CHALLENGES AND OPPORTUNITIES OF COMBINING TAKT TIME PLANNING AND OFF-SITE CONSTRUCTION

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INTRODUCTION

While other industries have steady increased their productivity, in construction sector has stood still becoming an urgent challenge [1]. Off-site construction has been seen as an effective method to reformulate construction from traditional site-based wasteful practices towards industrialization [2]. Besides, the term Lean Construction (LC) was formulated in 1992 as an adaptation of the Toyota Production System (TPS) suggesting that the sector should learn from the so-called Lean Management [3]. LC was then defined as a production system that tracks and eliminates every task with no value to the end product (*muda*) and follows continuous improvement principles (*Kaizen)*. Under the umbrella of LC exist several tools focused on resource and flow efficiency, such as Integrated Planning (IP), Last Planner® System (LPS) and Takt Time Planning (TTP) among others. Through this approach the interaction of off-site construction as a method to industrialize construction and TTP to optimize activities is explored to highlight efficient practices based on just value-adding tasks.

OFF-SITE CONSTRUCTION AND TAKT TIME PLANNING

Prefabrication has been linked since decades to mass production, where all elements look alike with no customization and run along a production line within a Push Planning. At present it can be understood as a systematic work methodology where standard sub-pieces, when combined, form an end-product with bare constrictions. Since parallel work can be executed on-site and in a factory under optimal conditions, construction time can be reduced by overall 25% [4]. For an optimized management, a Pull Planning as a main pillar of LC should be implemented, where specific products and components are delivered only after being asked, easing a smooth production flow and a Just In Time (JIT) delivery with no overproduction, nor stock and nor waiting time (*muda)*.

The *Takt* principle was firstly formulated by Porsche and is considered as the *beat* of construction, referred to the time for one trade to finish its activities. Accordingly, TTP is a method used to streamline those activities in a construction sequence with the purpose to harmonize and accelerate the flow [5]. Although TTP can be applied to non-repetitive activities [6], the basis of an effective TTP relies on detecting repetitive elements and the so-called smallest multiple units (SMU) [5]. Consequently, a systematic approach based on standardized prefabricated elements, components and joints seems to be the best scenario for applying it effectively. Despite theories have explained how to apply TTP and its potential benefits, there is a lack of documentation about practical approaches and analysed empirical data [7].

WORKSHOP AND RESULTS

In the field of this research a workshop was conducted consisting in three rounds simulations of a production line, where elements and prefab components were delivered from different sub-producers in a semi-structured timeline, being together assembled, further delivered to quality control management and finally to the client. Each participant assumed a role and agreed the interdependence with their closest partner understanding how the production line works. A TTP was given where some constraints related to transport logistic and order and delivery capacity were included to simulate real conditions. The first simulation started and although each trade worked on their activities as efficiently as possible delivering their components according to their production speed and the TTP given, the production line not able to deliver the whole product to the client. Furthermore, delays and errors occurred throughout the line in the delivery of some components and elements, being out of the *takt*, and implying rework, over-processing, waiting time and deficient production rate. The factors constraining a right workflow were discussed in a collaborative workshop where changes and potential improvements were proposed, and the TTP consequently adjusted. Although there were significant improvements in the second simulation, a considerable amount of stock was produced traduced to overproduction, inventory, poor quality, and unneeded transport and movements. Within the second collaborative meeting, the Pull Planning main principles were explained, and thereafter implemented in the production planning optimizing again the TTP for both flow and resource efficiency. In the third simulation, the production line got optimized in a way that trades were able to produce all components on *takt*, even when errors occurred, since they were detected earlier in the production process and sent back to be fixed, while the whole process stood on sequence. Furthermore the number of workers was optimized, the over processing and unneeded movements were minimized and no overproduction from components nor inventory or stock from elements occurred.

CONCLUSION

The combination of off-site construction as a system to industrialize construction, with TTP as a method to optimize activities appear to bring several benefits to the sector in terms of productivity and flow efficiency. However, it is important to highlight that TTP as an isolated tool would not be enough to effectively align the activities and uncover potential improvements. Such an approach implies a tight involvement and trust-based relationship between producers, sub-producers and specially workers, since they know exactly how the tasks should be done. That is the main foundation of the LPS formulated by Glenn Ballard [8], and should be the basis of an optimized TTP. Aiming to quantify the benefits of such a combination and stablish some applicable principles, practical approaches should be implemented and analysed.

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