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Article

Improving Building Design Processes and Design Management Practices: A Case Study

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Abstract: The aim of this case study, underpinned by participative action research and design science research methodologies, is to show how design and design management practices can be improved based on a new conception of design activity and lean design management. First, problems related to design and design project management are identified using a triangulation of methods, and a root-cause analysis is conducted. Second, interventions are developed, implemented, and evaluated over two iterations. The methods and practices employed in the organization under study imply it had adopted the transformation view of the conceptualization of design. It was also observed that the organization considered design strictly a technical activity. Both choices appeared to be the root causes of the problems faced by the organization. To complement the transformation view, methods and practices following the flow and value views were introduced. To counteract the strictly "technical understanding of design", "social" concepts were introduced. As a direct result of theory-driven interventions, there were significant improvements in building design processes and design management practices.

Keywords: building design; lean design; lean design management; design theory; technical design; social design

1. Introduction

The now vast body of design knowledge, beyond the capacity of any single individual to possess [1], has led to the division of the master builder role into dedicated specialized disciplines. Also considering the escalation in complexity of construction project delivery [2], a high level of collaboration, cooperation, and coordination within design and engineering processes has become inevitable [3]. Design management has been introduced to address these challenges [4].

Many long-standing problems in the construction industry are, directly or indirectly, related to poor designs, design processes, and design management practices [5,6]. According to Love and Li [7] and Love et al. [8], design problems have been the primary "contributor to building and infrastructure failures as well as project time and cost overruns" and to fatal accidents and injuries during the construction and operation of buildings [9].

According to Lopez et al. [10], regarding the problems and complexity of design project delivery, adherence to proper management practices and the provision of an environment for individuals to learn from mistakes have the most significant potential to improve building design. However, considering the numerous reports on design errors and failures [5,11,12], it is clear that design management has not been up to the task.

Kannengiesser and Gero [13] and Koskela et al. [14] contended that poor practices are the result of the lack of a common underlying theory of design and design management. In other words, to advance building design and design management practices, one must first understand the nature of design and design management activity.

In this study, in agreement with Koskela et al. [14] and Ballard and Koskela [15], design and design management are considered part of the broader phenomenon of production—the design and making of artefacts. This is justified because every design is meant to be produced, and all artefacts produced have been designed. Over the last three decades, lean design and lean design management have been developed on the basis of the transformation, flow, and value (TFV) theory of production (management) [16,17].

The productive nature of design activity and its embeddedness in a particular context means that design involves both technical and social activities, which address causality [18] and interpretation [19], respectively. However, in the current theorization on design, scholars tend to dichotomize design and design management as either a technical or social activity. As a consequence, no unified theory of design and design management has emerged [14,20].

The aim of the present study is to use a new conception of design as the basis for the improvement of design processes and design management practices. Specifically, the intent is to focus on the instantiation and development of practical support for building design processes and design management practices. The rest of the paper is divided into the following four sections: (1) research design and methods; (2) diagnosing as-is situation and theoretical explanation of problems and possible solutions.; (3) development, implementation and evaluation of interventions; (4) a summative evaluation and discussion, and conclusion.

2. Research Design and Methods

To improve design processes and design management practices in the organization under study, the methodologies of (participative) action research [21,22] and design science research [23] were used to structure the research process. The study consisted of five phases with the following objectives:

- Diagnosis of the as-is situation—to develop a proper understanding of problems with theoretical and practical relevance using a triangulation of methods.
- Theoretical explanation of problems and possible solutions—to develop a theoretical understanding of the problems based on a root-cause analysis of poor practices.
- Intervention development and implementation—to develop and implement practical support in design processes and design management practices.
- Evaluation of interventions—to measure the effects of new interventions.
- Clarification of lessons learned—to formulate generalized evaluative statements about the impact of interventions.

2.1. Case Organization

The present case study is a longitudinal study focusing on the activities of an Estonian design office founded in 2005 that provides building design and design project management services. In 2015, half of the projects were public design projects, the other half private design projects in either Estonia or Scandinavia. By the end of 2016 and continuing into 2017 and 2018, the portfolio of projects consisted mostly of private projects. The organization had been using building information modelling (BIM) since 2009, and by this time, all projects, no matter the size, were being completed using BIM. As of 2018, a total of about 40 people were working for the organization.

2.2. Research Methods

Research methods employed during the as-is situation analysis and intervention phases are described below.

2.2.1. Diagnosing the As-Is Situation

In the first phase—the diagnosis of the 'as-is' situation—the following three different methods were used to collect and analyze data: (1) surveys were used to identify the main challenges; (2) observations of three design projects were used to gain contextual understanding of the problems and challenges; and (3) a statistical analysis based on data from enterprise resource planning (ERP) software was used to quantify the challenges.

The survey was sent to 34 designers: 10 architects, 12 structural engineers, eight building services engineers, and four project managers. A total of 24 people responded, representing a response rate of 70.5%. In the survey, respondents were asked to assess the importance of issue statements related to design management and organization on a five-level Likert scale (from strongly disagree to strongly agree).

The observations of three projects can be divided into two categories, the observation of a single project over eight weeks and the observation and analysis of communication practices in two different but related projects. The single project observation, conducted over eight weeks between July 2016 and September 2016, entailed the observation of designers two days a week. Architects and engineers were observed from morning until evening, and all work activities and communications were recorded. In the second category of observations, the email communications of two related projects (amounting to about 3000 emails) were analyzed.

The design organization had been using an ERP system since 2011. This made it possible to carry out a retrospective analysis of the data for past projects. The answers to the following questions were sought: What type of projects had been completed and how successful were they? How well were they able to plan and execute their projects? How was time spent during the design process? What was the amount of resources expended on fixes, changes, and meetings before and after project contract deadlines?

For the database query, the following criteria were set: a minimum of two disciplines from the design organization had worked on the project; the project lasted for at least two stages out of the typical four in Estonia (schematic design [SD], preliminary design [PD], design development [DD], and construction documents [CD]); projects were executed between January 2014 and September 2016. Data for a total of 28 projects was retrieved and analyzed: ten residential buildings (35%), five industrial and warehouse buildings (18%), four office and four public buildings (14%), two commercial and two infrastructure facilities (7%), and one industrial and office project (5%). A total of 13,421 data points (activities) accounting for a total time of 51,357 h were exported to Excel for statistical analysis.

2.2.2. Intervention Development, Implementation, and Evaluation

The development and implementation of interventions was carried out together with members of the design organization: two board members, three heads of functional departments (architecture, structure, and building services), one project manager, one senior architect, and one senior engineer. The artefacts produced laid the foundation for several other interventions.

After the second iteration, a thorough evaluation consisting of two steps was carried out. In the first step, a focus group meeting was arranged to assess the impact of changes in the design organization. Participants were invited to take part in the focus group by e-mail; relevant information regarding its purpose and general guidelines were also included. Besides the design staff who had been involved in the iteration, a few additional staff members were included, bringing the number of participants to 10. Participants of the focus group meeting were divided into three groups of three or four persons and asked to evaluate the impact of the interventions on the organization.

In the second step, a general analysis of projects that began after the introduction of the interventions and completed before the end of this research project was carried out. The analysis here relied on the same database query criteria used in the as-is situation analysis. Data for a total of 10 projects was analyzed—three residential buildings (30%), one industrial and warehouse building (10%), two public buildings (20%), two commercial buildings (20%), and two infrastructure facilities (20%). A total of 2654 data points (activities) representing a total time of 15,297 h were exported to Excel for statistical analysis.

3. Diagnosing As-Is Situation and Theoretical Explanation of Problems and Possible Solutions

This section is divided into two parts. First, the problems identified in the organization under study are presented, summarized, and discussed. Second, a root-cause analysis of the problems is presented.

3.1. *Diagnosis of As-Is Situation*

In this sub-section, the objective is to identify the main problems in the organization under study using a triangulation of methods—surveys, observations, and an ERP database analysis.

3.1.1. Survey Results

Survey results are shown in Figure 1. Designers in the organization believed that better design projects could be delivered and that they knew where things were going wrong and why. In other words, designers/engineers recognized that practices in the organization could be improved. The main problems were considered to be related to poor coordination, the inherent uncertainty in information flows, and the lack of timely responses from clients.

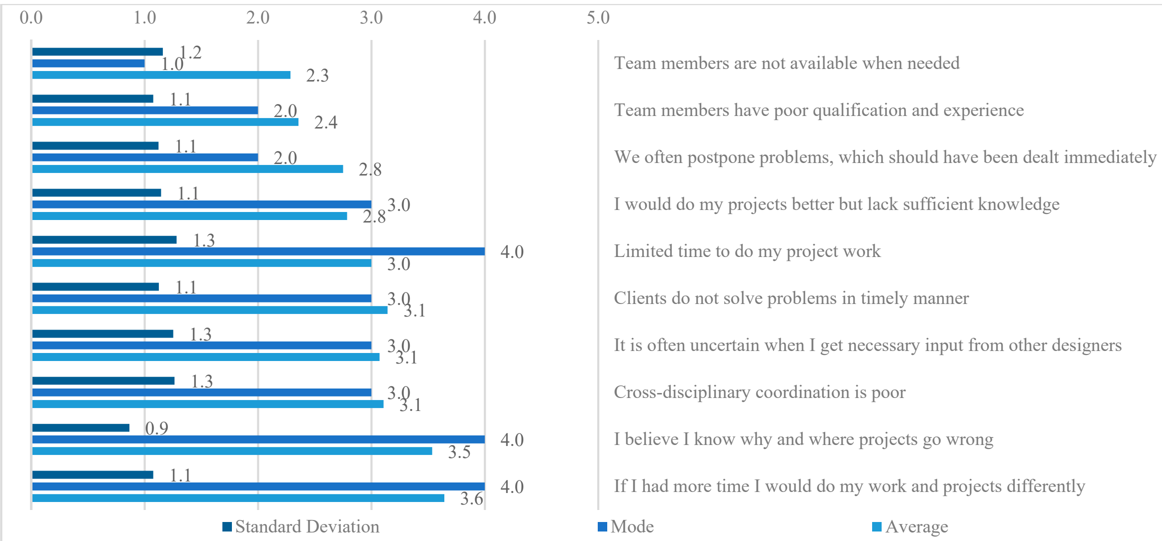


Figure 1. Summary of results of survey on design management and organizational issues in the design organization (0—strongly disagree to 5—strongly agree).

Responses were also analyzed according to the respondent's specialization and years of work experience. For experienced designers, engineers, and design managers, the most significant problems were related to lack of information/communication and late changes. For design managers, technical IT solutions were considered important, and the main challenge for project managers was limited time resources. For building services engineers, as their work depended greatly on the decisions made by clients, architects, and structural engineers, the main problems were related to late changes and poor coordination.

3.1.2. Observations of Design Development Stage and Communication Practices

In the first category of observations, the planned work, progress, and problems discussed during the stand-up meetings were the focus of observations. A total of 154 events were recorded over the eight-week period. Events were coded as one of three types—activities (57%), exchange of information (20%), and problem-solving (23%). Out of 154 events, 20 were interdisciplinary events: one design activity out of a total of 88 (about 1%); nine exchanges of information out of a total of 31 (about 29%); and 10 problem-solving events out of a total of 35 (29%).

Interestingly, out of a total of 88 activities, just one was recorded as a collaborative design activity. The architect and building services engineer addressed (before the actual designing of the ceilings) the issue of what the elevation of the ceilings from the floor should be to provide adequate space for the building services above it. However, in all other instances, solutions were prepared from the perspective of individual designers first and then coordinated retrospectively.

Out of the total of 88 design activities, 58% were design and engineering activities (calculations, drawings, specifications, and model coordination), 28% changes, 6% waiting (designers had to stop working on a planned activity and work on something else while waiting for inputs), 5% control activities, and 3% other activities. It could be argued that only 58% of the 88 design activity events recorded were directly value-adding, the rest being non-value adding. In other words, the proportion of value-adding activities could be considered low.

Next, problems in the design process were analyzed to understand their origin. A total of 35 problems were recorded: 9% architectural, 20% structural, 43% building services related, and 29% interdisciplinary. The problems within disciplines were due to a lack of information and changing requirements, while conflicting needs and legislative requirements, faulty input information, and poor coordination were the leading causes of problems between disciplines. Also, many problems (26%) were directly related to the usage of information and communication technologies: e.g., something could not be modelled in Revit, or the skills required to use it for a specific design task were lacking.

In the second category of observations, the email communications of two projects were analyzed. A total of 2899 emails were exchanged. In the case of the first project, out of a total of 935 emails, 40% were directly sent to the project manager, and 49% were received by the project manager; in the case of the second project, out of a total of 1964 emails, the figures were 37% and 44%, respectively. This is an indication that the project manager spent a significant amount of time managing and sharing information. As the project manager was responsible for managing several projects at the same time, the project manager thus became the communication bottleneck.

A content analysis of emails revealed no clearly defined stage for the specification of owner needs and requirements. Not unexpectedly, the specification and re-specification of requirements lasted throughout the entire project lifecycle. Arguably, a large proportion of late changes could be related to poor requirements capture. Also, a lack of timely responses, known as latency [24], was observed in the communication patterns. The analysis also showed that the average duration of email exchanges (the entire thread from beginning to end) between the client and delivery team in days was longer than that between delivery team members, 3.78 and 2.04 days, respectively. Although not a substantial difference in absolute numbers, the long response times of the client had a significant impact on the progress of the two small-scale projects.

Several general observations were also made. The team was focused on problem-solving instead of the avoidance of problems. There was little collaborative discussion or study of design alternatives. The principal tools used for project management were the resource Excel tables for each discipline (per design phase), lump-sum contracts, Gantt chart and critical path methods, weekly or bi-weekly meetings, and BIM enabled clash detection and resolution for design coordination. The focus of the weekly or bi-weekly meetings was on the mapping of the deviations of actual due dates from the planned ones without reference to higher level plans (master and phase plans) and resource consumption. Issues related to design input information and work to be executed were also discussed at the meetings. Finally, instead of meeting in person to discuss solutions and alternatives, they tended to communicate by email to identify, develop, and analyze design alternatives and verify or validate them with a client or team members.

3.1.3. ERP Database Analysis

Data from the ERP database was used for a quantitative analysis. First, the difference between planned project work hours and actual work hours was analyzed. Excluding sub-contracting hours, a total of 50,795 h of design work were planned, while 50,051 h were reported. Thus, the overall difference was about −1%, meaning that less time was spent on work than planned. However, the difference between planned and actual work time varied significantly across project categories. The figure was 32% for office buildings, 23% for residential buildings, 38% for infrastructure facilities, −6% for commercial facilities, −10% for industrial and warehouse buildings, −9% for industrial and office buildings, and 10% for public buildings. The difference between planned and actual work time at the project category level was 33%. Thus, although, the organization may be considered successful at the project category level, there was a significant difference between the actual time spent and the time planned.

Next, the percentage of total design time spent across all 28 projects on each project stage in three different disciplines was calculated. It turned out that the greatest amount of time was spent on the design development stage (37.3%) and the construction documentation stage (51.1%). Considerably less time was spent on the schematic design stage (2.9%) and the preliminary design stage (9.2%). In these early stages, structural engineers and building services engineers were only minimally involved. In general, a lot of project time was spent on producing drawings but not on collaboratively generating and studying alternatives to maximize value for the client.

Twelve projects (out of 28) which included the SD, PD, and DD stages were also analyzed. When calculating the distribution of work time expenditure, project durations were normalized (to a scale of 1–100, where 1 unit = 5%), and the curve was projected using a fourth-order polynomial. The average contract deadline was determined by adding up all the normalized planned durations of projects expressed in the given units and dividing this sum by the total number of projects. For example, if one project ended four units in, the second nine units in, and the third six units in, then the average would be 6.33 (calculated as (4+9+6)/3) (see Figure 2).

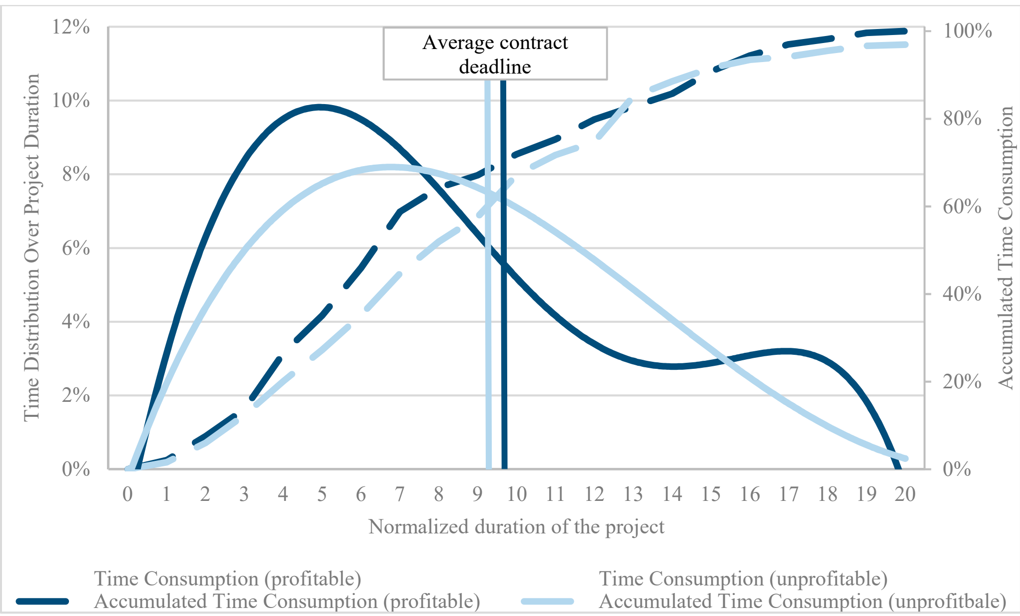


Figure 2. The average work time expenditure over the lifetime of 12 design projects on the left axis and accumulated time expenditure on the right axis. (profitable: blue lines; unprofitable: gray lines)

The analysis showed that projects with a resource peak that occurred around the middle of the contract duration (dark solid blue line) were more likely to be profitable. The unprofitable ones had a significantly flatter resource curve (light solid blue line) throughout the entire life of the project. All unprofitable projects had very long tails. As clients often do not have a contractual obligation to cover the costs of extra time and resources spent, overly long tails make projects unprofitable.

To develop a deeper understanding of the reasons for these tails, the projects were further analyzed in terms of the time spent on design fixes, changes, and meetings. In the case of profitable projects, 0% was spent on design fixes before the contract deadline and 0.7% after; 2.7% was spent on changes before and 1.6% after; and 7.5% was spent on meetings before and 2.3% after. In the case of unprofitable projects, 3.7% was spent on design fixes before and 2.0% after; 1.0% was spent on changes before and 0.7% after; and 4.5% was spent on meetings before and 1.6% after. The most significant difference was in the amount of time spent on fixes; that is, more design fixes throughout the design project delivery tended to make projects unprofitable. Arguably, the key to making projects profitable is to assure the quality of designs from the beginning of a project.

According to discipline, the distribution of time across 14 different types of activities and across 28 projects showed that little time was spent on monitoring and supervising work activities within the discipline. This might explain the poor project oversight, design problems, and errors that led to numerous fixes in unprofitable projects. In other words, the limited focus of design management could be considered one of the potential causes of project failure.

3.1.4. Summary of Findings and Problem Areas

Evidence revealed that the design and design management in the company was underperforming. The main findings included client's lack of timely responses (see Section 3.1.1); unnecessary rework (Section 3.1.1); uncertainty in information flows (Section 3.1.1); late changes (Sections 3.1.1 and 3.1.2); misalignment of designs across disciplines (Sections 3.1.1 and 3.1.2); wrong use of email (Section 3.1.2); low proportion of value-adding activities (Section 3.1.2); no concentrated effort to specify client requirements (Section 3.1.2); lack of collaborative study and discussion of design alternatives (Section 3.1.2); latency in information flows (see Section 3.1.2); project managers as the information bottlenecks (Section 3.1.2); lack of competencies to use BIM and information technologies (Section 3.1.2); unprofitable projects with more significant proportion of design fixes (Section 3.1.3); high variation in the level of individual projects (Section 3.1.3); and the focus in design was on the production of drawings (see Section 3.1.3).

Observations showed that the primary methods and tools used to plan and organize design work were resource planning and monitoring, contracts, traditional Gantt charts and critical path methods, and weekly or bi-weekly meetings (see Section 3.1.2). For design coordination, only BIM-based clash detection was observed. The focus of the design meetings was on progress monitoring, the acquiring of necessary design input information, and discussions of the tasks to be executed (see Sections 3.1.2 and 3.1.3). No methods, techniques, or tools were identified for scope specification, phase planning, work sequence optimization (such as a design structure matrix), the preparation of design work for execution, the weekly and daily management of design work, the updating of plans, and the facilitation of learning from mistakes (see Section 3.1.2). Also, besides formal design reviews, no specific methods or techniques for quality assurance and control were observed. Furthermore, no strategic allocation of resources to requirements capture and systematic study of alternatives was observed (see Sections 3.1.2 and 3.1.3). For example, without a strategic allocation of resources to the earlier stages of design, there can be no concurrent engineering (Koskela 2006).

The empirical analysis revealed that traditional design project management was the only visible framework for the management of design projects and activities. In design management, the focus was on the task (who, what, and when), the contract, and resource management (i.e., allocation of hours per discipline and stage). Further, the fact that about 40% of emails were either sent or directly received by project managers (see Section 3.1.2) reflects the command and control based view of project management [25].

It could be argued that it is the poor conceptualization and understanding of the nature of design and design management. For example, no time was allocated to the early stages of design to properly engage customers and users or to study and analyze requirements and alternatives. This may be due to the assumption made by designers and design managers that clients and users know their needs and requirements. Moreover, though design is also a social activity, the lack of collaboration and poor coordination seem to indicate that design was seen primarily as a technical activity. In summary, the most significant problem areas were related to client and user engagement, requirements capture, a systematic study of alternatives, design quality, the planning and control of design processes, communication, collaboration and coordination, design (project) management, the understanding of design, and competencies.

3.2. Theoretical Explanation of Problems and Possible Solutions

In this section, to identify the root causes of (performance) problems, design and managerial practices in the company under study are evaluated from three different theoretical perspectives: lean design as part of production, lean design management, and the new design theory.

3.2.1. Lean Design as Part of Production

Koskela [16] argued that "production consists of three core phenomena: product development, order delivery and production proper, which all face the customer". Koskela [16] further proposed the transformation, flow, and value theory (TFV) of production (management). In this conceptualization, design is seen from three different views [14] as (1) the conversion of inputs to outputs, (2) the flow of information and materials through time and space, and (3) the process of generating value for the customer.

The main principles of the transformation view of design include hierarchical decomposition and the control of decomposed activities. Typical methods and practices include the work break-down structure, the critical path method, and organizational responsibility charts. The focus is on getting the design task done, i.e., task management [26]. However, the transformation view neglects time and the customer as essential features of the design 16. This is due to the following assumptions: "the project goals and targets are clear and given from above; . . . the means of reaching the targets are identifiable and plannable" [25]; and it is the responsibility of project management to command and control the progress of design work [27].

But designing almost always involves aspects and phenomena beyond individual activities [1,28]. This means that designing needs to be seen from the flow perspective as well [26]; it needs to address the structuring of information flows to reduce uncertainty and eliminate waste (unnecessary rework or work that is not value-adding). In the flow view, typical methods and practices include the design structure matrix, tool integration, and partnering [16]. A team approach and design information batch reduction are also advocated [15]. The focus is on spending as little time as possible on activities that are unnecessary (wasteful).

The main principles of the value view include the elimination of value loss, systematic requirements analysis, requirements flow-down, and optimization [16]. Typical methods and practices include quality function deployment, requirements management, value engineering, and robustness engineering [26]. In the value view, the focus is on taking care that customer needs and requirements are met in the best possible manner.

Poor client and user engagement, poor requirements analysis, the absence of a systematic study of alternatives, and shortcomings in design quality point to deficiencies in the value view. The problems related to the planning and control of design processes, communication, and collaboration and coordination also suggest that the flow view of design and design management was neglected. At the same time, the use of conventional project management methods together with their underlying assumptions (requirements are given, means are identifiable, and tasks can be managed through command and control) implies that the transformation view of design was dominant. Thus, the first root cause of problems in the organization is now evident, namely the neglect of flow and value views.

3.2.2. Lean Design Management

Lean design management was developed over the last three decades [29]. Based on TFV theory, lean design management has three functions [16]: design system design, design system operation, and design system improvement. Principles, methods, and tools to facilitate and support these functions have been introduced in lean design management. These include, for example, cross-functional teams, a set-based design strategy, structured design work, the minimization of negative iterations, and the Last Planner System® (LPS) [30] and related technologies (e.g., BIM), which all serve to facilitate design processes [15,17].

Design system design must be approached from the three perspectives of production [26]—value generation (why), transformation (what), and flow (how). Principal design system activities include a proper start-up of the design project (e.g., decisions related to the physical layout of designers (co-location), and information and communication technologies, and contract forms); the preparation of project guidelines (e.g., decisions on standards, decision-making structures, validation and verification structures, and methods and tools), and the establishment of a shared project vision (e.g., decisions on design project targets) [6].

Design system operation is divided into planning, supervising, and correcting management activities [15]. These managerial activities recur throughout the different design project stages and at different levels of resolution (phase, lookahead, weekly, and daily) [30]. Methods such as the design structure matrix, collaborative planning, and strategies for managing unnecessary iterations have been introduced [15]. The LPS, which embodies the principles of social processes for design production system control, has also been proposed [30]. As a collaborative approach, it was devised to make design production reliable and predictable by improving work flow, building trust, and reducing waste.

In design system improvement, the focus is on the gathering of contextual information for the improvement of design system design and operation throughout the different stages of project delivery and at the end of the design project [15]. To prevent the reoccurrence of breakdowns, a root cause analysis of deviations is conducted, and action is taken in the given and future projects.

Based on this brief description of lean design management functions, it is possible to evaluate the methods and practices followed in the organization under study. It was observed that the principal methods and practices followed in the management of design projects were resource planning, traditional contracting, and master planning. Thus, the neglect of flow and value views of design system design could have been a factor contributing to the development and implementation of partial and fragmentary design processes and design management practices in the organization.

The principal methods and practices followed in design system operations in the organization under study included weekly or bi-weekly meetings and BIM-based design coordination (clash detection). Part of the focus in weekly or bi-weekly meetings was on the identification of persons responsible for the deviations. Again, aspects such as phase planning, design work sequencing, the study and analysis of alternatives, and preparatory work were either omitted or left for self-management by the team.

Regarding design system improvement, no specific methods and practices besides the monitoring of project resources and project financial accounting were observed. There was little organizational learning during and between projects. Thus, in comparison with those of lean design management, the design management practices of the organization under study exhibited many deficiencies.

Overall, the focus appeared to be on technical aspects, and the management of the social dimension of designing was overlooked. That is, social dimensions of designing were overlooked [1]; no shared understanding to coordinate building design was established [31]; and social dimensions of design management were neglected [32]. However, there is little explanation on what social dimensions of design mean [31]. Thus, there is a need for a more comprehensive theory of design that integrates the technical with the social aspects of designing.

3.2.3. Design Theory

Despite the considerable work on design theory [33], no unified theory of design has emerged [20]. According to Love [28], the reasons for there not being a unified theory of design include the neglect of philosophical issues, domain-specific approaches, the absence of agreed definitions and terminology, and poor integration of theories across disciplines.

Pikas [34] proposed a conceptualization that integrates the technical and social aspects of design, embodying object- and subject-oriented activities, which address causality [18] and interpretation [19], respectively. From the perspective of causality, the focus in design is on the design object (e.g., the theory of technical systems [35]) and activity (e.g., design methodology and methods [36]), and from the perspective of interpretation, the focus is on human purposes (e.g., human-centered design [37]) and interactions (e.g., design as a social process 1). However, moving beyond this dichotomization, Pikas [34] argued that all acts of design consist of varying degrees of causality and interpretation (see Figure 3).

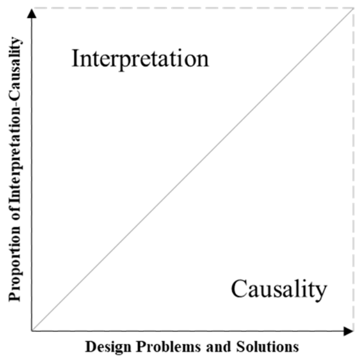


Figure 3. Design acts contain varying proportions of interpretation and causality [34].

Regarding the operationalizing of the interpretative and causal dimensions of designing, Koskela and Ballard [38] argued that the method of analysis [39] and rhetoric [40] represent two different yet complementary methods for design conceptualization. The idea that the two ancient strategies of inquiry independently inspire design conceptualization is not new to the design research domain [18,41–45]. However, only Koskela and Ballard [38] have attempted to integrate the method of analysis with design rhetoric.

The method of analysis, as a strategy of inquiry, introduces basic ideas, principles, factors, and processes to solve or discover solutions (theorems and constructions) for geometric problems [39]. Rhetoric, as a strategy of inquiry, also introduces basic ideas, principles, factors, and processes, but for the development and study of persuasive communication [40,46]. The method of analysis has been used to conceptualize human technical activity [18,47], while rhetoric has been used to conceptualize both technical and social activities [19].

Pikas [34] introduced a new design model (Figure 4) based on the method of analysis and rhetoric that provides a process structure for integrating technical and social design activities. The objective here is not to explain and justify the construction of this new design model (see the original work), but rather, the focus is on the application of the design model to facilitate the improvement of design processes and design management practices. The new conception of design developed by Pikas [34] is expected to contribute to the better development, integration, and implementation of methods and tools.

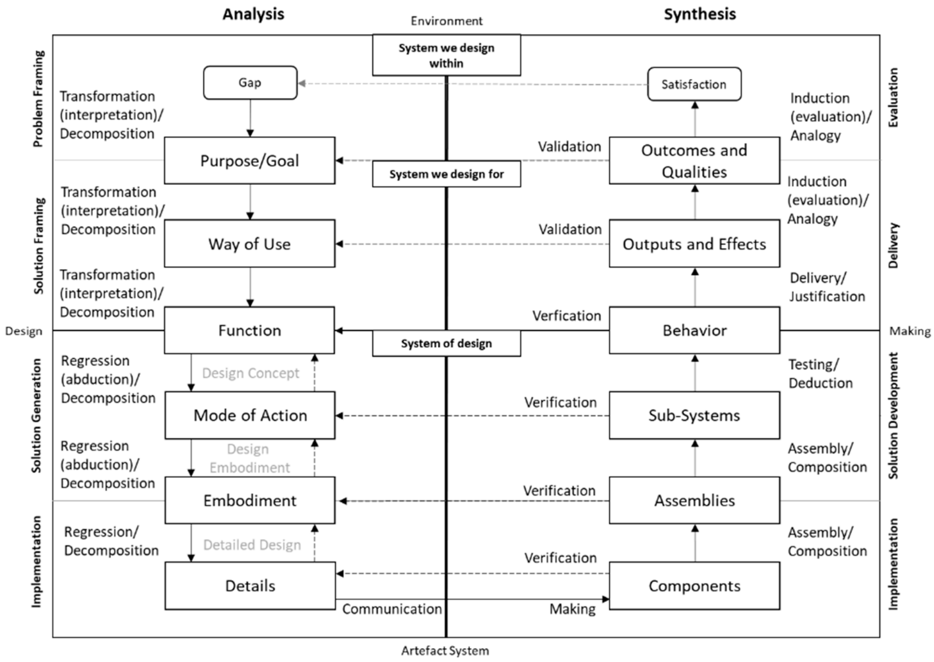


Figure 4. The design process model for integrating object- and subject-oriented activities [34].

3.2.4. Summary and Discussion

Design processes and design management practices in building projects are beset with many longstanding problems, as evidenced in the organization under study. The root problem appeared to be that the organization proceeded from a partial theory of production. That is, the flow and value views were disregarded in favor of the transformation view. It was also observed that the social view of designing had been neglected. These choices appear to be the root sources of problems in the organization, and the problems can thus be viewed as self-inflicted.

To balance the prevailing transformation view, methods, and practices compatible with the flow and value views needed to be introduced. To counter the "technical" bias, "social" concepts had to be introduced. However, though the need for the social conceptualization of design has been acknowledged in lean design and lean design management, no unified theory addressing technical and social processes has yet been developed [31].

Pikas [34] proposed that better practices might be developed using a new integrated design model. Specifically, it was argued that the integration of the method of analysis with design rhetoric could facilitate the operationalization of technical and social design activities. Table 1 presents the conceptual framework for the development, implementation, and evaluation of interventions in the organization under study.

Table 1. The conceptual framework for improving building design processes and design management practices in the organization under study.

Dimensions	Contributing Concepts
Lean Design as Part of Production	Transformation, flow, and value theory of design production
Lean Design Management	Design, operation, and improvement of design production systems Strategies, principles, methods, and tools compatible with the flow and value views
Design theory	Causality and interpretation Technical object- and social subject-oriented activities Method of analysis and design rhetoric

4. Intervention Development, Implementation, and Evaluation

In this section, the development and implementation of interventions across two iterations are described. The focus is on the improvement of building design processes and design management practices based on the proposed conceptual framework in Table 1.

4.1. First Iteration: Development, Action Planning, and Implementation

The first iteration focused on design management practices, and problems connected with the neglect of flow and value views and social factors were tackled. Specifically, client and user engagement, design quality, the planning and control of design processes, communication, and collaboration and coordination were addressed.

As a first step, the lead author of this paper facilitated the development of a common design management system (framework), which was discussed and agreed on with members of the design organization. Woods [48] argued that frameworks are important: "The form of ... frameworks is as much about the order that our own minds require to move forward effectively as it is about the accuracy with which some aspect of the world has been captured".

The configuration of the design project management framework is shown in Figure 5. First, the typical design project life-cycle from the perspective of the organization was divided into three stages: sales, delivery, and closeout. Next, the three design management functions (design system design, design system operation, and design system improvement) were mapped onto the project life-cycle stages. It was agreed with members of the organization that design managers and lead designers needed to be involved as early as the end of the sales stage and up until the design project closeout so that false promises would not be made to the customer and the team would be able to learn from project successes and failures. Design system design and design system improvement partially overlap with the delivery period. These overlaps are justified, as design of the design system and improvement of the design system are managerial functions that continue throughout all stages of design delivery. Design system operation, divided into plan, execute, and control management activities, falls within the delivery period.

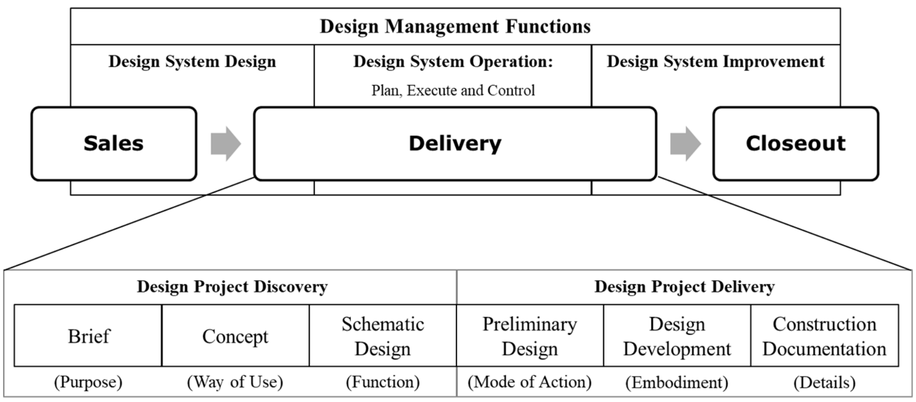


Figure 5. The developed common design management framework in the design organization.

The delivery period, broken down according to the new process model (Figure 4), and in accordance with the Estonian Building Design Standard, comprises the brief, concept, and schematic design stages of design project discovery and the preliminary design, design development, and construction documentation stages of design project delivery. Other ideas related to the new design model, such as design contexts, which provide different perspectives of the object and subject-oriented activities and design iterations, were also introduced to design managers and designers [34].

Next, on the basis of this common framework, the logic of the LPS [30] was aligned with design management processes. The LPS was devised to ensure reliable design process flow by enabling the right conversations and establishing a network of commitments. Thus, means were established to facilitate both technical aspects (designing the design process) and social aspects (conversations between project parties) of design process management. The implementation of the framework followed.

The lead author of this paper worked together with the project manager, design team, and client to establish a master schedule, quality plan, communication plan, and financial plan during the project briefing stage. The lead author also supported the design team in its efforts to implement the LPS in a design project in eastern Estonia. Each design phase began with phase scheduling based on 'pull' principles to help the design team better manage the sequence of work through the communication of what needed to be done, why they needed to do it, and what the best way for them to do it was. As part of the pull planning, the required clash detection and intermediate design review meetings were introduced.

During the implementation of the framework, an emphasis was placed on 'lookahead' planning, which was connected to the tasks identified in the pull planning. The 'lookahead' plan was continually managed and tracked by the project manager. Every second week, a client meeting was held to provide the client with an update on progress, plans, and problems that needed to be addressed. After each client meeting, a team meeting was held, and the necessary changes in the pull schedule were made.

Thus, problems were addressed by implementing the common design management framework. This new understanding was implemented together with the LPS, bi-weekly client meetings, required clash detection, and design review meetings. The input required from the client was determined in the collaborative pull planning meetings. Poor technical coordination was addressed by adding the necessary BIM-enabled design coordination tasks and meetings to the phase plans. Similarly, the lack of quality was addressed by including compulsory design reviews in phase plans for individual designs and the design as a whole.

4.2. Second Iteration: Development, Action Planning, and Implementation

In the second iteration, problems related to client and user engagement, requirements analysis and the systematic study of alternatives, design quality, the planning and control of design processes, communication, collaboration and coordination, design (project) management and the understanding of design were addressed. This focus was selected on the basis of the initial feedback from designers and design managers.

First, a simplified structure for phases was established. Every phase was agreed to begin with the design briefing and end with a design review meeting involving all stakeholders in the design project. The structuring of the process was inspired by the new design model, while the focus would first be on the rhetorical perspective (subject-oriented activities), then on the method of analysis perspective (object-oriented activities), and finally, back on the rhetorical perspective (subject-oriented activities).

At the beginning of each phase, the rhetorical approach was concerned with the establishment of expected value propositions and a commitment to phase objectives, while at the end of the phase, it was concerned with an evaluation of design solutions when measured against value propositions. In other words, two meetings were required: a design briefing meeting and a client review meeting. For these meetings, a standardized structure and procedures were established (objectives, participants, typical agenda, and expected outputs); i.e., the means to structure and facilitate social interactions in the design process were established.

From the managerial perspective, the planning, execution, and control phase consisted of two sub-cycles of planning, execution, and control: weekly or bi-weekly and daily cycles. The weekly or bi-weekly cycles describe the work flow from the planning of meetings between the client and team, to work execution and control, then to the coordination of work-in-progress through model coordination and resolution, and finally, back to team planning sessions. The daily cycle is followed by individual designers in their daily work.

From the design perspective, the flow from one milestone to the next requires completion of activities and deliverables that form a baseline for the subsequent phase. Two types of standardized second level process descriptions were developed based on the high-level framework, one for project briefing and the other for the remaining design phases.

The managerial and design activities in the project briefing stage were mostly related to strategic aspects of the project, such as assessment of the need for a technology project, surveys, research, resources, and trade partners. Activities also included the development of a project program and establishment of a shared understanding of project objectives, working methods, collaboration practices, and expected behaviors through team and start-up meetings.

Second level process descriptions were also developed for other project delivery phases. Standardized phase descriptions were developed on the assumption that each phase would involve a similar process. Of course, in reality, processes are never the same, and it is the skill and experience of project managers, lead architects, and engineers that determines which activities are necessary or not in a given phase. These interventions were introduced to the whole organization, department-wise, by participants at the model development meeting; i.e., the structural engineering lead introduced the model to the structural engineering department, the architecture lead to the architecture department, etc.

The design model also became the basis for the development of further improvements, including but not limited to the following: checklists, a new classification system for design activities, a BIM execution plan, and visual control tools. Key tasks from the common design management framework were included on the checklists for design managers. On the checklists for designers, questions were structured according to design project stages, material type, and part of the building (e.g., walls).

Notably, to make the new process-oriented management of the projects more effective, departments were replaced by disciplines in the organizational structure. The typical tasks of the heads of the departments were shared by the CEO, project managers, lead designers, and engineers. Also, the bonus system was changed from department-based to project-based, where bonuses were tied to a project's overall success, thus motivating different disciplines to work together.

In summary, many interventions were introduced in the second iteration. Most importantly, problems were addressed by introducing process models, checklists, meeting templates and structures, and visual controls. A new organizational structure and bonus system were also introduced to align the interests of different participants in the organization.

4.3. Evaluation of Interventions

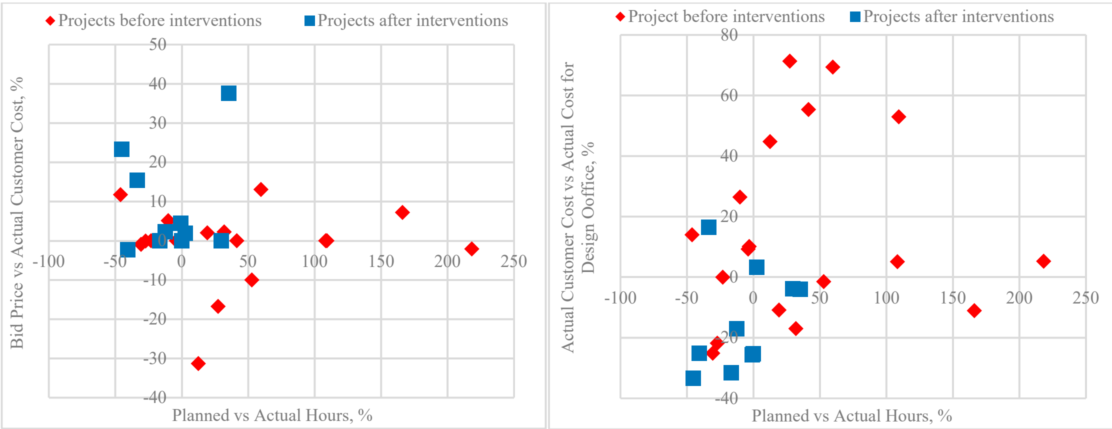
After the second iteration, a two-step evaluation consisting of a focus group interview and an ERP database analysis was conducted.

4.3.1. Focus Group Interview

Ten people from the design organization took part in the focus group interview. The task of the groups was to assess the impact of the interventions based on statements of the problems/issues identified in the first survey (see Section 3.1.1). Focus group participants experienced improvement in all categories of problems. All groups seemed to agree that planning, execution, and control systems were more coherent and transparent. The improved design management system led to better change management, resource management, coordination, and communication practices. However, one group did point out that the changes made sometimes caused new interdependencies, and these were not adequately communicated. Thus, change management and design coordination issues would need to be addressed in future iterations. That is, as was stated by the project manager in the focus group interview, the organization needs to adopt the continuous improvement mentality in order to sustain the advances that company had made.

4.3.2. Database Analysis Results

To be able to compare the projects that began after the introduction of the interventions with the ones analyzed in Section 3.1.3, an additional macro-analysis was carried out. Out of the 28 projects that were completed before the first iteration of interventions, only half were profitable. However, out of the 10 projects selected for this analysis, only two projects did not make a profit. Figure 6a,b summarize the overall performance level of design project delivery.



(**a**) (**b**)

Figure 6. Two-dimensional comparison of project performance and variation of time, cost and price before and after the interventions: (**a**) the vertical axis represents the relative difference between initial resource need (budget) and actual consumption; (**b**) the vertical axis represents the relative difference between the actual cost for the customer and actual cost for the design organization.

The horizontal axis in both Figure 6a,b represent the design organization's ability to meet the initial resource commitments (number of hours of design work). The blue dots tend to lie closer to zero along the horizontal axis, meaning that time-wise these projects deviated less from the initial plan. In the case of pre-intervention projects, however, there was a tendency for significantly more design hours to be spent to complete the work than was initially planned. In one case, the design hours required to complete a project exceeded planned hours by more than 200%.

The position of the dots along the vertical axis in Figure 6a represents the percentage difference between the original bid price and the actual customer cost. The figure shows that, in the case of pre-intervention projects (red dots), in many instances the final cost for the customer was higher (above the horizontal axis) than initially planned. On the other hand, in the case of new projects (blue dots), only three projects turned out to be significantly more costly for clients.

The vertical axis in Figure 6b represents the percentage difference between actual customer cost and actual cost for the design organization. When the percentage difference was above the horizontal axis, the organization lost money. While just two of the new projects (blue dots) lost money, over half of the old projects (red dots) lost money.

As a high-level indication of impact, the design organization, which failed to make a profit in 2015, had a profit margin of 5.5% in 2016 and around 20% in 2017 and 2018. As such, the improvement of design processes contributed to the economic growth of the company and possibly, to the construction industry in general. Economic growth is one area in the UN's Sustainable Development Goals [49].

Benefits of applying lean design and design management principles have been demonstrated in other studies. For example, Freire and Alarcón [50] developed an improvement methodology for design processes, resulting in a 33% increase in the share of value-adding activities, a 44% reduction of design errors and 58% of waiting times. However, their study addressed neither the performance of the design company as a whole nor the social dimensions of designing.

5. Summative Evaluation and Discussion

Earlier research and the case study show that design and design management are beset with many problems. Adoption of an incomplete theory of design seemed to be the root cause of problems. The transformation view of production was favored over the flow and value views. However, a coherent theory of production requires a balanced implementation of transformation, flow, and value views [16]. Otherwise, performance will suffer.

In the as-is situation analysis, it was observed that design and design management were viewed as technical activities. Lean production and lean design management literature have recognized the need for a social conceptualization of design and design management [14,32,51]. However, Çıdık and Boyd [31] argued that no coherent social conceptualization had yet been developed. In the present study, a new design model developed by Pikas 34, integrating the technical and social dimensions of designing, was used to inform the development and implementation of interventions.

The development and implementation of theory-driven practices on the basis of a new understanding of design and design management brought about significant improvement in building design processes and design management practices in the design organization. For a more detailed evaluation of results, readers are encouraged to read the original study [34]. This study thus fulfilled its main objective, contributing to the development of lean production and lean design management by integrating technical and social activities. The further refinement and testing of interventions based on the new model is left to future research.

6. Conclusions

The aim of this study was to improve design and design management practices by applying a new understanding of design activity and lean design management. Participative action research and design science research methodologies were used. As implied by the methods and practices used in the organization under study, the adoption of an incomplete theory of production seemed to be one of the main reasons for poor performance. Flow and value views of production were neglected. Design had also been wrongly viewed as solely a technical activity. These choices led to self-inflicted problems and may be considered root causes. To remedy deficiencies in the choice of production theory, methods and practices compatible with the flow and value views were introduced. To balance the "technical" view of design, a new design model by Pikas [34] that integrates technical and social dimensions of designing was used to inform the development and implementation of interventions. Theory-driven practices finally brought about significant improvement in building design processes and design management practices in the design organization.

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References

1. Bucciarelli, L.L. *Designing Engineers*; MIT Press: Cambridge, MA, USA, 1994.
2. Fischer, M.; Khanzode, A.; Reed, D.; Ashcraft, H.W. *Integrating Project Delivery*; Wiley: Hoboken, NJ, USA, 2017.
3. Kleinsmann, M.S. *Understanding Collaborative Design*; TU Delft, Delft University of Technology: Delft, The Netherlands, 2006.
4. Emmitt, S. *Design Management for Architects*; John Wiley & Sons: Hoboken, NJ, USA, 2014.
5. Knotten, V. Building Design Management in the Early Stages. Ph.D. Thesis, Norwegian University of Science and Technology, Trondheim, Norway, 2017.

6. Biotto, C. Integration of Overlapped Design and Construction Stages through Location-Based Planning Tools. Ph.D. Thesis, University of Huddersfield, Huddersfield, UK, 2019.
7. Love, P.E.; Li, H. Quantifying the causes and costs of rework in construction. *Constr. Manag. Econ.* **2000**, *18*, 479–490. [CrossRef]
8. Love, P.E.; Edwards, D.J.; Irani, Z. Forensic project management: An exploratory examination of the causal behavior of design-induced rework. *IEEE Trans. Eng. Manag.* **2008**, *55*, 234–247. [CrossRef]
9. Chapman, J. Collapse of the Ramsgate walkway. *Struct. Eng.* **1998**, *76*, 1–10.
10. Lopez, R.; Love, P.E.; Edwards, D.J.; Davis, P.R. Design error classification, causation, and prevention in construction engineering. *J. Perform. Constr. Facil.* **2010**, *24*, 399–408. [CrossRef]
11. Borgstein, E.; Lamberts, R.; Hensen, J. Mapping failures in energy and environmental performance of buildings. *Energy Build.* **2018**, *158*, 476–485. [CrossRef]
12. Koskela, L.; Ferrantelli, A.; Niiranen, J.; Pikas, E.; Dave, B. Epistemological Explanation of Lean Construction. *J. Constr. Eng. Manag.* **2018**, *145*, 04018131. [CrossRef]
13. Kannengiesser, U.; Gero, J.S. An ontology of computer-aided design. In *Computer-Aided Design Research and Development*; Nova Science Publishers: Hauppauge, NY, USA, 2009.
14. Koskela, L.; Huovila, P.; Leinonen, J. Design management in building construction: From theory to practice. *J. Constr. Res.* **2002**, *3*, 1–16. [CrossRef]
15. Ballard, G.; Koskela, L. Design Should Be Managed as a Physical Process, Too. In Proceedings of the International Conference on Engineering Design, ICED'09, Stanford, CA, USA, 24–27 August 2009; pp. 251–261.
16. Koskela, L. An Exploration towards a Production Theory and Its Application to Construction. Ph.D. Thesis, VTT Technical Research Centre of Finland, Espoo, Finland, 2000.
17. Ballard, G.; Tommelein, I.; Koskela, L.; Howell, G. Lean construction tools and techniques. In *Design and Construction*; Routledge: Abingdon, UK, 2007; pp. 251–279.
18. Koskela, L.; Codinhoto, R.; Tzortzopoulos, P.; Kagioglou, M. The Aristotelian proto-theory of design. In *An Anthology of Theories and Models of Design*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 285–303.
19. Snodgrass, A.; Coyne, R. *Interpretation in Architecture: Design as Way of Thinking*; Routledge: Abingdon, UK, 2013.
20. Dilnot, C. Thinking design: A personal perspective on the development of the Design Research Society. *Des. Stud.* **2018**, *54*, 142–145. [CrossRef]
21. Iivari, J.; Venable, J. *Action Research and Design Science Research-Seemingly Similar but Decisively Dissimilar*; ECIS: Stockholm and Uppsala, Sweden, 2009; pp. 1642–1653.
22. Susman, G.I.; Evered, R.D. An assessment of the scientific merits of action research. *Adm. Sci. Q.* **1978**, *23*, 582–603. [CrossRef]
23. Kuechler, B.; Vaishnavi, V. Extending prior research with design science research: Two patterns for DSRIS project generation. In *Service-Oriented Perspectives in Design Science Research*; Springer: Berlin/Heidelberg, Germany, 2011; pp. 166–175.
24. Chachere, J.; Kunz, J.; Levitt, R. *The Role of Reduced Latency in Integrated Concurrent Engineering*; CIFE Working Paper# WP116; CIFE: Stanford, CA, USA, 2009.
25. Lenfle, S.; Loch, C. Lost roots: How project management came to emphasize control over flexibility and novelty. *Calif. Manag. Rev.* **2010**, *53*, 32–55. [CrossRef]
26. Ballard, G.; Koskela, L. On the Agenda of Design Management Research. In Proceedings of the Annual Conference of the International Group for Lean Construction, Guarujá, Brazil, 13–15 August 1998; pp. 52–69.
27. Koskela, L.; Howell, G.; Pikas, E.; Dave, B. If CPM is so bad, why have we been using it so long? In Proceedings of the 22th International Group for Lean Construction Conference, Oslo, Norway, 23–27 June 2014.
28. Love, T. Philosophy of design: A meta-theoretical structure for design theory. *Des. Stud.* **2000**, *21*, 293–313. [CrossRef]
29. Tilley, P.A. Lean design management: A new paradigm for managing the design and documentation process to improve quality? In Proceedings of the 13th International Group for Lean Construction Conference, Sydney, Australia, 19–21 July 2005; p. 283.
30. Ballard, H.G. The Last Planner System of Production Control. Ph.D. Thesis, University of Birmingham, Birmingham, UK, 2000.

31. Çıdık, M.S.; Boyd, D. "Shared sense of purposefulness": A new concept to understand the practice of coordinating design in construction. *Constr. Manag. Econ.* **2019**, 1–14. [CrossRef]
32. Rekola, M.; Mäkeläinen, T.; Häkkinen, T. The role of design management in the sustainable building process. *Archit. Eng. Des. Manag.* **2012**, *8*, 78–89. [CrossRef]
33. Cross, N.; Roozenburg, N. Modelling the design process in engineering and in architecture. *J. Eng. Des.* **1992**, *3*, 325–337. [CrossRef]
34. Pikas, E. Causality and Interpretation: Integrating the Technical and Social Aspects of Design. Ph.D. Thesis, Aalto University, Espoo, Finland, 2019.
35. Hubka, V.; Eder, W.E. *Design Science: Introduction to the Needs, Scope and Organization of Engineering Design Knowledge*; Springer: Berlin/Heidelberg, Germany, 1996.
36. Jones, J.C. *Design Methods*; John Wiley and Sons: Hoboken, NJ, USA, 1992.
37. Norman, D.A.; Draper, S.W. *User Centered System Design: New Perspectives on Human-Computer Interaction*; CRC Press: Boca Raton, FL, USA, 1986; Volume 3161.
38. Koskela, L.J.; Ballard, G. The two pillars of design theory: Method of analysis and rhetoric. In Proceedings of the International Conference on Engineering Design, ICED13, Seoul, Korea, 19–22 August 2013; pp. 1–10.
39. Hintikka, J.; Remes, U. *The Method of Analysis: Its Geometrical Origin and Its General Significance*; Springer Science & Business Media: Berlin, Germany, 1974; Volume 25.
40. Herrick, J.A. *History and Theory of Rhetoric: An Introduction*; Routledge: Abingdon, UK, 2015.
41. Stumpf, S. Analysis and Representation of Rhetorical Construction of Understanding in Design Teams' Experiential Learning. Ph.D. Thesis, University College London, London, UK, 2001.
42. Kaufer, D.S.; Butler, B.S. *Rhetoric and the Arts of Design*; Routledge: Abingdon, UK, 2013.
43. Buchanan, R. Declaration by design: Rhetoric, argument, and demonstration in design practice. *Des. Issues* **1985**, 4–22. [CrossRef]
44. Ballard, G.; Koskela, L. Rhetoric and design. In Proceedings of the 19th International Conference on Engineering Design, Seoul, Korea, 19–22 August 2013; The Design Society: Glasgow, UK, 2013; pp. 1–10.
45. Halstrøm, P.L. *Rhetorical Design Studies: The Art of Making Design Choices Explicit*; The Royal Danish Academy of Fine Arts: Copenhagen, Denmark, 2017.
46. Aristotle, F. *The Art of Rhetoric*; HarperCollins Publishers: New York, NY, USA, 2012.
47. Kroll, E.; Koskela, L. Applying the proto-theory of design to explain and modify the parameter analysis method of conceptual design. *Int. J. Des. Creat. Innov.* **2015**, *4*, 1–25. [CrossRef]
48. Woods, D. Rasmussen's SRK 30 Years Later: Is Human Factors Best in 3's? In Proceedings of the Human Factors and Ergonomics Society Annual Meeting, San Antonio, TX, USA, 19–23 October 2009; SAGE Publications: Los Angeles, CA, USA, 2009; pp. 217–221.
49. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: San Francisco, CA, USA, 2015.
50. Freire, J.; Alarcón, L.F. Achieving lean design process: Improvement methodology. *J. Constr. Eng. Manag.* **2002**, *128*, 248–256. [CrossRef]
51. Uusitalo, P.; Seppänen, O.; Lappalainen, E.; Peltokorpi, A.; Olivieri, H. Applying Level of Detail in a BIM-Based Project: An Overall Process for Lean Design Management. *Buildings* **2019**, *9*, 109. [CrossRef]