CONSIDERATIONS ON APPLICATION OF LEAN CONSTRUCTION PRINCIPLES TO DESIGN MANAGEMENT

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ABSTRACT

Several studies have pointed out the importance of the building design process in terms of improving the performance of the construction industry, and that it is a very difficult process to manage. It involves thousands of decisions, sometimes over a period of years, with numerous interdependencies, under a highly uncertain environment. As distinct from production, quality in the design process has to be achieved by a careful identification of customer needs and subsequent translation of those needs into specifications.

The aim of this article is to present an analysis on the application of some lean construction principles to design management, considering the three different views of design (design as conversion, design as flow and design as value generation), proposed by Huovila et al. (1997). This discussion is based on empirical data collected in two case studies developed in Brazil. Each case study involved the development of a model for managing the design process for a small-sized house building company.

KEY WORDS

Building design, design management, lean construction, process management.

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INTRODUCTION

The main causes for the poor performance of the building design process have been discussed by several authors, including Cornick (1991), Austin et al. (1994), and Ballard and Koskela (1998). Poor communication, lack of adequate documentation, deficient or missing input information, unbalanced resource allocation, lack of co-ordination between disciplines, and erratic decision making have been pointed out as the main problems in design management. Also, the design process usually lacks effective planning and control, to minimize the effects of complexity and uncertainty, to ensure that the information available to complete design tasks is sufficient, and to reduce inconsistencies within construction documents.

Huovila et al. (1997) proposed a conceptual framework for managing the design process in which three different views of this process are considered: (a) design as a conversion of inputs into outputs; (b) design as a flow of materials and information; and (c) design as a value generating process for the clients. Considering this framework, a research project has been carried out in Brazil, aiming to develop a protocol for managing the design process in the building industry. The content of the protocol was briefly described by Formoso et al. (1998).

This paper discusses the application of some lean construction principles to design management, considering the three different views of design. This analysis is based on only two of the case studies, in which a reflection on the way those principles can be applied was carried out.

GENERAL DESCRIPTION OF THE DESIGN PROCESS PROTOCOL

The protocol has been devised through case studies, carried out in four small-sized house building companies. All companies are involved in the development and construction of commercial and residential buildings. Each one of them has been devising its own model for managing the design process. Most of the work needed to develop the models in each company was performed by a team, which included company personnel, some of the external designers and a representative of the research team. The definition of each model was the result of a negotiation process involving all actors. Each model consists of a general plan for managing the design process. Its main elements are: (a) the content of the main activities, (b) their precedence relationships, (c) the main inputs and outputs for each activity, (d) tools that can be used for supporting the execution of such activities, (e) the role and responsibilities of the different actors, and (f) a model of the information flow.

Two main tools have been used in this study for modelling the design process. The first one is a flowchart, which represents graphically the process, including the division of the process into sub-processes, making explicit precedence relationships. In order to keep the flowchart of the whole design process as simple and as readable as possible, it was necessary to group information in a hierarchical way. There is a general flowchart presenting the seven design stages (inception and feasibility; outline design; scheme design; design for legal requirements; detail design; production monitoring; and feedback and operation), for each stage a flowchart of activities and, for the most complex activities, a flowchart of operations.

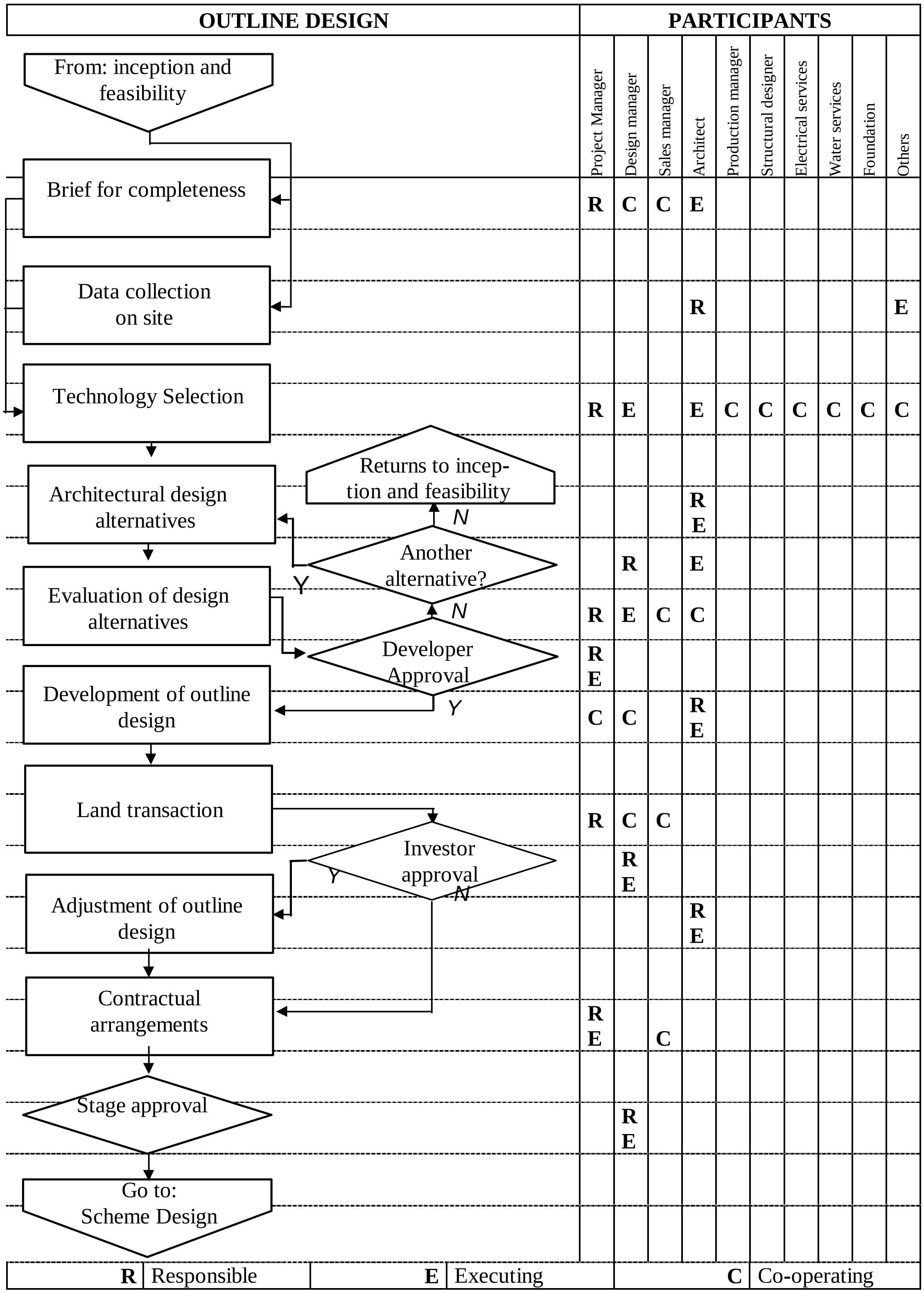

Figure 1: Example Flowchart (Outline Design Stage)

This form of representation gives a broad view of the design process, since the general flowchart is relatively short, and, at the same time, makes it possible to plan the design process at a relatively fine level of detail. Figure 1 represents an example of the flowchart for the outline design stage, in which the degree of involvement of the main participants is defined for each activity.

The second tool used for modelling the process is the input-output chart. It describes in more detail all activities represented in the flowcharts, by making explicit the inputs and outputs for each one of them. Figure 2 shows an example of an input-process-output chart for two outline design activities.

Besides that, procedures and work instructions were developed for a number of activities. Each procedure describes the objective of the activity, input information and their suppliers, steps for developing the activity, information produced and their internal clients. Work instructions consist of tools used for supporting the execution of the activity.

The model includes not only design activities but also other activities which are part of design management, such as production of legal and statutory documents, negotiation with the land owner, etc. This is due to the fact that the design process has many interfaces with other processes, which must be made explicit in the flow.

The main kinds of procedures developed so far are (a) product and process standards, (b) check lists for defining technological issues, (c) information flow control (electronic data and paper), (d) design contracts, (e) data collection from the building site, (f) post-occupancy satisfaction evaluation, and (g) maintenance and repair. In one of the building companies involved in the research project, 36 procedures were developed and 55% of them were implemented. In the other company, 29 procedures were developed, and 75% of them were implemented.

INPUT	PROCESS	OUTPUT
Briefing; Data collection from the site; Feedback data (from building delivered previously and from production); Definition of the design team; Strategic selection of technologies; Initial statement of performance statements; Regulatory and statutory information.	**ARCHITECTURAL DESIGN ALTERNATIVES**	Outline design alternatives
Outline design alternatives; Cost planning and sales price estimate.	**EVALUATION OF DESIGN ALTERNATIVES**	Choice of alternative(s) to be developed.

Figure 2: Example Input-Process-Output Table

THREE VIEWS OF DESIGN

Each process model has been developed considering the three views of design (conversion, flow and value generation). In the conversion view, the design process is divided in sub-processes, each one of them carried out by a specialist who transforms his/her perception on the client requirements into design decisions. Some important aspects of design are abstracted away in this conceptualisation (Ballard and Koskela 1998). For instance, there are customers who have needs and requirements concerning this process, which are not explicitly represented. Also, there are activities in design that do not contribute to conversion, such as waiting, moving and inspection of information (Huovila et al. 1997).

The excessive emphasis on the conversion view of design can be pointed out as one of the major causes for some of the persisting problems in building projects, such as (a) not all requirements are identified at the beginning of the project; (b) design errors are detected in later phases, leading to costly rework; (c) time consuming or insufficient interactions for improving design (Huovila et al. 1997); and (d) large incidence of non value adding activities in the design process, resulting in long duration and not enough time for generating design solutions (Tzortzopoulos 1999).

In the flow view, design is regarded as a flow of information, in which non value adding activities (waiting, moving and inspection of information) are made explicit. Most of these activities should be eliminated (reducing waste), rather than made more efficient (Huovila et al. 1997).

In the value generation view, the emphasis is to achieve the best possible value from the customer point of view. It is not clear in the literature what are the requirements for achieving effective value generation in the design process. Huovila et al. (1997) suggest that the quality of design can be improved by increasing the amount and quality of information about customer needs and requirements available, for instance, through rigorous requirement analysis, systematised management of requirements, and collaborative iterations for improvement.

However, value generation in design depends not only on the information available but also on the work conditions for the design team. This means that if the process is poorly managed the final product tends to be inadequate, even if all necessary information is available. Problem solving (value adding activities) in building design is strongly related to creative work. Thus, managing the design process should be concerned with removing obstacles to creativity, such as insufficient time, evaluation pressure, reluctance to change, etc. (Cooper and Press 1995).

Moreover, value generation also depends on the level of qualification of the design team. It means that an efficient design process does not necessarily lead to good design whoever the design professional are. Due to the nature of design process, the design team should be capable of transforming complex, uncertain and conflicting requirements into solutions.

The conversion view is the most explicit one of the models. The relationships between conversion activities are represented in the flow charts and the content of some of them are comprehensively described in the procedures. During the development of the models, there was an initial emphasis on defining conversions (value adding activities) because the design process was not properly defined. It was not possible to model or plan flow activities before the conversion ones were adequately consolidated. After an initial definition of the main conversion activities, flow activities was also included in the models. The transfer of information between sub-processes (or activities) is made explicit through the input-output tables, procedures and work instructions. These three levels of representation are necessary because of the complexity of the design process. The number of information inputs and outputs for each activity tends to be very large. On one hand, the input-output tables give a general idea on the content of information, and are easily linked to the flowcharts. On the other hand, procedures and working instructions define the inputs and outputs at a level of detail that enable the design team to perform their tasks. Nevertheless, it must be pointed out that it is not possible to define beforehand all the information involved in each activity at a very of detail, due to the complex and creative nature of the design process (Lawson 1980).

Some inspection activities are also represented in the models (Figure 1), specially those which are related to stage approvals.

Waiting activities are more difficult to represent in such models, because they are difficult to predict due to the uncertainty involved in the design process. Also, they have a different nature in a managerial process, if compared to the production process, since the notion of storage of information is not as clear as managerial inventory.

The value generation view was considered through the definition of some important customer requirement information that must be input in the design process, specially during its initial stages. This usually involves a set of data collection, analysis and feedback procedures, such as market surveys, post occupancy evaluation, repair and maintenance work, etc. However, this view has been the least advanced in the models, and is still under development.

Ballard and Koskela (1998) point out the need for integrating the three views of design and suggest a number of practical guidelines for such integration. Some features of the design models developed in the study are presented below, according to some of the guidelines suggested by those authors:

- Avoid a segmented and rigid sequence of design activities: some degree of flexibility is allowed in the models by establishing interdependent precedence relationships between design activities, by not defining all activities in a very fine level of detail and by encouraging teamwork in the design process (including early stages);
- Explicit internal client-supplier relationships between sub-processes: the information required for each internal client process was defined in the procedures, as well as the supplier process responsible for producing it;
- Encourage direct interaction between designers and customers: the final customer in house building projects is usually defined relatively late in the process. For that reason, some interaction was planned in the model in the later stages of design, through three different activities in which some minor design changes were allowed by demand of the final customers;

- Involve designers in joint solutions: as it was mentioned before the models define activities in which interaction and shared decision making are performed by the design team;
- Work with a set of design alternatives: a number of activities were defined in the models in which design alternatives have to be produced;
- Introduce control focus on flow activities: planning and control activities have been implemented in both design models. They are hierarchically organised and will involve the concept of shielding production (Koskela et al. 1997).

IMPLEMENTATION OF LEAN CONSTRUCTION PRINCIPLES IN THE DESIGN PROCESS THROUGH THE DEVELOPMENT OF DESIGN MODELS

One of the benefits of developing design models is the possibility of effectively planning and controlling the process. The benefits resulting from the implementation of lean construction principles can be properly assessed, because an explicit model of the process has been consolidated. Some considerations on the applicability of those principles in this study are presented below.

REDUCE THE SHARE OF NON VALUE ADDING ACTIVITIES

There were two main strategies for eliminating non value adding activities. The first one consist of gathering small tasks into larger activities and defining the necessary input information for each of those activities beforehand. This strategy was very useful for defining activities which tend to be very fragmented throughout the process, such as data collection and inspection.

The second strategy involves the identification of points in the process when a strong interaction between designers is necessary. This means that some of the activities included in the model are expected to be performed by teams of professionals, specially those activities related to the selection of technology, and to the evaluation of the different designs in terms of integration. This strategy was feasible in the study because there was a partnering relationship between the house building companies and some of their designers, which has created an environment that encourages multidisciplinary work.

INCREASE OUTPUT VALUE THROUGH SYSTEMATIC CONSIDERATION OF CUSTOMER REQUIREMENTS

This principle was applied by introducing some sets of data collection, analysis and feedback tasks, concerned with the identification of customers and their needs and requirements. Also, both models emphasise the importance of the initial design stages, when most of the client requirements must be considered.

The models also allow the requirements of the production process, which is a major internal client of the design process, to be considered in decision making. This is performed through the introduction of activities related to the selection of construction technologies. Also, a representative of the production team is involved in some design activities.

REDUCE PROCESS VARIABILITY

This principle was implemented through the clear definition of the process, including the activities that must be performed, their precedence relationships, roles and responsibilities and the main flow of information. Both models are relatively stable and feasible since they are a result of a negotiation process involving different sectors of the company and external designers. However, it must be stressed that some degree of flexibility in the process is necessary due to the nature of the design work.

REDUCE CYCLE TIMES

The application of this principle in design process is very complex, since the definition of cycle time in such a process needs further discussion. This study was more concerned with the reduction of design process lead time, as a market requirement for the companies. However, the development of the models made some contributions in terms of forcing the definition of cycles within the process, such as sets of design tasks, feedback from customer, feedback from production, and design evaluations.

SIMPLIFY BY MINIMISING THE NUMBER OF STEPS, PARTS, AND LINKAGES

The more complex is the design process, the higher tends to be the costs, and the more likely the occurrence of problems. The need for reducing the number of steps was considered right from the beginning of the study, since none of the companies had a well defined design process. At the development and implementation of procedures, further simplification of the process was performed. The simplification of the process was feasible due to the fact that most design tasks were defined at a very fine level of detail, including the necessary input information, subtasks and products. Based on this detailed description, it was possible to rearrange and group smaller tasks into larger activities.

INCREASE OUTPUT FLEXIBILITY

The importance of increasing output flexibility varies according to the market sector in which the company operates. Both companies are involved in a segment of the house building market were some degree of product flexibility is necessary. For that reason, both of the companies defined three activities in which the clients could submit demands for design changes. This allowed some degree of flexibility in the end product without causing disruptions in the production process.

INCREASE PROCESS TRANSPARENCY

Process transparency was achieved through an explicit and relatively simple representation of the design process. Despite the complex nature of the design process, the tools used for representing the models made possible an adequate communication of the process content to the actors involved. In this respect, the fact that there was a hierarchical subdivision of the process in stages, activities and operations (Formoso et al. 1998) played an important role in terms of giving an overall view of the process, and at the same time defining it at a level of detail fine enough to guide execution effectively.

It is important to point out that some more powerful information modelling tools, such as Data flow Diagrams (Austing et al. 1994) and IDEF-0 (Sanvido 1992) were rejected in this study because they were considered to be ineffective in terms of communication by the practitioners involved.

FOCUS ON COMPLETE PROCESS

One of the objectives of defining stages approvals throughout the process is to increase focus on complete process. Each stage approval was regarded as the moment of the process in which the design manager should analyse all aspects related to the decision made so far. Checklists and sets of performance indicators are being developed for supporting such evaluations. Some of this stage approvals can be considered more rigid than others, identifying soft gates and hard gates as proposed by Kagioglu et al. (1998).

BUILD CONTINUOUS IMPROVEMENT INTO THE PROCESS

The model itself was developed incrementally by building continuous improvement in the development and implementation method. Moreover, some feedback activities (mainly those at the production and operation stages) also contribute to the application of this principle once the model is implemented. It must be stressed that feedback activities should not be limited to data collection tasks, but also include procedures and guidelines for classifying and evaluating information, as well as feeding it back to the right users.

BALANCE FLOW IMPROVEMENT WITH CONVERSION IMPROVEMENT

The application of this principle is very much related to the need for integration of the conversion and flow views of design. This has already been discussed previously in this paper. Such balance was achieved through the way the development and implementation method was carried out. There was an initial emphasis on managing conversions, and as the model was consolidated the focus of the improvement changed to flow management.

BENCHMARK

Benchmarking was performed to a certain extent in the study by interviewing both design and design management professionals in a relatively informal way. Clearly, There is scope for carrying out more structured benchmarking studies in the future, both within and outside the industry.

FINAL COMMENTS

This paper discusses the application of some lean construction concepts and principles to the design process, based on two case studies concerned with the development of models for managing this process in small-sized house building companies. The study has indicated that the proposed models have been relatively effective in terms of integrating the three different views of design, although much refinement still needs to be done on those models.

The discussion presented in the paper has pointed out some gaps in the knowledge concerning the application of the theory in design, suggesting further research that needs to be done towards the consolidation of some concepts (i.e. value generation view of design, cycle time, waiting activities in design), and principles (i.e. reduce process variability, reduce cycle time).

Finally, it should be stressed that the development and implementation of models for managing the design process in practice is an important source of reflection and discussion for the consolidation of the lean construction theory, and that more studies using such approach should be carried out in the future.

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