APPLICATION OF 4D BIM FOR REDUCING TRANSPORTATION WASTE ON CONSTRUCTION SITES

BACKGROUND

Construction Site Layout Planning (CSLP) has been recognized as a critical step in construction planning. Construction logistics include the planning, execution, steering, documentation and the monitoring of all projects related to the flows regarding materials, people, space and information (Lange and Schilling, 2015). In addition, logistics planning and control should aim to eliminate or reduce material transportation operations, and to avoid congestion of flows in the construction site (Tommelein and Zouein, 1993). For that, the physical flows management can contribute to reduce transportation waste due to their operationalization (Pérez, Costa and Gonçalves, 2016).

Transportation waste event is defined as an unexpected phenomenon that happens in a transport activity, referring to an observable event with the possibility to register the fact, in a particular place and at a particular time, that affects the physical flows, causing the execution of unplanned tasks, and producing inefficiencies to the process (Pérez, Costa and Gonçalves, 2016) Those authors, based on Lean thinking, understand that even though transport is a non-value adding activity, and efforts for its reduction and elimination are possible, once transport activities are unlikely to be eliminated from the construction process.

CSLP has been well studied at a strategic and tactical level. However, there is a lack of planning that goes into managing it on an operational level (Cheng and Kumar, 2015). Therefore, some authors propose the use of 4D models to plan construction sites. However, most of studies in 4D BIM have focused in transformation tasks, which it means that flow activities are being neglected. Thus, the objective of this paper is to evaluate the use of the 4D BIM for flows simulation in an operational level aiming to reduce transportation waste. This study is part of a doctorate thesis which aims to develop a framework for reducing logistics waste on construction sites by using BIM and simulation-based approach.

RESEARCH METHOD

This paper presents an empirical study performed in a residential housing project located in Petrolina, Pernambuco, in the Northeast of Brazil. The jobsite studied occupies 92.050m², with 184 building of one floor totalizing 368 units. The main structural technology used is the Reinforced Concrete Wall Structure, involving the sub processes of steel formwork elements, reinforcement bars work, and concrete pouring work. 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 steel formworks were identified. Thus, the planning of the flows in an operational level plays a key-role to avoid unnecessary transportation activities. The case study took place from May to November 2017. Seven site visits of 8 hours each were conducted by the research team. The main activities performed were:

(1) **Data collection** during the site visits aiming to map the physical flows involved in the process studied. For that, photos, field notes, non-structures interviews with field engineers were used as source of evidence. Moreover, Layout Diagram, Process Flow Diagram and Work Sampling techniques were applied. The integrated use of the information collected from the source of evidence allowed to identify yard constrains, determinate the process lead time, and measure the amount of productive, contributory and non-contributory work, especially the time wasted in transportation activities.

(2) **4D BIM model development** aiming to represent the main physical flows of the process. For that, work schedule, site layout floor and the information collected during the site visit were used as entrance information in the software. During the site visits, problems regard to the lack of a sequence plan and the creation of unsafe conditions during the formwork installation were identified. Thus, the main objective of the 4D simulation was to optimize the execution sequence of steel formworks. To optimize the execution sequence of formworks the following activities were performed: (a) to propose a formwork nomenclature; (b) to develop in Revit Architecture the 3D model of the main processes involved; (c) to study the most suitable sequence plan; (d) to create the sequence schedule in MsProject software with the real times collected during the job visits; (e) to create a color legend to indicate the different kind of activity performed; and (f) to simulate the sequence with the 4D BIM in Navisworks.

(3) **Outcome analysis** aims at identifying the main contributions and limitations of the 4D BIM for simulate physical flows in an operational level to reduce transportation waste. To achieve that goal, the following activities were performed: (a) the 4D BIM model was presented and discussed in a seminar to the managers and in a workshop to the workers; (b) the proposed sequence was implemented in the field, being measured the new lead time and the time wasted in transportation activities after the sequence proposed implementation through work sampling technique; and (c) the contributions of the 4D BIM for transportation waste reduction were identified.

RESULTS

The 4D model of the building was created with a high level of development, modelling all the formworks that needed to be transported by the truck. During the 4D model development an important decision was to adopt color labels to identify the different kind of performing activities during the formwork installation. An example of this is presented in Figure 1, in which pink color means the mold release is being performing in that formwork, purple color means the crane is in use for holding up the formwork; and blue color means that all the elements in that color are involved in a transportation activity. The schedule developed in MsProject was useful to explore alternative formwork sequence installation in combination to the 4D model. Due to the fact of the truck be the bottleneck of this process, the sequence plan was developed aiming to reduce waiting time of that equipment. Each simultaneous activity occupied a different a workspace on the building to avoid the execution of several activities in the same place at the same time, and that decision was made to improve the safety conditions.

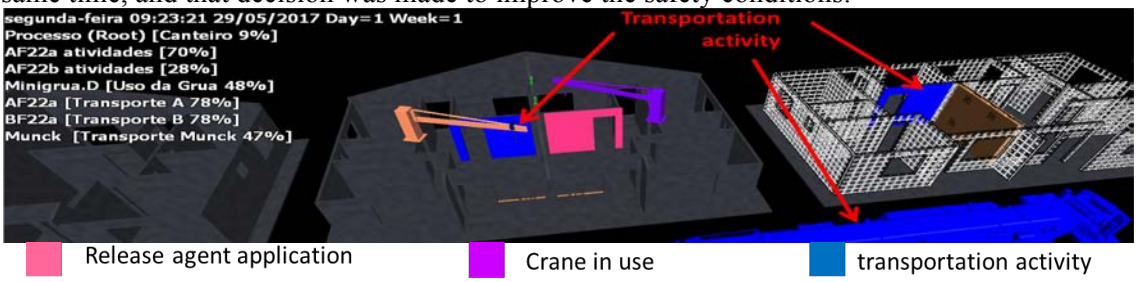

Figure 1 - Formwork simulation no Naviswork (The author)

After discussing and refining the sequence plan in a seminar with the managers and field engineer, the 4D model was presented in a workshop to the workers. After the workshop the virtual sequence was implemented. The lead time of this process was monitored and compared with the initial lead time, and it was reduced approximately 2 hours (25% of the initial lead time). These results show that simulation of the exactly formwork that is going to be moved was essentially to reduce the uncertainties and consequently to reduce unnecessary transports.

CONCLUSION AND CONTRIBUTIONS

The results of this research highlighted the need to plan transportation activities in constructions site. This paper presented the application of a 4D model for planning flows in an operation level that allowed reducing transportation waste. However, the stakeholders were not familiar with BIM tools, so the understanding of the 4D model was not a challenge. Therefore, 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. The screenshots from 4D model were a very useful tool to show to the workers the sequence in the construction site. Finally, this study provided insight of which are the main requirements to develop 4D model for logistics issues.

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