use that particular LDM concept, however, then the key domain is categorized as social. Several concepts include both social and technical domains. For example, the LPS includes formal social methods for making weekly plans and a method for calculating performance metrics (Ballard, 2000a). LPS is used as an example in this paper because of its widespread adoption in construction projects.

The social domain of the LDM concept covers the tools and methods that facilitate social interaction among project parties. Social interaction and inherent collaboration are necessary when solving problems that individuals cannot solve by themselves (Sloman and Fernbach, 2017). For example, LPS includes several social components: scheduling is performed collaboratively with all "Last Planners" present, and commitments to plans are actively sought. These features may be called the social aspects of LPS (Ballard, 2000a). Big Room and co-location are examples of LDM concepts that are totally based on improving social interactions.

The technical domain of lean construction concepts includes methods or technologies for collecting information in a systematic way, followed by structuring the information, processing information through calculation or visualization, or otherwise communicating information (Sacks *et al*., 2010; Seppänen *et al*., 2010; Uusitalo *et al.*, 2017). For example, LPS includes a technical component because the plans follow a predetermined hierarchy of master planning, phase scheduling, look-ahead planning and weekly planning, and the links between these planning levels have been defined. Similarly, calculations of percentage of plan completed (PPC) and other LPS metrics (Ballard, 2000a) are part of the technical domain of LPS.

The technical domain of LDM concepts is typically used to improve information flow through a more systematic approach. The improved information flow helps people share their knowledge with other project parties and to receive information from others in order to advance their part of the design work. The more transparent and fast the information flow, the more efficiently the team can solve design management problems through shared intentionality (Bar-Yam, 2004; Sloman and Fernbach, 2017).

Table 1 includes the categorization of the LDM concepts, identified by Uusitalo et al. (2017), into social and technical domains based on their key mechanisms. Most of the concepts are primarily technical in nature, with a focus on structuring the information and improving its flow between parties. A few of the concepts are purely social, and several concepts cover both social and technical domains.

Table 1. LDM concepts and their key domains in solving design management problems (adapted from Uusitalo et al. *2017)*

LDM concept	Category	Key domains	Sample literature sources
Big Room	Social process	Social	Khanzode *et al.* (2008)
Co-Location	Social process	Social	Thompson and Ozbek (2012)
Collaborative Planning in Design (CPD)	Social process	Social Technical	Bølviken *et al.* (2010)
Integrated Concurrent Engineering (ICE)	Social process	Social Technical	Ballard and Koskela (1998), Kunz and Fischer (2009), Knotten and Svalestuen (2014)
Last Planner® System (LPS)	Social process	Social Technical	Koskela *et al.* (1997), Ballard (2000), Bølviken *et al.* (2010), Fosse and Ballard (2016), Franco and Picchi (2016)
Target Value Design (TVD)	Method	Social Technical	Ballard (2006)
Choosing by Advantages (CBA)	Method	Social Technical	Munthe-Kaas *et al.* (2015), Kpamma *et al.* (2017)
Level of Detail (LOD)	Method	Technical	Uusitalo *et al.* (2017)
Location-Based Design Management (LBDM)	Method	Technical	Uusitalo *et al.* (2017)
Set-Based Design (SBD)	Method	Technical	Lee *et al.* (2012)
A3 Reports	Method	Technical	Sobek and Jimmerson (2004)
Real-Time Cost Estimation	Technology	Technical	Uusitalo *et al.* (2017)
Virtual Design and Construction (VDC)	Technology	Technical	Khanzode *et al.* (2008), Bølviken *et al.* (2010), Sacks *et al.* (2010), Franco and Picchi (2016)
Design Structure Matrix (DSM)	Technology	Technical	Huovila *et al.* (1997)

Trust in project settings

By its very nature, trust is known to be a complex concept to grasp. Paine (2003) identified several dimensions of trust, for example competence, integrity, multilevel and dynamic, and she also described trust being an important component of the quality of relationships. Lewicki and Bunker (1996) define trust on three levels; these levels can be effectively applied to professional

relationships. The first is calculus-based trust. In these relationships, people weigh alternative scenarios and the benefits or costs of cheating. The second level is knowledge-based trust, where people are able to anticipate the behaviour of their counterparts based on previous interactions. The third and highest level of trust is identification-based trust, where both parties can be confident that their counterparts will fully defend and protect their interests. Trust rarely develops above calculus-based trust (at least in working life), although professional relationships might deepen to the level of identification-based trust in some cases (Laine, 2008).

In a project setting, trust means believing in the other party's benevolence (Laine, 2008), sincerity, reliability, engagement and professional competence (Flores, 2016). In the design management context, the individuals in a project form a temporary project organization. That newly formed organization undertakes the task of solving design management problems while at the same time building relationships and project culture. According to Cerić (2015), research on trust in the construction industry has a strong emphasis on inter-firm trust, typically in the context of partnerships and alliances. When temporary project organizations are formed, the initial relationships are based on inter-firm relationships. After a project starts, the type switches to inter-personal relationships; following project completion, the relationship type returns to inter-firm relationships. Research on interpersonal trust within construction projects has yet to receive the attention it needs (Cerić, 2015).

In inter-personal relationships, trust is a matter of commitment, action and making decisions (Solomon and Flores 2003). Coleman (1988) has also argued that in some social structures, individuals are constantly undertaking activities for each other. When someone performs a task or delivers information on behalf of a second person, the first person can count on the second person at some point repaying the "debt" when needed. According to Coleman (1988), this transaction of obligations, expectations and trustworthiness is the basis of social capital and is part of organizations' relations among people. Although the authors of the current paper recognize that inter-organizational trust also plays a role in project settings, in this research, we define trust as an interpersonal and process variable between project actors; we also assume that trust is always targeted towards a person (and not, for example, towards a corporation).

Trust among project teams yields many benefits. Positive emotions such as trust help to build the team's psychological and social resources within a project. Trust promotes psychological safety for project parties (Edmondson, 1999; Edmondson *et al.*, 2004). Psychological safety is experienced at the group level, which is also the main difference between trust and psychological safety. Trust, in contrast, is experienced between two parties or individuals (Edmondson *et al*., 2004). Psychological safety, in turn, steers workers towards open-mindedness, information-sharing, resilience, motivation, persistence and organizational learning (Edmondson, 1999). These attributes then act as catalysts for increased humour, solution finding and divergent thinking (Fredrickson, 2013). Solution finding and divergent thinking are important when solving design management problems, although design, since it is a field of creativity and iterative loops (Ballard, 2000b), often requires time for ideas to mature; this maturation will benefit the project as a whole and will add customer value. Sometimes organizations place roadblocks, often unknowingly, to diminish creative and problem-solving work (Flores, 2016). These roadblocks might include distrusting individuals' competency, expecting

unreasonable efficiency or labelling all mistakes as bad. Having a sense of psychological safety within a project can lower or completely remove some of these roadblocks (Flores, 2016). Psychological safety and trust may both be thought of as organizational or project "moods". Flores (2016) argues that moods are highly effective within people's standards for behaviour and for automatic situation assessment. Positive moods are conducive to organizational learning, and they increase job involvement and team productivity (Brown and Leigh, 1996).

Trust among actors is especially important in collaborative projects (Coleman, 1988), which require open-minded and unconventional thinking when solving complex design management problems. A trustful environment helps each project party to feel empowered, thus leading to enhanced brilliance, passion, loyalty and tenacious creativity (Salamon, 2003; Chalker and Loosemore, 2016; Boies *et al*., 2015). Creative problem-solving, which requires effective communication, helps to develop trust between team members (Aapaoja *et al*., 2013; Cheung *et al*., 2013). Lean thinking promotes some of the social dynamics variables, particularly trust and goal setting (González *et al.* 2015). Similarly, the use of LDM concepts can deepen trust between project parties and can develop trust from the calculus-based level to more advanced levels, where people become more willing to participate in creative problem-solving through trial and error.

Trust is also one strategy to incorporate when attempting to minimize information asymmetries between project actors (Schieg, 2008). Cerić (2015) argues that trust within construction projects acts in a dynamic manner. After people first become acquainted, the levels of trust between them gradually rise at an increasing rate; if a major conflict occurs, however, then the event could turn trust into distrust. To prevent negative spiralling trust in projects, Cerić (2015) suggests focussing on communication inside the project to promote positive spiralling trust. Because focussing on communication is closely related to the social domain of LDM concepts, the authors of the current paper have sought to identify the potential reciprocal relationship of trust and LDM in this study.

Theoretical framework

After completing a review of previous research on trust and the solving of design management problems in the construction industry, a synthesis of the interconnections of the main concepts was conducted. Because several LDM concepts are mostly based on the social domain, creating trust between project actors through social interactions may be an important factor for successful design management. Based on these interconnections, various focal variables that are important in solving design management problems were defined, and a theoretical framework of the design management problem-solving process was created (see Figure 1). This study's postulation is that the social domain of LDM concepts improves trust between project parties, while the technical domain improves information flow in projects. The two sides are interconnected: both trust and information flow foster the other. As discussed in the previous section, projects may be thought of temporary organizations, and initial trust originates from inter-organizational levels; trust also varies in a dynamic way according to individual actions. For these reasons, we assume with the theoretical framework that trust and LDM are reciprocally interconnected: the social domains of LDM concepts improve trust among the project team, and at least a moderate level of trust among team members is required for actors' engagement with LDM.

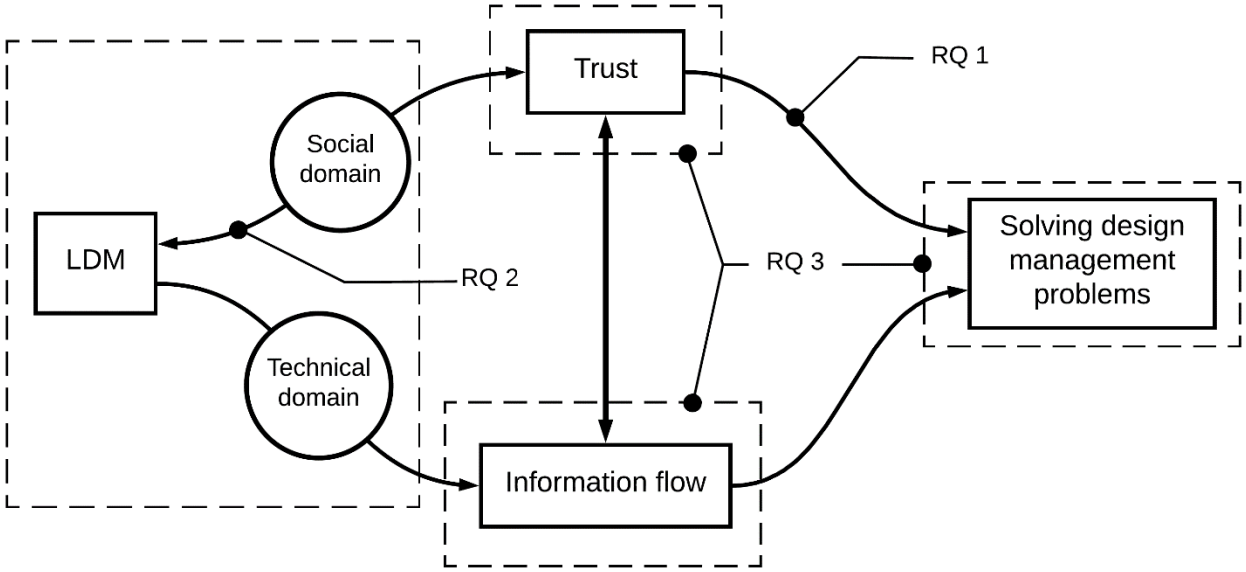

Figure 1. Theoretical framework for solving design management problems through LDM

Despite the potentially important role of trust as a mediator in solving design management problems within multi-actor projects, empirical research on the role of trust in the design management field remains scarce. The present empirical research should fill this gap in the literature by helping to answer the following research questions:

RQ1. What is the role of trust in solving design management problems?

RQ2. What is the relationship between LDM and trust?

RQ3. Are both trust and information flow required to solve design management problems?

Methods

The context of this empirical research is a real-world construction project, where each individual's experiences matter in terms of design management. Because the research questions are mostly explorative, with the aim of describing the role of the specific concepts or their relationships, the paper utilizes a qualitative research approach. The research design we have selected to answer the three research questions combines the perspectives of different construction professionals, gathered through 29 semi-structured interviews. Trust, as a concept, has indisputable importance to individuals and society, yet it is typically researched, defined and experienced as a highly subjective matter (Bauer, 2017); mapping the experiences and perspectives of individual professionals is thus necessary to thoroughly understand the phenomenon in the design management setting.

In order to probe the interconnections of the focal variables in the theoretical framework, triangulation was used during data collection to expand the theory and knowledge of previous construction management research (Love *et al*., 2002). In this case, data triangulation was adopted to answer different research questions using multiple data sources. The multiple sources of evidence, and their connection to the theoretical framework and the research questions, are presented in Table 2. Although interviewing construction professionals is an excellent method for collecting data about

interconnections between the concepts of LDM and trust, interviews do create a limited understanding of the phenomena involved. As a result, 11 focus group discussions were also organized to acquire practitioners' feedback on the interview findings (Gopaldas, 2016).

Table 2. Research design and description of multiple data sources (i.e. triangulation)

RQ	Research method and sources of evidence	Analyses
RQ1	16 Trust-themed interviews with 19 informants (general constructor, 14; design company, 2; project management consultant, 2; prefabrication company, 1)	Analysis 3: Mechanisms that build trust Analysis 4: Effects of trust
RQ2	13 LDM-themed interviews (general constructor, 8; design company, 3; project management consultant, 2)	Analysis 1: Causes of design management problems; Analysis 2: Impacts of LDM
RQ1, RQ2, RQ3	Thematic comparison of findings of the analyses 1-2, the analyses 3-4 and the previous literature to identify similarities that would indicate interconnections between LDM and trust, and trust and information flow to solve design management problems.	

To ensure that multiple perspectives were included, a total of 29 semi-structured interviews were conducted to collect in-depth experiences from 32 construction professionals from the United States (California), Finland and Brazil. One of the interviews was conducted with four informants at the same time; all the other interviews were conducted with a single informant. These countries were selected because they are active in the field of lean construction and because the authors' research group had already established diverse contacts from multiple disciplines within each country's construction industry. Each interview focussed on one theme: the role of trust or LDM in construction projects. The majority of the interviewees worked in managerial positions and were responsible for design management. The average length of the interviewees' professional experience was approximately 12 years. The length of the interviews varied from 15 minutes to 85 minutes, with an average of approximately 45 minutes. Before each interview, all informants were briefed on the purpose of the study. The interviewers made sure that no harm would come to the research subjects, and responsible conduct for research was followed during the interview sessions. The data gathered during the study was completely anonymized, such that no individuals may be recognized from the results. The recorded sessions (as well as other research-related materials) are stored in a private network that only the research team has access to.

All the interviews were recorded and transcribed verbatim. The anonymized transcripts were then analyzed and coded by applying the qualitative data analysis software QSR NVivo. The interviews were analyzed in two stages (see analyses in Table 2). In the first stage, two initial analyses used LDM-themed interviews as data, with the aim of identifying the causes of design management problems and the impacts of LDM. Similarly, trust-themed interviews were analyzed with the aim of identifying which mechanisms build trust, as well as determining the effects of trust. The thematic codes were inductively developed while analyzing the collected data (Creswell, 2013). In the second stage, the findings from these four analyses were compared and discussed with the literature to identify any similarities, which would indicate interconnections between LDM and trust. For example, if the

impacts of LDM and the mechanisms that build trust were found to have had similarities, then we could argue that some LDM concepts may improve trust in design processes.

To validate and acquire feedback to support the initial findings from the interviews, the findings were then presented to the appropriate focus group. Six focus group discussions were organized on LDM, and five were organized on trust. In general, focus group discussions are a valid method of gathering people with similar backgrounds or experience together in order to collect or analyze qualitative data and to reveal shared understandings or common views (Hennink, 2013). The discussions in the focus groups helped the research team to validate conclusions based on the interview findings. The focus group discussions were held bi-monthly, with participants drawn from Finnish construction and engineering companies. The number of participants varied from six to sixteen professionals. Each focus group participant held a managerial position in either a construction, prefabrication or design company.

Results

The results from the trust and LDM interviews are presented in Table 3. The interview results are categorized into two-level hierarchies. The structure of the hierarchies is stylized from the original analysis breakdown structure found in QSR NVivo. From the answers of the *trust* interviewees (N = 19), two second-order themes were grouped into *Mechanisms that build trust* and *Effects of trust*. Similarly, from the answers of the *LDM* interviewees (N = 13), the findings were grouped into the two second-order themes of *LDM impacts* and *Causes of design management problems*. Each second-order theme was categorized into sub-themes (first-order themes), which highlighted the themes mentioned in several interviews. For each of the first-order themes shown in Table 3, one to three illustrative extracts have been quoted for this paper from the interview transcripts.

Table 3. Mechanisms and effects of trust and LDM, as well as causes of design management problems: findings from the interviews

Theme	2nd-order theme	1st-order theme	Illustrative extracts from interviews
Trust	Mechanisms that build trust	*Building team chemistry through social interaction* (8)	1) "*Some of our project teams are very good at meeting their promise dates because we just have this team chemistry now that we understand each other and what it means to make a date".* 2) "*In a lot of projects we set out team building events* [and] *leadership building events, and we try to cultivate a virtual organization and culture".*
		Acting openly and transparently (12)	1) "*I think trust in this environment is as much about being transparent, that you're willing to be as transparent as possible and expose that, hey – maybe I don't have everything figured out, or maybe I have a problem over here, but I need your help to solve it*". 2) "*Above all, what feeds distrust is not knowing".*
		Communication (8)	"*I mean, I think it's vital. I think it goes back to communication; once you start the communication, I think the communication leads to trust, too".*
		Shared goal (9)	"*Like he mentioned, if they don't share the same goal, they always go for their own agenda or benefit; the trust will never be there".*
	Effects of trust	*Improving openness and transparency* (9)	1) "*And you also don't fear…asking for data, information or knowledge, because you have the confidence that if you ask for that, you'll get it*". 2) "*It's because of what we've said: trust allows transparency".*
		Improving collaboration (9)	1) "*Can we have collaboration without trust? I don't think so. Maybe you can, but I don't think so. It's a key component".* 2) "*I truly believe that…I think project teams that were successful in the past were successful because they built a lot of trust, they collaborated with one another, they overly communicated, they worked the plan".*
		Enabling innovation (4)	1) "*In our experiences, when the mood is good, people are satisfied, and they also tend to have more time to innovate and engage in improvement activities on projects that are smoother as a result of having high reliability and high trust".* 2) "*It's the spirit, and if you think about it, it's the delivery method, it enables* [situations where] *within the trust and spirit, people can freely express themselves, use all the creativity and get those good, best solutions which will benefit owner, constructor and everybody*". 3) "*Transparency is where we see problems, and then* [transparency] *allows us to address the problems collectively as a team and leverage everybody's intelligence*".
		Decreasing buffers (3)	"*…then people have their guard up, they're gonna start adding contingency, and then you start seeing that".*
LDM	LDM impacts	*Improving team chemistry* (8)	"*I think, in this project, we spend a lot of time up front getting to know each other and making sure we had expectations that were aligned".*
		Improving openness and transparency (3)	"*We're doing that collaboratively as a team; everyone is participating, and the information exchange and information openness are such that no one is holding anything back*".

	Improving information flow (technical domain) (10)	"*So, when the project is at its early phase, all we need to do is* [provide notification about] *the types of structures and the space* [these structures] *require; then it's enough that we deliver information to others by using a building information model".*
	Improving communication (6)	"*And that's something we've seen very strongly in terms of…there's never a good language developed on projects, so everyone talks* [about] *the same thing: 'cause if you're a framer, you talk studs; if you're a plumber, you talk piping, and it feels like people just talk past each other. So, having this language set up very early in the project allowed us all to always talk about the same things".*
Causes of design management problems	*Poor information flow* (7)	"*...why did you spend time developing that* [design]*? It's not even approved yet. Do you even know if we're gonna get paid for it?*"
	Poor communication (5)	"*And what bothers me is the dialogue between the designers; you still run into things like, 'I didn't get the information'. I'm like, heck, you have your phone and you have all the means…. We don't give you everything on a silver platter*".
	Making decisions late or not making them at all (7)	1) "*But I'd say the majority of the problems we've run into were delay-based or things* [that were] *unanticipated, where owners* [were unable] *to make a decision about something, you know*". 2) "*And sometimes those answers get pushed off based on the client, or some particular user group for the client, not being able to provide an answer about what they want*".
	Not being open and transparent (7)	"*But don't tell me two months from now that you don't have the colour selected, and for that reason you couldn't order a sample, and that's why we're now late on everything*".

Acting openly and transparently was the most frequently mentioned action for creating trust among project members. A reverse connection was also identified: trust among members improved openness and transparency. In interviews about LDM, not being open and transparent was connected to design management problems. Similarly, LDM was seen as a method that enhanced openness among actors. Building team chemistry and good communication were seen as impacts of LDM methods and prerequisites for trust.

For the effects of trust, participants most often connected trust to enhanced collaboration in solving project problems. The informants also connected trust with decreased buffers and improved potential for innovation in their work, both of which are relevant factors when designing under a tight schedule. The participants did not connect trust with improved information flow, although they did view such improvements as an important effect of LDM methods.

Discussion

The results from the trust-themed interviews highlight the social domain of LDM as a mechanism for building trust. First, informal social interactions improve team chemistry and develop people's understanding of one another, both of which create trust between people. For this study, the *Shared goal* theme was combined with the theme *Team chemistry*, because they both emphasize the sense of belonging in a group and sharing intentionality. Second, interactions among project parties –

including verbal and nonverbal communication as well as formal and informal communication – increase trust between actors. Third, having openness and transparency in motives, goals, capabilities and values helps in anticipating others' behaviour, which creates trust among project team members. These three assemblies work as "trust builders" that connect the social domain of the LDM concepts to the development of trust among project parties. Previous research has shown that trust and communication play interdependent and intertwined roles: trust enhances communication, and communication develops trust (Anumba *et al*., 2000; Swan *et al*., 2007; Phelps, 2012; Aapaoja *et al*., 2013; Cheung *et al.*, 2013; Cerić, 2015). The present study confirms the role of communication in building trust but also identifies other social aspects that build trust among project parties.

Improving trust has four substantial effects. First, trust enables innovation, thus making actors free to suggest and develop innovative solutions. Second, trust blurs the organizational boundaries between actors and supports the solving of problems in a collaborative way. The social domain of the LDM concept also emphasizes collaboration. Because trust supports collaboration, some level of trust may also be thought of as a requirement for effectively implementing the social domains of LDM. Third, distrust leads actors to make contingency plans that will ensure their own benefits (at the expense of the project), whereas trust enables buffers to be decreased and for resources to be better utilized for the best interests of the project. Fourth, trust between project actors leads people to share and ask for information more openly and transparently, since actors then believe that others will not use this information against them, but for a common goal. The existence of openness and transparency builds trust, while trust builds openness and transparency, thus demonstrating a reciprocal relationship. The strong connection between trust and openness and transparency is clearly derived from one definition of trust: the willingness to be vulnerable, i.e. the willingness to share information that will potentially allow others to harm you or your interests (Salamon, 2003; McEvily *et al*., 2003; Aapaoja *et al.*, 2013; Chalker and Loosemore, 2016).

According to previous research, the existence of improved information flow helps to solve design management problems (Khanzode *et al*., 2008; Lee *et al*., 2012; Kpamma *et al*., 2017). The present research found evidence from the LDM-themed interviews to support these previous studies: *improving information flow through the technical domain* of LDM tools and methods helps to solve design management problems. The findings of this research also indicate that a remarkable part of the effect of LDM is channelled through this improved trust. The results of trust and several mechanisms that help to solve design management problems were found to be same: improving *team chemistry*, *openness and transparency*, and *communication.*

For the last step in contemplating the results, the four themes related to the causes of design management problems were connected to other parts of the study's conceptual framework. First, poor information flow may be addressed by adopting the technical domain of LDM methods, as well as those aspects of the social domain that support openness and transparency. Second, addressing weaknesses in communication may also help to solve design management problems through improvements to trust between project participants. Third, delayed decision-making is often the cause of design management problems, both from designers' and other actors' points of view.

Fourth, openness and transparency can solve design management problems by improving both trust and information flow.

The empirical findings were then tested against the original theoretical framework. The findings support this study's theoretical framework and also illustrate how trust acts as a mediator and catalyst in solving design management problems. The findings enabled the formation of more detailed empirical patterns compared to the theoretical framework shown in Figure 1. Figure 2 illustrates these patterns. In the figure, the connection between LDM and trust (representing the social domain) has now been divided into several detailed trust-building mechanisms. The width of each line in the figure represents the strength of the connections, based on the number of individual respondents in each second-order theme. For example, the letter T in "T,12" indicates trust-themed interviews; 12 is the number of respondents who referred to that particular first-order theme. Correspondingly, "L" indicates LDM-themed interviews. The dashed grey line and arrow in Figure 2 represent the dynamic reciprocal spiral of trust. Some level of trust is required to effectively implement the social domain of LDM concepts. These LDM concepts then further build trust among project parties, thus enabling a positive spiral between trust and LDM.

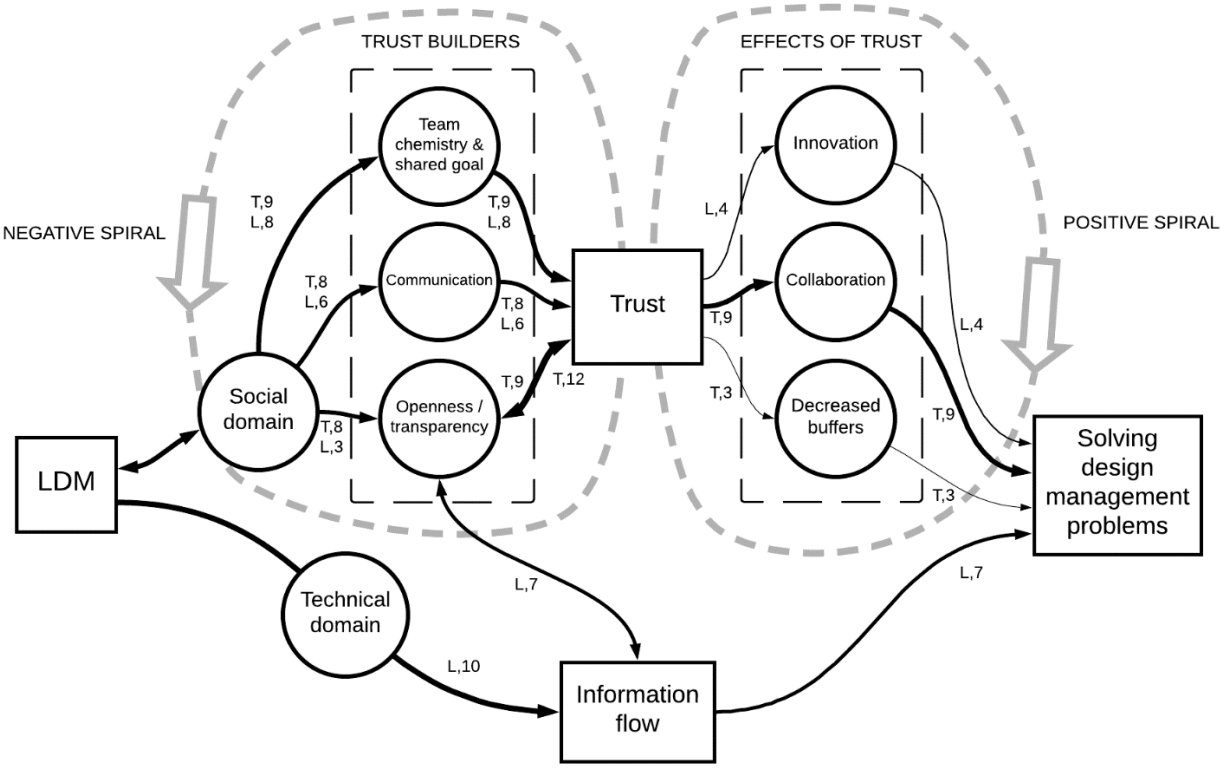

Figure 2. Conceptual framework for solving design management problems through LDM, trust and information flow. For example, the letter T in "T,12" indicates trust-themed interviews; 12 is the number of respondents who referred to that particular first-order theme. Correspondingly, "L" indicates LDM-themed interviews

This study makes three main theoretical contributions to the literature. First, we have shown that trust plays a pivotal role in solving design management problems. Trust strengthens a project's openness and transparency among the people involved, thus leading to better information flow and further fuelling trust building. Trust also has a significant positive effect on improving collaboration in projects. And, as Macomber and Howell (2003) state, innovation is a social phenomenon; one could

argue that the level of social interaction is deeper in trustful environments, which can potentially lead to improved innovation. In addition to innovation, this study has identified two other impacts of trust in design management settings – collaboration and decreased buffers – both of which play critical roles when solving design management problems.

Second, this study has shown that the social domain of LDM has major positive effects on building trust. The study has demonstrated that the use of LDM, especially those tools that are included in the social domain, can deepen the trust between project actors and develop trust from the calculus-based level to more advanced levels (Laine, 2008). The technical domain of LDM also has a positive effect in building trust by contributing to openness and transparency while improving the overall information flow of a project. Based on the interviews, the use of LDM tools showed no associated downsides.

Third, the findings indicate that trust and the social domain of LDM are reciprocally interconnected, such that trust is not only an outcome of LDM, but trust among the project team will also facilitate people's engagement with the social domains of LDM. Therefore, managers should first use LDM concepts (including the social domains), because doing so will strengthen trust among people, which again will facilitate the adoption of LDM concepts in general. An initial level of trust is required to effectively use the social domain of LDM, however. In the next phase, managers could also adopt LDM concepts from the purely technical domains. By doing so, projects with the required initial level of trust would best benefit from the LDM concepts. How much trust is needed is an open question, as is whether LDM concepts are beneficial in an environment without the initial moderate level of trust between parties. A few researchers on the implementation of lean in corrupt environments have argued that lean tools do not work in low-trust environments (Gehbauer *et al*., 2017).

As a practical contribution, this study's findings show that at the project level, managers should focus on any tool, method or process that will foster social interactions among the project team. The results from this study should urge construction professionals to continue to use LDM concepts that incorporate the social domain – such as LPS, integrated concurrent engineering (ICE), Big Room and other trust-building practices – in order to promote problem-solving in design management. Design managers rarely have contractual relationships with projects' design parties; when arguments arise, managers can typically only rely on inter-personal trust between designers and the design management team. Therefore design managers should focus on improving trust. Based on this research, LDM tools are a practical way to achieve that goal. We should note, however, that design management problems will not be solved by themselves, even in a project with high levels of trust. Trust fosters an optimal project climate where individuals have the possibility of utilizing LDM tools effectively.

Members of the construction industry have increasingly promoted collaborative initiatives in recent years (e.g. Aapaoja *et al*., 2013; Zimina *et al*., 2013; Boukendour and Hughes, 2014). Most collaborative contract forms do not specify a certain set of processes (Lahdenperä, 2012). The current study recommends that collaborative contract forms could yield improved results by utilizing LDM concepts to achieve a positive spiral of trust.

The vast majority of projects are still performed in the traditional way, and they routinely end in disputes and conflicts (Boukendour and Hughes, 2014). These conflicts are representative of the distrust among project parties, which could be a consequence of the negative spiral of trust being in circulation. The findings of this study demonstrate the possibility of achieving a positive spiral of trust by using LDM concepts. More action research should be conducted on whether negative spirals of trust can be stopped by implementing LDM tools from the social domain.

The present study also suggests that trust should have a more strategic role as a key performance indicator in projects and companies. The construction industry is generally considered to be highly conservative, and most of its managerial approaches are technically oriented and completely neglect various social aspects. The continuous measurement of trust and the selection of people based on their collaborative skills would likely result in better project outcomes. The findings from the present study suggest that local industry ecosystems should develop open platforms to openly evaluate and rate actors and their trustworthiness. Doing so would likely lead to a paradigm shift in the business models and relationships found in the construction sector.

Conclusions

The aim of this study was to elaborate on the connections between LDM methods and trust in solving design management problems within construction projects. This research has shown that trust plays a prominent role in solving design management problems. Trust decreases buffers within the planning of all project actors, fosters innovation and, most importantly, promotes collaborative behaviour. All these factors are critical in solving design management problems.

According to this study, the relationship between trust and LDM is a substantial one. The social domain of LDM improves team chemistry, communication, openness and transparency and creates a sense of shared goals. These attributes may be said to be trust builders in a project. The information flow between actors also plays a role in promoting trust through openness and transparency. The results from this study indicate that both trust and information flow are necessary for the efficient solving of design management problems. One limitation of this study, however, is that the relative importance of these factors cannot be decisively concluded.

Because this research has relied on qualitative data from limited sources who represent various professional fields, further research is recommended to quantitatively test the conceptual framework in various contexts, for example through survey studies in different cultural contexts. An examination of different case studies will also be necessary to further deepen the field's understanding of how managers use LDM concepts to build trust, and how trust enables the solving of design management problems. The use of case studies could also reveal the relative importance of information flow and trust. While the conceptual framework of the present study is based on the assumption of existing trust inside a project, more research is needed to determine whether or not some level of trust is a prerequisite for LDM to function in solving design management problems. Future researchers might therefore find it useful to test the framework in projects that have some but not all of the relevant parameters. Another important open question to be answered is whether LDM may be used to stop negative spirals of trust from developing when problems occur.

Acknowledgement

The research described in this paper was supported by members of the Vision 2030 consortium. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of members of Vision 2030.

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