HEIJUNKA SYSTEM TO LEVEL TELESCOPIC FORKLIFT ACTIVITIES USING TABLETS IN CONSTRUCTION SITE

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ABSTRACT

The use of new information and communication technologies (ICT) can bring benefits to the management of construction sites, such as material savings, productivity growth and the enhancement in the speed of information transmission. To manage the supply of more than 62 blocks of 14 apartments each, spread over an area of 55 hectares, a team of engineers from a construction company in Fortaleza (Brazil) developed a system to schedule and track the progress of activities of forklifts on site in order to avoid idleness of these machines and workers waiting for materials. Thus, this paper describes a computerized system for distribution and leveling (*heijunka*) of forklift work, using tablets to inform operators about supply and cleanup activities to be performed at the jobsite.

The work was developed in five steps: team training in lean construction concepts, recognition of real problems, system development as a problems solution, solution testing and identification of improvements and consolidation of results.

Results were reductions of idle machines, work stoppage due to the lack of material and distance travelled. This computerized system has also improved the organization of construction site and the productivity of workers.

KEYWORDS

tablet, *heijunka*, ICT.

INTRODUCTION

Several studies support the great potential existing in the construction industry for the use of Information Technology (IT) in their management system (Nascimento and Santos 2002, Santa Cruz 2003). Moreover, the rapid development of mobile and wireless information and communication technologies (ICT) and its devices are offering new possibilities for portability and access to information systems and communication tools for professionals of production management (Löfgren 2006). Mobile computing has great potential of improving the work on the site, team's productivity and construction management (Pascoe et al. 1998).

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According to Gehbauer and Sacks (2010), information systems tend to improve the flow of processes by eliminating activities that do not add value, reducing cycle times and errors in production, which reduces rework and mitigates the variability throughout the processes. Also according to the authors, in some cases, IT systems are introduced as part of lean construction planned initiatives. They are consciously and carefully generated to facilitate the implementation of lean construction.

In other cases, implementers of IT systems in construction are unaware of the benefits that the conceptual perspective of lean construction can explain, for example: pulled flow production, production system design to reduce batch size, eliminate waste, and clearance of information flow and transparency (Sacks and Gehbauer 2010).

The degree of success in IT implementations in construction is likely to be higher when information systems are part of a conscious strategy, which is oriented by lean thinking (Sacks and Gehbauer 2010). According to Dave et al. (2008), several initiatives of implementation of ICT in the construction industry have not considered holistically construction processes, thus obtaining only a partial success.

According to Koskela and Dave (2008), the application of lean manufacturing concepts along with the implementation of IT can increase about 20% of the productivity in construction, while the isolated IT implementation brings only 2% and best management practices increase in 8% the productivity.

Based on these information, a team of engineers from a construction company in Fortaleza (CE), Brazil, developed a computerized system for distribution and leveling of the activities of a telescopic forklift. The system was developed in order to solve problems experienced in construction site, as the main causes of non-compliance packages of short-term, which are: low productivity of labor and scheduling imbalances. Besides, some wastes as waiting for materials and cleaning, conveyance, motion, processing and overproduction needed to be eliminated.

The implemented system uses tablets as means of operators' mobile communication activities on the construction site. However, in addition, the system is based on concepts and tools of lean construction, as *heijunka*, *kanban* and *andon*. It tries to involve people from the construction site in a simpler and more efficient process of supply and cleansing of apartment blocks.

Therefore, the aim of this paper is to present the computerized *heijunka* system with the use of tablets for the management of telescopic forklift of a residential project and the benefits achieved by implementing the system.

INFORMATION AND COMMUNICATION TECHNOLOGY IN CONSTRUCTION

Information technology is defined as the body of knowledge that deals with the production, distribution, storage, recording, and especially the use of information (Rischmoller and Alarcon 2005). The same authors argue that there are three main and interconnected elements of IT: people, processes and tools. And, it is in the connections between them that lays the main causes for the low level of adoption and underutilization of IT.

The information management in construction has been benefited by the advances of information and communication technology. These advancements have increased the speed of information flow, efficiency and effectiveness of communication, and they have also reduced costs for information transfer (Chen and Kamara 2008). Advances in mobile devices at affordable prices and increased data transfer speed of wireless networks can improve the information management in construction site (Chen and Kamara 2008).

By increasing the flow of information between different departments and teams, it is easier to monitor, control and evaluate the progress of the project and consequently integrate the processes in the construction site (Bowden and Thorpe 2002).

CONCEPTS AND TOOLS OF LEAN CONSTRUCTION

REFERENCES

The Lean approach is a new way of looking at the wastes that exist throughout the production system and how to reduce or eliminate them to improve the efficiency of the system (Koskela and Dave 2008). In this study, 3 concepts and tools are explored in depth. According to the definitions of Lean Lexicon (2008) they are:

- *Heijunka* is the leveling of the type and amount of production in a fixed period of time. It allows production to meet customer demand, through batches and results in reduced inventories, capital costs, manpower and production lead time;
- *Andon* is a management tool that emphasizes the visual status of operations in an area via a signal when an abnormality occurs. It can indicate the status of production, for example; how many machines are operating, an abnormality such as a quality problem, defective tools, among others;
- *Kanban* is a signalling device to authorize and instruct the production in a pull system. The *kanban* cards correspond to parts containers, which notify how much can be produced in a process and give permission to start the activities.

WASTES

Wastes are activities that consume resources but create no value to the customer (LEI 2008). There are two types of waste. The inevitable due to current technologies and production resources, such as inspection activities used to ensure quality and safety. And the waste that creates no value and can be eliminated immediately, as an example, transportation activities or movement between processes (LEI 2008).

Wastes in construction site are related to overproduction, waiting, motion, processing and conveyance, and they are described below, according to the Lean Lexicon (2008):

- Overproduction: produce better, before or faster than necessary for the next process or customer;
- Waiting: idle workers due to the cycles of machinery, breakdowns in equipment, late arrival of necessary parts, among others;
- Motion: workers making unnecessary movements such as looking for parts, tools, documents, among others, during the execution of an operation;

- Processing: incorrect or unnecessary processing performance. Represents the processing work that could be eliminated without affecting the process of the product;
- Conveyance: moving parts and products unnecessarily.

RESEARCH METHOD

DESCRIPTION OF THE COMPANY AND THE PROJECT

Colmeia construction company was founded in 1980 and since then has built residential and commercial buildings in prime areas of Fortaleza, Manaus, Natal and Campinas, always striving for quality and comfort. In total the company has already delivered 100 buildings, including residential, commercial, and other flats. The company has Total Quality Program since 1998, and certifications PBQP H-Level "A" and ISO 9001/2000 since 2004.

The project is a condominium resort located in the city of Aquiraz, Brazil, an area of 553,545.74 square meters. The project began in 2010 and has a term of 10 years. In this period, it will be built an extensive leisure area with swimming pools, barbecue area, golf courses, sports and others facilities, 82 houses and 99 apartment blocks, distributed into three types (A, B and C). Figure 1 presents the perspectives of the project.

Figure 1: Plant of the project and the perspective of an apartment block

DESCRIPTION OF ACTIVITIES

The activities for the development of the computerized *heijunka* system contemplated the following steps:

1. Lean Training: lessons on concepts of *kanban*, *heijunka*, *andon*, Just in Time, continuous flow, pull production, TFV (Transformation, Flow and Value), waste, and others, were taught by consultants. The training allowed the engineering team to identify problems in the production system and possible solutions.
2. Recognition of a real problem: based on the concepts of waste, the engineering team was able to identify idle machines, teams waiting hours for materials arrival, cleaning of floors (waiting waste), long distances to transport materials (conveyance waste), displacement of rubble on the floors to open workspace (motion and processing wastes), long set-up time of the machines to various exchanges of blades for transporting different materials throughout the day. The

graph of causes of non-compliance of short-term packages, displayed in Figure 2, shows that the main causes are: low productivity of labor and program deviations.

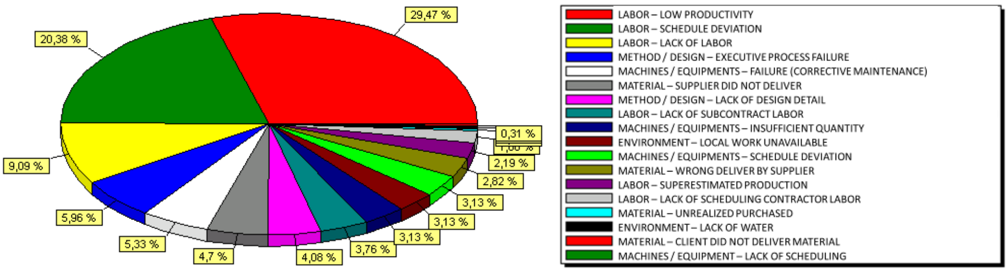


Figure 2: Graph cause of non-compliance of packages: weeks 38 to 41

These problems have encouraged the development of *heijunka* system for operators of telescopic manipulators and the need to use a mobile device - tablet - as *kanban* to overcome great distances from the construction site.

3. Development of the system: this step included the definitions of the system scope, its programming in Delphi language, the purchase of tablets and the setup of wireless networks throughout the construction site. The *heijunka* system installed in tablets is connected to the main Lean system, which supports the Production Planning and Control. The telescopic forklift activities are inserted into the Lean system on the day before of the operation. Then, the system distributes the tasks between the machines following a priority of services and the proximity of the machines to the workplaces. The system also warns the engineers, with a buzzer (*andon*), on the idleness of telescopic forklift.
4. Testing and improvements: for a month the system was tested in two telescopic forklift of the enterprise and major improvements were observed and implemented. This step was essential to disclose other problems that happened on the construction site and new *lean* tools had to complement the *heijunka* system, such as *kanban* cards.
5. Consolidation: after the test step, the *heijunka* system began to run outright. The system was evaluated and the results were measured using team productivity as indicator. There was an evaluation of wastes, such as the reduction in the number of time that machines supplied a pavement, and the number of time that machines changed their spades in a day, the decrease of idleness and waiting for materials by the crews, the increase of commitment of those responsible for carrying out the daily schedule of services, and others.

DEVELOPMENT

THE COMPUTERIZED *HEIJUNKA* SYSTEM

Daily, a technician set, in the system, activities that are collected from foremen and contractors, considering the supply needed for the production of batches that will run the next day. Then, the technician register on the central system of the PCP construction activities and quantities of material that operators should carry using the telescopic forklift (Figure 3). These activities can vary between 5 degrees of priority, as shown in Table 1.

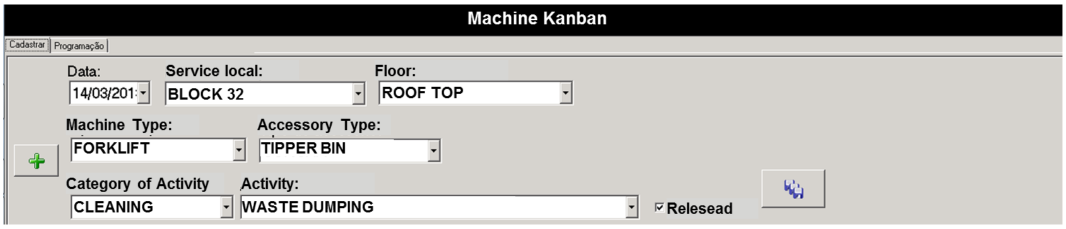


Figure 3: Image of the central system where team of engineers register telescopic forklift activities

Table 1: Degrees of priority activities

Activities	Priorities
Concrete	1
Emergency	2
Structure	3
Finishing	4
Cleanliness	5

Each apartment block has its geographical coordinates recorded in the system. Thus, the first activity of the telescopic forklift at the following day, the system distributes the machines to perform the activities of priority 1, at the largest possible distances between blocks, in order to spread the telescopic forklift all over the site. In the following activities, the system considers the machine closest to the block of flats; it will have an activity with high execution priority, thus decreasing the shift distances of telescopic forklift. The coverage area of wireless network and the step by step of data transmission are presented in Figure 4.

Figure 4: Step by step of transmitting information and coverage area of the wireless network in the construction site

The system indicates in the tablet of each operator the activity that has to be done, working as a *kanban* (Figure 5). After this, the operator performs such activity, and to finalize it, indicates its availability by clicking at "Finished". Then, the system signals the next activity to be executed.

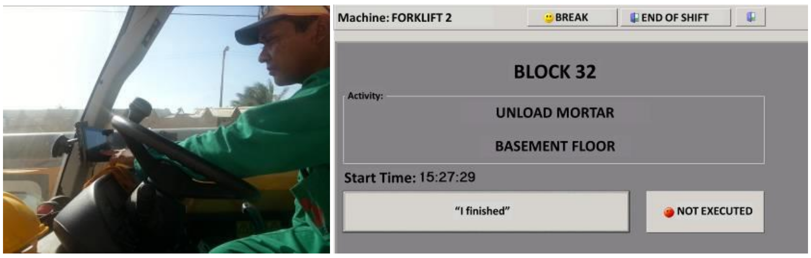
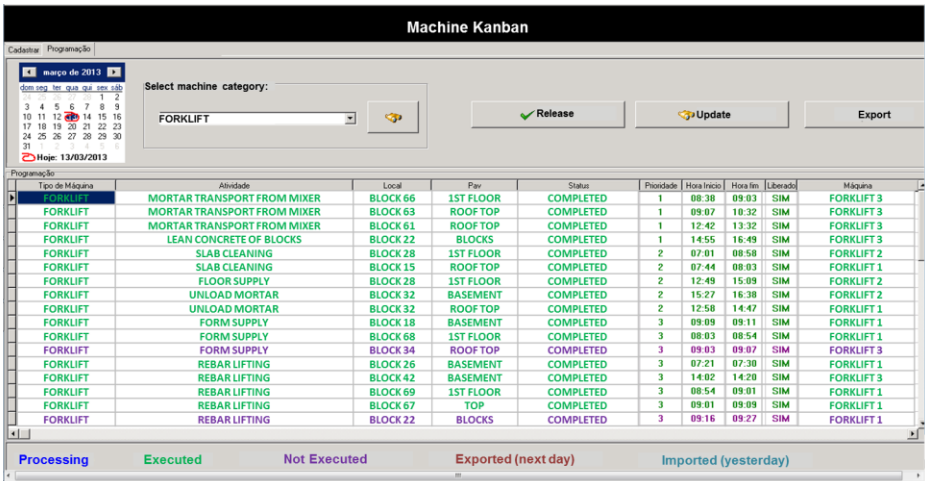


Figure 5: operator indicating their availability on the tablet after performing a scheduled activity for telescopic forklift 2

When occurs a stoppage at the telescopic forklift or a delay in an activity, engineers receive visual and sonorous signs on a TV at the working office, as an *andon* (Figure 6).

Figure 6: *Andon* of audible and visual telescopic forklift paralyzed

If during the day, it was displayed an activity with priority 1 (high), the operator will receive an order on his tablet to immediately stop the activity that he is working at the moment and he will immediately start the following one. All telescopic forklift programming activities are recorded in the system, which shows the real-time status of them (Figure 7).



Tipo de Máquina	Atividade	Local	Pav	Status	Prioridade	Hora Inicio	Hora fim	Liberado	Máquina
FORKLIFT	MORTAR TRANSPORT FROM MIXER	BLOCK 66	1ST FLOOR	COMPLETED	1	08:38	09:03	SIM	FORKLIFT 3
FORKLIFT	MORTAR TRANSPORT FROM MIXER	BLOCK 63	ROOF TOP	COMPLETED	1	09:07	10:32	SIM	FORKLIFT 3
FORKLIFT	MORTAR TRANSPORT FROM MIXER	BLOCK 61	ROOF TOP	COMPLETED	1	12:42	13:32	SIM	FORKLIFT 3
FORKLIFT	LEAN CONCRETE OF BLOCKS	BLOCK 22	BLOCKS	COMPLETED	1	14:55	16:49	SIM	FORKLIFT 3
FORKLIFT	SLAB CLEANING	BLOCK 28	1ST FLOOR	COMPLETED	2	07:01	08:58	SIM	FORKLIFT 2
FORKLIFT	SLAB CLEANING	BLOCK 15	ROOF TOP	COMPLETED	2	07:44	08:03	SIM	FORKLIFT 1
FORKLIFT	FLOOR SUPPLY	BLOCK 28	1ST FLOOR	COMPLETED	2	12:49	15:09	SIM	FORKLIFT 2
FORKLIFT	UNLOAD MORTAR	BLOCK 32	BASEMENT	COMPLETED	2	15:27	16:38	SIM	FORKLIFT 2
FORKLIFT	UNLOAD MORTAR	BLOCK 32	ROOF TOP	COMPLETED	2	12:58	14:47	SIM	FORKLIFT 1
FORKLIFT	FORM SUPPLY	BLOCK 18	BASEMENT	COMPLETED	3	09:09	09:11	SIM	FORKLIFT 1
FORKLIFT	FORM SUPPLY	BLOCK 68	1ST FLOOR	COMPLETED	3	08:03	08:54	SIM	FORKLIFT 1
FORKLIFT	FORM SUPPLY	BLOCK 34	ROOF TOP	COMPLETED	3	09:03	09:07	SIM	FORKLIFT 3
FORKLIFT	REBAR LIFTING	BLOCK 26	BASEMENT	COMPLETED	3	07:21	07:30	SIM	FORKLIFT 1
FORKLIFT	REBAR LIFTING	BLOCK 42	BASEMENT	COMPLETED	3	14:02	14:20	SIM	FORKLIFT 3
FORKLIFT	REBAR LIFTING	BLOCK 69	1ST FLOOR	COMPLETED	3	08:54	09:01	SIM	FORKLIFT 1
FORKLIFT	REBAR LIFTING	BLOCK 67	TOP	COMPLETED	3	09:01	09:09	SIM	FORKLIFT 1
FORKLIFT	REBAR LIFTING	BLOCK 22	BLOCKS	COMPLETED	3	09:16	09:27	SIM	FORKLIFT 1

Figure 7: Programming and status of telescopic forklift activities.

TEST PHASE AND IMPROVEMENTS

The test phase lasted approximately one month. In this period, several problems arose and solutions were implemented. The *heijunka* system by itself was not able to solve many requirements for materials in a non-organized way. The teams were not organized; dissatisfaction and low productivity grew due to the continued lack of materials.

So a team of cleaning and supplies, with an intern as a coordinator, was created. Its function was to follow the activities of the short-term plan, scheduling the supply of floors two days before the beginning of activities. Thus, the workers would only enter at the jobsite to perform their activity, without worrying about materials requests or collecting debris when finished the activity.

Moreover, the supply team created “kits” with the types of inputs required in the necessary amount to be transported when necessary in order to supply the floor only once. This new system avoids the telescopic forklift coming several times to the production lot with insufficient material to complete the service.

Another need observed was the use of *kanban* cards, because as each team presents variation in the quantity of inputs used in an activity, the *kanban* cards served as a way for workers to request materials or cleansing in a timely manner and in lesser quantities, just to complete the service. The cards were first developed for masonry activity, containing therein the possible inputs and cleaning activity.

RESULTS OF CONSOLIDATION SYSTEM

PERCEIVED IMPROVEMENTS

The lack of transparency and formalization of the programmed activities that were transmitted by the masters to the telescopic forklift operators facilitated the scheduling imbalances and idle machines, which had a "ripple effect" on productivity.

The formalization of the programmed activities, increased transparency of information and control services at the jobsite were the main benefits obtained by the system.

After a month of implementing the *heijunka* system, some improvements have already been observed. First, the productivity indicator of the teams of brickwork already increased approximately 50% in the first two weeks of using the full system (weeks 42 and 43), and then, in the weeks 51, 52 and 53, the indicator stabilized at 16,53 m²/man/day (Figure 8).

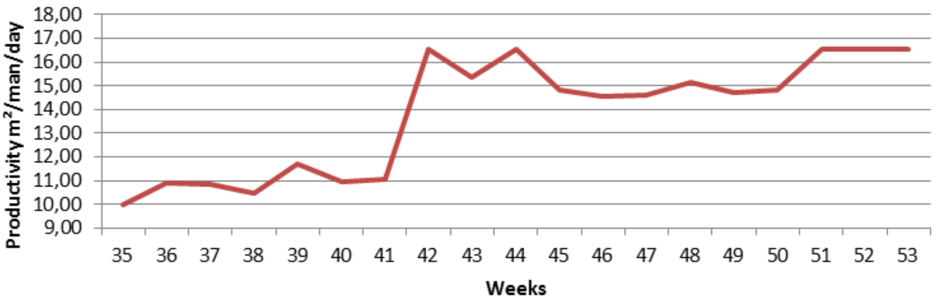


Figure 8: Brickwork team productivity of labor before and after using *heijunka* system.

The use of tablets to authorize the execution of activities helped the reduction on the planning deviation made by the foremen. Operators of telescopic forklift reported that despite attempts, they followed the scheduled activities in the tablets.

Another improvement in relation to reduce wastes in the construction site was a decrease in the number of times that the telescopic forklift supplied a floor for the same activity. Before, the machines performed more than 15 trips with small batches of materials for masonry activity. Currently, there are only two trips, one with the team that supplies the kits and other to gather the spoils. Thus, wastes with conveyance and motion were reduced.

The supply team began to demand from workers to leave the workplace clean for the distribution of the materials before the start of the following activities. Thus, the floors became more organized and ceased the crews' stoppages to clean and organize the workplace in an attempt to have space to perform the services (Figure 9).

before

after

Figure 9: Jobsite before and after the implementation of the *heijunka* system.

This procedure also allowed the reduction of waiting for materials by the crew, who have to take responsibility for claims of missing inputs by the usage of *kanban* cards.

Another improvement was the reduction of idleness of machines: the *andon* alarmed only twice in a month. Prior to the system, telescopic forklift stops were seen by the site, but without measuring the exact time.

Since only the cleanup activities use the tipper bin to transport materials, while the others use the fork, the time of set-up (part exchange) decreased, occurring once a day, for the cleaning activities, that are the last to be performed during the day due to the low priority (level 5).

DIFFICULTIES DURING IMPLEMENTATION

Even after implementing the *heijunka* system, foremen still tried to deviate machines activities to others out of the schedule.

Also, there are still late requests for machines, or workers that even forgot to schedule their activities. There is some difficulty by workers to request inputs with two days in advance.

For uninterrupted supply to occur, teams must make the cleaning of the floors when finalizing an activity and meet the exact locations for unloading and storage of materials. It is essential to use kits with right types and amounts of materials for each floor for its supply at once.

CONCLUSIONS

The computerized *heijunka* system for telescopic forklift got several benefits for managing the supply of building blocks in the construction site. The transparency of information on programming activities provided improvements in several areas of production, such as the reduction of various types of wastes in the site, scheduling imbalances, and increased productivity.

The computerized *heijunka* system initially proved insufficient to organize the supply of site, requiring the creation of team kits with supplies and the use of *kanban* cards as its complement. From the moment in which teams had autonomy to ask for missing inputs for completing the activities, liability and workers' sense of participation in planning increased.

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