DEVELOPING A PROTOCOL FOR MANAGING THE DESIGN PROCESS IN THE BUILDING INDUSTRY

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ABSTRACT

The performance of the design process in the building industry has a great influence on the success of subsequent processes in construction projects and also on the quality of the final product. Despite its importance, relatively little attention has been given to the management of the design process.

The main objective of this article is to present the preliminary results of a research project which aims to devise a protocol for managing the design process in house building firms. The protocol will consist of a general plan for developing design activities, including the content of the main activities, their precedence relationships, the role and responsibilities of different actors, and a model of the information flow. The protocol has been developed through case studies, carried out in four different construction companies from the South of Brazil.

The development of this research is based on the conceptual framework of the New Production Philosophy (Lean Production). The suitability of its concepts and principles has been tested on the management of the design process.

KEY WORDS

Design Management, Lean Construction, Process Management, Building Design

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INTRODUCTION

Several studies have pointed out that a large percentage of defects in building arise through decisions or actions in design stages (Cornick 1991). Also, it is widely known that poor design has a very strong impact on the level of efficiency during the production stage (Fergunson 1986). In recent years, the increasing complexity of modern buildings in a very competitive market-place has significantly increased the pressure for improving the performance of the design process in terms of time and quality. For instance, it has been fairly common to overlap the design and the production stages in order to reduce project duration and increase the flexibility of product design.

Despite its importance, relatively little research has been made on the management of the design process, in relation to the research time and effort which has been dedicated to production management and project management in general (Austin et al. 1994, Koskela et al. 1997). The relatively small cost of the design process compared to the production costs probably disguises its true importance for the performance of construction projects (Austin et al. 1994).

To some extent, the fact that design management has been neglected is understandable. Building design 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. A large number of personnel are implicated, such as architects, project managers, structural engineers, service engineers and marketing consultants. Each category of professional has a distinct background, culture and learning style (Powell and Newland 1994). Moreover, feedback from the production and building operation stage takes a long time to be obtained, and tends to be ineffective.

The design process needs to be planned and controlled more effectively, in order to minimise the effects of complexity and uncertainty. The lack of design planning results in insufficient information being available to complete design tasks and inconsistencies within construction documents. 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 (Cornick 1991, Austin et al. 1994, Koskela et al. 1997).

NATURE OF THE DESIGN PROCESS

Markus and Arch (1973) pointed out that most descriptions of the design process, both theoretical and empirical, recognise two patterns. One consists of an individual decision making process, usually performed by a designer, concerned with the creation of alternative solutions. The second one is a management process, divided into phases, which develop from the general and abstract to the detailed and concrete. A complete picture of the design method requires the consideration of both patterns. These are discussed in the sections titled “Design as a Creative Process” and “Design as a Management Process” respectively.

DESIGN AS A CREATIVE PROCESS

Designers are traditionally known by the solutions which they produce, rather than the kind of problem they deal with (Lawson 1980). In design, the problem is usually poorly defined, i.e. the clients sometimes are not able to make their needs explicit. Often, there is no way to develop an adequate solution from existing information, since the client requirements are vague. The solution does not necessarily comes directly from the problem. The attention of the designer oscillates between the comprehension of the problem and the search for a solution (Cross 1994).

Each designer approaches the design problem in a particular way. One of the traditional ways used by designers for dealing with the problem is to develop quickly a potential solution or a group of potential solutions, which are used as a way to define and understand clearly the problem (Cross 1994).

A number of models of design as a creative process are presented in the literature. For example, the model proposed by Markus and Arch (1973) is presented in Figure 1. In this model there are four main activities in design: analysis, synthesis, evaluation and dissemination.

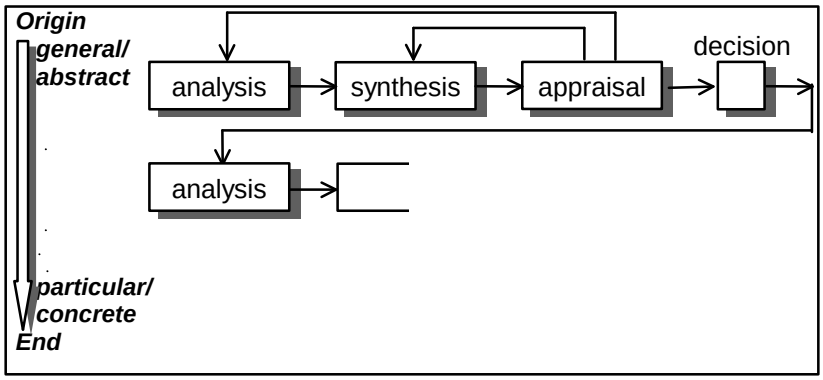

Figure 1: Design as a creative process (Markus and Arch 1973)

One of the main contributions of such models is the fact that they make clear that individual design processes tend to be very unstructured and chaotic. This should be taken into consideration when developing a model for managing the design process. It means that the steps for producing a design solution cannot be established at a very fine level of detail (Lawson 1980).

DESIGN AS A MANAGEMENT PROCESS

In the building industry, design is traditionally regarded as a single stage in building projects. This is due to the fact that the participation of the design team tends to start relatively late in the project and finish as soon as the production stage starts. In the present study, design is regarded as a process which takes part of all stages of the building process, from inception to building operation. In fact, design is one of the most important processes in building projects, since it defines the product to be built and has many interfaces with several other processes.

The way the design process is divided into stages varies considerably in different studies both in terms of content and the names given to each stage (Cross 1994). In this research work, the design process is divided into seven stages: (a) Inception and

Feasibility, (b) Outline Design, (c) Scheme Design, (d) Design for Legal Requirements, (e) Detail Design, (f) Production Monitoring, and (g) Feedback from Operation.

Each design stage can be further divided into sub-processes, which successively transform information from client requirements and project constraints into product design. In this research project, the design process is analysed from the point of view of the New Production Philosophy (Koskela 1992), which means that there are four kinds of activities involved: conversion, waiting, moving, and inspection. Only conversion activities are value adding. Waiting, moving and inspection activities are non value adding and should be eliminated, rather than made more efficient. Part of the conversion activities are not value adding, since they cause rework, due to errors, omissions and uncertainty (Huovila et al. 1997). This kind of rework should not be mixed up with the iterative process that occurs when a design alternative is generated, as shown in Figure 1, which is an inherent part of design as a creative process.

Based on the view of design as a flow, Huovila et al. (1997) proposes a number of principles and methods for eliminating waste in the design process:

1. Reduce uncertainty, which is one of the main causes of rework, specially in the early stages of design. This can be done by increasing the effort in terms of clearly defining the project restrictions and the requirements of internal and external clients;
2. Reduce waiting time by decomposing adequately the design tasks so that they can be properly planned, and also allow the transfer of information to be made in smaller batches;
3. Reduce the effort needed for information transfer through team work, and by rearranging the design tasks.

DEVELOPMENT OF THE PROTOCOL

The protocol will consist of a general plan of the design process which can be used as a basis for devising a model to manage the design process for individual companies. The main elements of the protocol 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.

The development of a model for managing the design process can potentially bring a number of benefits for design and build organisations, such as:

1. The fact that a stable, consensual and explicit model of the design process exists makes it easy the identification of the necessary improvements, e.g. simplification of the information flow, reduction of the number of steps, etc.;
2. All actors involved in the process are able to understand the process as a whole, their roles and responsibilities(Cornick 1991). This increases the process transparency and tends to improve communication between them;
3. It is possible to increase the effectiveness of the information flow, since the necessary information for performing each activity is formally established, as well as the information which must be produced by each activity. This tends to

improve both the quality of design and creates the possibility of reducing the duration of the design stage;

4. It becomes easier to devise and implement tools for measuring and controlling product and process performance;
5. An effective feedback into the process is facilitated, since the design tasks are monitored and registered in a systematic form, including those design related tasks which are performed during the production and the building operation stages. The data collected during those two stages can be used for feeding back future projects and the company strategic planning process.

The protocol has been devised through case studies, carried out in four small sized house building companies from the State of Rio Grande do Sul, Brazil. Their main activity is to develop and construct commercial and residential buildings. Each one of these companies is devising its own model for managing the design process. Two of them are also working towards getting ISO9001 certification. This work has been developed as a partnership between the building companies and NORIE,[4] and is sponsored by FINEP, a Federal Government research funding agency.

Most of the work in each company is performed by a team of four to five people (called "operational group"), which is formed by representatives of different sectors involved in design, including the design manager, and one representative of the research team, which acted as a facilitator. The "operational group" usually meets once a week for two hours. Occasionally the "operational group" is extended by including some of the external designers (architects, structural engineers, service engineers, etc.) who work for the company, forming the "extended group". This is necessary every time it is important to consider the point of view of other actors in the development of the model.

Although there have been differences between the companies, the development of the model can be divided into three main stages:

1. Preliminary investigation: a number of interviews with design managers and external designers were made, aiming to identify their perceptions about the sequence and the content of the main design activities, and about the main managerial problems in design.
2. Design Model: a model of the design process was devised for each company by the "operational group". This model was represented by flowcharts and input-output tables (see section "Final Comments").
3. Design Manual: written procedures and working instructions have been made for some of the activities of the flowchart. All written information have been put together in a Design Manual, which reflects the culture and working methods of each company. In both companies that have been working towards ISO9001 certification, the design manual is part of the Quality System. The procedures and working instructions have been gradually implemented in the four companies.

Two main tools have been used in this study for modelling the design process. The first one is the flowchart, which represents graphically the process, including the division of

[4] NORIE is a research group on Building Engineering at the Federal University of Rio Grande do Sul

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, for each stage a flowchart of activities and, for the most complex activities, a flowchart of operations. 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 2 presents the main criteria used for organising the design tasks into stages, activities and operations and describes three possible kinds of precedence relationships between activities - sequential, parallel, or dynamic interaction. The third kind of precedence relationship occurs when two activities or operations are iterative and it is not worthwhile to model the sub-process at a very fine level of detail, because it is unstructured or too uncertain.

There are limitations in terms of representing the flow of information in the flowcharts. Very often the output of one activity is not necessarily the input for the following one, but for several different activities. For that reason, not all flows are made explicit in the flowcharts, otherwise this would make the flowchart difficult to understand.

The second tool used for modelling the process is the input-output charts. It describes in mode detail all activities represented in the flowcharts, by making explicit the inputs and outputs for each one of them.

GUIDELINES FOR DEVELOPING MODELS OF THE DESIGN PROCESS

Based on the development of the four case studies, a number of guidelines have been proposed for developing models of the design process, which are presented in this section.

The model includes not only design activities but also other activities which are part of project 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 first step for developing a model of the design process is to establish or to make explicit the company's competitive strategy. This is an important requirement at the beginning of the design process, since it defines the product strategy (i.e. the market in which the company operates, its clients, their needs), and the process strategy, in which the main decisions related to the technologies to be used by the company in different projects are made.

There are some design tasks which need to be developed in phases, developing from the general and abstract to the detailed and concrete, such as the identification of client needs, negotiation of the land, selection of construction technologies, and market and financial analysis. It means that they have to be split into separate activities, which take part in different design stages.

The model developed in each company was not based only on its current practices. Some innovations were introduced in the design process, based on the literature review and also on some identified best practices. The main innovations introduced are presented below:

1. Early participation of structural and services designers in the design process;

2. Oral presentation of the design to both production and sales people, in order to communicate clearly the design intentions and philosophy;
3. Some activities were rearranged in order to reduce flow activities. For instance, a procedure was made for collecting a large number of information at the building site in the same visit;
4. There are a number of sub-processes which are cyclic and repetitive. They are usually started by an event, such as design changes demanded by clients or by production management, repairs demanded by clients during building operation, etc.
5. Due to market pressures, the production stage usually starts before the completion of detail design. Thus, it was necessary to identify which documents or information should be available at the beginning of the production process and at some important production milestones. In such a context, planning the design process becomes very important.
6. There are three main points at the design process in which there is a concentration of efforts for integrating different disciplines. The first one is

CRITERIA	STAGE	ACTIVITY / ACTIVITY	Operation / Operation / Operation
PRODUCT	• The product of each stage relates to the whole building, in different levels of detail (e.g.: scheme design)	• The product of each activity usually relates to parts of the building (e.g.: selection of structural system)	• The product of each operation usually relates to smaller parts of the building, in relation to activities (e.g.: bathroom wall tiles design)
SEQUENCE	• Linear – dependent tasks • One stage starts when the previous one is finished and approved	• Linear, independent or interdependent tasks • There might be overlapping between activities. Also, the activities can be looped	• Linear, independent or interdependent tasks • There might be overlapping between operations. Also, the operations can be looped
	Dependent tasks (series) → A → B	Independent tasks (parallel) → A, B	Interdependent tasks (coupled) → A, B
WHO DEVELOP	• Involves several participants	• Involves a small number of participants	• Involves usually only one designer
TIME SCALE	• monthly	• weekly	• daily
	←		
APPROVAL/ VALIDATION	• Tends to be formal and external • Check lists can be used for control	• Intermediate situation between stage and operation	• Tends to be informal and internal (self control) • Check lists supports decision making
	+ FORMAL ←		→ **+ INFORMAL**
NUMBER	• 5 to 10	• 8 to 16	• variable
SUBDIVISION	• It is always subdivided	• It is often subdivided	• It is not subdivided

Figure 2: Criteria for dividing the design process into stages, activities and operations

soon after the first sketch of the structural design and water and electric services design, at the outline design stage. The second one is at the end of scheme design, and the third in the detail design stage. This integration effort is usually represented as a cycle of activities, involving a team work activity, followed by individual adjustments by different designers and an evaluation activity.

7. A detail plan of the design process is made only at the detail design stage. In the initial design stages, the level of uncertainty is very high, and only a rough estimate of the duration of each stage is usually made. Also, some important dates in terms of project strategy are defined at the beginning of the project, such as the date for commercial release and the beginning of the production stage.

FINAL COMMENTS

This paper describes the preliminary results of an ongoing research project, in which a protocol for managing the design stage has been developed. The implementation phase of the research has started gradually, and the effectiveness of the model will be evaluated by using performance indicators, related both to the design process and the product.

Once the model is fully implemented in each company, an analysis of the information flow related to the design process will be made. *Based on that analysis, it will be possible to develop an in depth investigation on the actual content and impact of* flow activities in building design.

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