EVALUATION OF SUPPLY AND SERVICE OF STEEL ASSEMBLY OF STRUCTURES

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ABSTRACT

The Brazilian construction market experienced a period of great acceleration which led the enterprises to struggle to find new ways of keeping themselves competitive, always aiming at the fundamental triangle in this sector: quality, time limits and cost. One strategy chosen is the application of concepts derived from Toyotism and lean production. This thought seeks to add value to the product in order to please the customer, seeking to avoid waste and reducing time. An area under direct influence of these factors is the supply sector in civil construction. The management of this sector is of great difficulty due to its complexity. This article discusses the application of the lean thinking to the management of this sector, named Lean Supply. This study was based on the analyses of the supply of steel bars and strands for the service of assembly of structures in a construction site. Initially, the constructive and technological process was studied, followed by the analyses of the supply system, contract management and logistics work. Thus, it was possible to make a Value Stream Mapping (VSM) in the current state. After analysis, a VSM was prepared in the future state. This study generated suggestions for the application of Lean Supply to the construction project studied, involving aspects of external logistics, production cycle, hiring of suppliers, administrative organization, executive technology and projects analysis.

KEYWORDS

Civil Construction, Lean Construction, Lean Supply, Value Stream Mapping.

INTRODUCTION

Companies currently operating in the building industry are seeking differentials since the market is very competitive. Therefore, there was the application of Lean principles with the goal of increasing the quality of processes. Toyotism derived, these principles began to be studied for the automotive industry in the mid-50s in Japan, when Toyoda sought an alternative to mass production for his country. The success has expanded to other areas of the consumer goods industry. In civil construction these ideas started to emerge in the 1990s with the publication Koskela (1992). The concept of lean construction emerged from this paper and it has been studied throughout the world by several researchers.

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Other principles derived from consumer goods industries have recently been studied to be applied to construction, including the Lean Supply, which is the use of Lean tools and principles to manage the supply chain.

However, for Gosling and Naim (2009), it is necessary to determine which lean principles are suitable to the production environment in supply chain type of engineer-to-order (ETO), as it is in the civil construction sector. For Arbulu *et al.* (2005), the ETO of materials is commonly characterized by long lead times and implementation of material management systems to pull materials through the value stream with proper work-in-process levels in the supply chain.

For Gosling and Naim (2009), lean and agile strategies can be applied to supply chain structures to help determine their applicability. Both paradigms attempt to rationalize tools, techniques, philosophies and approaches to manufacturing and supply chain management into a coherent framework.

According to Sanchez and Nagi (2001), agile manufacturing is a response to the complexity brought about by constant change. In this changing market, management must be prepared to approach outside organizations, to present their single view of the future and to develop methodologies for the evaluation and selection of partners.

Vrijhoef and Koskela (2000) mention that because of construction peculiarities, supply chain management has four specific roles in construction: firstly, the focus is the impact of the supply chain on site activities; secondly, the focus is the supply chain itself with the goal of reducing costs, especially those relating to logistics, lead-time and inventory; thirdly, the focus is transferring activities from the site to earlier stages of the supply chain; fourthly, the focus is the integrated management and improvement of the supply chain and the site production. For these authors, the four roles identified are not mutually exclusive, but are often used jointly.

Due to the complexity of the sector and the number of suppliers in a single project, Arbulu and Ballard (2004) propose a strategy to improve the management of supply systems in construction using lean principles and techniques. The objectives are to simplify the configuration of construction supply systems, reduce variability embedded and improve visibility across supply systems. They mention the need to install a logistic center in the construction site to provide a global management of the supplies system based on Lean Supply.

For Salvén (2013), the use of distribution centers can solve a number of problems in construction such as excessive material handling on construction site and late changes to the projects causing disruptions. The benefits of this strategy is a logistics process with various solutions, such as buying the material from multiple suppliers which can be combined into smaller batches and delivered Just-In-Time.

Thus, the supply chains have been widely studied due to the recognition of the need of integration between the activities in the construction sites and the delivery system in general (LONDON and KENLEY, 2001).

According to Souza and Koskela (2012), the management of the supply chain has been discussed with both qualitative and quantitative emphasis. The International Group for Lean Construction (IGLC) in their annual meetings has been highlighting Supply Chain Management (SCM) in civil construction, collaborating to generate the Lean Supply approach. Several authors have presented their research on the topic at conferences of this group.

In order to evaluate the concepts of lean and supply chain in civil construction, the Value Stream Mapping (VSM) is an important analyses tool, once it consists of a graphic way of visualizing what is happening in a certain moment and enables the proposal of future improvements.

This work aims at studying the application of the Lean Supply philosophy on civil construction projects, with a focus on site activities which use the VSM as a tool for the representation of this case. In order to do so, a case study was developed where the framework assembly of steel on concrete was studied.

LEAN SUPPLY

According to Walter and Rodrigues (2011), the application of Lean principles and solutions facilitated the supply chain management and emerged as a practice which helped reach significant reduction of time (lead time), costs and stocks.

For Arbulu *et al.* (2005), the use of lean aspects with SCM can target the main objectives which are :(1) to improve the accuracy of site demand (increase workflow reliability) by enabling a better planning and production control process; (2) to increase transparency across value streams by working with production management tools, and (3) to manage physical and information flows in real time by linking production level workflow with material supply.

For Stratton and Warburton (2003), Lean Supply is closely associated with the activation of flow and to the elimination of the waste variation in the provision and supply chain. The concept of Lean Supply is based on the management of the supply chain, focusing on minimizing waste such as unnecessary transport, oversized stocks and waiting time. Lean Supply is not only related to the provision of materials or services, but to everything which involves the supply chain, such as the reliability of suppliers and the management of contracts.

Arbulu and Ballard (2004) described the reliance on the supplier as directly linked to the size and quantities of stock possible. The more reliable the supplier is, the better the programming of deliveries and the closer one gets to a continuous flow with zero stock. The management demanded by the philosophy of Lean Supply is hampered by the complexity of the sector of civil construction, so in order to apply it; a previous study of the operation of all the processes involved is needed.

In order to make the analyses easier, a mapping of the process can be conducted. Then, based on the data obtained of this mapping, it is possible to understand the flows and ways of this process.

VALUE STREAM MAPPING (VSM)

According to Womack and Jones (2003), the Lean ideas depend on three basic concepts: definition of flow, definition of value and definition of perfection. The Value Stream Mapping (VSM) already comprises in its name practically two of these concepts, so it can be said it is a good tool for the application of Lean.

The VSM, for Rother and Shock (2003), consists of a tool which diagnoses the possible problem in a system and point out the possible solutions based on the flows occurring in the production, either from materials or from services.

Furthermore, the VSM presents a current state and plans a future state, named in these cases current VSM and future VSM. Therefore, while the first map is made from data collected on the field, the other map is made describing the possible alterations in the flow which can improve the pace of the system as a whole. The advantages of elaborating a VSM are in the information retreated from it, as described in Table 1.

Table 1 – Information contained in one VSM

INFORMATION	DESCRIPTION
Takt Time	It is the time to process a task without considering any waste and any activity which is non-value added.
Continuous Flow	It is the sequence of activities which can be done by thinking of pulling the former activity, decreasing the intermediary stocks.
Number of Operators by Cell	According to the detailing of the Map it is possible to optimize the number of operators of a cell.
Interval (size of lots)	The interval always depends on the slowest activity, which is the bottleneck of the production. After the VSM is completed, it is possible to know the processing time of all the activities, and then the size of lot and the cycle time is determined according to the activity which process fewer parts in the longest time.
Kanban	It is the warning of the pull type production system. Kanban can always be established in the places of continuous flow, starting from the first activity.
Supermarket Systems	The supermarket systems represent a better control of the stock and it is usually possible to implement in the beginning of the continuous flows.
Precursor Process	The precursor process must always be the last in the flow line. It is the objective which will be reached in the continuous flow line, or some other service further to the line.
Frequency of command releases	When thinking of future map of flow value, it is necessary to bear in mind the commands for the beginning of processes. By using VSM it is possible to position Kanban and according to the time of cycle, to determine the frequencies in which they are released.
Improvement of processes	The VSM shows the Takt time and the time of activities cycle, besides the process needed for each one of the activities. Through these times, it is possible to improve the process in order for the time of cycle to be always the closest possible to the Takt time.

METHOD OF SURVEY

Here the method of exploratory study case, proposed by Yin (2008) was adopted. Firstly, a bibliographical review was conducted on the theme of Lean Supply, followed by a field research. It was initially decided that the case study should be done on a specific task, due to the complexity of simultaneous activities taking place in a construction site. Thereby, the service of steel assembly of concrete was chosen, being detailed in two cases: macro - the service of assembly of the pavements and micro - the service of assembly of pillars.

The data was collected considering the documental analyses provided by the enterprise (supply contracts, issuing receipts and requests of materials), an interview with the project production engineer and trainee who provided the charts demonstrating the constructive sequence and the pace of the task production, and also the photographic recording of the activities being done.

The following data was collected for the elaboration of the VSM: the type of contract with the supplier (time limit, sizes of lots, time of delivery); the period of work in the project (length of work per day and number of employees at work); the person responsible for checking the services and releasing the upcoming operational services. The VSM of the studied service used the software MSVision – Microsoft.

Based on the choice of services to be studied, the guidelines for this work were defined. The analysis of the service was conducted to identify the processes, with emphasis on activities in the construction site and the relation with the suppliers. Firstly, a survey was conducted for further understanding of the operational service and general and specific conditions present in that construction project. After that, two analyses were conducted with the VSM: a macro one, considering all the way of the steel from the supplier through the project until the checking of the service, as well as a second analysis, conducted only for the service of the assembly of pillars.

Enclosing the article, the study findings were extracted.

THE CONSTRUCTION PROJECT STUDIED

The construction project studied is located in the city of São Paulo, in the area of Itaim Bibi, near the crossing of two busy avenues inserted in an area with movement restriction for trucks during business hours. The region is named “Quadrilateral Zone of Maximum Circulation Restriction” defined by the Traffic Engineering Company of the city of São Paulo (SILVA, 2011), banning the traffic of trucks from Monday to Friday, from 10:00 to 20:00 and on Saturdays from 10:00 to 14:00. Figure 1 shows the location of the construction site highlighted in blue.

Therefore, most of the materials delivered to the construction site were done on Saturdays, or, in some cases it could be done on weekdays at night, as long as a crane was not needed to unload the trucks because the silence should be maintained in the neighborhood.

The contractor responsible for the execution of the project is large-sized and works with all direct labour outsourced. It is the construction of a commercial building with 17 type floors and 5 basements. The ceiling height of the structure is 4.14 m. Figure 2 shows a sketch plan of frames on the type floor of the building, which contains some of the main dimensions of the project. The building structure is made of solid slabs and pre-stressed beams, to beat the minimum span of 25 m. Because it is a complex project, the steel rate is quite high, around 193 kg/m³; this was a fact which motivated the researchers to study the assembly service.

The construction site does not have many areas available to stock materials as you can see in Figure 3, which shows the layout of the construction site.

Figure 1: Location of the construction site

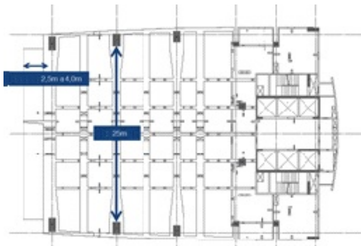

Figure 2: Sketch of the type floor

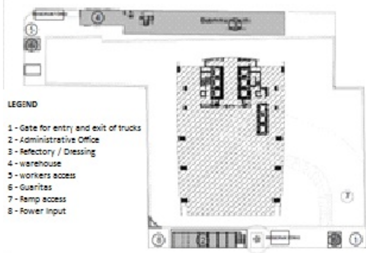

Figure 3: Layout of the construction site

As the region has a high movement of vehicles, delivery trucks must enter the construction site to reduce the risk of accidents involving pedestrians and disorders in the area. The receipt of the steel is checked, documented, being removed from the truck by crane and placed in the stock provided for in a construction site. The steel stock is located near the crane and to the ground floor area where the beams are assembled to be hoisted almost ready for the floor. Figure 4 shows the receipt at the construction site of a truck containing steel.

There were 2 suppliers of steel for the work, identified as Supplier I and Supplier II. Supplier I provided the steel bars required for pillars, beams and slabs, and also frame in specified amounts according to the project. The Supplier II provided the strands for use in pre-stressed beams.

Figure 5 shows the stock of the steel at the construction work located on the ground floor of the building. The Figure 6 shows the strands on the floor waiting to be used while the framed beams on the ground floor were being positioned in their molds. Notice that the strands were in rolls, each roll representing the strands of a determined beam, labeled to enable the identification and corresponding handling.

Figure 4: Unloading of a truck with steel

Figure 5: The steel stock at the construction site

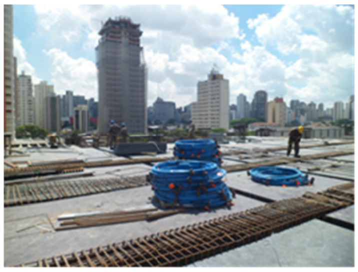

Figure 6: Strands on the floor under construction

MACRO STUDY - IMPLEMENTATION OF THE FRAME STRUCTURE OF TYPE PAVEMENT

For the entire pavement structure, the steel was supplied cut and folded, but the assembly of the frames was done at the construction site itself. The strands, however, were delivered in rolls, cut according to the size defined in the design, made to fit the pre-stress, and identified according to the names of the beams.

The procedures for the services of steel assembly were as follows: the frames of the beams were pre-assembled on the ground floor of the building in construction, and then hoisted by crane to the place where they should be inserted in the mold, and the strands of beams were positioned afterwards. Finally, the frame of the slab, which was also assembled in parts at the ground floor, was placed on the floor, so the slab would be ready to be concreted after the validation by the person in charge of checking the frame.

MICRO STUDY – ASSEMBLY OF PILLARS

The frame of the pillars had several peculiarities due to the characteristics of the building, such as the large spans. There were 19 pillars per slab and the bars used were 32 mm in diameter. A major difficulty for the assembly was the inability to do the trespassing for the connections, once according to the Brazilian Standard (NBR 6118 - Design of Concrete Structures - Procedure), the trespassing is only allowed in bars with diameters of less than 32 mm. Thus, the solution adopted in the project was the use of pressure gloves to connect the frame of the pillars. However, due to the small spacing between the bars, the press equipment could not make the connection of all the bars. In Figure 7 one can notice the complexity in the assembly of these pillars, since there were 72 steel bars with 32 mm diameter in a column with dimensions of 85 x 150 cm.

In order to solve the problem, the engineer in charge of the structure project proposed the use of welding on the bars of the pillars which could not be pressed. Figures 8 and 9 show the two different ways of connecting the pillar bars. At the case study, it was noticed that for each one of these tasks the number of workers needed and the operation difficulty were different.

Figure 7: Image of the steel of pillars and the stock of bars on the floor

Figure 8: Pressing of the pillar steel

Figure 9: Welding to union the bar of pillars

VALUE STREAM MAPPING (VSM) OF THE STUDY CASE

With this information identified, the VSM of the current state was drawn. The first VSM, Figure 10, shows the macro case: the receipt of all steel, and the second VSM, Figure 11, shows the micro case: frame of the pillars.

Some analyses were made from the data collected and the VSM. In the macro case, it was observed that the production needs depended on the pre-established schedule. The two suppliers of the work had signed a contract for the supply of all steel work. However, the conditions of each contract are different. Supplier I required that the orders for deliveries were made at least 10 working days before the scheduled date for delivery at the construction site, considering the constraints of logistics already described. Thus, the steel stock at the construction work was big, enough for about two weeks of work. The initial period of study of a pavement was 12 days, and the deadline for installation of pillars corresponded to 8 days.

The contract with the Supplier II was also done to provide for all the work, although they were committed to ensure the price for only four months. The time limit for delivery was 5 days, requiring a stock at the building site enough for a week of work. Another curiosity of this contract was the fact that the strands were cut by another supplier, hired by the Supplier II. So, the schedule for delivery was directly made with the supplier hired to cut the strands.

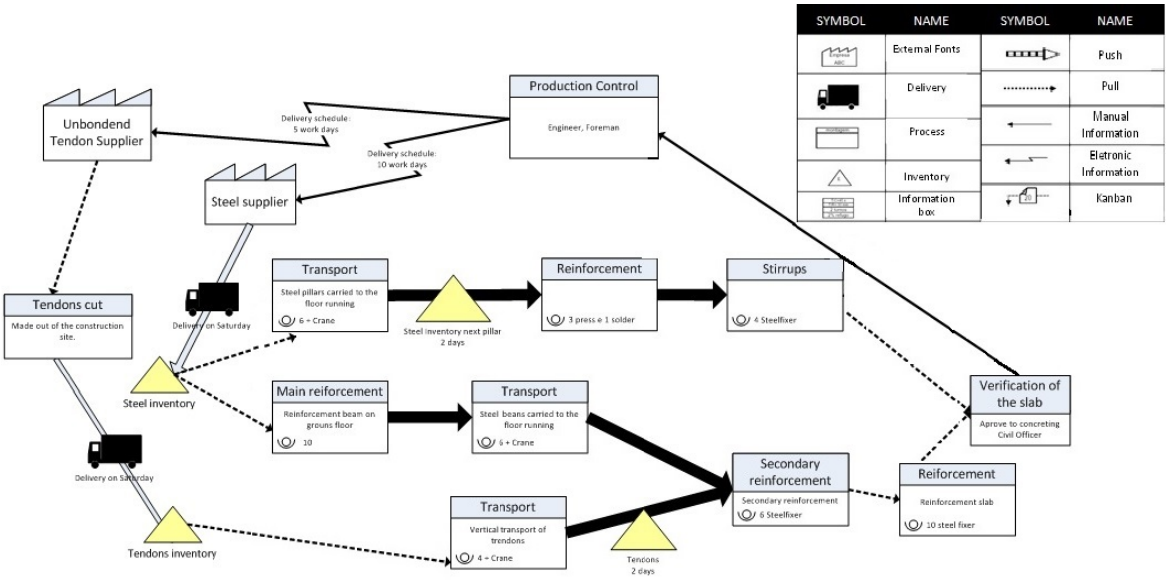

Figure 10: Current Value Stream Mapping of the macro case.

Other details needed to be observed concerning the VSM of the specific task of assembly of pillars (Fig. 11). The cycle began at the steel stock of the construction. The period in stock varied according to the duration of the cycle of the floor. After the release of the beginning of the task, the concrete slab of the lower floor acted as pacemaker process, thus the bars of the pillars were hoisted to the new floor. On this floor during construction, the bars were positioned near the pillars in which they would be used.

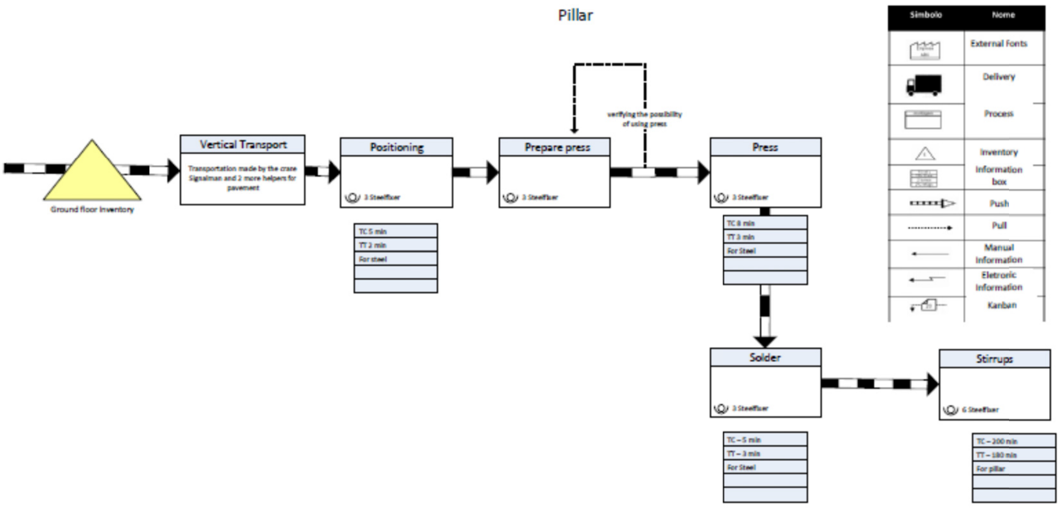

Figure 11: Current Value Stream Mapping of the micro case.

In service of assembly of pillars, firstly, the connections were carried out by the press, and in the lack of space between bars, the welding process of the bars in the sequence took place. It was noticed that there was not a defined criterion for the use of welding or press. The preference was for the press, and only when there was not enough space for the machine the welds were used, because the gloves ensured better quality in trespassing, besides the greater speed of execution. This process was repeated for all the bars in all the pillars. After the pillar was with all its bars placed and fixed, it could start putting the stirrups and spacers. After this diagnosis, then the suggestions for the future VSM are presented.

DISCUSSIONS AND VSM OF FUTURE STATE

One of the ideas of the lean construction and SCM, which is the reduction of stocks based on the reliability of the supplier, can be applied partially because of the restriction to the arrival of trucks at the construction site. It was necessary to gather big stocks of steel which only arrived on Saturdays and were used during the week. The steel stock to be used all over the week was determined according to the planning and considering the principles of economic lot. Nevertheless, a contract was established to ensure the partnership and the reliability at the periodical deliveries needed. In order to produce the VSM of future states, it was considered that the formation of stocks could not be modified because it depended on the logistics constraints.

Thus, it was established that in VSM of future study the main changes would be related to changes in services pushed to pulled services, and the focus on the generation of process flow, as described by Rother and Shock (2004).

It was proposed that for the macro case, more services would be performed outside the place of processing, as done with the beams which were pre-assembled on the ground. The use of Kanban to pull the production and better manage the stocks was adopted. It proposed a specific Kanban for mounting each pillar, to be sent by the production sector to the industry vertical transport of steel bars for floor mounting.. In organization of tendons inventory was utilized a strategy of distribution FIFO (First In, First Out), streamlining the transport work in process. Figure 12 shows the VSM proposed for future states of the macro case.

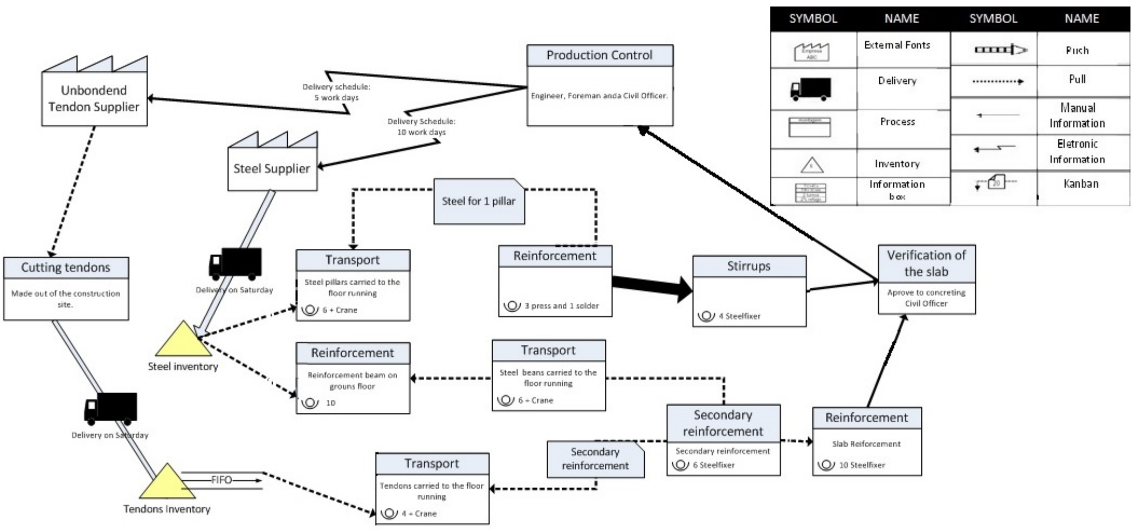

Figure 12: Value Stream Mapping of Future state for the macro case.

As for the micro case, the use of Kanban for the operation of the presses was defined. Also, a new organization of work was established, in which different workers were put in charge of the bar transport and the positioning of the press, since these activities were currently being done by the same three employees. A specific Kanban was proposed to mount each pillar, which would be sent by the production sector to the vertical transport of steel bars for floor mounting. Thus, the flow would be more efficient. The Figure 13 shows the VSM proposed for future states for micro case.

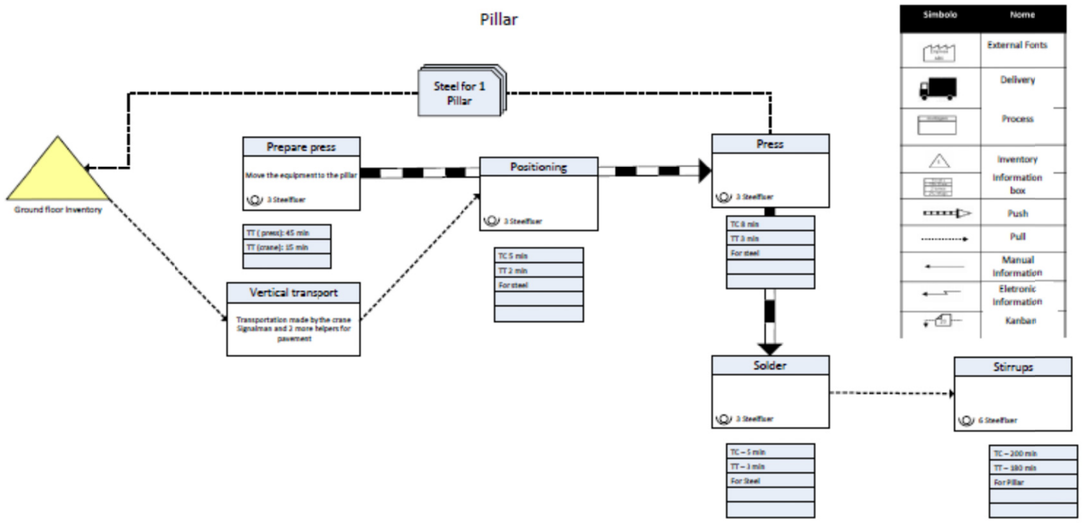

Figure 13: Value Stream Mapping of Future State for the micro case.

By doing so, it was possible to reduce the cycle time of activities on the floor in three days. The period of implementation of a pavement decreased to 9 days, and the deadline for installation of pillars decreased to 6 days. Table 2 shows a comparison between cycles of structure before and after applying the Lean Supply and SCM concepts. One result of this analysis was the identification of operational activities at the site and how logistics coordination might contribute for compressing time.

This study enabled the definition of Takt times, which in this case would be the time for preparing and performing the pressing of the pillar frames. It was possible to apply the continuous flow throughout the entire process, both for the macro case and the micro, defining the predecessor services and their respective people in charge.

Therefore, the size of lots in the VSM of micro case can be defined as being the making of one pillar. The Kanban process was used to regularize the transport of materials. The release of the work orders was also done by pillar.

In order to complete the analysis, we classified the organization and management of the work in accordance with the focus presented by Vrijhoef and Koskela (2000). It was observed that the strategies used in this case study focused on reducing costs, especially those relating to logistics, lead-time and inventory.

A solution adopted was the establishment of a logistics center, as presented by Arbulu and Ballard (2004). The existing work in the sector, which was responsible for controlling measurement services as well as hiring and controlling the warehouse of the work, became part of the proposed logistic center. Thus, we obtained a logistics control that prevented the mismatch of information for the purchase of inputs for assembly of the structure and other services in the construction site.

Table 2 – Comparison between the two cycles of structure

Day	FORMER CYCLE		NEW CYCLE	
	Floor in construction	Other place	Floor in construction	Other place
1	Labelling of axis and transport of pillar bars	Transport of materials	Labelling of axis and transport of pillar bars	Transport of materials
2	Assembly of pillars	Separation of the slobs frames	Transport and framing of pillars and assembly of shoring	Separation and beginning of assembly of the frames of beams
3	Assembly and closing of frames of pillars, and assembly of shoring	Assembly of beams on ground floor	Assembly and closing of frames of pillars, and assembly of shoring	Assembly of beams on ground floor
4	Assembly and closing of frames of pillars, and assembly of shoring	Assembly of beams on ground floor	Assembly of shoring and assembly of the frames of slabs	
5	Assembly and closing of frames of pillars, and assembly of shoring		Assembly of slab frames and concrete pouring on pillars	Pre-stessing of the lower beams
6	Assembly of shoring and assembly of the frames of beams and slabs	Pre-stessing of the lower beams	Concrete pouring on the pillars and transport of beams	Transpor t of framed beams and assembly of beams and slabs
7	Assembly of shoring and assembly of beams and slab frames	Assembly of slabs on the ground floor	Assembly of pre-stressed beams and transport of beam frames	Assembly of slabs on the ground floor
8	Concrete pouring on pillars	Assembly of slabs on the ground floor	Transport and assembly of slabs	Transport of materials
9	Transport of framed beams and transport of strands	Aid for transport of materials	Concrete pouring on beams and slabs	
10	Assembly of pre-stressed beams and assembly of slabs			
11	Assembly of pre-stressed beams and assembly of slabs			
12	Concrete pouring on beams and slabs			

The logistics of steel transport could not be altered since there was a statutory restriction for heavy vehicles in the city. The vendors are aware of these conditions and sometimes when there are no workers in the construction site, the unloading is done by the supplier. As for other works or for other services, whenever possible, delivery is reduced to smaller batches that can be carried by smaller trucks and are free from restraint.

CONCLUSIONS

The case study of this work was performed in a large company which has strategic sectors of control of suppliers and work. Nevertheless, this study presented some problems for the application of a central management for the entire supply chain of a given material, still dependent on the forms of contracts and procedures in the company. It is important to have a sector in charge of the acquisition process, as well as one responsible for monitoring and analysing the conditions of delivery, especially of inputs considered critical.

The study analysis was done on a specific service. Yet there are problems to generate a continuous flow and control all flows and activities that are interrelated with the service studied, such as concrete pouring. Another problem found was regarding logistics of deliveries, which prevent some actions to achieve the concept of Lean Supply optimally. There was the need of stocks of one or two weeks, which was the time of delivery of the materials studied. There was a reduction of the production cycle with the better organization of the process and definition of responsibility.

Thus, the exploratory study evidenced that the philosophy of Lean Supply and VSM tool can be useful for the construction industry. The use of the principles may present important opportunities for specific enhancements and influence the analysis of local logistics and supply chain management as a whole. For global application, this philosophy should be better studied and industry Lean mentality should mature a little more and reach the suppliers of materials and services.

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