ADAPTED USE OF ANDON IN A HORIZONTAL RESIDENTIAL CONSTRUCTION PROJECT

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ABSTRACT

The *andon* is a visual management tool used mainly in manufacturing systems to highlight the status of the operations. In construction industry, its use is not widely known nor reported in academic literature. In understanding the difficulties imposed by this kind of production, it is necessary to adapt this tool to the construction sites. An *andon* device was implemented in a 55 hectares area of large horizontal residential project, with more than eight hundred apartments, at Fortaleza, Brazil, in order to indicate for the engineer team the exactly position of the problem in each workstation. The device was adapted to a touch screen terminal inside the workstations and it was shared for nine hundred workers, each one has its own identification number. They have to log in at the *andon* terminal and indicate the actual status of the operation he is executing.

As a result, the *andon* allowed increasing operations transparency, to identify some planning issues and to solve the main causes of interruptions that were classified in four main areas: lack of material, problems with manpower, design documentation and safety. Also, the *andon* improved worker's sense of responsibility by forecasting future problems that will affect the production. The use of the *andon* adapted to a horizontal project is an inspiration to other construction companies of how to implement this Toyota system traditional tool at extent construction sites.

KEYWORDS

andon, information technology, lean construction, production control.

INTRODUCTION

Originated with the Toyota Production System, the *andon* has been widely used in manufacturing plants to improve product quality (Mayne *et al*. 2001, Strozniak 2001, Inman *et al*. 2003, Tierney 2004 *apud* Li and Blumenfeld 2006). However, its application in construction industry is very scarce due to its special kind of production, which is very different from the one found in manufacturing. According to Bertelsen and Koskela (2004), the construction is indeed a turbulent kind of

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production "makes one-of-a-kind products and does so at the site by cooperation within multi-skilled ad-hoc teams". Ballard and Howell (1998) also affirm that the construction industry is characterized by site construction conditions, unique product and temporary organization. These characteristics hamper the adoption of *andon* on construction sites due to the difficulties to install the *andon* devices in every workstation or site offices.

Even so, as analyzed by Kemmer (2006), there are cases of successful application of this tool in some high buildings, where the *andon* system uses the electrical infrastructure of the building to enable workers to request help and avoid the activity interruption. This known technological application has an expensive adaptation at a horizontal residential project, imposed by large distances to be covered and wired.

An engineering team faced the challenge of implementing an *andon* system at its own construction site, which has 99 apartment blocks spread over 55 hectares. In this project, the administrative team and the employees were already using the concepts and the tools of Lean Construction, which facilitated the implementation of the *andon* and allowed the packages fulfillment planned by the team during the weekly commitment plan.

ANDON

The *andon* is the basis for one Toyota Production System main pillars – *jidoka*, which means "machines with human intelligence". It is a management tool of visual control that shows the operation status in a workstation (LEI 2008).

The idea is to provide workers the autonomy to send a signal seeking help from their supervisors and stopping the production flow when there is a problem in their workstations (Shingo 1989, Liker 2004, Liker and Meier 2006). That trouble is immediately communicated to the team and the group leaders are the ones responsible to check where exactly is the problem (Liker and Meier 2006). The most important action is the solution to this problem (Shingo 1989). It is the basis of a culture of stopping the work to solve problems in order to get quality since the beginning (Liker 2004, Liker and Meier 2006).

In many companies, when trying to implement an *andon* system, workers usually have difficulties in admitting the need for support. And if resentment develops among workers or leaders, the *andon* will be ineffective (Liker and Meier 2006).

The *andon* system includes an audible alarm to alert and a visual light to indicate the location of the problem (Liker and Meier 2006). It describes the actual status of the production, for example; how many machines are operating, an abnormality such as a quality problem, defective tools, among others (LEI 2008). When implementing an *andon*, the problems cannot be hidden anymore, but detected and fixed (Li and Blumenfiled 2006).

ANDON IN CONSTRUCTION INDUSTRY

In a high building, the *andon* is used together with *kanban* cards and *heijunka* box. Each workstation of the building has an *andon* panel composed by three triggers switches: green, yellow and red (Kemmer et al. 2006, Valente 2011). These switches turn on the Light Emitting Diode (LED) on the control panel installed at the management office so the engineering team can visualize the production status in every stage. The green button turns on a green LED to indicate that the activities are occurring normally. The yellow one turns on a yellow LED to indicate that an activity

will be interrupted in the next 30 minutes. And the red one is to indicate that the production is completely stopped. This function is presented on the figure 1.

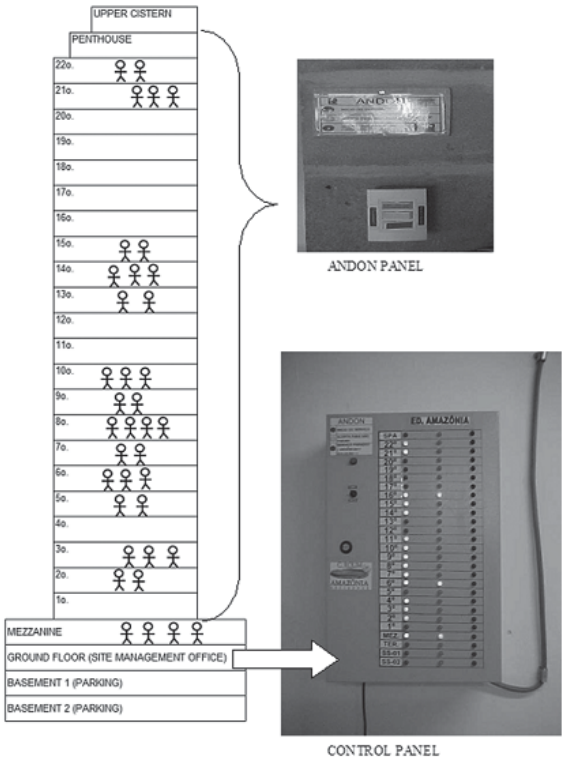

Figure 1: *andon* hardware and operation (Kemmer et al. 2006)

Every morning, when the staff arrives in its workplace, the employees press the green button in the *andon* panel. If they know that there will be a lack of some material, tool, information, or that any detail will be missing on the drawings, or that any resource could stop their job, one of the workers will press the yellow button and wait for the supervisor to get in touch by radio to solve the problem. But if the team interrupts the work, and the red button is pressed, the supervisor gets in touch, immediately, with his staff at the workplace and tries to fix the problem aided by the management team (Kemmer et al. 2006, Valente 2011).

The collected information for controlling concern about the reasons of work interruption, which can be for instance: labor training, system capacity, planning and supplier delay. All these reasons are found after applying the 5 Why's technique (Kemmer et al. 2006).

In projects with this kind of *andon*, the work interruptions were reduced significantly. Also, the transparency was enhanced, improving the communication among the management team and the employees.

The main difficulties to keep this manual system running are: getting the workers to press de buttons in the *andon* panel according to the status of their activities; making management team to record the minutes of production stoppage, its reasons and which crew has stopped; and the necessary communication via radio.

Also, it is easier to use the *andon* in a LED control panel when the building has its structure already executed, because after it, the workstations are physically defined.

DESCRIPTION OF THE CONSTRUCTION COMPANY AND PROJECT

This case study reports the implementation of *andon* at construction company founded in 1980 at Fortaleza, Ceará, Brazil. Currently, it has branches in Campinas (São Paulo), Manaus (Amazonas) and Natal (Rio Grande do Norte). It has delivered 100 buildings, including commercial and residential projects, flats and others, all in prime areas of the cities, always striving for quality and comfort. The company has not only a Total Quality Program since 1998, but also the certification ISO 9001/2000 since 2004, and has begun lean implementation, in its sites and offices in 2013.
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. During this period, an extensive leisure area with swimming pools, barbecue area, golf courses, sports and others facilities will be constructed, with 82 houses and 99 apartment blocks, distributed into three types (A, B and C). Figure 2 presents the perspectives of the project.

Figure 2: Plant of the project and the perspective of an apartment block

DESCRIPTION OF ACTIVITIES

The main difficult to implement the manual *andon* system on this site was its extensive size and the high number of apartment blocks and floors, the difficulty was to install an *andon* panel in each one. At total, it would be necessary 744 trigger switches and more than 100 kilometres of electrical cable for this site to connect all the workstations to the control panel in the main office.

Therefore, the engineer team decided to use information technology to transfer the data around the site using an existent Wi-Fi infrastructure, derived from one year of lean construction implementation in this project (Barbosa et al. 2013). Due to it, the *andon* implementation is the continuity of different lean concepts, tools and techniques implemented. Then, all the programming language and infrastructure remained the same. So, the engineering team added the *andon* at the "Lean Terminal" where the workers can trigger the device anytime it is necessary for them to finish their job.

The *andon* system development activities contemplated the following steps:

1. Development of the system: this step included the system scope definitions and its adaptation to the extensive construction site. It was programmed in Delphi language, using SQL Server 2008 database and a web service to send SMS messages to employees' cell phones. In this step there was the "Lean Terminal" touch screen purchase. The *andon* system was connected to the main "Lean

System" software through the site wireless network, which supports the Planning and Control Production (Barbosa et al. 2013).

2. Testing and improvements: during 15 days, the *andon* system was tested in only one terminal that was one apartment block at the site. During this step, it was necessary to train one employee how to use the *andon* and he was supposed to share all the information with the others in the "Terminal Lean". This phase occurred during from end of September through beginning of October, 2013.
3. Consolidation: after the test step, the *andon* system began to run outright. The system was evaluated and the results were measured according to some indicators with data from October, 2013 until February, 2014.

DEVELOPMENT

THE *ANDON* SYSTEM

It have been installed three "Lean Terminals" spread throughout the main streets of the site. They are in the apartment blocks ground floor (blocks 18, 42 and 71) and their locations are indicated by signposts on site (Figure 3). The *andon* must be activated through the "Lean Terminal" which contains others systems used by employees (Figure 4).

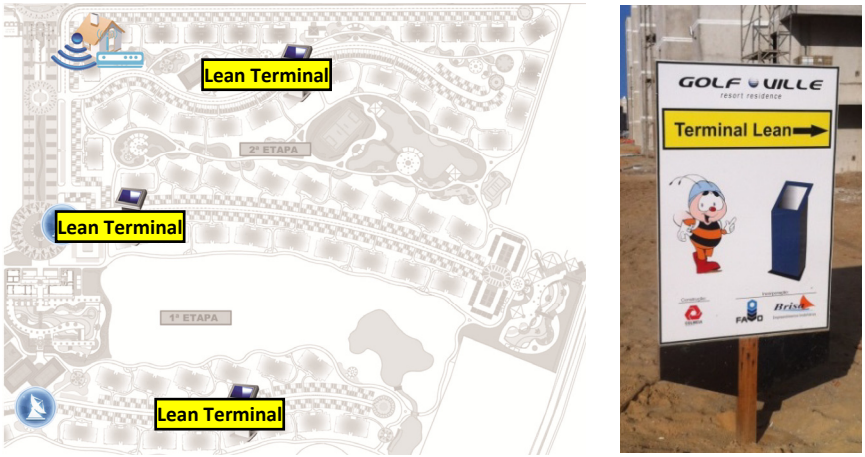

Figure 3: "Lean Terminals" location and signalization on construction site

Figure 4: "Lean Terminal" where workers can access the *andon* device

The activation can be done by any worker, keeping the principle to adopt *andon* for the front-line workers. If one of them wants to signalize that his crew will stop the production, he needs to login in the system, choose the *andon* screen, inform his

workstation, the reason why they are going to stop and confirm his activation. It was selected four categories of activities stoppages: material, crew, design and safety. Further, the engineering team receives an alert in the site office screen and they have until 10 minutes to solve the problems referred to safety and 30 minutes to others categories before the production stops.

The administrative assistant identifies the activities could be interrupt and their reasons. He is responsible to solve the supply problems on the site. Most part of the *andon*'s problems is simple to solve, and the engineers are not notified.

The step by step of the procedure to trigger the *andon* in "Lean Terminal" is shown in Figure 5.

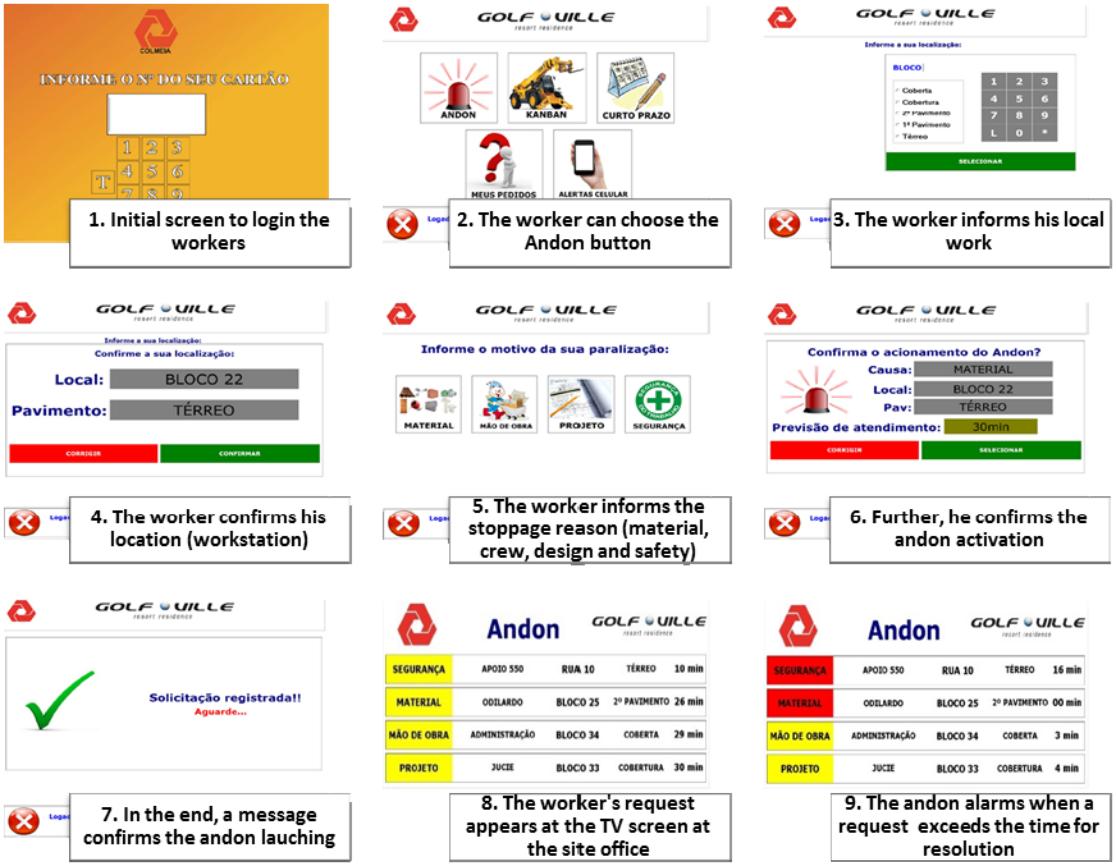

Figure 5: step by step of how workers can activate the *andon* device

RESULTS OF *ANDON* SYSTEM

STATISTICS

Some *andon* indicators could be easily produced due to the automatic collection of data in the system database. All data were collected during a period of five months, from October, 2013 through February, 2014. The total of *andon* activation up at this point is 187. This amount is categorized in crew, material, design and safety problems as it is shown in the chart of the Figure 6. It can be visualized that material is the main reason of *andon* activation by the workers, representing 82%.

The distribution of *andon* activation during the months also can be seen in Figure 6, that shows the intensive use of this tool in the first two months of its implementation, 62 activations among October and November, 2013. In the following months, this number decreased consecutively, probably, because the engineers learned how to program the resources for their commitment plan, or the workers were using intensively the *kanban* cards to request the resources.

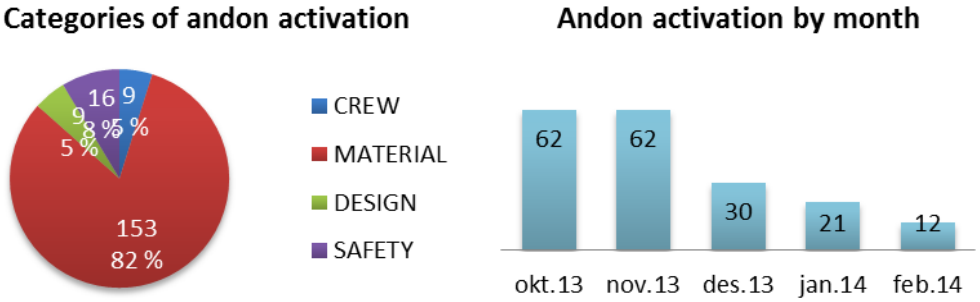

Figure 6: *andon* activation by category and month

Another indicator was the *andon* activation to find the schedule deviation. During 5 months, 92% of all *andon* activation was to request some resource to the same workstation and activity that was planned in the commitment plan. The chart in the Figure 7 shows that 8% of all *andon* activation was from activities with schedule deviation or informal which were not planned to occur.

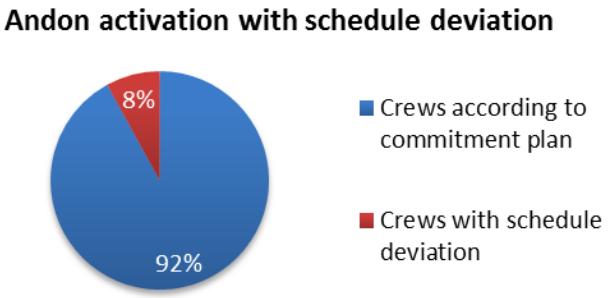

Figure 7: *andon* activation with schedule deviation

It was evaluated the efficiency of the engineering team in solving problems before the activity interruption (Figure 8). It was possible to visualize that the safety category was the most difficult to be solved in a few minutes. Only 59% of all activities in the *andon* system were resolved before their stoppages.

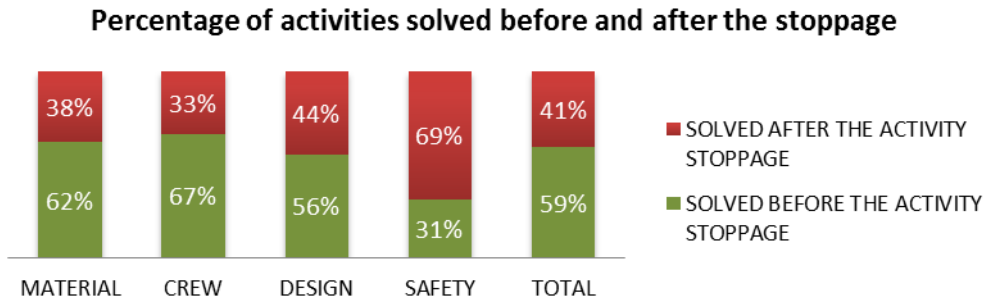

Figure 8: Percentage of activities solved before and after the stoppage

Of all *andon* activations, it was possible to analyse the time deactivation average by the four categories. The material category is the one that consume more time to turn off the *andon*: 37 minutes is the average to turn the *andon* off, i.e., to solve the problem; 48 minutes is the average for activities that have stopped, i.e., exceeded the 30 minutes to be solved; and 11 minutes was the average for the activities that were solved before the stoppage, i.e., before the 30 minutes.

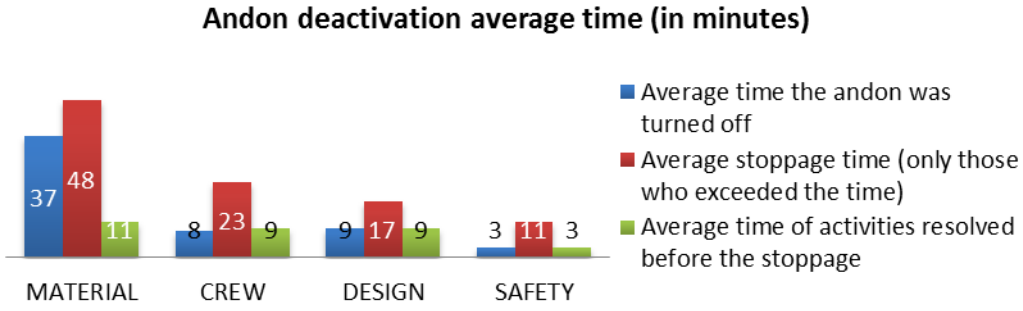

Figure 9: *andon* deactivation average time (in minutes)

The next indicators are concerned about the labor (Figure 10). The first one shows that only 3% of all *andon* activations were done by the outsourced labor, and 97% from own labor. The reasons can be because of the good resources that were planning by the outsourced enterprise, or if there was a lack of some resource, only the outsourced enterprise can solve the problem of its labor, and the *andon* activation was not necessary.

In the second chart is possible to visualize the professional that mostly used the *andon* was mason, 48%, followed by the servant, 31%.

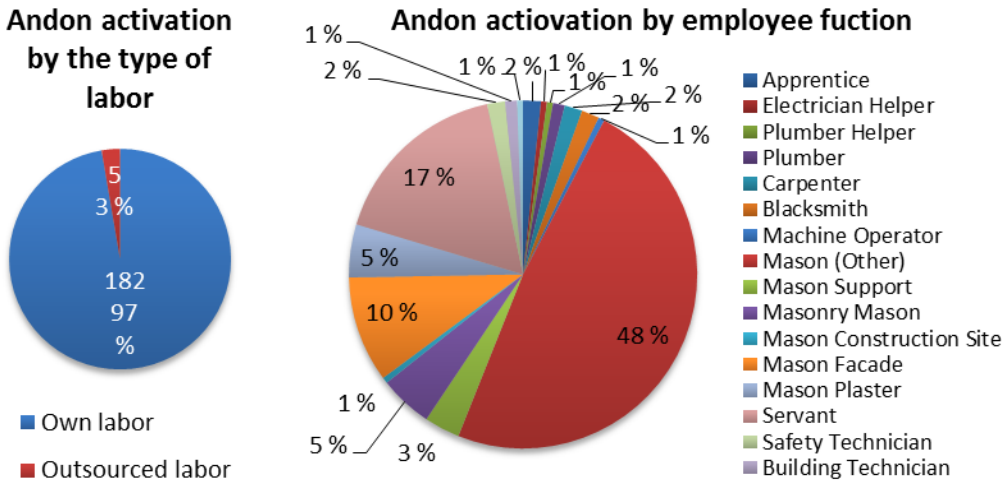

Figure 10: *andon* activation by type of labor and employee function

As soon as the worker activates the *andon*, it is possible to know his location on construction site. The next chart (Figure 11) is about the *andon* activation by apartment blocks and other buildings in the project common area. The location with more *andon* activation is the block 70. In this block it is installed the "Lean Terminal", but it is necessary more data to assume that the *andon* localization on site is influencing its activation.

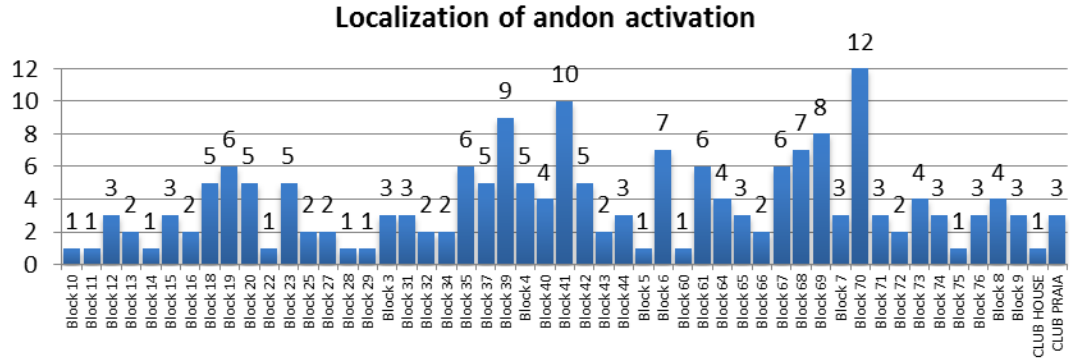

Figure 11: localization of *andon* activation

PERCEIVED IMPROVEMENTS

As it is a computerized system, the data collection is automatic. When the *andon* is triggered, an alert appears at the screen of the engineering office with a countdown to resolve the problem. From this moment, all data are registered in the system, which improved the communication speed and the activities transparency with the problems for all engineering team.

In this *andon* system the worker is the one who informs why he is going to stop the activity. This fact decreased the timing to fix the problem, because the engineer does not have to search the crew only to ask them the reason of stoppage.

As the worker needs to register his job location, the *andon* system confers automatically where he should be according to the commitment plan and where he

actually is. Thus it is possible to find schedule deviations that justify a lack of resources to perform an unscheduled activity. So, it is also possible to find the informal activities that can generate wastes by making-do.

Data related to cost reduction, such as stoppage time, is being collected so the authors can analyze the tool efficiency.

The most important benefits that the *andon* system enabled are fixing the problems and improving commitment planning quality by the engineering team. Also, a very expansive resource as manpower will not become idle due to supply problems and the wastes of making-do can be reduced.

DIFFICULTIES DURING IMPLEMENTATION

The difficulties encountered in the *andon* implementation at the site are related to employees' engagement. Training must always occur for them to be updated and because they must understand the importance of notifying the engineering team when they will stop or when they have already stopped their production. The opposite also happened when early in the implementation, there were some workers who triggered the *andon* without having done their requests through the *kanban*.

One limitation of this *andon* system is the employee's impossibility to trigger the *andon* to signalize the green situation of production: they are working in the right place with all the necessaries resources. Currently, the *andon* just indicates a yellow or red situation of production, and that is the reason why the engineering team does not know if the workers are in the right workplace as scheduled.

CONCLUSIONS

The *andon* system got several benefits by managing the supplies of building blocks in the construction site. The information transparency provided improvements to the commitment plan and decreased the stoppages in production.

The *andon* system still faces problems with the employee committed to trigger the device and to obtain the real production status. Nevertheless, it was an adaptation of the *andon* concepts to an extensive construction site that supported the kaizen for production planning and control.

ACKNOWLEDGMENTS

The authors thank the directors of the Colmeia construction company for the opportunity to develop this work and the purchasing department collaborators for the will and effort in Lean implementations with SIPPRO consultant's partnership.

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