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A MODEL FOR MANAGING THE PRODUCT DEVELOPMENT PROCESS IN HOUSE BUILDING

Managing product development in house building

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ABSTRACT

The performance of the product development process has a critical influence in the efficiency and duration of building projects, as well as on the quality of the final product. Despite its importance, relatively little attention has been given to the management of this process, if compared to production.

The main objective of this paper is to present some results of a research project which aimed to devise a general model for managing the product development process in small sized companies involved in the development and construction of residential and commercial buildings. This model consists of a template for the product development process, which can be used by different companies as a basis to devise their own models for managing individual projects.

The development of the model was based on case studies carried out in two companies from the South of Brazil and also on a benchmarking study.

KEYWORDS: Product development, Design, Process, Management, Building

INTRODUCTION

Product development can be defined as the process in which a product is conceived, designed and launched in the market and includes also the feedback from both production and product use (Ulrich and Eppinger, 1995). It includes product design and also some process design activities, as far as both tasks need to be performed together. Although most of the tasks performed consist of design work, there are other kinds of activities involved, such as financial and economic evaluation, legal design approval, and customer surveys. It begins with the perception of a market opportunity and typically involves the identification of customer requirements, concept development, product design, product validation, market launching, and collection and dissemination of feedback data (Cooper, 1998; Yazdani and Holmes, 1999).

In recent years, the increasing complexity of modern buildings and the growing competition in the market has significantly augmented the pressure for improving the performance of product development in the building industry. In general, clients are more demanding in terms of product quality. Also, shortening lead time and offering some degree of product flexibility have become important competitive dimensions in the building market.

The design of buildings poses difficult management problems. Even a product of modest complexity requires thousands of decisions about details, with numerous interdependencies. There are conflicting requirements, demanding an effort to recognise, understand and manage trade-offs, and decisions must usually be made quickly and without complete information. A large number of personnel are implicated, such as architects, project managers, structural engineers, building services engineers and marketing consultants. Moreover, feedback from the production and the building operation stages takes a long time to be obtained, and tends to be ineffective.

The product development process needs to be planned and controlled more effectively, in order to minimise the effects of complexity and uncertainty. The lack of design planning and control results in poor co-ordination and communication between disciplines, unbalanced resource allocation, insufficient information being available to complete design tasks, and inconsistencies within construction documents, among other problems (Austin et al. 1994; Koskela et al. 1997).

Prasad et al. (1998) suggest that modelling the enterprise process and decomposing it into workflow activities is necessary to organise the work of the product development team and direct its efforts. Smith and Morrow (1999) point out that developing models of product development is useful for both learning about this process and suggesting ways to control it. In fact, much effort has been spent in devising models for the product development and design processes, most of them for the manufacturing industry. Their scope, objective, and conceptual basis vary widely. Several models simply try to describe the process, some of them focusing on the product development process as a whole (for instance, O'Brien and Smith, 1994; Prasad et al. 1998; Yazdani and Holmes 1999), while others depict the design process itself (for example, Goldschmidt 1992; Frankenberger and Badke-Schaub 1998; Mazijoglou and Scrivener,1998).

There also models that attempt to provide protocols and tools to support product development and design management. They can be used as templates that contain a general process model and a set of methods and techniques that can be used to support different managerial tasks. This is the case, for instance, of the Process Protocol proposed by Kagioglou et al. (2000) for the whole lifecycle of construction projects. Ulrich and Eppinger (1995) recommend the use of such models, arguing that they make the decision making process explicit and thereby allow everyone on the team to understand the decision rationale, reducing the possibility of moving forward with unsupported decisions. Those authors also state that such models can be used as checklists of the key steps in a development activity, ensuring that important issues are not forgotten, and also as a basis for documenting the actual process in order to create a record of the decision making process for future reference and for educating newcomers.

This paper discusses the main results of a research study in which a general model to support the management of the product development process for the building industry was devised. The scope of the proposed model was limited to the residential and commercial building sector, since focusing on a limited range of products tends to make it easier to develop an abstract representation of the process. This market segment was chosen due to its importance for the Brazilian construction industry in terms of output, and because housing shortage is a major social problem in this country.

Also, the focus of this study was on product development rather than design, due to the fact that the performance of house building projects is strongly influenced by the interfaces between design and other processes, such as sales, production, and customer servicing. In fact, some authors have pointed out that the results of research on design modelling have had a limited impact in the industry because most studies regarded design as a relatively autonomous and bounded activity, and did not take into account business issues such as availability of resources, time constraints, and organisational structure, which are essential considerations for conducting effective design (Andreasen et al., 1998; Maffin, 1998).

THE NATURE OF THE DESIGN ACTIVITY

Most traditional business process modelling techniques have been developed for relatively structured and stable processes, and do not address the issues prevalent within product development. Design is a very complex and multi-disciplinary activity, and the information involved is both dynamic and semantically rich (Boston et al. 1998; Andreasen et al., 1998). This section presents a brief literature review on the nature of the design activity, pointing out some important features that must be considered in the development of process models.

Several descriptive models of design have been developed since the early Sixties, aiming to understand the design activity at a highly abstract level. Most of them suggest a basic group of activities which usually include (Lawson, 1990): (a) analysis - ordering and structuring the problem; (b) synthesis - generating a solution; and (c) appraisal - critical evaluation of suggested solutions against the objectives identified in the analysis phase.

The well known model for the building design process proposed by Markus (Markus and Arch, 1973) suggests that two dimensions are necessary to describe the iterative and cyclical nature of design. As shown in Figure 1, this model contains a vertical structure of sequential design stages and the horizontal structure of iterative and cyclical tasks.

The analysis-synthesis-appraisal paradigm has been criticised over the years by several authors. Lawson (1990) argues that this paradigm has derived from thinking about design rather than through experimental observation, and that it resembles more closely the systematic view of scientists (non-designers) on how design should be, rather than that of designers. Based on the observation of the work of town planners, Levin (1966) stated that only by actually generating a solution designers become aware of problems, such as the conflict between two user requirements. A similar result was found in the study of Eastman (1970), who concluded that there is no meaningful division to be found between analysis and synthesis, but a simultaneous learning about the nature of the problem and the range of possible solutions.

The fact that the number of customer requirements tends to be very large makes it difficult to formulate a problem statement without implicitly or explicitly referring to a solution concept. The study of Darke (1978) suggested that architects tend to latch onto a relatively simple idea very early in the design process, which is used to narrow down the range of possible solutions. This is an organising principle that directs the decision making process, enabling designers to rapidly explore the problem by generating a scheme. Indeed, clients often find easier to communicate their wishes by reacting and criticising a proposed design than trying to draw up an abstract comprehensive performance specification (Lawson, 1990). Therefore, the attention of the designer oscillates between the comprehension of the problem and the search for a solution (Cross, 1994).

The fact that there are many loops of interdependent decision areas also contributes to make iteration a common feature of design (Levin, 1966; Golsdschmidt, 1992; Austin et al., 1994). As a result, it is not possible to plan the design process as a sequence of well defined steps, since most decisions are affected by some that have been made before and also by others that will be made in future stages of the project.

Another oversimplification of some design models is the top-down approach. It is widely recognised that there is a hierarchical structure of decisions, from overall concepts to details. Typically, the design of an artefact can be divided into three main stages (Cross, 1994):

(a) Conceptual design: based on an initial statement of the problem, designers generate broad solutions in the form of schemes;

(b) Embodiment design: schemes are worked up in greater detail and a final choice is usually made between alternatives. Important technical and economic considerations are made at this stage;

(c) Detail design: a very large number of detail decisions are made, such as dimensions and forms of elements, and specification of materials.

However, design is not a strictly hierarchical process. Most designers use a random search strategy, in which they move freely between different levels of detail, especially in the early stages of design (Cross, 1994). Designers often think about the overall concept and at the same time think about detail aspects of the implementation of that concept (Cross, 1999).

In building design, the problem is usually poorly defined at the beginning of the product development process. In some projects, actual customers are only known when the design is at a relatively advanced stage. Although it is often possible to take some steps towards improving the initial definition of the problem, by questioning the client, collecting data, and carrying out research, it is important to bear in mind that some of the customer needs cannot be made explicit (Crosby, 1995). Besides, design is an exploratory process: designers are required to transcend the obvious and mundane needs of customers, and to produce proposals that are exciting and stimulating (Cross, 1999). As a result, the design brief is not used as a specification for a solution but as a kind of partial map of an unknown territory (Cross, 1999).

Thus, design can be described as an ill structured, solution-focused, iterative, and opportunistic process. It means that the steps for producing a design solution cannot be pre-established at a very fine level of detail (Cross, 1999). Such considerations clearly indicate that devising product development models is very different from the development of managerial process models in general.

PRODUCT DEVELOPMENT FROM A MANAGERIAL POINT OF VIEW

Besides understanding the nature of the design activity, it is also important to discuss the main concepts involved in product development from a managerial point of view. Product development is often defined as a process for transforming customer needs and requirements into the description of a product. This approach is based on what Koskela (2000) named as the transformation model, and assumes that process improvement can be mostly achieved by managing and improving each of its parts (sub-processes) separately. However, this is not adequate for the product development process, since there are many iterations between design activities.

The transformation model has, to some extent, contributed to the lack of transparency in construction, since it abstracts away the flows between the conversion activities, and does not encourage the clear identification of internal and external clients in each process (Koskela 1992). The focus of control only on the conversion activities is a major cause of uncertainty in process management, increasing the share of non-value adding activities (Alarcón 1997).

Product development should also be regarded as a flow of information in which there are four kinds of activities (Huovila et al., 1997): conversion, waiting, moving, and inspection (Figure 2). Only conversion activities can add value from the point of view of customers. Waiting of information, transferring information and inspection are non-value adding activities and, if possible, should be eliminated, rather than made more efficient. Part of the conversion activities do not add value whenever rework is necessary, due to errors, omissions and uncertainty. Finally, product development must also be seen as a process that generates value not only for the final customer, but also for internal and intermediary clients. The fulfilment of client needs and requirements is carried out in a cycle, through one or several stages, in which client requirements are captured and converted to a product or service delivered to the customer (Koskela, 2000).

In this study, these three different views of design have been considered in the elaboration of the product development model. This means that the proposed model must have mechanisms for managing both transformation activities and information flows and also for systematically considering both internal and external client requirements in design decisions.

RESEARCH METHOD

Research strategy

The research strategy adopted in this study was action research, because the aim was to devise and test a process model considering the point of view of product development and design professionals. Action research is a strategy for obtaining at the same time both knowledge and change in social systems. It is a cyclic process, involving the diagnose of the problem, planning, action, and an assessment of the results. In this approach, the main focus of the investigation is the result of an intervention in the subject being studied (Eden and Huxham, 1997).

Each case study involved the development of a model for managing the product development process. This model consists of a template which can be used by each company as a basis for designing the product development process for individual projects. The main elements of the model are: (a) the content of the main product development 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 roles and responsibilities of the different actors, and (f) a model of the information flow. The proposed process model is not merely a representation of the existing practices in each company – a number of improvements were introduced, based on propositions made by the members of the product development team, good practices identified in a benchmarking study, and the literature review carried out by the researchers.

The development of two case studies provided the chance to devise models for different organisational environments. Compared to a single case study, this creates a richer learning opportunity since the strengths of one model may compensate the weaknesses of the other, and the comparison of both creates favourable conditions for reflecting on the product development process at a higher level of abstraction. As a result, the evidences are more compelling and the results are more robust (Remennyi et al., 1998).

In the long term, the aim is to consolidate a general model (or protocol) that can be used as a starting point for designing the product development process for a range of project types carried out by companies involved in the development of residential and commercial projects in Brazil. Compared to the Process Protocol proposed by Kagioglou et al. (2000), this process model is more specific, since it is limited to the residential and commercial market segment, and also contains more details to guide the production of procedures and the implementation of tools in real projects. This is partly due to the fact that the general model was devised in a bottom-up approach: two actual models for managing product development were devised in different companies, and, based on that, a model at a higher level of abstraction was proposed.

In each company, the development of the model was carried out by a group of people, including company directors and employees, external designers, and members of the researcher team. Therefore, the previous experience and perceptions of the main participants of the product development process were taken into account in the study. This tends to increase the richness of the model, since contributions were made from a wide range of building professionals – some of them had had much experience working for other companies. Also, a consensual approach was expected to have a positive effect in terms of removing barriers for the implementation of the model. Given the large amount of work involved in developing such a model as well as the need to keep all participants motivated, the decision was made to implement it and test it gradually.

The two companies involved in the study were based in the Metropolitan Region of Porto Alegre, the capital of the State of Rio Grande do Sul. They were both small sized, and their main business activity is to develop and construct commercial and residential buildings. Most of the construction work is sub-contracted, and typically one to three projects are launched every year. The main criteria for choosing them were their willingness to participate in the project, and the fact that they were relatively well organised.

In Brazil, a construction project in this market sector usually starts when a business opportunity is found, the company buys a piece of land and then hire externals designers to conceive and develop the design. In general, the sales of dwellings or commercial spaces start after the design is relatively advanced, usually close to the beginning of the production stage.

Their range of products is relatively limited. Company A builds mostly residential high rise buildings for the higher-middle class, while Company B usually offer two kinds of products: office buildings, and residential units for the middle and lower-middle class. Both of them usually allow some design changes to be introduced by customers after they buy the property. Their supply chain strategy can be defined as "fit out to order" (Childerhouse et al. 2000) – it means that the customer has a limited opportunity to change some of the product attributes, usually the ones related to finishing stages.

Both case studies were developed at the same time. This provided the opportunity for both companies and their designers to exchange experience and points of view. The study reported in this paper started in April 1997 and finished in May 1999.

Research design

Overview

Most of the work for devising the model was performed by a team of four to five people, named operational team, which was formed by representatives of different sectors involved in design, including the design manager, at least one production or site manager, and one representative of the research team, who played the role of team facilitator. In specific occasions, a larger group, named extended team, was involved. This included the operational team, and also some external designers and subcontractors, who were considered to be partners of the company in a long term basis. Typically, each extended group had at least two architects, one or two structural engineers, and one or two building service engineers.

The case study was divided into three main stages, which are described below: (a) preparation, (b) model development, and (c) model refinement and evaluation.

Preparation stage

The preparation stage involved the presentation of the general plan of work to the top management of each company, and the definition of the group of people to be involved in both the operational and the extended team. A number of meetings involving the research team and the board of directors were carried out aiming to make them to articulate their vision on the corporate strategy, in which a well defined profile of the customers was established. This was considered to be an important pre-requisite for devising a suitable process model.

Also, members of the product development team – top managers, product development managers, and external designers – were individually interviewed by the research team. The aim of the interviews was to obtain their individual perceptions about existing problems in the process, and the sequence and the content of the main design activities in which they were usually involved. Most of them had only a partial view of the process, and often distinct definitions were used by them to refer to the same product development activity or deliverable.

At the end of this stage, a very broad definition of the current product development process was made and also a number of possible improvements were identified. In July 1997, a seminar involving the operational team was carried out in each company, in which the scope of the study was discussed, and the process modelling tools to be used were presented.

Model development stage

The stage of model development consisted of two main activities: (a) operational team meetings; and (b) seminars involving the extended team. The operational team met as often as three to four times a month, and each meeting took approximately two hours. Their task was to devise the elements of model, e.g. flowcharts, procedures, information flows, etc. Some of these elements were discussed at the extended team meetings. Also, some members of the extended team were occasionally invited to participate in the operational team meetings, when it was necessary to define elements of the process model in which their point of view was necessary.

The extended team seminars were held as often as four times a year. Some meetings involved the presentation and discussion of existing versions of the process model or its parts, prepared by the operational team. Also, some training activities were carried out, such as workshops and presentations led by product development or design management academics and consultants.

Some contributions for devising the model were also obtained from a benchmarking study. This study involved an investigation of good product development practices adopted by other construction companies in Brazil. One product development consultant and six product development managers of firms that had a reputation for good design management were interviewed.

The definition of the model involved three main steps (Figure 3). Initially, a graphic representation of the process was generated using flowcharts. This tool was chosen, instead of more powerful alternatives such as DFD or IDEF0 diagrams, because it is very simple and well known by most construction professionals. In order to keep the flowcharts as readable as possible, and at the same time comprehensive, information was organised in a hierarchical way. There is a general flowchart presenting the main product development stages, and for each stage a flowchart of activities. For some complex well structured activities, flowcharts of sub-activities were also produced. Figure 4 presents an example of flowchart for the Outline Design stage.

As far as process modelling is concerned, two strategies were used to cope with the ill structured, iterative and opportunistic nature of the design process. The first one consisted of keeping the definition of some activities at a relatively broad level of detail. This was the case of most design activities – for example, the architectural outline design in Figure 4. The other strategy was to use three types of precedence relationships between activities. Besides the traditional sequential and parallel, interdependent (or dynamic interaction) precedence relationships were also used (Austin et al., 1994) - see Figure 5. They occur when two activities are iterative and it is not worthwhile to model their sub-processes at a very fine level of detail, because these are ill structured or too uncertain.

The second step in the definition of the model was to represent flows of information by using input-output charts. This tool was used to systematically describe the main information inputs and outputs for each activity. Figure 6 shows an example of the input-output chart for two outline design stage activities. Once this step was undertaken, it was usually necessary to adjust the flowcharts that had been previously made (see Figure 4).

The production of the initial version of the model using flowcharts and input-output charts was time consuming and not very stimulating for the participants due to the large amount of details involved and also because it was difficult to reach a consensus. In October 1997, a seminar was organised in each company for discussing this version with the extended team.

For some product development activities, written procedures and working instructions were made – this was the third step in the definition of the model. Such practice can be used for reducing process variability, being one of the core ideas of the Scientific Management School. According to Smith and Reinertsen (1998), procedures should be produced only for product development activities that are predictable and well structured. For that reason, most of the procedures developed in this study were not related to design itself, but to the interface between design and other managerial processes, such as sales, approval at local authorities, and establishing contractual arrangements. Both electronic and paper working instructions were designed as aids to perform certain tasks – for example, checklists, spreadsheets, contract minutes, questionnaires, etc.

The procedures played an important role in terms of defining the exact content on the input and output information for each activity at a much more detailed level than in the input-output charts, as well the suppliers and internal clients of such information. Often flowcharts and input-output charts had to be adjusted when procedures were made, as shown in Figure 3.

It took approximately 14 months to develop an initial core of procedures and working instructions for each company (from September 1997 to November 1998). Compared to the previous steps, the product development team was more motivated participate. This was mostly because they were interested in discussing their work at a more concrete level, rather than at the level of relatively abstract process maps.

In December 1998, a seminar involving the extended team was carried out at each company, aiming to discuss the model developed so far. From January to May 1999, existing procedures and working instructions were refined, and also some new ones were developed

Model refinement and evaluation stage

The stages of model building and model refinement and evaluation were overlapped to a great extent, since each procedure (and related working instructions) was implemented as soon as its first version was consolidated. Initially, a pilot study was undertaken, in which some incremental improvements were made in the documents. Then, after another round of discussions, if necessary involving also other members of the product development team, the procedure was finally approved by the operational team, and implemented in a permanent basis. By May 1999, 36 procedures had been developed in Company A and 55% of them implemented. In Company B, 29 procedures had been developed, and 75% of them implemented by then.

The evaluation of each model involved a variety of data collection procedures: (a) feedback from the extended team collected during the seminars; (b) observation of procedures and working instructions being used in the companies; (c) interviews made with company employees, members and non members of the operational team; and (d) perception of the researchers who played the role of facilitators in the operational teams. No testing of the model as a basis for the product development process planning and control has been performed yet. This is an important step for evaluating the effectiveness of the model, and will be performed in the future.

Based on this evaluation, the first version of the general model was produced by the research team. This included an abstract description of the product development process, a collection of procedures and working instructions that were successful, and a number of guidelines for developing models for specific companies. The aim of this model is to be a template for the product development process that can be used by different companies as a basis to devise their own models for managing individual projects. The content of the model is comprehensively discussed by Tzortzopoulos (1999). Its main features are presented in the following section.

DESCRIPTION OF THE MODEL

Overview

The product development process was divided into seven stages, as shown in Figure 7. Although there are differences between the models developed for the two companies, their contents were relatively similar. Each stage is briefly described below:

(a) Inception and Feasibility: this stage involves the identification of a business opportunity, the definition of the project objective, and a broad evaluation of its feasibility. It is mostly related to strategic issues, involves fairly confidential information, and may take a very short time. For those reasons, only a few people are involved. Based on the project objectives, brief information about the site and local authorities regulations, the architect produces a very coarse proposal for a product to be developed – often this proposal is expressed by using only the external dimensions and other general attributes the product, such as gross floor area, number of floors, and number of units. This is typically the first step to narrow down the range of possible solutions, as suggested by Darke (1978). The opinion of a marketing consultant or a estate agent might also be considered in the definition of the product. Based on that, a feasibility study is carried out, involving economic, technical and legal issues. At the end of this stage the decision is made on whether or not to carry out the Outline Design stage.

(b) Outline Design: the main objective of this stage is to define the architectural design at a conceptual level. Initially, the first version of the design brief is produced, and more data related to the site conditions is collected. Then, the first meeting involving the whole design team and representatives of the production team is carried out, in which they define a range of alternatives and parameters for the design of sub-systems (structural, plumbing, electrical, etc.). Then, based on the design brief, the description of the site, and on guidelines and parameters related to sub-systems design, the architectural design is produced at a conceptual level. This design is subsequently evaluated by the company in a second feasibility study, and, if approved, it may be used for the negotiation with the owner of the land, since the lot is often exchanged for a number of units in the building. If an agreement is established between the company and the land owner, the project proceeds.

(c) Scheme design: this stage initially involves the development of the architectural design at the embodiment level. After that, the second stage of subsystems definition is performed by the design team and production management representatives, including a discussion on the construction site layout. Then, the first stage (conceptual level) of structural and building services design is undertaken. Based on that, an evaluation of the integration between the different subsystems is performed. Once all necessary adjustments have been made, a final evaluation of the design is carried out, including issues related to customer satisfaction, approval by local authorities, and economic and financial feasibility.

(d) Design for Legal Requirements: this stage involves the preparation of information and documents for submitting the design to the assessment of local authorities, and also for the preparation of sales. These activities are very important for the success of the project, since they enable the company to start the construction stage and also to sell units.

(e) Detail Design: it involves a very large number of activities, including architectural detail design, and structural and building services design at both embodiment and detail level. A thorough evaluation of the design in terms of integration between subsystems needs to be carried out at this stage, before the preparation of shop drawings. In most projects, there is an overlapping between this design stage and the production phase. As the sales process is undertaken throughout this stage, depending on the contractual arrangements it may be necessary to introduce design changes demanded by clients.

(f) Production Monitoring: this stage is concerned with getting feedback from production, and also introducing design changes due to demands by clients and also by the production team. At the end of this stage, all design changes need to be properly documented in as-built design drawings.

(g) Feedback from Operation: it involves obtaining feedback from building operation. Two main mechanisms for feedback can be used: (a) post occupancy evaluation, and (b) analysis of customer complaints. Such feedback plays a very important role in product development for the kind of company involved in this study, since their projects tend to be fairly similar.

In general, the three views proposed by Koskela (2000) - transformation, flow and value generation - were considered in the development of the model. Initially, during the production of flowcharts there was an emphasis on defining transformation (value adding) activities because there was no clear definition of the process. As soon as a consistent process map was produced, flow activities were also included in the model. Information flows were made explicit through the input-output charts and procedures. Inspection activities, such as stage approvals, were also represented in the flowcharts. Waiting activities were not represented in the model, because it is difficult to predict them due to the high degree of 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 information storage is not as clear as physical inventory. Finally, the value generation view was considered by introducing a number customer requirement management activities, such as customer requirement data collection activities, check lists, and feedback procedures.

Improvements and limitations of the model

Both companies decided to form a product development team, including designers, subcontractors, and representatives of other sectors of the company, such as production and sales. The designers and subcontractors invited to be part the team were the ones considered to be long term partners of the company. The model assumed that this team would be involved in product development decisions as early as the Outline Design stage. However, the early involvement of some designers and subcontractors could not be fully implemented for the following reasons:

(a) Companies are reluctant to hire the whole design team before the land is acquired, since there is a risk for the project to be suspended. In general, the architect is only hired at the beginning of the Scheme Design stage. The other designers are usually hired at the beginning of the Detail Design stage, after the architectural design has been approved by the local authorities and the company has started selling the units;

(b) Some engineering designers, such as the structural and building services designers, are generally not willing to get heavily involved in the project before a contract is signed, because this represents also a risk for them, in case the project is suspended. They usually agree to participate in discussions and to provide information when necessary, similarly to the role of a consultant;

(c) Some other designers and subcontractors cannot make themselves available in the early stages of design if the project is relatively small, mainly because they tend to be overloaded with work that seems to be more urgent for them. This problem seems to be more serious in small sized companies, since they have not much bargaining power in relation to designers and subcontractors, if compared to larger firms.

Although there is a certain degree of concurrency in the proposed product development model, its approach is more similar to what Yazdani and Holmes (1999) named as design centred models. This means that the design function takes into account downstream activities when developing the product, and a higher level of design analysis is necessary at the front end process, requiring a greater understanding of downstream processes, rather than having an intense involvement of the whole product development team since the early stages of the process. This means that the process is sequential to some extent, but there is a higher level of confidence in the design information.

The division of the process in stages was defined by milestones (see Figure 7). However, some overlapping exists between stages. Some of the milestones define only the conclusion of the preceding stage or the beginning of subsequent stage, rather than both – this is the case of milestones 2, 3, 4, and 5, shown in Figure 7. The overlapping between the Detail Design stage and the production phase is necessary for reducing the project lead time, and also due to the need to provide some degree of design flexibility to final customers. The overlapping between Outline, Scheme and Detail Design stages to some extent exists naturally, due to the random search strategy that exists in design (Cross 1999). Besides, the degree of overlapping tends to increase when the likelihood for the project to be suspended is low, and if the product development team is willing to carry out some design work before financial commitments are made.

This indicates that there is a good scope for improving product development by increasing the rate of success at the "fuzzy front end" (Smith and Reinertsen 1998), i.e. Inception and Feasibility, and Outline Design stages. If the company has a clear and effective corporate strategy and is able to assess properly business opportunities, and the customer requirements are adequately captured, the risk of the project being suspended tends to be reduced. As a result, it becomes easier to involve designers and subcontractors early in design.

For most building subsystems, it was possible to clearly identify and plan three design phases – conceptual, embodiment, and detail design. However, due to the existing risks and contractual limitations mentioned above, it is difficult to align such phases, i.e. develop concurrently the design of different subsystems. For instance, structural, plumbing and electrical engineering designs at the conceptual level are carried out in the Scheme Design stage, while all other engineering designs at this level are undertaken in the Detail Design stage.

A number of data collection and project definition activities were introduced in the process. Although these do not eliminate the continuous need for obtaining more information as design solutions are generated, the introduction of such activities tends to improve the performance of product development, because it increases the availability of information to perform design tasks (Huovila et al, 1997). As a result, there is less waiting for information, and the need to make assumptions due to missing data is diminished, which tends to improve the quality of design solutions and reduce the occurrence of needless iteration (Ballard, 2000). This also contributes to increase the efficiency of data collection activities, since these can be planned to some extent. For instance, a procedure was devised for collecting a large number of information at the building site in the same visit, rather than doing several visits.

A number of design reviews were introduced in the process as major quality control checkpoints. These can be divided into two categories. First, comprehensive design reviews were established for evaluating the product development process from a range of different perspectives, such as information completeness, customer satisfaction, cost, technical feasibility, and legal requirements. They define what is named by Cooper (1998) as “stage gates”, in which the decision on whether to continue or not the project is made. Usually, such design reviews involve the use of metrics and a number of well defined deliverables.

At each stage gate, the degree of maturity of the design needs to be evaluated, and typically a number decisions are frozen. A mature design means that it has been properly consolidated and completed in order to allow the release of information to downstream activities (O’Brian and Smith, 1994). This makes possible to establish some linearity in the design process, with no back tracking. Such reviews usually can be associated to some major project milestones (see Figure 7), in which financial commitments are made (Smith and Reinertsen 1998): the decision to go ahead with design (milestone 1), the decision to make a proposal for the land owner (milestone 2) or other kind of business negotiation, and the decision to send the design to local authorities for approval (milestone 3).

The second type of review has a strictly technical scope, and it is mostly concerned with configuration management (O’Brian and Smith, 1994), i.e. the effort to integrate different sub-systems. In general, this effort involves a design team meeting, followed by individual adjustments carried out separately by different designers. Then a review is carried out to check whether the different subsystems match.

Although some procedures for electronically exchanging information were devised, the model also emphasizes the need for face to face communication. This form of communication was formally planned in design meetings. Also, design presentations for both production and sales people were included, in order to clearly communicate the design intentions and philosophy.

Impacts of the model in the companies

In general, both companies and their designers were very responsive to the proposed models, and also interested in participating of this research project. One evidence for that was the fact that they were engaged in the development of relatively long case studies, and made themselves available to participate in further developments of the general model.

Some impacts related to the development and implementation of the models were detected in the evaluation stage of the research. This evaluation was mostly based on the perceptions of the product development team as well as on the observation of specific activities. The most important improvements detected so far are presented bellow:

(a) All people involved in the process were able to understand the process as a whole, their roles and responsibilities, as well as main internal client-supplier relationships, based on a common language. This has increased process transparency, and made it easier to integrate the work of designers in the product development team. In this respect, the use of relatively simple process modelling tools played an important role;

(b) The fact that a stable, consensual and explicit model of the design process exists makes it easier the identification of the necessary improvements. In fact, several decision making supporting tools were developed as part of the model and the role of each one in the process was well defined. These included checklists for project definition and configuration management; economic and financial feasibility models; performance measures; tools for customer profiling; as well as procedures for tracing back design errors and implementing design changes;

(c) The implementation of the models, although partial, has increased to some extent the control of the companies over their product development process. As a result, they have improved their capacity to identify problems and their main causes, and to implement the necessary corrective actions in real time;

(d) Continuous improvement has been systematically introduced into the process, since feedback from the production stage and building operation was formally established. Data collected during these two stages can be used for improving future projects and for realigning the company competitive strategy. It must be stressed that feedback activities should not be limited to data collection, but also include procedures and guidelines for classifying and evaluating information, as well as feeding it back to the right people;

(e) The development of the models has encouraged the establishment of a team attitude among the product development members. It also helped each company to assess the commitment and the managerial competencies of its designers – some of them were reluctant to participate in the discussions, and were eventually replaced by others. As a result, the remaining team has become strongly committed to perform joint product development activities, as established in the process model; and

(f) The companies have been able to provide some degree of design flexibility to final customers without causing much disruptions to the production system. Both of them defined three activities in which the customers are allowed to submit demands for design changes, within pre-established deadlines.

CONCLUSION

This paper describes the main results of a research project, in which a general model for managing the product development process in residential and commercial building projects has been devised. This model consists of a template from which process models for individual projects can be established.

The development and implementation of the model was an important source of reflection and discussion about the process for both the researchers and practitioners involved in the study. The main contribution of this research study is that the development and implementation of the model contributed to increase our understanding about the nature of product development in the building industry, and provided an opportunity for joint efforts towards consolidating a mature process model. In addition, some major barriers for improving the management of product development in small sized construction companies were identified and analysed, such as the need to reduce risk, and the lack of bargaining power of small sized companies.

The model also increased process transparency and provided a common language that improved communication between the different actors involved. Moreover, the team attitude created throughout the development of the model contributed to establish long-term partnerships among actors, resulting in a stronger commitment in the management of product development.

An initial evaluation of the model has been performed, mostly based on the perception of product development team members and on the observation of specific procedures being implemented. Further evaluation of the model needs to be undertaken. It has not been tested yet as a basis for the product development process planning and control. This is an important step for evaluating the effectiveness of the model, and will be performed in the future.

The proposed model has become a framework that can be used for identifying research gaps and positioning research efforts. In fact, a number of further research studies have been developed, focusing on specific elements of the model, such as electronic exchange of data, customer requirement management, sub-system configuration management, and customer servicing.

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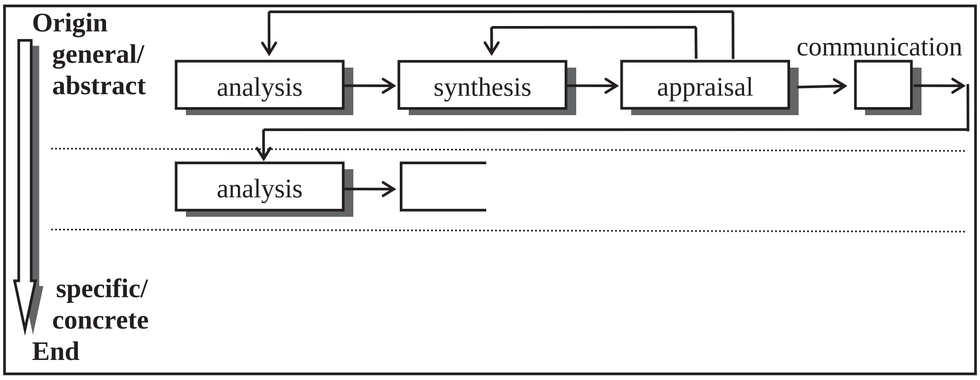


Figure 1 - A model of building design proposed by Markus and Arch (1973)

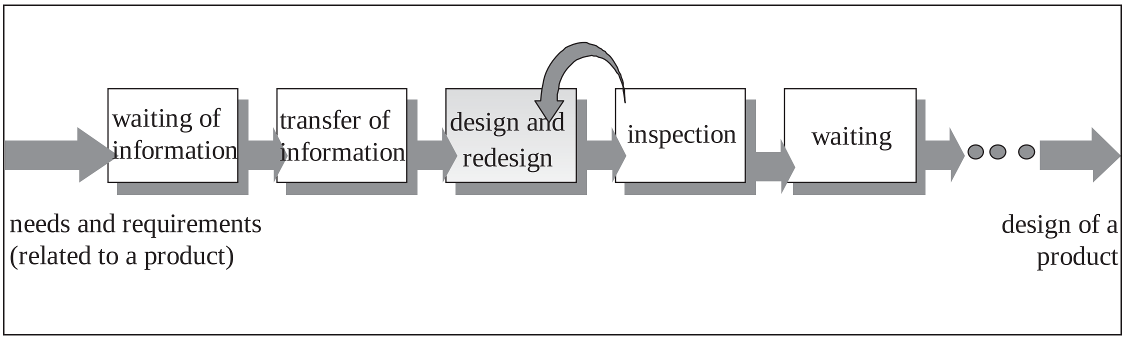


Figure 2 - The flow model of the design process (Huovila et al., 1997)

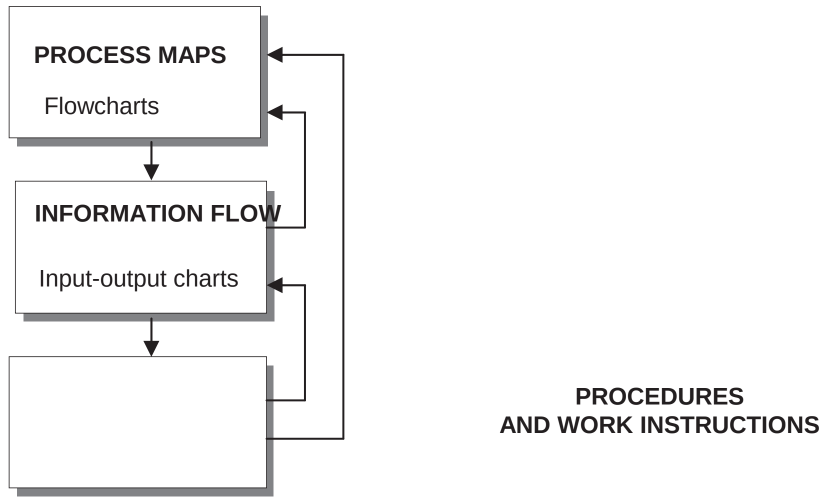
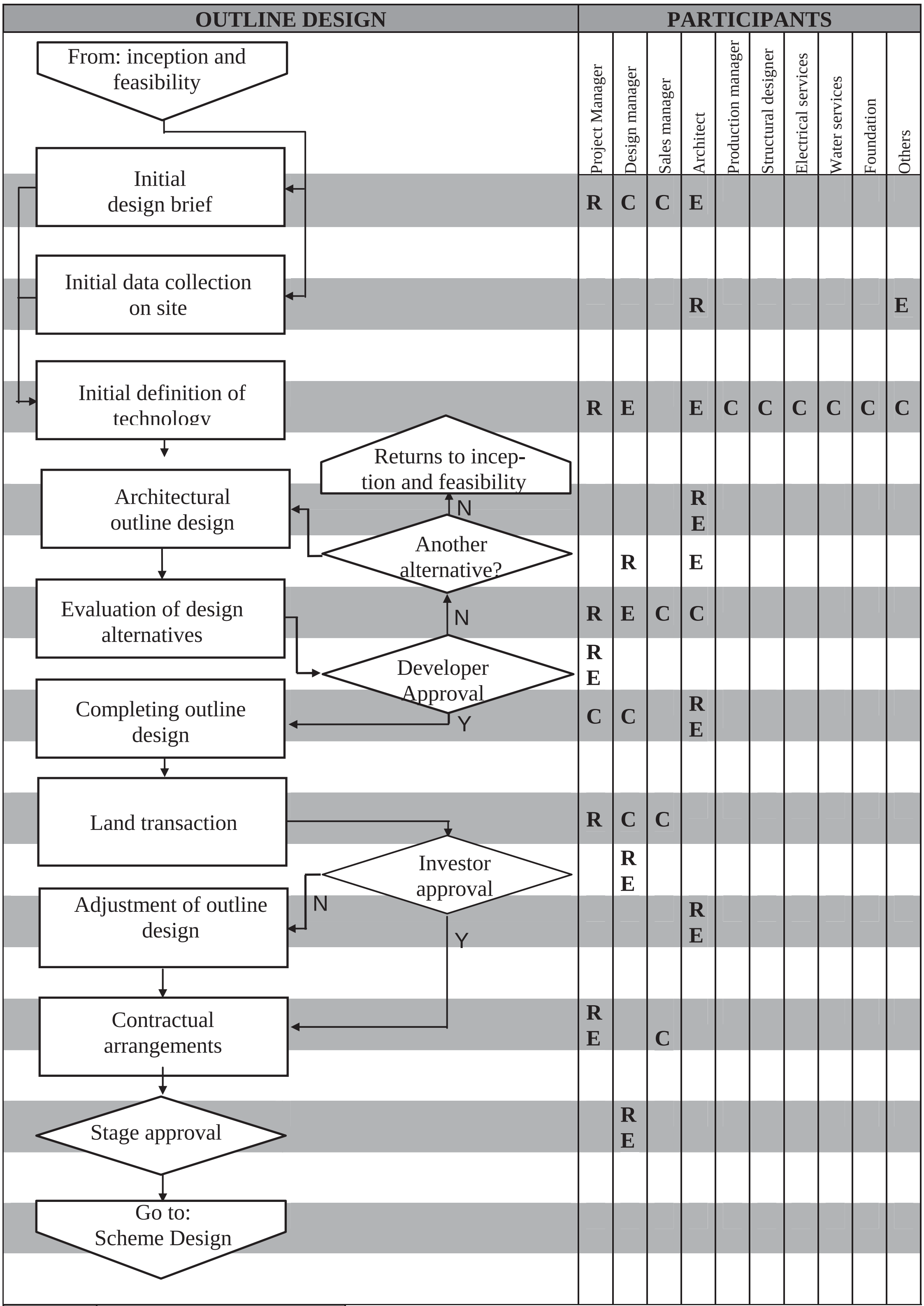


Figure 3 – Steps involved in the development of the model



R	Responsible
E	Executing
C	Co-operating

Figure 4 - Example of flowchart for the Outline Design stage

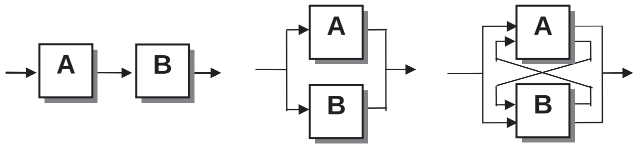
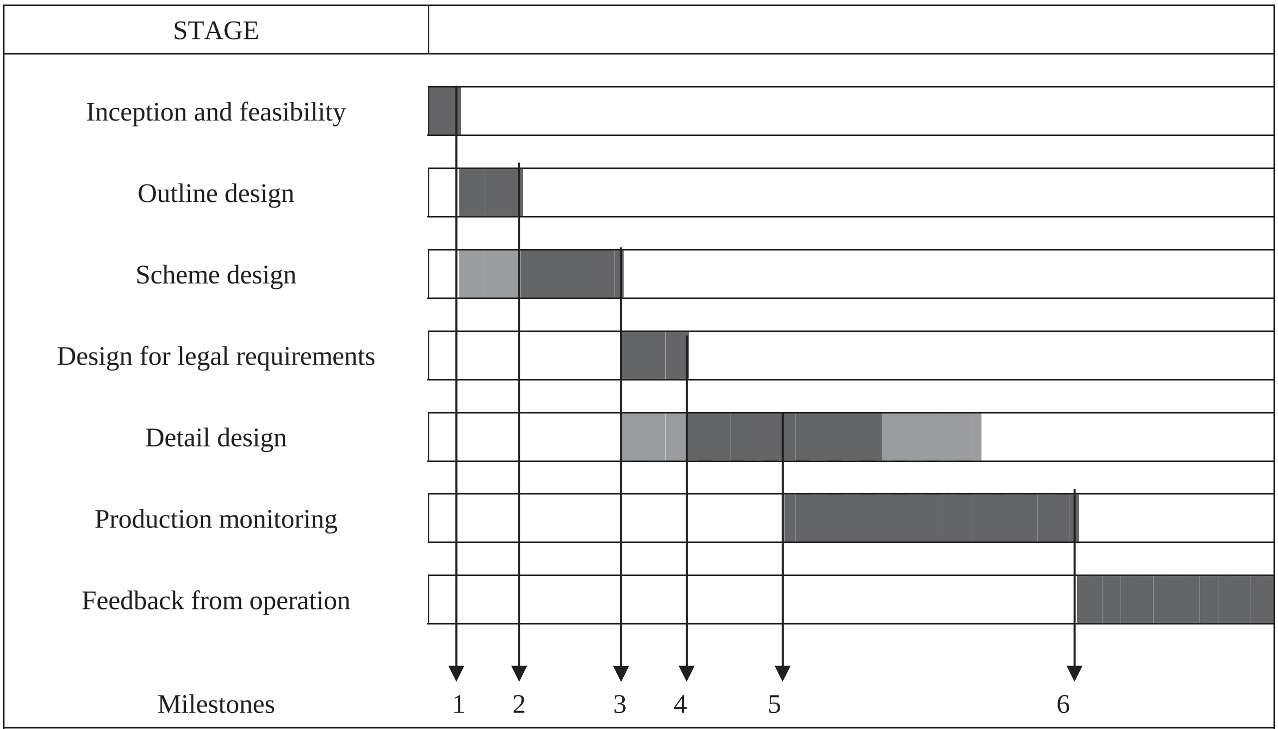


Figure 5 – Sequential, parallel and interdependent precedence relationships

INPUT	PROCESS	OUTPUT
Briefing Data collection from the site; Feedback data (from buildings delivered previously and from production). Definition of the design team; Strategic selection of technologies Initial statement of performance requirements; 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 6 - Example of input-process-output chart



1. Decision to go ahead with design
2. Land acquisition
3. Design is ready to be submitted to local authorities
4. Design has been approved by local authorities
5. Beginning of the production stage
6. Product delivery

Figure 7 – Product development stages