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ANALYSING THE VALUE ADDING ACTIVITIES IN THE BRAZILIAN CONSTRUCTION COMPANIES

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ABSTRACT

This paper presents an update of a study carried out by Etges (2018) in which an approach to answer the question about the level of value adding activities in Brazilian companies is presented. Taking into consideration the concepts of Lean Construction, adding value and wastes, and Value Stream Mapping (VSM) allied to the perspective of Operational Excellence, the study was conducted in 26 different companies divided into 7 categories of construction works, namely: airports, buildings, renewable energies, highways, Intracity, pipelines and railways.

The analysis of the methodology consisted of characterizing the concepts of wastes and of the Value Stream of processes, and this was added to field analyses using the Work Sampling Method (WSM), which consists of measuring and identifying the level of wastage and adding value to the operation at the place of execution. The results show a low level of activities that add value in the sectors analyzed, representing, in the general analysis, 28% of the total time in manhours available. The results are also categorized by the predominant wastes in each category of construction works, and, in the general analysis, 48% of the wastes are related to Waiting.

This analysis makes it possible to identify great opportunities for reducing waste and it is extremely important for the construction industry to promote critical actions aimed at leaner construction management.

KEY-WORDS

Lean Construction, Value-adding activities, Value Stream Mapping, Work Sampling Method.

INTRODUCTION

One of the main problems of the construction industry is the lack of improvement in its productivity over time (Abdel-Wahab and Vogl, 2011; Fulford and Standing, 2014). The study carried out by Barbosa et al (2017) identified that in the last two decades, the growth rate in productivity in the construction industry was only 1%, a figure well below the average of the world economy, which is 2.8%, and almost 4 times smaller when compared to industries such as manufacturing. The reflection of low productivity can also be identified in the most recent study presented by the Brazilian Chamber of the Construction Industry (CBIC, 2022), which

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pointed out that 45% of projects exceed budget and 27% are completed after the expected deadline.

In this context, one of the alternatives that companies have adopted are the principles and concepts of Lean philosophy (Fabro et al., 2020). Coming from the automotive sector, Lean strengthens the culture of continuous improvement in companies by systematically reducing losses and waste (Shinohara, 1988; Pheng et al., 2016; Salgin, 2016). Under the lens of Lean, companies in the construction sector are starting to see the everyday existence of activities that do not add value and that result in low productivity. Such activities consume resources, time or space and do not add value to the product (Neve et al., 2020).

Hence, the use of concepts and tools that help the construction industry to reduce this waste is of fundamental importance for the survival of companies in the sector and for the conservation of the vast quantity of material resources consumed by the construction industry (Cardoso et al., 2005). This search by the construction industry to improve its productivity has been identified by Etges (2018), and this paper sets out to update the work already carried out. Still according to Etges (2018), to understand the level of value adding activities on the sites under study, three main concepts need to be integrated, namely: waste identification, value stream mapping and Gemba routines. In the latter, the Work Sampling Method (WSM) will be applied to enable the volume of activities that add value and their wastes to be monitored.

This study aims to update the analysis carried out by Etges (2018) by identifying opportunities and create a reference to allow academics ans professionals in the sector to be aware of the amount of waste in the sector, allowing insights to improve productivity in the construction industry. Thus, this diagnosis aims to illustrate the state of added value in construction industry during execution of activities based on using value stream mapping and observing wastes by using Gemba. Analyses were undertaken in 26 Brazilian companies in two specific periods, between 2013 to 2016 which was carried out by Etges (2018) and the second period between 2018 to 2022 which aims to update the analyzes in the first study.

The article is divided into three phases. The first phase consists of exploring the conceptual references in the literature on adding value, wastes, value chain and value stream mapping, and on how to identify value by seeking to understand the production process. The second stage will address the methodology used to identify activities that add value to the production process and, finally, the results and discussions of the analyses will be presented.

REVIEW OF THE LITERATURE

This section will address the literary review of the three main concepts and tools used to build this paper. They are: (a) definitions of activities that add value and waste; (b) Value Stream Mapping and (c) the Work Sampling Method.

VALUE-ADDING ACTIVITIES AND WASTES

The activities within a production process can be classified as follows according to Hines and Taylor (2000): Activities that add value, these being the activities that make the product or service more valuable to the customer; Necessary activities that do not add value are activities that the customer does not consider valuable but which are necessary; and finally, Activities that do not add value, which are activities that are not valuable to the customer and are not necessary in the current circumstances (Pothen and Ramalingam, 2018). Koskela (1992) also argued that activities that do not add value have three main causes, namely: design, ignorance and the intrinsic nature of production. This definition is in line with the discussion proposed by Koskela et al, (2013) in which the seven classic wastes are in fact in a specific context and that, for the construction context, the crucial wastes must be identified and defined from the characteristics of this type of production. Koskela (2000) defined that in order to apply these concepts in civil construction, what must be understood is what the main wastes to be eliminated in construction are. Thus, the seven wastes defined by Ohno (1988) are: excess production, time on hand, transportation of products, processing itself, stock on hand, motion and the manufacture of defective products.

In this scenario, to analyze the list of construction-related wastes, three main requirements stand out, namely: the list of wastes must be conceptually compatible with the construction industry, empirically justified, i.e., the focus is on the most relevant wastes, and is persuasive and motivating for improvement actions (Koskela et al., 2013). For this reason, Value Stream Mapping is a key tool for understanding wastes in each project, considering the seven losses being considered as possible references.

It is sought to increase the share of work that adds value by eliminating wastes, thereby progressively reducing activities that do not add value (Ghinato, 1996). Thus, the complete understanding of the production process is fundamental for identifying what to eliminate, since, very often, the activities that do not add value are not easily visible. Hence, opportunities to reduce these losses and real improvements arise (Ohno, 1997).

VALUE STREAM MAPPING (VSM)

According to Womack (2004) value stream mapping is the identification of all specific activities that occur along a flow referring to a product or family of products. It is a simple but effective approach to understanding the flow of material and information as value is added to a product or service throughout its processing (Slack, 2002). Thus, to map the value stream, the production trail from the beginning to the end of the process, from the consumer to the supplier, and then a map of the current state of its material and information flows should be drawn up. Following on from this, one should draw up the map of the future state of how its value should flow, and thereby improve the current flows (Rother and Shook, 1999; Rentes et al., 2004).

By doing so, the main function of the VSM becomes to identify when and where the value starts to be triggered and where there is waste, since the team members become more objective in eliminating losses with the use of this tool (Menezes, 2003; Tapping et al., 2002). Recently, new studies, such as Covarrubias et al (2016), have been carried out focusing on the construction industry, in which VSM was used to improve administrative processes in construction. Another study demonstrated that the use of VSM and the Work Sampling Method are two important tools for the Lean philosophy, which have the objective of reducing and minimizing waste in the life cycle of a process and, consequently, of increasing productivity (Pothen and Ramalingam, 2018).

WORK SAMPLING METHOD (WSM)

One of the ways to monitor the number of activities that do not add value which are performed by laborers is to apply the Work Sampling Method. This method, initially applied in industry by the British engineer Leonardo Tippett in 1927, aimed to observe and quantify the time spent on different tasks in order to deeply understand the factors that increase or decrease their efficiency (Neve et al., 2020). Introduced in the civil construction sector around the 60s (Thomas and Guevara, 1984), the tool has enabled the effectiveness of using manual labor to be measured, thereby indicating the portion of time allocated to non-productive activities and exposing the soundness of the planning of the work fronts.

The WSM consists of making a series of snapshot observations, such as photos, of work in progress over a period of time to measure workers' productivity (Jenkins and Orth, 2003). This method, therefore, enables moments of low productivity to be identified, which in turn, can generate enough information to carry out the necessary corrective actions (Thomas and Napolitan, 1999). Despite criticisms regarding the reliability of the method, Wandahl et al (2022) monitored data through nine days of continuous WSM application considering Direct Work, Indirect Work and Wastes. They concluded that the WS Method is robust, considering the three types of testing involved in the Research (Wandahl et al., 2022; SALLING et al., 2022).

A study conducted by Perez et al (2015) used the WSM to measure the amount of productive and non-productive work regarding transport waste in physical flows of construction processes, and thus demonstrated activities that are necessary, avoidable and unnecessary. Another study carried out by Pothen & Ramalingam (2018) obtained positive results when using the VSM tools and the WSM to understand the current productivity scenario in a construction project and to identify and reduce the non-productive time spent by workers, thereby increasing the productivity of the process. Recently, digitization has been used as a way to capture samples of workers' behavior and the respective value adding activities. Perez et al. (2022) added the geographic location for each WSM observation in order to be able to better understand the workers' behavior when carrying out their activities, thus analyzing, jointly, the workplace.

METHODOLOGY

With the objective of supporting the understanding of the productivity scenario in civil construction in Brazil, this research carried out by a consulting company applied the WSM in two different periods, from 2013 to 2016 and from 2018 to February 2022. Data were collected in 26 different companies divided into 7 categories of construction works, namely: airports, buildings, renewable energies, highways, Intracity, pipelines and railways. The activities in each category was selected based in two criteria, (a) the activities that was in execution during the construction on VSM current state; and (b) activities that was identify as bottlenecks during the construction routines.

The WSM was used to measure the number of activities that add value and activities that do not add value (Perez et al., 2015). The traditional definition for adding value to activities set by Koskela (1992) states that activities that add value are activities that transform materials or information into what is requested by the customer; Activities that do not add value, also called waste(s), can be considered as activities that consume time, resources or space, but do not add value.

Applying the WSM in the present research consisted of direct observations and data collection construction sites. The laborers acting in a certain activity were the object of analysis. At each fraction of time, (approximately 5 min), a sample of the work was analyzed and the activities that the laborers performed were classified into macro categories in accordance with Hines and Taylor (2000) which is represented in Table 1.

Table 1: Macro classification of the activities

Category	Description	Value Category
Value-adding activities	Activities which transform material or information into what the client is looking for	Adds value
Activities with hidden wastes	Activities which do not add value, but are necessary to support activities that add value (e.g., motion, transport)	Auxiliary
Activities with evident wastes	When the activity does not add value (e.g., waiting, rework, etc.)	Does not add value

The macro classification of activities facilitates the visualization of process inefficiencies, thus enabling an understanding of the potential for reducing waste in the system. In order to better understand waste, during each analysis, the activities performed by the laborers were classified into 11 subcategories that enabled the work to be understood. This classification was based on the definitions of Ohno (1988) and these are represented in Table 2.

Table 2: Classification of wastes

Category	Description	Value category
Area	When the excessive use of area occurs	Does not add value
Delays	When a time challenge occurs in carrying out the activity	Does not add value
Loading and Unloading	When the need to load and unload materials occurs	Auxiliary
Defects/ Rework	When production errors occur resulting in the need for repairs	Does not add value
Waiting	When the work front is paralyzed and the worker is kept waiting	Does not add value
Inventory	When the presence of materials and products in excess occurs in the production chain or in the storage areas	Does not add value
Excess production	When processing occurs beyond that requested by the client	Does not add value
Motion	When the employee needs to undertake more movements and displacements to carry out the activity	Does not add value
Preparation	When preparing to conduct the activity occurs	Auxiliary
Quality	When the conduct of the activities is checked	Auxiliary
Transport	When the materials or products are moved	Auxiliary

RESULTS

The data presented in this study correspond to the collection of 4374 samples, totaling more than 218 hours of observation. The analyses were collected by consultants and the general public, trained by specialists. The collection time in each macro category of work is detailed in Figure 1.

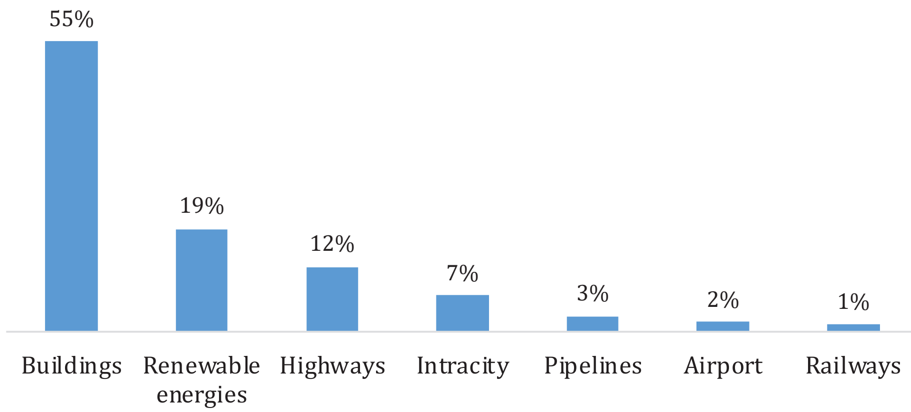

Figure 1: Collection time by category of construction work

From the data collected and analyses carried out under the WSM, a significant level of 72% of the efforts of manual labor dedicated to activities with some type of waste was identified. That is, of the 218 hours of work analyzed, transformation processes that add value to the customer were occurring in only 28% of this time. The results presented below show the relationship between the activities that add value and the wastes observed in civil construction, related to auxiliary activities (hidden waste) and activities that do not add value (evident waste) to the product. Figure 2 presents the absolute data referring to the addition of value in the activities carried out by the laborers.

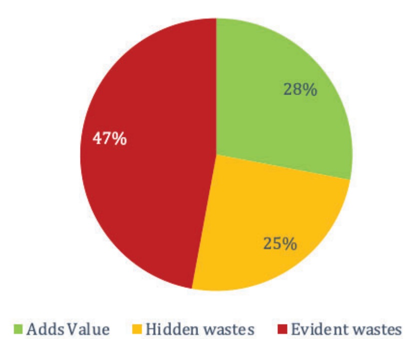

Figure 2: Analysis of added value

On stratifying the results obtained in the main civil construction segments, we can observe that the best results in terms of value adding activities are linked to works with high repetitiveness, as is the case of railways (37%) and buildings (34%) (Figure 3). In the case of buildings, this category of work was the one with the lowest percentage of activities that did not add value (30%). Even considering that building construction have high variety of typologies, one may say that the repetitiveness and flow of activities is objective for a more productivity performance, which is associated with a more consolidated construction system, in which the composition of teams and the division of tasks are mostly standardized.

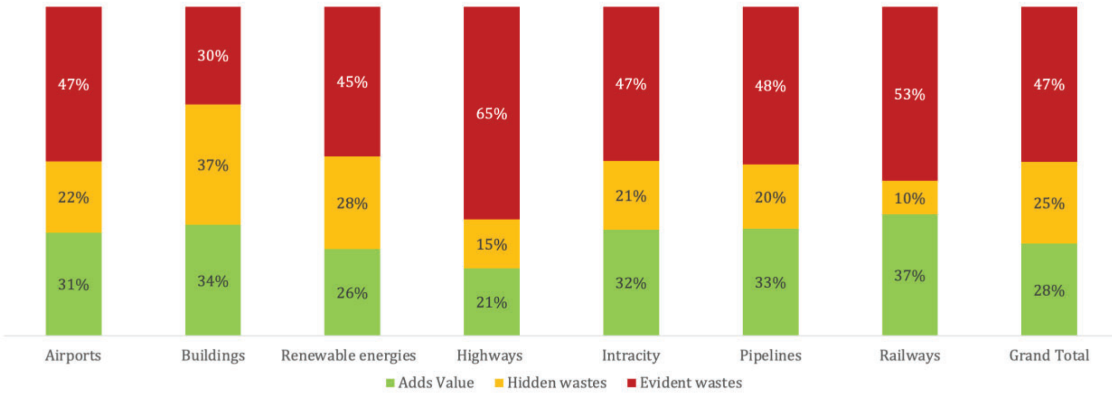

Figure 3: Analysis of value adding activities by type of construction works

On the other hand, the segments of Renewable Energies and Highways presented a lower value adding activities (26% and 21%). The two segments have the following characteristics in common: (a) long longitudinal distances that demand efficient planning and logistics; (b) characteristic complexity related to relief and vegetation; (c) strong dependence on heavy equipment that requires more attention to response time for maintenance.

TYPES OF WASTE

From the work sample analyzed, the types of waste that make up each activity were mapped and it was identified that three categories represents the major wastes: Waiting – 48%; Transport/Motion 19%; and Preparation – 18%, which are represented in Figure 4.

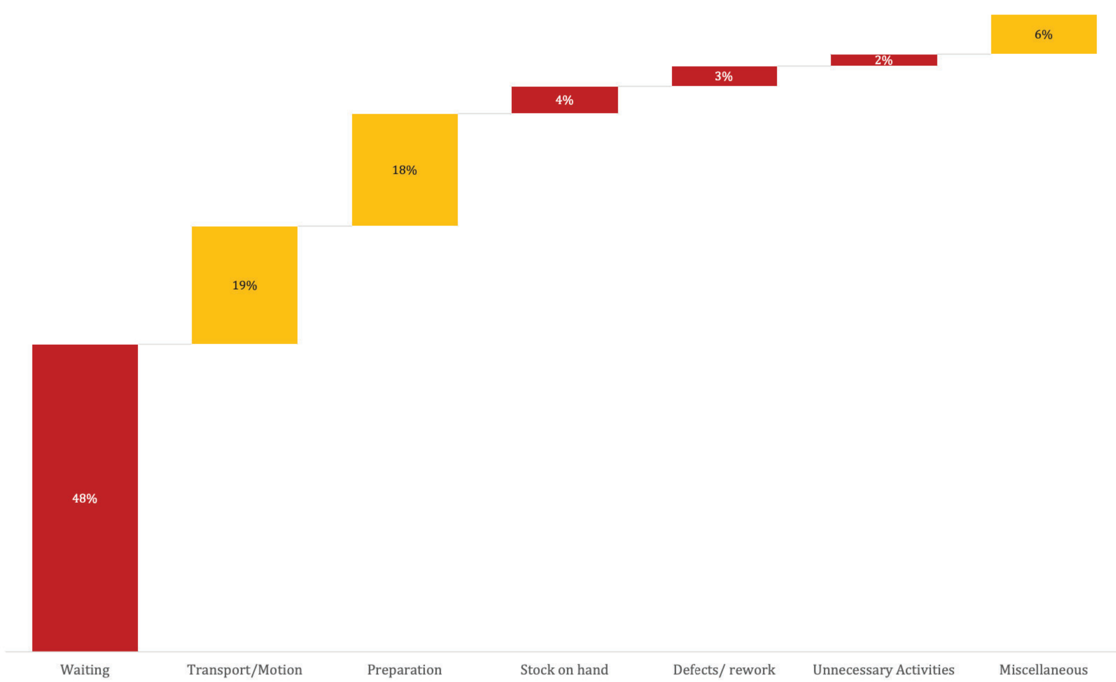

Figure 4: Percentage of wastes per category

Waiting (48%) was the mains waste identified, often perceived in civil construction due to idle workers, waiting on a availability of materials, equipment or even information. This can be reduced by adopting an assertive planning of the work stages, aiming to predict which materials and equipment will be needed in each work stage and ensure that they are available at the right time. In addition, constant monitoring of the production process is essential to identify problems and bottlenecks in production and to be able to act quickly and agilely in solving problems. The use of lean routines and tools, such as the Last Planner System, significantly reduced this waste and led to more efficient work management.

Transport and handling waste (18%) can be reduced with efficient logistical planning in civil construction. For this, collaboration between work sectors, especially between planning and logistics teams, is essential to ensure efficiency. The definition of routes and routines must also be guaranteed in order to minimize excessive movement and transport at peak times and minimize the distances traveled by employees and materials. In addition, the adoption of tracking systems can help control and monitor equipment and work materials, allowing managers to identify bottlenecks and opportunities for improvement.

Another important set of data shown in Figure 4 is the number of defects/reworks in the sector, which corresponds to 3% of the waste analyzed. Despite the low number, given the reality of the sector, it is important to make it clear that the analyses were mostly carried out under the main execution of the services, i.e., the traditional reworks or repairs that are normally carried out in a more advanced phase of the projects were not contemplated in the analysis.

Performing a focal analysis on the three types of construction work with the highest volume of samples collected (Buildings, Renewable Energy and Road), what can be identified is that the three main wastes are the same. They only differ in proportion (Figure 5):

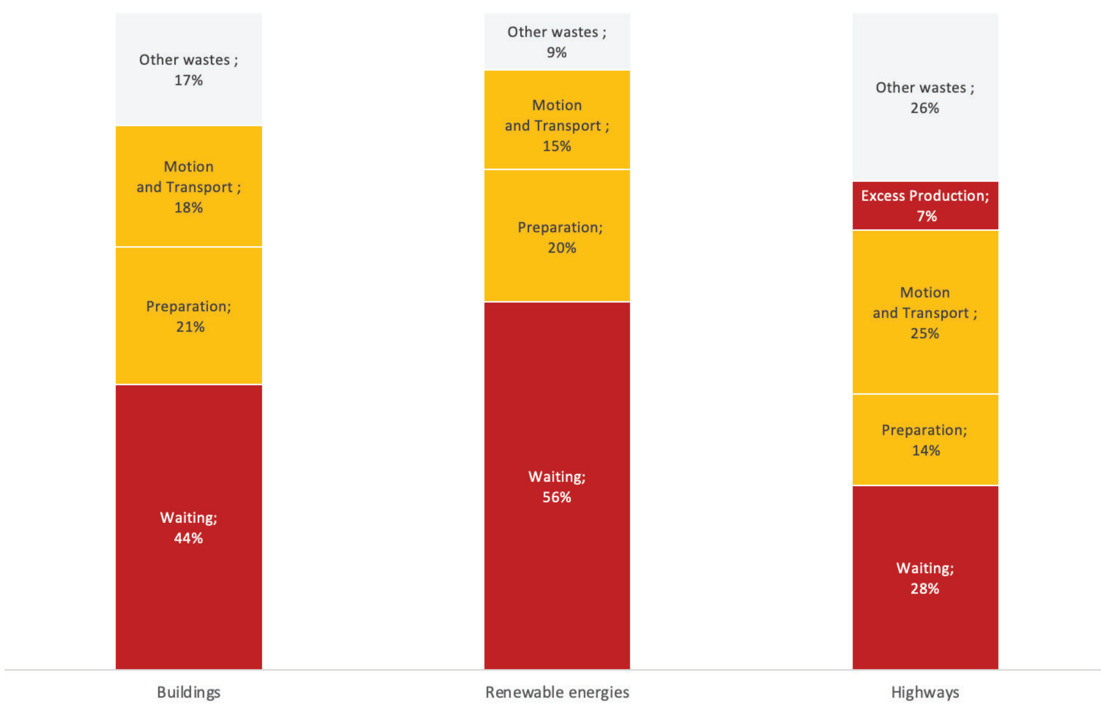

Figure 5: Percentage of wastes by category

Analyzing the proportion of waste presented in each sector, it is possible to infer that:

- The building sector has characteristics that allow greater efficiency (reduced size of construction sites, standardization of the product such as houses or building floors, greater specialization of manual labor) in relation to other types of works. However, it presented a high percentage of waiting (44%) and of motion and transport (18%) in the observations due to factors such as sharing logistics equipment (elevator rack, manipulator), poor sizing of auxiliary teams (laborers) or even errors in the distribution of activities between teams.

- In the Renewable Energies sector, we highlight as reasons for 56% waiting, the high frequency of moments of teams being idle at workstations waiting for formal clearance to start activities, such as: work safety clearance, clearance to work in a given environment, clearances from the previous work front.
- In the highways sector, we draw attention to the waste of excess production (7%), which was sometimes noticed due to the fragility of the control of executing the service. For this reason, the work carried out on the road section is greater than what would be necessary - for example in a base or sub-base compaction, or in precast production centers used in the construction of highways, which can lead to wasted resources and increased costs. In short, due to the difficulties of following up on execution, excess becomes the default. In addition, Transport and Motion (25%) also have great opportunities for reduction, commonly caused by lack of material delivery schedule, excessive stock of materials, difficulties in accessing roads with remote areas and excessive movement of materials due to lack of organization on construction site. To reduce this waste, the adoption of collaboration and visual management tools through the Last Planner System practices is an efficient alternative to reduce these problems, in addition, the use of technologies such as drones and monitoring systems, it can help to optimize the production process, allowing a more efficient management of resources and a reduction significant waste.

DISCUSSION AND CONCLUSIONS

By determining the current status of companies in the construction industry regarding adding value to their processes, it can be stated that the study achieved its objective. The study also enabled the construction companies, by using tools, to perceive the possibilities and needs for improvements applicable to their respective processes. The samples analyzed demonstrate that the Work Sampling Method was an efficient tool for identifying value-adding activities in construction projects.

The results analyzed in this study showed that 72% of the construction activities observed do not add value to the process, a slightly better number compared to Etges (2018) who presented 74% of time spent on wasteful activities. Recognizing these data is of paramount importance for the construction industry to promote critical actions aimed at improving performance, reducing waste and costs, and mainly, achieving leaner construction management. Experiences similar to those of Thomas et al. (1991) were perceived. They suggested that the results can stimulate discussions between managers and, in this way, serve as support to stimulate the search for improvement. Analyses are fundamental to demonstrate to managers the time spent on activities that do not add value.

The building sector has shown great opportunities for reducing waiting and movement and transport waste. In view of this, implementing practices that optimize performance related to layout improvement, in terms of reducing waste, improving the movement of material, storage organization and the use of technology, such as BIM-4D for planning layouts and work phases, can facilitate and reduce losses in the operation, which are fundamental for companies to obtain a competitive advantage in the current scenario.

The logistical issue is also essential to reduce waiting and wastes in movement and transportation in works that have long distances to be covered, such as road works, wind farm works, transmission lines works and photovoltaic plants. In these cases, the supply of materials is one of the issues that can be taken into account in terms of travel time. In road works, intermediate points for stocking equipment and materials can be considered. In addition, using technologies such as digital systems to control their equipment can help companies to carry out a more robust data analysis in order to eliminate this waste.

Due to the large number of companies that were analyzed, one of the limitations of the work is the availability of access to customer data, therefore, as suggestions for future work, it is interesting to analyze it by type of activities. Besides, it would be interesting to apply improvements in a process and to compare value adding activities after implementation. Case studies applying technological solutions aimed at reducing waste in an infrastructure company can help make it more competitive, which can contribute to the answer of the question: how many infrastructure companies use a real sampling of their equipment?

Furthermore, it would be interesting to expand the data sample and increase the number of projects analyzed. Different regions, branches of construction, with different types of technology can be relevant for the comparison between sectors and projects aiming at the continuous improvement of the industry. The main gain from the study was the perception that the Brazilian construction industry is susceptible to changes and that this is fundamental for building a more competitive and efficient sector.

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