MANAGING THE INFORMATION FLOW IN CUSTOMISED APARTMENT BUILDING PROJECTS

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ABSTRACT

The adoption of customisation strategies increases the degree of clients' involvement in apartments building development and production and also the amount of information that needs to be managed. In such strategies, clients' specific requirements need to be translated into design and construction instructions. Failure in efficiently and effectively processing this information can result in apartments that do not fulfil clients' requirements and/or drawbacks in the construction process such as delays or reworks. As a result, having an appropriate information flow among companies, clients, and suppliers is an important success factor for a customisation strategy. This paper presents the evolution of the information flow in four apartment building projects developed by a Brazilian construction company. This research follows a previous study on the same topic (i.e. customisation in house-building) published in 2010 at the IGLC conference. While that paper sought to describe a set of practices applied by this company for managing customisation and its connections with lean concepts and principles, this one aims to show how those practices have evolved through time. Thus, based on the analysis of these practices, this paper aims to provide guidance on how to manage the information flow in customisation strategies.

KEYWORDS

Customisation, production, information flow, apartment building project.

INTRODUCTION

Customisation and mass customisation (MC) strategies increase the amount of information that needs to be managed. Companies need to gather and process clients' specific requirements so that customised products that meet these requirements are provided. Such a level of information exchange is not necessary when providing standard products since these do not have to meet clients' specific requirements.

Indeed, the success of MC strategies has been argued to be highly dependent on well-designed information systems to create a direct information flow among the

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company, clients, and suppliers (Frutos and Borenstein 2004). These information systems usually take the form of interface devices, also termed as configuration toolkits (Von Hippel 2001), choice boards (Oliva 2002), and choice menus (Fogliatto et al. 2003) in the literature. They can range from simple menu with customisable attributes for client to select from to intelligent aids, but usually enable client to select what they want in an economical way (Oliva 2002).

These interfaces are often designed so that that the choice made by clients are translated into a product design and manufacturing instructions (Da Silveira et al. 2001, Frutos and Borenstein 2004). In addition, they define to what extent client may customise the product (preventing inappropriate product variants to be created) and also enabling client to feed back the information on their choice (Da Silveira et al. 2001). This greatly simplifies the management of the information flow between clients and companies. Nonetheless, interfaces devices also have downsides. For instance, clients can face difficulties in matching their needs with specifications (Piller et al. 2005). According to Piller et al. (2005), even the configuration of a rather simple product as a pair of shoes can become puzzling if one has do decide between several attributes.

Buildings are inherently complex products (Linner and Bock 2012) and thus their configuration via on-line interface device might not appropriate in all customisation strategies. The client's lack of technical skills may create difficulties in configuring a product, and discrepancies between expectations and results, leading to low levels of clients' satisfaction (Juan et al. 2006). This is particularly the case when a broad scope of customisation (e.g. clients can customise all of the internal layout of an apartment rather than select from a number of pre-defined layout options) is offered. In this case, designers often need to be involved to translate clients' requirements into a design. In other instances the use of such devices might not be desirable, even if possible. For example, Linner and Bock (2012) reports that Japanese house builders choose to engage in a close dialogue with clients off-line rather than rely on on-line interface devices.

Clearly, computer based information system and interface devices can help construction companies to manage the information flow. In fact, many studies recommend their use and/or present examples of application (e.g Frutos and Borenstein 2004). Nonetheless, there is still limited guidance on how to manage the information flow when these systems are not used. Hicks (2007), in reviewing studies in information systems, states there is a relative lack of principles for improving the management of information flow. This also seems to hold true for the information flow management in customisation strategies.

Seeking to contribute towards fulfilling this gap, this paper describes the practices developed by Company CRE (C.Rolim Eng. Ltda.) to manage this flow and how these have evolved throughout four apartment building projects. In these projects (A, B, C and D) developed between 2005 and 2011, a broad scope of customisation was offered (i.e. clients were allowed to customise all the interior layout and specifications of the apartments) and computer based information systems were not used. As a result, the analysis of these practices can provide some guidance on how to manage the information flow in customisation strategies. It is important to highlight that the strategy offered in these projects can be defined as a customisation strategy since the broad scope of customisation allows a limitless number of product variants

(apartment designs) to be created. This differs from MC in which pre-defined options are usually offered and, thus, product variants are limited to a number of combinations.

INFORMATION FLOW IN CUSTOMISATION STRATEGIES

In this paper we take the same perspective adopted by Tribelsky and Sacks (2010) and assume that information flow is comparable in nature to production flow since inputs are transformed into outputs. Expanding this analogy, it is considered here that information flow involves transformation, value, and flow features similarly to the TFV production theory (Koskela 2000) as discussed by Huovila et al. (1997). Considering customisation and MC strategies, customisation requirements are the input of this flow, which needs to be converted into design instructions to be executed by the construction team. Clearly, this conversion is not straightforward and needs to be broken down into a number of sub-conversions since this information needs to be translated into different formats to address each stakeholder needs. For example, the format needed for production planning is different from the one needed for materials procurement. In the former, spatial information (i.e. the location of the parts that need to be produced), which is provided in architectural drawings, is necessary to plan the workflow. In the latter, information should be presented in terms of quantities of the different materials that need to be purchased to build the customised apartments.

In this sense, studies focusing on mass customisation in manufacturing (e.g. Da Silveira et al. 2001, Turowski 2002) and construction (e.g. Frutos and Borenstein 2001, Sacks and Goldin 2007) can help to elicit the activities that form the information flow and consequently the conversions involved. Within the context of manufacturing, Da Silveira et al. (2001) suggests that this flow has three activities: (i) collect and store information on client choices, (ii) transfer data from retailer to manufacturer, (iii) translate client choices into product design and manufacturing instructions. Turowski (2002) presents a more detailed set of activities: (i) client configures the customised product guided by the retailer, (ii) client demands an offer (price, delivery time) for the customised product, (iii) retailer sends an order for the customised product to manufacturer, (iv) manufacturer evaluates parts and subassemblies that can be produced and which must be acquired, and how long it would take to fulfil the order, and (v) manufacturer sends an offer to client, and (vi) client accept the order which is sent to production.

Within the construction context, Frutos and Borenstein (2004) describe the activities that an information system for the mass customisation of apartments building projects should support. These include: (i) register project changes, (ii) assess manageability of changes based on production schedule, (iii) calculate the price of changes, (iv) record these changes in production schedule and design documentation, and (v) screen real information about production program. Sacks and Goldin (2007) also present the activities for the information flow in the construction of high-rise apartment building projects. This flow includes the following activities: (i) client design meeting and drawing preparation, (ii) design approval, (iii) cost estimation, (iii) client approval, (iv) contract amendment and payment, (iv) order and delivery of special materials, and (v) provision of drawings to the production team.

EVOLUTION OF PRACTICES TO MANAGE THE INFORMATION FLOW IN CUSTOMISED APARTMENT BUILDING PROJECTS

The information flow in the four projects analysed (A, B, C, and D) has six main activities (Table 1). The evolution of practices and also changes in the information content are summarized in Table 1 and will be presented as follow.

ACTIVITY 1: DEFINITION OF CUSTOMISATION REQUIREMENTS

This activity involves the presentation of the scope of customisation to clients and the collection of their decisions regarding the desired customisations, namely, the customisation requirements (Table 1).

Communication between Company CRE and clients

The scope of customisation should be clearly communicated to clients to ensure that their requirements fall within the defined scope of customisation. This also avoids reworks (i.e. re-definition of requirements in case these are outside the boundaries). As shown in Table 1, Company CRE has introduced a number of improvements throughout the projects to enhance the communication with clients (item 1.1 in Table 1).

In Project A, a simple letter was sent to clients informing the possibility of customising the apartment and the deadlines for submitting the requirements. Architectural drawings (i.e. floor plans) were sent only to clients who asked for alterations. In Project B, the amount of information increased. Besides the documents used in Project A, Company CRE also provided clients with a list of standard materials to be installed in the apartments and their specifications. Also, a list of constraints was made available and informed what could not be altered in the customised designs (e.g. exterior walls, shafts, columns). In Project B, a set of architectural drawings (floor plans, elevations, and details) was also sent out to all clients. In Projects C and D, the letter was further detailed. A document set out the formatting standards for the drawings (e.g. layers to be used in the drawings, files' name, printer configurations, colour codes, and architectural symbols). In addition, the set of architectural drawings sent by Company CRE was already formatted according to these standards so that they could be readily used by the interior designers to create the bespoke designs.

Period for clients to make customisation decisions

The definition of a deadline for clients' to submit their customisation requirements is an important decision (item 1.2 in Table 1). Delays in receiving this information can produce delays or stoppages in production tasks and require alterations of production plans. Thus, the definition of such deadline and also of the period available for clients to make the customisation decisions has improved throughout the projects (Table 1). In Project A, clients had 120 days for decision making, but this proved to be too long: clients forgot to make the customisation decisions and most of them (estimated 95%) missed the deadline. As a result, in Project B, this period was reduced to 45 days. This new period proved to be too short and consequently, a significant percentage of clients (estimated 80%) missed the deadline. In Projects C and D, Company CRE decided to adopt an in-between time period (i.e. 75 days).

Table 1: Changes in the apartment building projects

Activities	Project A	Project B	Projects C and D
1.1 Communication between CRE and clients	Merely informative on the possibility of customise the unit	List of materials + specifications + list of constraints + basic set of drawings	List of materials + specifications + list of constraints + full set of drawings + standards
1.2 Period and batch size	120 days Unique batch	45 days Batch of 2 units every week	75 days Batch of 8 units every two weeks
1.3 Communication between clients and CRE	Written format	Written format + set of basic drawings (no formatting standards)	Written format + minimum set of drawings (with a formatting standard)
2. Technical assessment of customisation requirements	Quality manager (no check list)	Quality manager + technical director (basic check list)	Customisation department + quality manager + technical director + site managers + designers (full check list)
3. Communication of customisation requirements back to clients	List of materials (provided by clients) + contract addendum + client's obligations + budgetary sheet	List of materials (provided by clients) + contract addendum + clients obligations + budgetary sheet + control of products provided by clients	List of materials (provided by clients) + contract addendum + clients obligations + budgetary sheet + control of products provided by clients + material specifications (A3 colour-coded)
4. Communication of customisation requirements to production	Alteration's list + drawings upon request of site manager	Alteration's list + some drawings + colour-coded drawings (customised areas) + floor plan with notes + control of materials provided by clients	Alteration's list + full set of drawings + colour-coded drawings (customised and standard areas) + floor plan with notes + control of materials provided by clients
5. Communication of customisation requirements to procurement	List of materials for procurement	List of materials for procurement	List of materials for procurement (more detailed and colour-coded)
6. Communication of customisation requirements to other areas	List of alterations and materials specification (sent to site upon request)	List of alterations and materials specification (more detailed and colour-coded)	List of alterations and materials specification (colour-coded and even more detailed)

In addition, the manager responsible for the customisation process started to monitor the client decision-making process more closely. Telephone calls were made to all clients to inform that the letters were already sent. Additional calls, reminding about the approaching deadline, were also made to clients who did not get back to the company. These actions increased the number of decisions received by the deadline: an improvement of 150% in comparison to Project B.

Batch size

The batch size used to request clients' customisation requirements is another important definition to ensure a continuous an even information flow (item 1.2 in Table 1). In Project A, the letters were sent to all clients in a unique batch. This created an overload in the processing of customisation requirements. In order to address this problem, the letters were sent in smaller batches in Project B (i.e. the letters for the apartments of two building floor were sent per week). In Projects C and D, this batch changed to eight floors every two weeks. The batch was increased because the number of apartments in these projects is larger than the number of apartments in Project B.

Communication between clients and Company CRE

The way clients communicate their customisation's requirements to Company CRE is another aspect that changed (item 1.3 in Table 1). In Project A, the customisation was communicated in a written format. This means that clients had to fill a form informing the desired customisations. In Project B, this information was presented in a graphic format (i.e. architectural drawings) and was supplemented by a list of specifications. In Projects C and D, the customisation requirements were also submitted in a graphic format and needed to comply with the formatting standards defined by Company CRE. In addition, a minimum set of architectural drawings that needed to be submitted was also set out as an effort to further standardise the communication between clients and Company CRE.

ACTIVITY 2: TECHNICAL ASSESSMENT OF CUSTOMISATION REQUIREMENTS

This activity involves the technical assessment of the architectural drawings to identify and block customisation requirements that do not comply with the defined scope of customisation. This activity is particularly important to ensure that unfeasible requirements (e.g. alter the position of a column) will not continue in the information flow, thus avoiding their conversion into production instructions that cannot be carried out.

In Project A, only one person (the quality manager) carried out such assessment and thus some unfeasible requirements did continue in the information flow and, in some cases, were identified only prior to production. In Project B, a checklist comprising questions related to architecture and services system (electrical, plumbing, air conditioning) was devised to facilitate the identification of unfeasible requirements. The number of people involved in such assessment also increased. It included an intern of architecture, who was responsible for checking the architectural drawings, the quality manager, and also the technical director, when necessary. In Projects C and D, the number of questions in the checklist was expanded and included additional questions. Site managers and interior designers also became

involved in the assessment of customised designs when needed. In addition, a customisation department was created in Company CRE and an architect was assigned to manage the information flow.

ACTIVITY 3: COMMUNICATION OF CUSTOMISATION REQUIREMENTS BACK TO CLIENTS

Once the customised designs are approved from a technical viewpoint, a budget is generated and presented for clients' approval. After this approval, Company CRE communicates the customisation requirements back to clients. Company CRE only buys the apartments standard materials and, thus, if the customised design contains bespoke materials these should be purchased and delivered to the construction site by the clients. As a result, this communication is needed to inform the delivery date of bespoke materials. Such delivery is scheduled just prior to the material installation to minimize the storage period (and also damage risks) and to facilitate site logistics.

In Project A, the communication from Company CRE to clients entailed: (i) the list of materials and dates that these should be delivered, (ii) a contract addendum and (iii) a budgetary sheet with the scope of works for building the customised design and prices agreed. A fourth document stated the client's and the company's obligations (i.e. who does what and when). For instance, it can state that Company CRE will build the balcony using a special material provided by the client in a certain date. It also states which parts of the apartment Company CRE will not build. This happens when the customised design contains materials that are not installed by Company CRE. In such cases, clients' are required to complete the installation after the apartment handover. In Project B, the same set of documents was used, except for an additional document for controlling the materials delivered at the construction site. This document describes the materials specification, the quantities, and also the area of the apartment where they should be installed. In Projects C and D, a colour-coded sheet with materials specification was also used. In addition, Company CRE sent a set of architectural drawings of the customised design for clients' approval.

ACTIVITY 4: COMMUNICATION OF CUSTOMISATION REQUIREMENTS TO PRODUCTION

This activity involves the communication of customisation requirements to production. The format in which such requirements were communicated has changed throughout the projects to facilitate their understanding by the production team and, ultimately, ease the production process.

In Project A, these requirements were sent to the construction site in a written format, termed as alteration's list. Architectural drawings were only sent upon requests of the site manager. In Project B, the alterations list remained in use, but architectural drawings were added to clarify the location of the customisations in the apartments. In addition, a drawing called "floor plan with notes" in which call-outs were used to highlight the customisation requirements in the drawings. Also, the colour-coded sheet with material specifications was sent to the construction site. The colour code was particularly helpful to the crews as red (which means "stop") marked items to be installed by the client after the apartment handover, yellow (which means "attention") marked bespoke materials and green (which means "go ahead") marked the standard materials. These document were also used in Project C and D. Yet, in

such projects, the full set of architectural drawings (and not only the ones that shown customisation requirements) was sent to the construction site to provide a comprehensive understanding of the customised design.

ACTIVITY 5: COMMUNICATION OF CUSTOMISATION REQUIREMENTS TO PROCUREMENT

The architectural drawings provide useful information for the production but not for the procurement. This is because the quantities of materials that need to be purchased are not readily available in such drawings. Clients can use bespoke finishing's and fixtures and, thus, Company CRE needs to adjust the total quantities of standard materials to be purchased. In Project A and B, a list of materials was sent to the procurement manager to indicate changes related to customisations (Table 1). In Projects C and D, this list was colour-coded and presented more details. For each apartment, a list of materials containing the status of each material subject to customisation (i.e. if this was bespoke or standard) was created. Based on the list of materials of each apartment, the total quantities could be easily calculated.

ACTIVITY 6: COMMUNICATION OF CUSTOMISATION REQUIREMENTS TO OTHER AREAS

Besides the communication of customisation requirements to clients, production, and procurement (activities 3, 4, and 5), these requirements also needed to be communicated to other areas of Company CRE (e.g. marketing, finances) in a summarized format. This led to the creation of a customisation summary report, which has also evolved throughout the projects (Table 1). In Project A, this document comprised the list of alterations along with the materials specifications. This report was sent to the construction site upon request of the site manager. In Project B, this document was colour-coded to indicate the status of each apartment: (i) if it was sold and (ii) if it was customised or not. In Projects C and D, colours were still used to indicate the status of each apartment but more details (e.g. deadlines for sending the drawings to site) were added.

CONCLUSIONS

Customisation strategies increase the amount of information that needs to be managed since dwellings need to meet clients' specific requirements. This paper discussed the information flow involved in such strategies, which starts with the collection of clients' customisation requirements and ends when these are communicated to production and procurement. Such flow needs to be appropriately managed to ensure that the customisation requirements are accurate, presented in appropriate format, and available when needed for production. Failures in efficiently and effectively managing this flow can create stoppages and reworks in the production flow, compromising its efficiency.

This paper presented the evolution of the information flow in four apartment building projects (in which a broad scope of customization was offered) and also the improvements yield by the changes introduced by Company CRE. Quantitative evidence that substantiate these improvements is still limited. In this paper, only data regarding clients' adherence to the deadline for submitting the customisation

requirements is presented. The results of this metric suggest that the period available for decision-making influences the adherence to deadlines.

The definition of other metrics to assess the impact of changes in the management of the information flow seems to be the next step. In this respect, the lead-time of such flow (i.e. time that elapses between presenting the scope of customisation to clients and sending the architectural drawings to production) is a potential metric. However, the lack of numbers at this point does not invalidate the improvements achieved and perceived by the company. For example, it is clear that the changes presented here increased the transparency, contributing to a better understanding and communication of clients' requirements throughout the information and production flows.

Nonetheless, it is important to highlight that the changes presented here only create minor improvements in the information flow when compared to major improvements that can be produced by reducing the scope of customisation. Narrowing down the scope of customisation (i.e. having a number of pre-defined options) is likely to simplify this flow since apartment variants become limited (and are not limitless as in the projects presented here). As a result, budgeting and procurement activities can be much simplified since variants are constrained to the combinations of options offered.

In fact, the recognition that a broad scope of customisation is likely to create a burden on the information and production flows has led to some changes in Company CRE. These changes are related to the scope of customisation (and thus the customisation strategy) to be offered in upcoming projects. Currently, a broad scope of customisation (such as the one offered in Projects A, B, C, and D) is limited to project with large apartments (with an area between 201 and 300 m^2). This is termed as an individualized customisation strategy by Company CRE. For projects with apartment area between 101 and 200 m^2, a narrow scope of customisation is offered. In this strategy, termed as mass customisation by Company CRE, clients can select from a number of pre-defined options to customise the apartment. Previously, there was not a clear criterion for applying each of the strategies and a broad scope of customisation was usually made available upon clients' request.

Finally, the scope of customisation offered should also be considered when defining the configuration mode (i.e. on-line or off-line). The on-line configuration (use of interface devices in which clients can select the desired options) seems to be adequate when a narrow scope of customisation is offered and there is a number of pre-defined options to select from. Yet, it is important to consider potential problems that can be faced by clients such as burden of choice and difficulties in matching requirements with specifications (Piller et al. 2005) in devising the options and the interface device. Off-line configuration (creation of product variants guided or carried out by designers) should be preferred when a broad scope of customisation is offered. This is because clients are likely to require assistance to present their customisation requirements in the format needed (i.e. architectural drawings).

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