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EVALUATION OF 4D BIM USE TO REDUCE TRANSPORTATION WASTE IN CONSTRUCTION PRODUCTION PROCESSES

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ABSTRACT

The use of 4D Building Information Models (BIM) for planning construction site logistics has increased in recent years. However, most 4D BIM studies have focused on transformation tasks, neglecting flow activities. Hence, the objective of this paper is to evaluate the use of 4D models for flow simulation at operational level, aiming to reduce transportation waste. A field study was conducted on a residential housing project in Brazil. The study included three stages: data collection; 4D BIM simulation; and outcome analysis. Data collection during the site visits aimed to map the physical flows involved in the construction processes studied. Transportation waste were identified, constructive details were collected and time studies were conducted. This information was used for the 4D model development. During the outcome analysis the 4D BIM was presented and discussed in a seminar to the managers and in a workshop to the workers. After that, the model was implemented in the field and the contributions of the 4D BIM for transportation waste reduction were identified. The results highlighted the need to plan transportation activities in constructions site. The use of the simulation developed contributes to the reduction of transportation waste consequences, such as: unsafe working conditions, new transportation activities, and longer distances.

Keywords: *4D BIM, transportation waste, flow simulation, construction site, non-adding value activities.*

1 INTRODUCTION

The construction industry is behind other industries when it comes to waste reduction and improvement of productivity, specifically in construction site logistics. Construction site logistics include the planning, execution, steering, documentation and the monitoring of all projects related to the flow of materials, people, space and information (LANGE; SCHILLING, 2015).

Considerable research has been conducted to address construction site layout planning and construction material logistics planning. Most of this research has focused on the planning of transportation routes and activities at a tactical and strategic level, neglecting operational activities (BATAGLIN *et al.*, 2017). Operational inefficiencies in construction logistics can be seen as time waste in transportation activities. Examples of operational inefficiencies include incorrect deliveries, large travel distances between material storage and installation areas, and double handling of materials (SAID; EL-RAYES, 2014).

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Pérez and Costa (2018) argue that although transport is a non-value adding activity, transport activities are necessary and they need to be planned just as other adding value activities are planned. They proposed a taxonomy of transportation waste in construction production processes based on the understanding of transportation waste causes and consequences that can be applied to reduce operational inefficiencies.

Some recent studies (PÉREZ; COSTA, 2018; VRIJHOEF; DIJKSTRA; KOUTAMANIS, 2018) suggest the adoption of Technology Information and advanced planning methods, such as simulation models, for transportation waste reduction due to the complexity and the number of factors involved in construction site logistics to increase productivity through the simulation of value adding and non-value adding activities. According to Jupp (2017), 4D BIM capabilities for construction site planning can be used for managing of site logistics, pedestrian and traffic flows, material delivery and storage, temporary works, welfare facilities, and site safety.

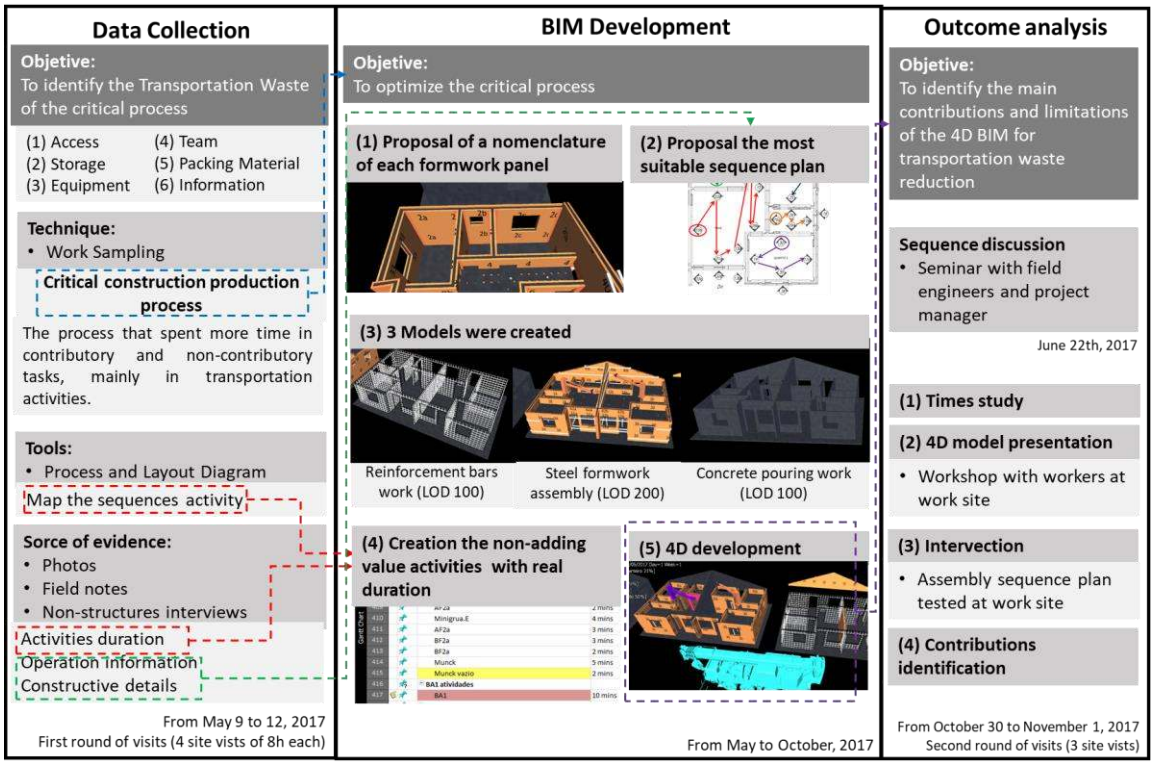
This paper contributes the body knowledge because even though the use of 4D BIM for construction logistics planning has been studied in some many studies, most os them simply translate the output of a Critical Path Method network that contains only transformation activities, which it means that flow activities are being neglected. Hence, the objective of this paper is to evaluate the use of the 4D BIM for flow simulation at operational level aiming to reduce transportation waste in construction production processes and to optimize construction site logistics.

2 RESEARCH METHOD

The case study strategy was adopted aiming to evaluate the 4D BIM simulations to improve the efficiency of the construction site logistics. This study was performed in a residential low income housing construction project located in the Northeast of Brazil. The jobsite studied occupies 92.050m², with 184 buildings of one floor totalizing 368 units. The steel panel formwork system was used to the reinforced cast-in-place concrete wall structure. That technology mainly involves four sub processes: steel reinforcement installation, electrical trade, formwork assembly and concrete placement. As a main project feature, the modular steel formworks used were made by large panel frames, which depends upon heavy lifting equipment as a hydraulic telescopic boom truck crane.

This research was developed in partnership with the construction company. At the beginning of the study logistics problems related to the truck which transported the massive formworks were identified. Thus, the planning of the flows in an operational level plays a key-role to avoid unnecessary transportation activities. The study was developed according three stages (Image 1): (a) Data collection; (b) BIM development; and (c) Outcome analysis.

Image 1 – Case Study Strategy



Source: Authors

Data collection aimed to identify the critical construction process that affects on-site logistics efficiency. In this research, the process that spent more time in contributory and non-contributory tasks, mainly in transportation activities, was understood as the critical process. For that, a first round of four site visits of 8 hours duration each were performed by the research team. During the visits, photos, field notes, non-structures interviews with field engineers were used as source of evidence. The Lean tools Process and Layout Diagram were used to map the sequences activity, allowing to represent the sequence and the place of various activities that make up the process. The work sampling technique was used to identify the productive, contributory and non-contributory work in the four sub processes studied. A total of 1820 observations were taken, with 94% confidence level and 5% relative error.

The transportation activities identified, the transportation waste and its consequences were classified according to the taxonomy of transportation waste proposed by Pérez and Costa (2018). According the authors, Transportation Waste Causes could be originated by problems related to: access/mobility; storage; equipment; team; packing material; and/ or information. In addition, the main Transportation Waste Consequences could be: damaged of material; unsafe working conditions; a new transport operation; a longer distance; and/or ergonomic problem.

The 4D BIM model aimed to optimize the critical process. The 4D model was developed with the sequence of construction activities involving three sub processes. The sub process of electrical trade was not simulated because the time spent by workers performing electrical tasks was not significant for the study goal. The first activity performed during the BIM development was the proposition of a nomenclature of each formwork panel. The second step was the study of the most suitable sequence plan. The third activity consisted of the 3D model development using Autodesk RevitTM.

Fourthly, the sequence of activities was created in MS Project TM format with the real durations, constructive details and detailed schedules. Finally, all these files were imported to NavisworksTM.

The outcome analysis aimed at identifying the main contributions and limitations of the 4D BIM for transportation waste recution. To achieve that goal the 4D model was presented and discussed in a seminar to the project manager and field enginers; and a second round of three work site visits were conducted. During the second recond of visits; the following activites were performed: (1) a new time study was conducted; (2) the 4D model was presented in a workshop to the workers; (3) a intervection which consisted in the adoption of the proposed formwork assembly sequence was tested in the field; and (4) the contributions of the 4D BIM were identified.

3 RESULTS

The findings of the work sampling revealed the steel formwork assembly as the critical process. It was the most time-consuming process with 51% of the observation made on labor force they were working in the panels assembly, and with more non-adding value activities, 67% of contributory tasks and 11% of non-contributory task. The random observation showed that 48% of the contributory task in the formwork assembly was related with transportation and handling activities.

One of the reasons for such a huge time spent on transportation activities was due to the lack of sequence planning. Although the formwork frame was planned for being installed in 8 hours cycle time, the lack of a sequence made that the cycle time lasted more than 10 hours. Hence, the lack of information related to a sequence plan of the formworks panels was the main cause of transportation waste events. Image 2 shows three examples of transportation waste events identified, its causes and its possible consequences.

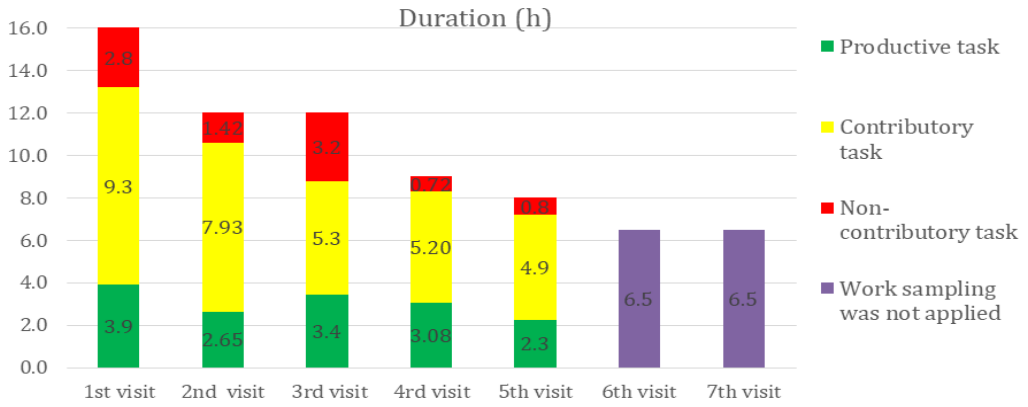
The 4D model created was very useful during the workshop (5th work site visit) with the workers performed during the second round of visits to provide visual support, to be familiar with the sequence plan and with the time spent in each movement. The same day of the workshop (6th work site visit) the sequence proposed was implemented for the first time. The new cycle time duration after the workshop was 6.5 hours (Image 3). Thus, the sequence adoption allowed reducing almost 30% of the cycle time.

Image 2 – Examples of Transportation Waste events identified

Transportation Waste cause	Information	Information	Access/Mobility
Transportation Waste event	Improvised anchors are used unappropriated for keeping stand the steel formwork panels 	Formwork transportation above the workers. Workers are not aware which formwork panel was supposed to be installed, and consequently transported 	The presence of formwork panels stocked in the main the paths 
Transportation waste consequence	- Unsafe working conditions - Material damage	- Unsafe working conditions	- A longer distance - A new transport operation - Unsafe working conditions

Source: Authors

Image 3 - Cycle time varion during the construction site visits



Source: Authors

4 DISCUSSION

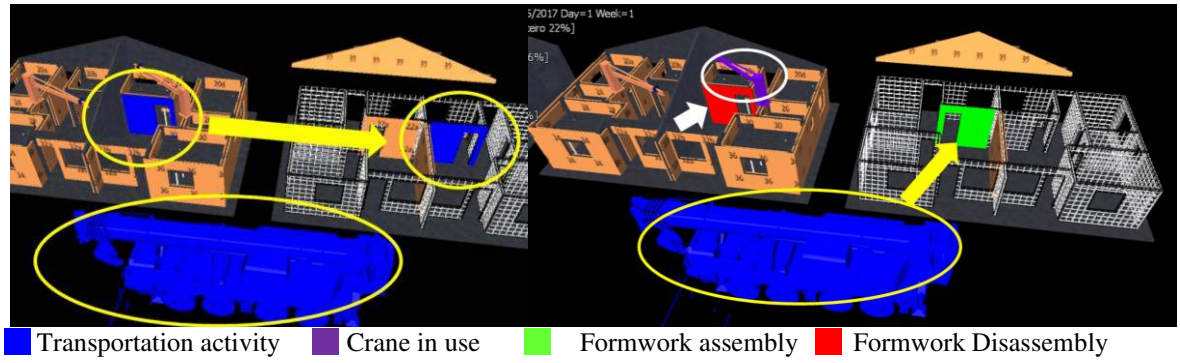
The 3D model creation was the most time-consuming effort. Although the graphical LOD was between 100 and 200, the creation of steel formworks model took a large amount of time because it was necessary to review every single picture took at the work site in order to identify constructive details. The 4D model creation was also another big time-consuming task, because the information provided by the master schedule did not represent operational tasks.

The main challenge during the creation of the sets in Naviswork was the representation of activities made by the equipment such as: the transportation of the formworks (Image

4), the movement of the equipment empty to perform a new transport, and the use of an equipment for doing an assembly task (Image 5). The solution adopted for representing non adding-value activities, as a transportation activity, that cannot be allocated in a specific place was to color the original point of departure of the element, the final point of installation and the equipment used for the transport with the same color (Image 4).

Image 4 - Transportation activity made by the telescopic handler

Image 5 - Crane being used for the formwork disassembly and Telescopic handler working in the formwork assembly



Source: Authors

The reduction of the cycle time considerably (30% of reduction) was the main practical contribution. This reduction was due to the information exchange allowed by the 4D model with the stakeholders. Second, through 4D model, it could be showed in detail the formwork sequence assembly to the managers and field engineers and thereby discuss the possible constraints or difficulties previously its application. Finally, the screenshots from 4D model were a very useful tool to show to the workers the sequence. However, the workers and engineers were not familiar with BIM tools; the understanding of the 4D model was not a challenge.

The 4D model allowed the time reduction through the reduction of transportation waste consequences. The sequence plan allowed the complete removal of improvisation activities due to provide the correct information at the correct time. It enabled that formworks were not disassembled until the exact time that they are going to be lifting and transporting, avoiding work-in-progress and unsafe working conditions. In addition, transportation waste caused by access problems were not identified because paths after the sequence implantation were always clean and clear.

5 CONCLUSION

This paper reported a 4D simulation field study conducted in a housing project in Brazil. The 4D model was developed aiming to end logistics problems reported by the construction company. The 4D model creation for planning the physical flows took in consideration temporal and spatial aspects, constructive details and durations observed at the work site, and non-adding value activities. The critical task that need to be performed in order to guarantee a high temporal information LOD is the collect of operational information.

The main practical finding in this field study is the reduction of transportation waste events caused by access/mobility and information problems. Such reduction allowed the reduction of the time wasted in avoidable and addle transportation activities and consequently the reduction of the process cycle time. The non-adding value activities simulation was reported as an important way for removing improvisation and improving the working conditions.

REFERENCES

BATAGLIN F. S.; VIANA D. D.; FORMOSO C. T.; BULHÕES I. R. Application of BIM for Supporting Decision-making Related to Logistics in Prefabricated Building Systems. In: 25th Ann. Conf. of the Int'l. Group for Lean Construction (IGLC), **Proceedings**… Heraklion, Greece, p. 71–78, 2017.

JUPP, J. 4D BIM for Environmental Planning and Management. **Procedia Engineering** v. 180, p. 190 – 201, 2017.

LANGE, S.; SCHILLING, D. Reasons for an Optimized Construction Logistics. In: 23rd Ann. Conf. of the Int'l. Group for Lean Construction (IGLC), **Proceedings**… Perth, Australia, July 29-31, p. 733-742, 2015.

SAID, H.; EL-RAYES, K. Automated multi-objective construction logistics optimization system. **Automation in Construction**, v. 43, p. 110-122, 2014.

PÉREZ, C. T.; COSTA D. B. Developing a taxonomy of transportation waste in construction production processes. **Built Environment Project and Asset Management**, v. 5, n. 8, p. 434-448, 2018.

VRIJHOEF, R.; DIJKSTRA, J.T.; KOUTAMANIS, A. Modelling and simulating time use of site workers with 4D BIM. In: 26th Ann. Conf. of the Int'l. Group for Lean Construction (IGLC), **Proceedings**… Chennai, India, p. 155–165, 2018.

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