VIRTUAL DESIGN AND CONSTRUCTION LEANER THAN BEFORE

João Bosco P. Dantas Filho[1], Bruno M. Angelim[2], and José de Paula Barros Neto[3]

ABSTRACT

Virtual design and construction is turning into a more essential service to develop construction designs. Builders-developers are demanding virtual design and construction even in pre-BIM design processes. In this context, companies specialized in virtual construction need to get ready to meet its increasing demand. The aim of this study is to identify how virtual design and construction process works to suggest improvements from lean construction tools. Based on a qualitative methodology and through lean construction diagnostic tools to collect data, process structure elements are described, stream mapping are designed, cycle times are analyzed, restriction are identified, process changes are suggested. Through feedback from case study respondents, this research has concluded that there would be a meaningful improvement in global productivity and decrease in total amount of time.

KEYWORDS

Value Stream Mapping, virtual design and construction, VDC, BIM, Lean construction.

INTRODUCTION

In the markets of low level designs towards BIM maturity, leading companies develop their work through traditional design processes. Although this scenario, contractors, who have understood BIM competitive advantage, demand BIM services, even in processes of situated projects in pre-BIM stage. In this context, companies specialized in virtual construction rise and work in an intermediate stage at the end of projects and before construction. Contractors are interested in design compatibility; quantity takeoff; and production planning. Currently, the meeting of these three goals in one stream is named after the new preconstruction. The study of office-related activities, when it comes to preconstruction phase, has been overlooked (Reginato and Alves 2012).

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Section 4:Product Development and Design Management

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The trend is virtual construction becomes a more essential service in design process and virtual construction companies must make effort to meet demands. On the other hand, designers gradually and eventually need to implement radical changes to increase the level of BIM maturity in design markets.

There is a lot of waste in current virtual design and construction (VDC) practices (Mandujano et al. 2015). A few studies have been applied focusing on the VDC processes inefficiencies. Then improve the performance of processes based on BIM from the application of lean principles is a knowledge gap observed.

The goal of this research is to suggest improvements in virtual construction processes from a lean perspective. The contribution is highlight opportunities for improvement of virtual construction process and to meet demands associated with a more essential service in low level BIM-maturity markets.

BACKGROUND

VIRTUAL DESIGN AND CONSTRUCTION

In this paper, VDC is understood as a methodology, which uses models based on multidisciplinary computers in construction field, including product (the building), design organization, construction, operational team, economic processes and outcomes (quality, cost, time) to support objectives of integrating design, construction, operations and business strategies (Fischer and Kunz 2004).

VDC is considered a structured process, a set of measurable activities conceived to produce a specific outcome (Mandujano et al. 2015). VDC is contained in Building Information Modeling knowledge domain, which is more embracing. BIM is a growing research field, incorporating several knowledge domains in architecture, engineering, construction and operation industries (Succar 2009).

LEAN CONSTRUCTION TOOLS

Lean Tools can be applied in hospital flows (Henrique et al. 2015), in shoe factories (Lima et al. 2016), in construction companies (Bulhões et al. 2005; Pasqualini and Zawislak 2005), in processes of housing projects (Leite and Neto 2013), in power plant processes (Venkataraman et al. 2014), in automatized assembly lines (Azizi and Manoharan 2015), in the development of software products (Ali et al. 2015).

Lean tools have been developed and applied with success in construction industries worldwide. Such tools can generate benefits as they improve company's organization, its development and competition as well (O'Connor and Swain 2013). They can be grouped in two types: diagnostic tools and improving tools (O'Connor and Swain 2013).

METHOD

This study is classified as a functionalist epistemological paradigm. Analyze how VDC processes work, makes it possible to propose improvements, and the suggestion of benefits to stakeholders. Virtual construction process is our research topic. Research strategy is case study, since there are questions such as "how" and "why"; the focus is on contemporary

phenomena in real-life context (Yin 2001). We began with the question: "How is it possible to improve virtual construction process?".

Figure 1 shows research's first development, which presents as its first step the literature review about research topic and also about improving strategies based on lean philosophy. Literature evidences have contributed to protocol design in data collection, which was the second step in this study. The choice for case study happened through information-oriented selection (Takahashi 2013) to maximize collected information utility to reach our goals.

Next step was data collection in field by the case study application. At this moment, interviews with professionals from specialized companies were conducted. Then, collected data were analyzed qualitatively and result was elaborated according to chosen lean tools. Following step was going back to the case study company, and interviewing again its professionals in order to obtain validation and review of qualitative data and of the proposed improvements as well. Necessary corrections due to professionals' feedback were realized and, then, last step could be applied: the case study final report.
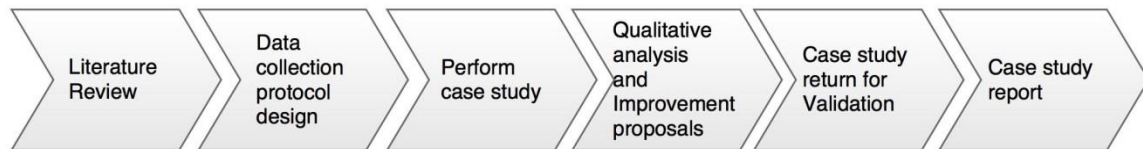

Figure 1 – The research development

Some lean construction promoted tools were used, focusing on process diagnosis. They are SIPOC Map, Swim Lane and Value Stream Mapping (VSM).

SIPOC presents process elements structuring, synthesizing description and facilitating understanding. SIPOC is a process of more detailed characterization to help design a "customer-centered" process (O'Connor and Swain 2013).

Swim Lane Diagram allows us to see stream and changes between participants.

VSM is about surveying all actions to come up with a raw matter product to customer, since its conception until its release (Rother and Shook 2003). Besides, VSM focuses on flow and time variable analysis.

RESULTS

CASE STUDY'S VIRTUAL CONSTRUCTION

This research is situated in a context which design companies have a low BIM maturity level. In this context, the practice of virtual construction specialized service occur after designs' conclusion developed by traditional process. For contractor, which is a constructor and an incorporator, the requisites are design compatibility and emission of BIM-based quantities.

The company in case study has already worked with 9 different hirers and incorporators. It has virtually built the total of 13 multifamily houses, as shown in table 1. These constructions represent 60% of the 440.000m² total set virtually built.

Table 1: Set of multifamily housing virtual construction

Work	1	2	3	4	5	6	7	8	9	10	11	12	13
Area (m²)	11.780,00	12.643,00	15.144,62	16.539,00	17.316,00	17.597,10	17.791,46	19.483,72	20.601,00	21.212,00	26.967,00	28.147,00	33.427,30

SIPOC MAP

With the aim to describe virtual construction process of this case study, table 2 reports following elements: Supplier, Input, Process, Output, Customer. Research's focus lies on process element.

In planning process, an engineer receives all design documents and checks them in order to conclude if designs are complete. Frequent identified examples are the absence of an element structural design as security cabin and crowning of building. This stage produces templates of virtual construction files. With specified constructive elements, these templates are defined by premises from design analysis. The idea is molding of building elements following denomination, specification and standards of design and its analytical structure.

In modeling process, construction technicians virtually build design models in Autodesk Revit software. Structure and facility models are built from the company's digital collection templates, while architecture models are built from template created by planning process specifically designed for work.

BIM analysis receives 3D models from courses and creates the coordination model. In this process occurs a software change for the Navisworks Manage. A civil engineer navigates through the model to be aware of questions that could be only visualized physically in construction site. Information requirements are added to coordination model and this 3D model containing an info requirement note panel is the report. Contractor and designer can access the model and its information through the software Navisworks Freedom, which is a free 3D viewer to Navisworks' NWD file format.

The 5D emission process generates numbers extracted from 3D models through the Vico Takeoff Manager software. But it can be only developed after the effort of designers equalizing their designs and after virtual construction team update their models. This stage contributes so the budget activity time is not invested in quantitative survey task, but the budget engineering happens with a reliable basis in the quantities.

Table 2: Case Study's SIPOC Map

Supplier	Input	Process	Output	Customer
Designers and builders-developers	Designs, construction method, quantitative assumptions	**Planning**	Checking of design documents and creating the architecture template	Modelers
Planner	Template and projects: structure, architecture, sanitary plumbing, fire fighting, water plumbing, electrical and communication	**Modeling**	BIM Model: structure, architecture, sanitary plumbing, fire fighting, water plumbing, electrical and communication	Following modelers, BIM analyst Emitter 5D
Designers and Modelers	All disciplines Projects and BIM Models	**BIM Analysis**	Review of BIM models and analysis of constructability	Designers builders-developers Emitter 5D
Modelers BIM analyst	BIM Models fixed, construction method, quantitative assumptions	**5D Emission**	Quantity Emission based on BIM	Builders-developers

SWIM LANE

Figure 2 presents activity stream and information exchange between professionals of the virtual construction team in this case study.

A modeling sequence inspired in "real world" construction sequence was noticed. This spreads out the fact that the modeling sub process of each course becomes an inward client of previous stage. Architecture modeling is applied in a virtual environment that already sees structure. Sanitary plumbing is first setup to be modeled by other setups. Water plumbing and firefighting gear are done by the same modeler in charge of sanitary plumbing. Finally, communication and electrical installation courses are modeled by "detouring" from previous modeled elements.

Continuous stream is interrupted by passage from BIM analysis to 5D emission. That is so because at the end of BIM analysis, design reviews are done by designers. This takes about 30 to 90 days waiting, according to interviewed virtual construction coordinator. After emission of new design versions, 3D models need to be adjusted to new designs. At this moment, virtual construction team always makes following question: "do we change it or remake it?". Then, depending on quantity or complexity of changes, making a new modeling of design may demand less time than identifying differences between design versions. At the end of the process, emission of the model quantities can be accomplished.
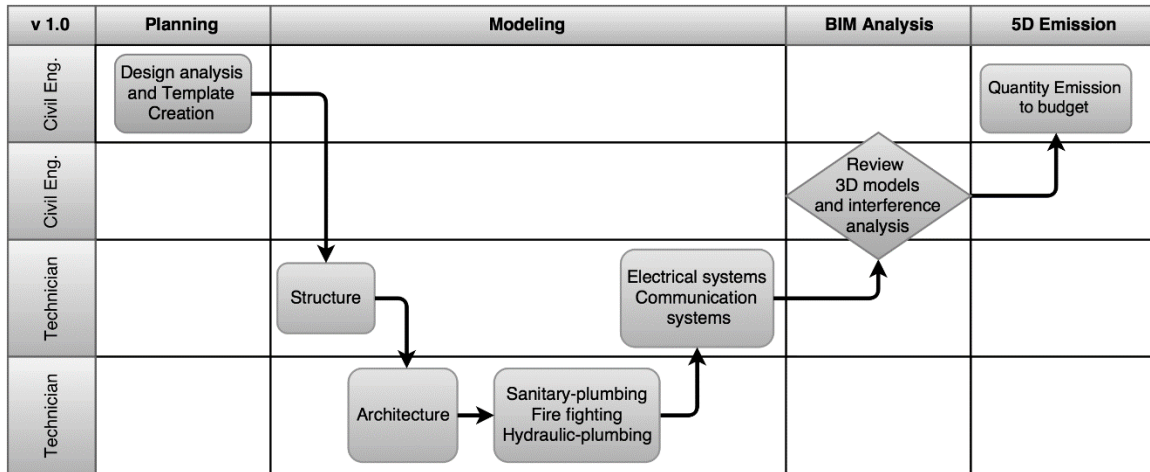
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Figure 2 - Swim lane of the virtual construction process

CYCLE TIME

The time to accomplish each virtual construction process was informed by professional responsible for the interviews. This time is a personal perception depicting reality, which may be different towards the design complexity. Figure 3 shows the cycle time analysis, as well as the average, median and mode. Activities that demanded time superior to average stand out. Activity time average is understood as takt time for virtual construction process (Hicks et al. 2015) .
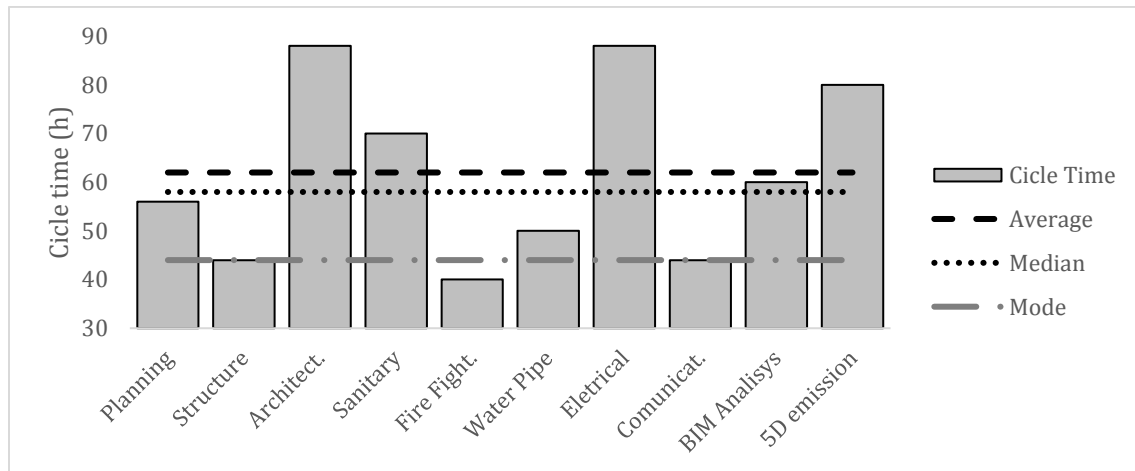
VALUE STREAM MAPPING

Value Stream Mapping presented in figure 4 stands for current stage of the case study, while figure 5 shows the proposed future stream. Through occasional implementation of proposed changes is expected to save time

According to the future work stream proposed, it was recommended that structural modeling is done along with planning. That is possible once design document checking,

Figure 3 - Current state VSM

Figure 4: Future state VSM

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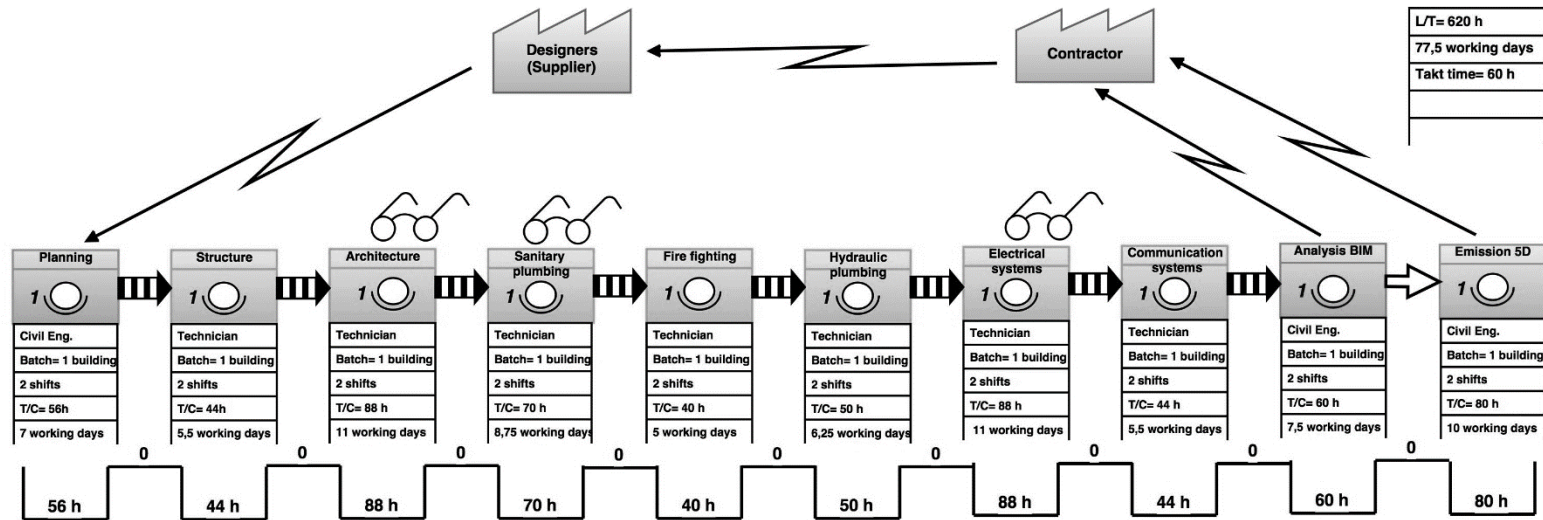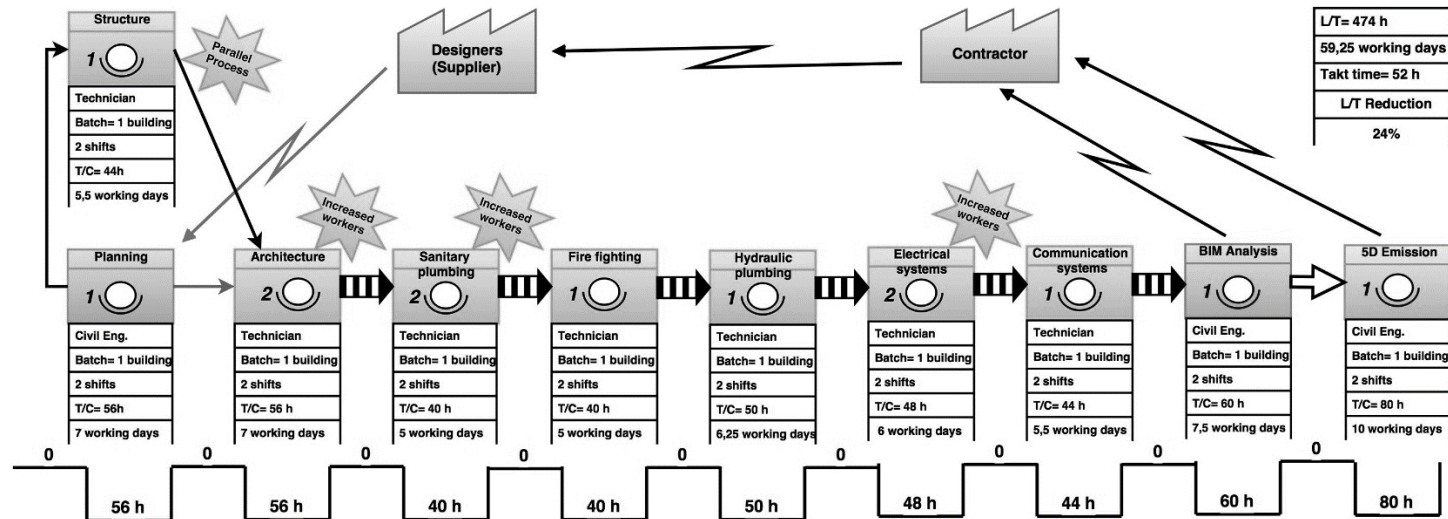
planning task, develops structural document checking in first place. It was also suggested creation of smaller batches for cycle time designs superior to Takt time. Separation of design into two smaller batches allows team to split effort and work in parallel. Taking that into consideration, cycle time in the future stream corresponds to the Batch 1 time of each changed design (Table 3).

Table 3: Batch Reduction Proposal

Design	Batch 1	Time (days)	Batch 2	Time (days)
Architecture	Basements	7	Tower	4
Sanitary plumbing	Connector Pipe	5	Main Stack	4
Electric Systems	Tower and Electrical Supply	6	Basements	5

Results show the possibility to reduce virtual construction lead time in 24%, if proposed changes are implemented.

CONCLUSION

Through lean tools, it was possible to visualize all virtual construction process and identify opportunities to offer improvement. The application confirmed the literature review, allowing us to state this technique is extremely important to have a better understanding of processes in general, including virtual construction.

Characterization of each activity, visualization of stream and time survey allows us to identify stages of process most distant from takt time of virtual construction process. Therefore, aiming lead time reduction is possible to accomplish the proposals of studied improvements by lean construction.

As a suggestion for future studies, we recommend the following of virtual construction companies with modified processes from action plans created through diagnostic tools and lean construction improving tools.

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