BENEFITS OF BATCH SIZE REDUCTION: A CASE STUDY IN A RESIDENTIAL PROJECT

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ABSTRACT

The line of balance (LOB) is a tool used for long-term planning of projects, especially because it highlights visually, several information such as work place, sequence of activities, number of teams and work in progress (WIP). Because the LOB makes transparent workflows for project managers, this tool can be used to simulate different alternatives and discuss plans and installment strategies. This research presents a continuous improvement of a previous study in the same issue (using line of balance on simulation of execution strategy) published in 2008 at the IGLC Conference. This article aims to indicate through a case study at a Brazilian construction company, improvements that can be expanded to project's management through reduction of batch sizes and balance of workflow. The methodology for developing this paper includes: literature review regarding the concepts of just-in-time and line of balance, in order to identify which variables should be modified during the simulation of different scenarios; characterization of the company and the project to be studied; simulation of two scenarios with changes in the variables chosen; analysis of the simulated scenarios; choose the scenario that was leaner and met the needs of project managers, and, finally, identification of improvements from this new scenario. The results of this study reinforce the benefits suggested by the reduction of batch size, like reduction of amount of teams, increased repeatability, increased learning effect and greater control of project managers on site logistics. In fact, it was also identified a better adherence to production batch, reducing by 12% the project's total term. Moreover, it's possible to mention the difficulty of subcontractors to adapt to pace of the new LOB.

KEYWORDS

Lean construction, line of balance, batch size reduction.

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INTRODUCTION

The line of balance is a planning tool that can provide information on which resource (crew or equipment) will perform an activity, when and where this activity will be performed (Mendes Jr., 1999). Due to its graphic features, it's easy to understand and visualize paths, production rates and duration information (Schramm, 2004).

Ioannou and Srisuwanrat (2007) discussed about LOB with focus on variables such as cycle time, lead time, batches sizes and delays. Brodetskaia and Sacks (2007) using LOB, could study about variability, lack of activities sequence, workflow discontinuity, and change in task cycle time in construction projects.

Several authors have discussed the importance of reducing batch sizes (Tommelein et al. 1999; Alves and Tommelein, 2004) and cycle times (Santos et al., 1999; Ballard, 2001).

Birrel (1980) and Mendes Jr. and Heineck (1998) highlight the importance of considering the continuity of workflows in projects with repetitive characteristics through the use of the LOB.

The premise for the company to accept implementing reduction of production batch size is that it can increase the control of project managers on site logistics and reduce the project's total term. In fact, despite good planning and the constant search for goals set in short, medium and long term, the company's project teams fail to adhere to the current transfer batch size from line of balance and also to keep the production rate planned. Because of this, the final stage of construction is often troubled, with a greater peak of employees during and little control of production teams. The main objective of this study is to indicate benefits and improvements that can be expanded to project's management through reduction of batch sizes and balance of workflow.

In a more specific level, the objectives are presented next: perform simulations of scenarios for projects' long-term planning using the line of balance and compare these scenarios with the current model of line of balance, in order to indicate which one is more appropriate to the reality of the project.

METHOD

CASE STUDY DESCRIPTION

The Construction Company

Founded in 1975 at Fortaleza, Brazil, the construction company of this case study focuses specifically to Classes A and B. It has more than 530.000m^2 of constructed area and 172.000m^2 under construction, distributed into more than 12 buildings and 500 private units.

The lean journey in this company started in 2004, when its top managers attended the 1st International Seminar on Lean Construction (CONENX) in the city of Fortaleza. They realized that the lean philosophy was aligned with the management and production interests and concepts of the company of continuous improvement, product flexibility and additional value to the client. So, lean was defined as a management philosophy, and more studies were organized by the technical managers on the subject, in order to increase this knowledge among all administrative team of construction sites and central office.

Over these nine years, the company has been using many lean tools: *kanbans* for inventory and mortar management, *andon*, material flow's *kanban*, *poka- yokes* for concret structure and mansory stages, inventory materials design for masonry and plaster, pallet transportation, supermarket concepts in the warehouses, panel of materials and ceramics that will be installed at the apartment, new solutions formatted in the A3 tool and many others.

The Project: Lumni

The project of study is a residential tower of 23 floors on an area of 2,630.00m^2, at a wealthy neighborhood of Fortaleza. There are two units per floor and each one has a private area of 206.30m^2. Figure 1 represents façade and private unit of Lumni. There are also two duplex penthouses at the top. The total area of built environment is 15,408.00m^2 and it addresses especially to Class A.

Scheduled for finishing on May 2014, the construction site has started its works on May 2011.

Figure 1: Lumni's façade and private unit

Activities Developed

This case study may be divided into four stages.

- Training in concepts and tools of lean construction: at first, engineers of the construction company were trained in lean construction concepts by professors of NORIE[7] from UFRGS[8] during four months in 2012. The classes subjects were: lean concepts and tools; production system design and 4D modeling; and lean concepts in design management.

Along the classes, one of the professors questioned the company's engineers about the workflows at the construction site and the batch sizes of production and transferring. It was suggested for them to initiate a workflow study based on the line of balance and the opportunity to improve it, especially due to engineers' own testimony that, currently, there was little adherence to planned batch and the final stages of construction are quite troubled.

- Simulation of Scenarios: the next step of the case study involved the proper development of new scenarios for the line of balance, through reduction of batch sizes and balance of workflow. There have been simulated five different

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scenarios, but, for this paper purpose, only two of the new scenarios will be discussed.

- Comparison of Scenarios: after the simulations, it was necessary to compare all scenarios, in order to understand which one would be most suitable for the construction site and company. For these comparisons, four details were extracted from the lines of balances: work in progress (WIP), total term, number of teams and transferring batch size.
- Evaluation of new scenario implementation: finally, after choosing the best scenario, it was made official and taken as long-term planning by the project's team. The latest activities consisted on the evaluation of the practical results obtained with the implementation of this new scenario (hereafter indicated as C3) in order to realize its advantages and disadvantages and indicate some improvements that can be made in a new implementation.

DEVELOPMENT

Simulation of Scenarios

As mentioned above, the simulations of long-term scenarios were performed with the line of balance tool (already used by the company) at the MS Excel software. The scenarios presented below vary in three points: transferring batch size, balancing of teams and production pace.

Scenario C1

The line of balance C1 was used by the team of engineers in the project Lumni and was developed based on Kemmer (2008). Figure 2 shows a part of this scenario. It is possible to see that the pace of activities accelerates from half the tower to top. This is done by allocating more production teams to perform the same activity. Furthermore, although the production batch is the residential unit (apartment), but the transferring batch is the entire floor (two apartments) and, sometimes, even four entire floors (eight apartments). To view the complete line of balance C1 and better comprehend its features, see the related link[9].

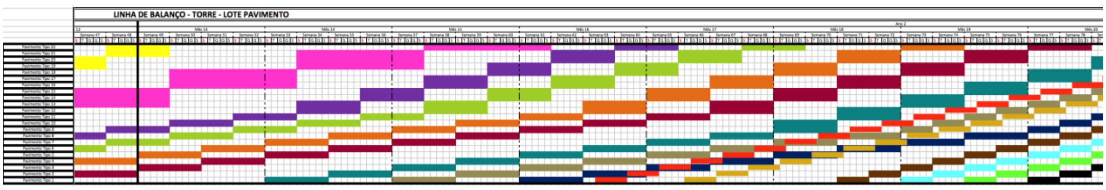

Figure 2: Section of scenario C1

Scenario C2

The line of balance C2 represents the first simulation performed. The transferring batch size was reduced to one apartment, becoming equal to the production batch.

[9] www.crolim.com.br/pdf/scenarioc1.pdf

Furthermore, it was attempted to maintain the same pace from the beginning to the end of the activities, allocating only one or, at most, two production teams for each activity. It is possible to see that there is no buffer between the activities, which means that once a service is completed, the next starts right away at the same place. Figure 3 represents a section of the scenario C2. In order to view the complete line of balance C2 and better comprehend its features, see the related link[10].

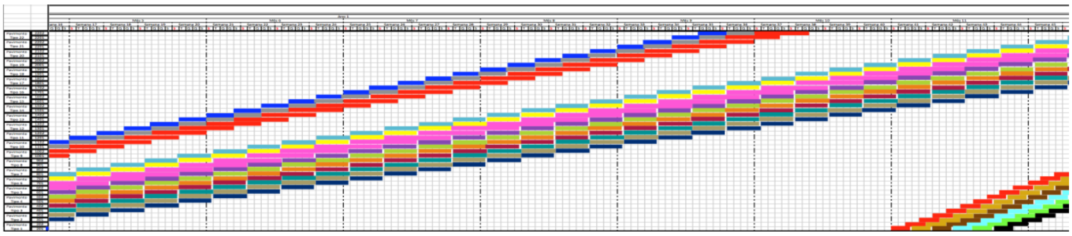

Figure 3: Section of scenario C2

Scenario C3

The line of balance C3 is the last of two simulations performed during the case study. However, C3 represents the evolution of other simulations and its section is represented at Figure 4.

Regarding to the transferring batch size, it remains equal to the production batch size: one apartment. In addition, the slow and steady pace of most activities were maintained, with allocation of few teams (one or two) per services. The changes relatives to C2 are on the existence of a week of buffer between activities of the same apartment and an adjustment of starting times, total term and pace to the requirements of subcontractors, especially of the final stages of the project. The reason for the planned buffers is to protect the production from uncertainty and variability inherent of the construction industry. No scientific method was used to define the buffer size, but both project managers and past projects database were consulted. As a week is the smallest part of the planning (short term), so every delay in one week of short term planning could be reprogrammed to the next week. In regard of the second change, it is possible to mention as an example the subcontractors of installation of metal fittings, plugs and switches, which deserved a faster pace in line, because they can not start their work so early (risk of loss and wear of materials and equipments at site). To view the complete line of balance C3 and better comprehend its features, see the related link[11].

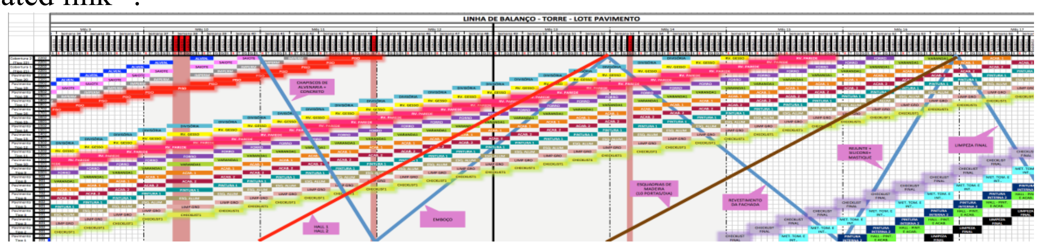

Figure 4: Section of scenario C3

[10] www.crolim.com.br/pdf/scenarioc2.pdf
[11] www.crolim.com.br/pdf/scenarioc3.pdf

COMPARISON BETWEEN SCENARIOS

In order to compare the three different simulated scenarios of long-term planning, Table 1 is displayed below with four main informations extracted from the lines of balance: days of work in progress, total term of project, total amount of teams and transferring batch size.

Some considerations, however, are important to be mentioned before this analysis:

- This case study took place 11 months after the start of construction. Thus, these past 11 months will be added to the total times of the lines for determining the total term of the project;
- The scenario C3 has four more services (one production team each) compared to previous scenarios, precisely in order to achieve better adherence with the planned goals with inclusion of other critical activities, like heavy cleaning and checklists for repairs. However, for the purpose of comparison, the amount of teams will be counted only for the services that are common to the three lines of balance.

Table 1: Comparison of simulated scenarios

SCENARIO	DAYS OF WORK IN PROGRESS	TOTAL TERM (MONTHS)	TOTAL AMOUNT OF ACTIVITIES	TOTAL AMOUNT OF TEAMS	TRANSFERRING BATCH SIZE
C1	4456	36	19	31	1 FLOOR
C2	3783	27	19	21	1 APARTMENT
C3	7143	32	23	21	1 APARTMENT

The project team has chosen the scenario C3 for implementation on site, because the lowest total amount of teams and reduction in total term of the project in 4 months showed to be very positive attributes for project managers. In any case, one can then question why not to opt for scenario C2, which promotes a reduction in the total term of nine months. The main reason is related to the lack of buffers between activities, which leaves the project unsafe to consequences of variability and uncertainty. Moreover, there is also a financial reason: the cash flow of the project in 27 months is very concentrated and the costs increase significantly per month, requiring clients to pay for apartments in a smaller amount of plots with higher values. In a total term of 32 months, the distribution of cash flow suffers a slight reduction, and does not jeopardize the financial sustainability of the company and clients.

It is important to comment on the difference between days of work in progress between scenarios C1 and C3. Observing the table, the difference of 4456 days to 7143 days gives a percentage increase of 60%. In any case, this increase is questionable.

In fact, in the scenario C1, if the production batch is the apartment and the transferring batch is the floor, then there is a work in progress masked over the first apartment of the floor, which has already been finalized and is awaiting the second to be finalized for receiving a new service. Therefore, if these days of hidden work in progress are accounted, there would be a total amount of 6002 days, ie 35% more if compared to the 4456 days of work in progress recorded previously.

Moreover, as mentioned, the scenario C3 has four activities more than the scenario C1. If the days of work in progress of these four activities are excluded, there would be a total amount of 6307 days, ie 12% less than in the first calculation. The difference now, with these new amounts of work in progress, between C1 and C3 will be only 5%, which is perfectly acceptable, once reducing batch sizes make the work in progress more transparent.

Thus, after choosing the line of balance C3 to be implemented at the construction site, the project managers started to observe its practical results at site. It was suggested for them to analyse the physical flow and the control of teams, the learning effect by repeatbility of services.

RESULTS

It has been nine months since the line of balance C3 has been implemented at Lumni (since July 2012). The project managers have evaluated as very positive the improvements made at long-term plan, however, there are also some difficulties. Below, the results are divided into quantitative and qualitative improvements and difficulties.

QUANTITATIVE IMPROVEMENTS

The main quantitative result is related to adherence to production batch. Comparing the project Lumni with another project of the same company that uses the line of balance similar to C1 and at the same relative time (16 months for official ending of construction), it is observed that Lumni is only 6.95% lagging behind the physical schedule, while the other project is 16.51% lagging behind the physical schedule.

Fortunately, these delays in relation to planning do not represent delay in completion and final delivery of the project, because project teams are committed to the deadline and prepare a schedule of recovery of the planning at line of balance during the last year of work. In any case, further delay will require a recovery schedule with more teams and over a longer period in the construction site. It is even possible that this delay of 6.95% at Lumni can be corrected over the working days, without entering more teams at the construction site.

It is important to mention that, until the end of this case study, no improvement of productivity rate was quantitatively identified, but it is inferred that all qualitative improvements presented below are consequence of the stability of production achieved by reducing the batch size.

QUALITATIVE IMPROVEMENTS

In general, project managers noted a great improvement in the control of site logistics. It was noticed that it was better to control more activities at the same time in C3 rather than more production teams at the same time in C1. According to their statements, the constant and slower production pace and the fewer amount of teams favored a series of processes, including:

- Better planning of materials' purchasing, with a minor variation of resources at site. In fact, the steady pace of one or two teams from beginning to end of activities helped, for example, the fact that it could be programmed several deliveries of flooring for apartments (two to four deliveries by type of material). Because there were a limited and constant number of teams per activity, the programming and delivery of purchases was facilitated. Furthermore, there was no change in weekly demand for cement during seven months. Project managers have scheduled the delivery and use of 300 bags of cement per week, which was not feasible in past projects, because while teams consumed in a week 450 bags of cement, in the next week they could consume only 100 bags. At present, with the C3 scenario implemented, it is possible to avoid peaks of materials on site, large inventories and wear of these materials at the construction site;

- A great improvement on the physical flow of site, promoting better organization and construction site layout, easing tower's transport through lift, considered a major difficulty on buildings of multiple floors;
- Reduction on the number of steps or parts of processes, especially in relation to materials receive and conveyance, which is considered an inherent waste of the process. Project managers have accomplished that gypsum blocks, for example, went straight up to the apartments where they would be used, avoiding the need to first unload the truck on the ground floor and then lift these materials up to apartments. The elimination of this primary storage on ground floor was only possible due to the better physical flow of site, because the lift was not always occupied;
- Reduction of inventories and release of work fronts, especially in basements, because of scheduled deliveries of materials. Typically, due to uncertainties of suppliers and lack of programming, basements receive big inventories for the entire term of construction. Besides the possible wear of these materials, there is also an inability to move forward with production teams on these floors in the early stages of construction, because of the large areas taken by inventories. The result of this is a troubled end of projects, mainly at the common areas. Scheduling deliveries in smaller batches released work fronts in these floors, which could be worked out over all period of construction. As a result, within more than a year for official finishing of the project, the second basement has already concluded its flooring (ceramic) and the first basement is already 80% completed.

DIFICULTIES

There were identified two major difficulties regarding the implementation of the line of balance from C3 scenario. The first one is related to subcontractors, and the second one, to the process and technologies of construction.

It was observed that the subcontractors could not keep pace activities according to plan, which is, slow and steady. When project managers suggested to subcontractors start the services on site with only one production team during eleven months, they completely rejected the idea. Their intent is to work with three or four teams, when there were already enough work front, and then, finish the activity in three or four months. This resistance is due to the fact that subcontractors have diverse construction sites from various construction companies to manage. Therefore, it is preferable for them to control, at the same time, less construction sites with more teams in a shorter period of time than more construction sites with less teams and in a larger period of time. In summary, it is a matter of difficulty of decentralization of production control.

Unfortunately, it was not possible to convince them otherwise and the project managers had to deal with this adversity trying to keep the pace of the following activities as planned.

FURTHER WORK

As ideas for further work, it is suggested that long-term planning is conducted in partnership with the subcontractors, so that the project managers can observe their point of views on services, promoting the proper commitment to the pace and amount of teams planned. Despite this has been already indicated for some time in many theoretical researches, its implementation in practice is difficult because, at the time of preparation of long-term planning, mostly subcontractors have not even been hired. Yet, it may also be possible to link the deserved pace of activities, according to C3, in subcontractors' contract agreement, so that it can help choosing the right subcontractors as they would have a legal motivation to keep the pace as project managers need.

Finally, it is also suggested the implementation of a long-term planning scenario similar to C2, which has almost no buffers between activities and thus requires almost zero delays and a much greater control over uncertainties, in projects of low complexity, shorter total term and making use of most industrialized or advanced building technologies and stronger partnerships.

CONCLUSIONS

The results obtained by comparing the simulated scenarios and evaluating the implementation of the scenario C3 at the project showed many benefits by the batch size reduction and of workflow balance in long-term planning. The benefits extended trough improvements on physical flow on construction site, increase of adherence to long-term planning, reduction of total term, and facility in managing teams. Moreover, it was possible to perform simple simulations of scenarios for project's planning using the line of balance, enabling the comparison of the study and the implementation of the most appropriate scenario for the project.

It was also possible to observe some difficulties in implementing the new scenario that may be considered in future researches. It is known that, however good balancing of teams and production rates, some activities cannot get into the pace of others, maybe because the complexity of work and/or the needs of the subcontractor and/or the variability inherent to the service.

About the limitations of the research, it is important to note that the project has not been finished yet, which is why it could not be possible to draw more definitive conclusions on the implementation of this new strategy of execution with the reduction of the transferring batch. Additionally, this case study refers only to one project. So, more researches about the subject need to be done.

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