VALUE STREAM IN HOUSING DESIGN

Kelma Pinheiro Leite[1] and José de Paula Barros Neto[2]

ABSTRACT

The introduction of lean thinking in construction, and the achieved benefits, is prompting companies to adopt Lean Design. This research aims proposes improvements to the flow of information in the design of housing enterprises according to the Lean Thinking principles (LT). The companies' lack of knowledge about its own design processes hinders the identification of activities that do not add value, and it brings about the question "how to minimize the waste generated in the construction companies' design process?" This research uses the lean tool Value Stream Mapping (VSM) to represent and analyze information throughout the elaboration of vertical multi-familiar housing projects. The method adopted to achieve the goal, includes a case study in a construction company that uses lean principles and is implementing Lean Design, and data analysis. The results highlight the current and future/ideal VSMs, with suggestions for improvements in the analyzed process.

KEYWORDS

Architecture, Value Stream Mapping.

INTRODUCTION

The use of lean thinking in construction, coupled with the benefits that come from it, has boosted many companies' interests in adopting this project philosophy. Lean thinking has as its main objective the implementation of low cost improvements through waste reduction[3]. In this context, lean production, lean construction, lean office, lean in the public sector and lean design were brought about (Bisio, 2011).

An essential part of product development is the generation of information stream, in which waste (isolated or successive) cause quality and value decrease from the customer's point of view. Waste may occur when the information management system is poorly organized or structured (Koskela, 2000).

The elimination of waste and the definition of improvements for the design process regarding the information stream are challenges when implementing lean thinking in projects. However, the companies' lack of knowledge concerning their design process hinders the identification of activities that do not add value (Koskela, 2000), leading to the question: "how to minimize the waste generated in the construction companies' design process?"

The main objective of this research is to deploy the lean tool Value Stream Mapping (VSM) to represent and analyze the information stream throughout the

[1] Architect and Urban Planner, Master student at the Federal University of Ceará, Brazil. Tel.: +55 85-99696902, kelmapinheiro@yahoo.com.br

[2] Civil Engineer, PhD in Business Administration from Universidade Federal do Rio Grande do Sul, Titular Teacher of the Federal University of Ceará, Brazil, jpbarros@ufc.br

[3] In the lean philosophy, the concept of waste is understood as all the activities executed in the production process that do not add value to the product from the customer's point of view (Koskela, 2000).

elaboration of vertical multifamily housing projects. Moreover, it also aims to analyze critically the mapped streams of these processes as an attempt to identify losses, elaborate improved VSMs for the future.

LEAN DESIGN

According to Tzortzopoulos (1999) and Koskela (2000), the application of lean construction principles in the design process must take into consideration three different views of the project: (1) design as conversion; (2) design as flow of information and (3) design as a source for generating value (from the customer's point of view).

In lean production, projects must be oriented by the customer's needs (internal or external) and, among others, new technologies or new products/solutions must not be randomly used. In a lean approach, the internal customer is the next phase of the process, which must receive the product (the previous phase is finished) with the necessary quality, in a continuous flow from the beginning to the end of the design process (Cloke, 2000). Furthermore, the project team needs to know what has to be done to satisfy the customer (Ballard, 2008).

As observed in Figure 1, an improvement or change in the pre-design phase can generate a higher impact on value and functional capabilities with a lower impact on the project costs. This relationship is reversed on the use and operation phases. Changes in the later phases of project development may lead to extensive reworks.

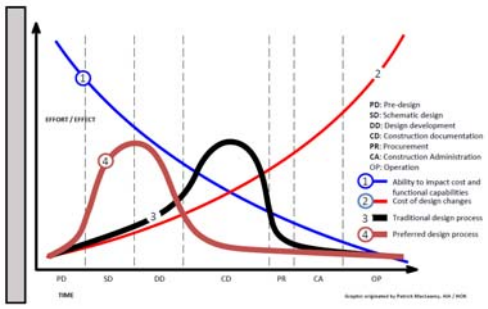

Figure 1: Preferred design process and traditional design process comparing (Graphic originated by Patrick MacLeamy, AIA / HOK)

The study of the materials and components used to build the project are frequently defined only in the construction phase. The early selection has not been observed, however it will avoid losses and re-processes (Orihuela et al 2011. The participation of the construction team and suppliers in the early phases of the project can bring about improvements, reducing uncertainties throughout the project (Freire and Alarcón, 2002).

A better execution can take place without increasing the costs of the construction or reducing the requirements that generate value for the customer. It can be achieved through a clear definition of the project activities on the lean design and construction, i.e., through the use of the lean system on the project delivery (Ballard, 2008).

According to Orihuela's et al (2011), in the design phase, the resources and tasks necessary to elaborate the project have been poorly defined and the lead time is not easily measurable. Therefore, the control and programming processes are, in general,

informal or simply not implemented. To plan the work in the design phase, the authors suggest the identification of the different tasks that must be carried on during the project definition and elaboration phase. The stream diagrams must indicate the complete sequence of tasks to the design team (Orihuela et al 2011).

Due to a big variety of projects, activities and products developed by the design companies, the amount of worked hours of each professional integrated in the group and the deadlines for finishing specific services are very complex. It is important to highlight that the productivity coefficients will vary among professionals and among the teams mainly because it depends on each member's knowledge and ability and on the efficient integration of the team as well. So, we can affirm, in this case, that the design team is more complex than the production team (Orihuela et al 2011).

VALUE STREAM MAPPING (VSM)

VSM is a tool essential to identify and comprehend the productive stream focused on making feasible the identification of waste sources, such as accumulated waiting products and inventories, rework, information lost in the process, activities that do not add value, and wastes with unnecessary works, besides the identification of opportunities for improvement (Rother and Shook, 1999).

VSM requires the development of an implementation plan to follow the evolution actions from the current state to the future/ideal state. Therefore, the maps help organizations to achieve two basic objectives: analyzing and eliminating wasteful activities.

With VSM, it is possible to improve the information stream in the design process through the suggestion of alternative methods of control. This tool creates a base for incentives and future actions to generate value (Freire and Alarcón, 2002).

Using a graphic standard language (Rother and Shook, 1999), the productive design process has all its phases mapped, elucidating which activities add value and which do not, simplifying decision making.

Among the advantages presented by the use of the MSV, Rother and Shook (2003) highlights: the possibility to visualize the whole and not only isolated parts of the process; monitoring products, documents and information throughout the time in different departments and organizations; simultaneous visibility of streams of materials and information; visualization of indicators such as throughput time, percentage of value aggregation, lots size and cycle time for the performance of activities, among others.

Womack (2006) proposes steps for the VSM process. The first step, for any mapping activity, is to focus on a family of products (Rother and Shook, 1999). In this study, the families are represented as the specialties design.

The next step is to map the current state of the value stream. Achieving the current state accurately is a complex task because the future value stream map, in which the stream improvements take place, is generated based on the precise identification of problems during the current VSM (Rother and Shook, 1999). It is a challenge, as data must be judiciously gathered and the research team is generally used to work by connecting the problems with flaws in the system (Womack, 2006).

Initially, to draw the future value stream map it is necessary to verify if each stage of the stream is really generating value. Reworks and stocks do not add value to the customer, so they must be cut out as long as possible (Rother and Shook, 1999). In

the sequence, it is proposed the transformation of the value stream into a continuous stream. Finally, conditions must be created to execute the production. Whenever it is not possible to keep a continuous stream, the lean techniques are used as supermarkets, FIFO's and kanban's to set the stream.

To measure the performance for the activities that constitute the Lead Time of mapped process, metrics such as Time for Activities Performance (TAP) and Permanency Time (TP) are used.

Dos Reis and Picchi (2003) define the Permanency Time (TP) as the time for information to go from the beginning to the end in a determined process. The time in which information waits in lines (inventories) is added to the TP or, in other words, the time of activities that do not add value. The sum of all the TPs is the Lead Time of the whole process. According to those authors, the Time for Activity Performance (TAP) is the time for effective execution of work that is transformed into the creation of value within the process. Thus, it is smaller or equal to the TP.

Tapping and Shuker (2002) propose adaptations for the VSM application to the information stream, once the value stream is focused on this stream, in case of projects. This mapping includes volumes and types of information and documents that move throughout the process, the identification of the responsible subjects for activities, the necessary time to prepare and exchange documents, besides the waiting time for each activity (Keyte; Locher, 2004).

The method proposed by Tapping and Shuker (2002) suggests the adoption of eight steps: (1) to engage with lean philosophy; (2) to choose a value stream; (3) to learn about lean; (4) to map the current state; (5) to identify the lean metrics; (6) to map the future state; (7) to create improvement plans (kaizen) and (8) to implement the improvement plans.

This work consists in the application of steps number 2, 4, 5 and 6 of Tapping and Shuker's method in a project environment formed by offices and development company, similar to Bisio 's (2011) adopted methodology.

The other steps were not used because the research focus is restricted to the applicability of value stream mapping for the design process and the suggestion of improvements for the future state of the stream.

METHOD

This research proposes the use of the lean tool Value Stream Mapping (VSM) to represent and analyze the information stream throughout the elaboration of vertical multi-familiar housing projects. It is an ongoing Master's research about lean design and it presents data gathered in a development company through the use of a case study.

The research method consisted of three phases: choice of the value stream, case study of a construction company that uses the lean principles in constructions and is implementing the Lean Design and data analysis. As results, we have the current and future/ideal maps, with suggestions for improvements in the analyzed process.

The exploratory phase of this research included the analysis of documents related to the design process, observation of activities in six meeting of design and five semi-structured interviews with the people involved directly with the project (the design offices and the construction/developer). In the phase of data analysis, this work attempted to identify possible opportunities for improvement in the studied project

streams, based on the literature, and analyze the application of the tool VSM for the design process. The diagnosis process lasted three months and it allowed the process identification.

CASE STUDY

The researched construction company has more than 20 years of experience in the market in Fortaleza. It owns an NBR ISO 9001:2008 certificate and a PBQH – level A certificate[4]. The project in focus is a multifamily high-rise building, with one tower, in which there are two apartments per floor and a penthouse.

Chart 02 – Main characteristics of the enterprise

Type of condominium	Housing
Number of towers	1
Number of floors / tower	23
Units / floor / tower	2 and 1 penthouse
Total of units	37
Partial area of the unit (m^2)	136,45
Number of parking spaces	3 to 4

To select the project team, there was a market consultation. The team chose to work with the construction company's partners, who had previously worked together. They are five design and consultancy offices, thus the technical subjects are not developed in the same company. Each professional works in his/her own office, managing his/her own work.

The role of design coordinator (responsible for monitoring the execution) was created in this project. The engineer of the construction is also the project coordinator. The administrative management is realized by the company's board of directors. A specific objective of the company, in the studied project, was to create new working methods based on regular meetings with the project team to improve team communication and iteration. Furthermore, BIM was being implemented to support decision making of projects and there was a specific consultant for this area to improve the project development.

Biweekly meetings were pre-scheduled with the whole team and meetings on demand were scheduled with a few members, in general the board of directors and the designer of a discipline, or the designers of two specific disciplines, depending on the topic to be discussed. As a total, six planning and project control meetings were realized in four months, involving a multidisciplinary team of 9 professionals: designers, consultants, directors and managers of the construction company. These meetings lasted for 2 or 3 hours each. The researcher was present in all of those meetings as an observer.

To analyze the current VSM, tools such as project analytical structure of the project (WBS) were used to better understand the activities, which provided an initial view of the whole process, indicating the families of the stream elements (groups and

[4] Quality certificate of the Brazilian government

work blocks). In this work, only the activities positioned in a more strategic level were mapped, i. e., the disciplines and the project stages. Mapping all the activities of each discipline would be very difficult because the designers were positioned in different offices, with different teams. Moreover, the diversity of enterprises and activities of the design companies makes very complex the survey on the worked hours of each professional allocated to the team.

The architectural design was taken as a guideline of the value stream mapping because it is the discipline that starts off the project and runs throughout the whole process. It also demands more elaboration time, as verified when data were gathered. Thus, its lead time overlaps the project lead time. In addition, the architectural project represents a critical process for generating product value, and it is also the base for other complementary projects and integration of specificities. The current value stream was mapped, according to figure 02.

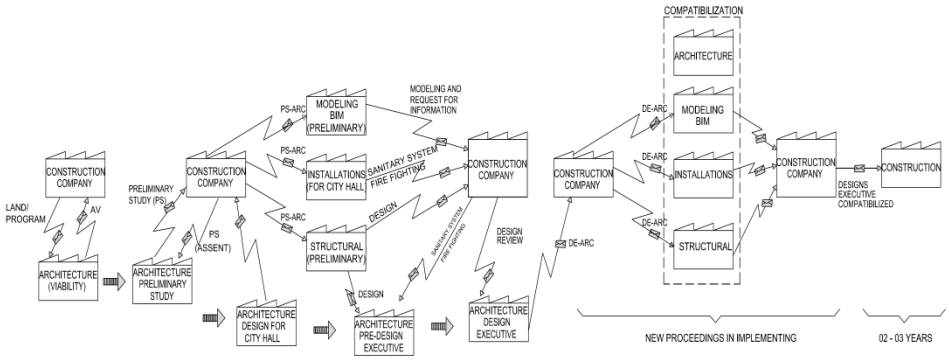

Figure 02: The current Value Stream Mapping. Source: the authors

The current VSM was useful to visualize how the design process is developed within the company, to recognize the different activities involved and to identify wastes. It was possible to measure each production phase time and gather data such as: review, correction and distribution. From audit in drawings, observation and interviews, it was possible to gather data about project elaboration time (TRA) and time for making the project available for the team (TP), according to what we can verify in figure 03. Furthermore, the concluded planned percentage (CPP) of the current VSM was measured as an indicator, as exposed in figure 04.

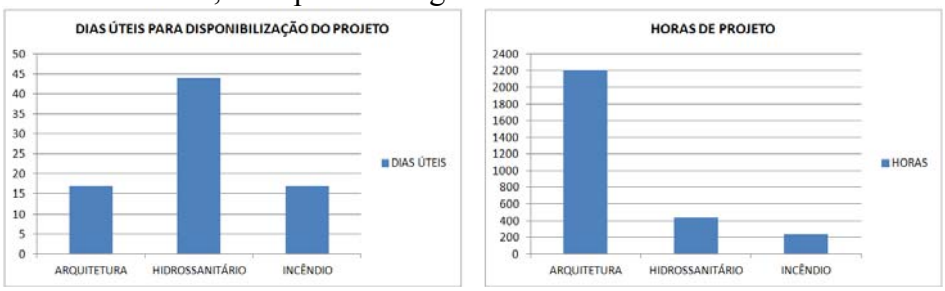

Figure 03: Project Permanency Time x Project Real Activity Time (RAT), in the phase of legal project (approval). Source: the authors.

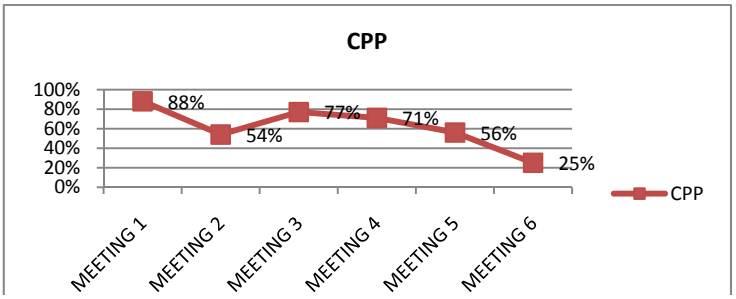

Figure 04: CPP (Concluded Planned Percentage) in the first phase of the project. Source: the authors.

After the architectural design got planning permission, a change in the design was requested by the contractor, changing the construction system originally proposed, which resulted in rework for all the design disciplines. These changes raised the pressure on the architecture design and generated waste that had to wait for those changes to carry on the work. It is important to highlight that those changes generated new project iterations.

ANALISIS

It was verified that the communication among the team members occurs as follows: the communication is centralized in the construction/developer (the company's board of directors and project/construction manager), who receive information requests and the project files and distributes them to the other members in a virtual depository. The information stream in the project development was documented through minutes and e-mails. However, it was also observed a less intense information stream in an informal and non-documented way.

Concerning the management meetings, the design team point out to a relatively excessive number of participants in the meeting, which contributes to the team defocusing. So, it is clear the need for a better elucidation of objectives, establishing shorter meetings. According to the team understanding, there is waste of time in meetings when the topic is not directly concerned with a specific professional. Another mentioned aspect was the fact that many times a non-specialist shows his/her opinion about a determined topic, which is considered prejudicial by the team. Despite the wastes throughout the process, the designers were reluctant to admit lack of matching and reworks.

One of the main research findings is that there is a great quantity of waiting work or work in progress among the different production phases of drawings and documents. In the legal project phase for agencies approval, while it was observed a percentage of 90% of worked hours, in the cycle time, in the architecture project, this value decreased for 10% in the sanitary project and 30% in the fire protection. Thus, the real time used effectively to design was only a small fraction of the total cycle time, similar to what is pointed out in Freire and Alarcón's (2002). Documents and drawings were mostly waiting for information to be carried on.

FUTURE VSM

Based on the diagnostic analysis, a value stream map for the future was proposed by the researchers to the organization. The objectives of this new map were to reorganize phases of the project, to cut out rework and stocks[5] and to allow a continuous stream of information and documents.

The participation of all the stakeholders in the design phase must be optimized by encouraging iteration among the technical subjects, incorporating the production oriented by the projects (see VSM in figures 06 and 07) (Rother and Shook, 1999, Cloke, 2000, Ballard, 2008, Bisio, 2011 and Orihuela et al 2011).

Waiting for information in the projects elaboration, presented the highest amount of waiting time, i. e., when a work could not be executed due to variables external to the designers. So, a virtual and accessible database was organized with the purpose of working as a "supermarket". This library system is virtual to guarantee full access to the team. The idea underlying the supermarket/library is only to "pull" necessary information for a specific project, enabling the designers to select their data whenever it is needed. The next step will be to gather learned lessons with projects and constructions (throughout time) in order to guarantee the unceasing improvement of the design process within the organization.

The incorporation of the lean principles in the future VSM is going to reduce the wastes, decreasing costs and the lead time. (see figures 05 and 06).

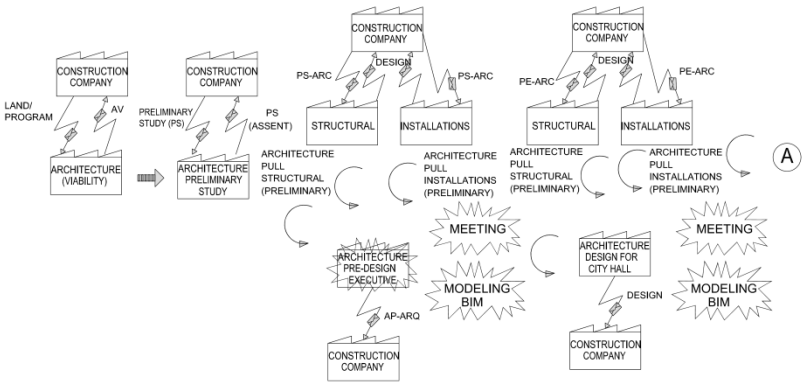

Figure 05: The future Value Stream Mapping – part 1. Source: the authors

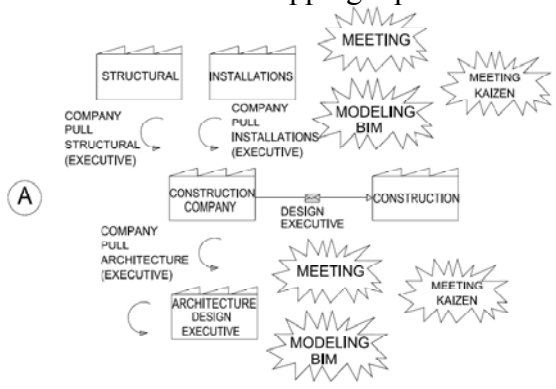

Figure 06: The future Value Stream Mapping – part 2. Source: the authors

[5] Design waiting information to be finished

Even with the project systematic meetings, one of the categories with more frequent wastes was the rework caused by the beginning of projects without all the necessary information. A minimum quantity of data should be guaranteed before starting off a phase, saving time then.

The company has checklists to monitor and analyze critically the project focused on the delivery of documents. Nevertheless, they were not fully appropriate to the lean philosophy, so new checklists were recommended before the project phase to determine the minimum quantity of information necessary for a drawing or project discipline to be started off.

CONCLUSIONS

Identifying problems and creating more efficient processes is not an easy task, but reduce waste is a much bigger challenge. Makings changes in organization and culture that effectively cut out waste requires a lot of effort. The Value Stream Mappings can guide the organizations to the lean change.

It is not easy to implement changes in companies. As a matter of fact, many people feel controlled when the diagnosis and the evaluation phase process are being carried on. In general, designers do not like to specify their activities, especially how they manage time. This is a reaction to be considered natural (Freire ad Alarcón, 2002). In fact, streams are really understood when they are scrutinized and it is possible to determine its characteristics as a whole. However, there may be barriers in the implementation process of the lean philosophy, but they tend to decrease as long as improvements begin to show up and the team benefits from new methods of work.

A first map of the current state is submitted to the analysis of the organization to determine how it reflects the current process and is aligned with the value stream for the customer. After successive refinements, an appropriate map is established. After the conclusion of the current map, a new one is developed, and the iteration continues until the moment when an appropriate future value stream mapping is produced, and once it is implemented, it becomes the current map. The successive value stream mapping can continue for the entire process cycle as a way of searching for perfection. (Rother and Shook, 1999).

Thus, the future map presented in this work represents a step of the value stream optimization process in the design phase, and it can be continuously improved. Other researchers can be conducted using the value stream mapping for different types of projects in order to find out better practices for the design process.

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