

# LEAN MONITORING AND EVALUATION IN A CONSTRUCTION SITE: A PROPOSAL OF LEAN AUDITS

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## ABSTRACT

The positive situation currently experienced by building industry, towards to an industrialization and rationalization, is the result of various new technologies of production and management emerged in the 90s, in order to enhance the competitiveness of firms, increase the flexibility in the final products and improve the quality of these. One of these philosophies, specifically the one is against waste and seeks to add value to the product by understanding needs of the final customer, is known as lean construction. In accord to this, the objective of this study is to propose, through a case study in C. Rolim Engenharia Ltda. (Brazilian building company), guidelines for internal evaluations at the construction site about the level of application, implementation and consolidation of this philosophy in a company that already has embedded in its organizational culture. The methodology for the development of this proposal includes: characterization of the company which will be evaluated in this case study; formulation of the lean tool checklist according to lean practice of the company; and the definition of the application parameters, such as frequency and evaluation criteria. For this case study, the lean audits were applied monthly, from June 2011 to October 2011. These, in fact, point out to reach the goals set, once: all audits have attended more than 80% of the lean checklist requirements, and performance and areas for improvement in the lean aspect are reported on the Lean Diagnosis generated from the Lean Checklist, besides the fact that the audits and their Lean Diagnoses impact positively the process of making strategic and tactical decisions in the construction site.

## KEYWORDS

Lean construction, lean audits, performance measurement, construction site, quality.

## INTRODUCTION

The construction industry has passed in recent years, by a leap in technology of production and processes management. This is due to the new production systems formatted, which have sought to raise the competitiveness of enterprises through cost reduction, improved quality and flexibility.

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One of these new approaches to the production system is the lean construction philosophy, based on the principles of lean production system (Womack et al. 1990) and adapted to the needs of the construction industry, focusing on waste reduction and searching for continuous production flow (Koskela 1992).

Once construction companies are interested in the principles of lean construction and seek to implement these lean practices, it emerges the need for performance evaluation of the implementation of this system. So, that its management team can evaluate the advantages of the lean philosophy and set new goals to be achieved towards the consolidation of this lean philosophy. Similarly, companies which already have lean construction philosophy in their routines seek for ways of periodic performance evaluation of this system, in order to maintain the motivation to evolve in the practical use of lean tools and concepts and also self-evaluation.

The tools and methods published for evaluating performance in lean construction are few, still quite recent, and have very different methods of application. Some deal with a general and punctual classification of the company, others include customers' perceptions on the use of lean concepts by the construction company (Carvalho 2008). And some others are only helpful for those primary efforts for implementation of lean concepts (Nogueira and Saurin 2006 *apud* Carvalho 2008).

The main question that will guide this case study is to know the way that a periodic internal review, regarding the use of lean tools and concepts in construction sites, can be implemented in order to positively impact the evolution and consolidation of the lean philosophy. Therefore, it is hoped that these lean construction periodic evaluations, based on lean references and prepared in accordance to the construction company of this case study, can measure the degree of implementation and consolidation on use of lean tools and concepts. Finally, it is expected that these periodic evaluations motivate continuous improvements by monitoring performance and the evolution of lean ideas at the construction site in general.

To justify the company for joining in this case study, it is proposed that the diagnosis, generated from the proposed lean audits, of all construction sites, can feed the quality management system of the construction company, which, with some other strategic and tactical indicators, will serve as a tool for decision making. In addition, the company will have a comparative and competitive overview of all construction sites, allowing benchmarking between all of them. At last, there will be a new flow of information between the construction site and top management crew, because the evaluation will inform about quite operational tools and practices of lean construction system that cannot be analyzed carefully by the top managers compared to more strategic activities of them.

The main objective of this study is to propose guidelines for periodic evaluations that operate as internal auditing, and characterize the degree of implementation and consolidation of lean construction practices and concepts in construction sites.

In a more specific level, is expected to: develop a checklist of evaluation according to the case study, establish parameters for lean audits, develop and feed in a panel of lean evolution of audits results from all construction sites, and generate analysis of these results for the company's management team, in a more strategic approach.

## **CASE DESCRIPTION**

The methodology for implementation and conclusion of the proposed work consisted, initially, in conducting bibliographic research about internal audits and performance evaluations on the implementation of the philosophies of lean production or lean construction.

Then, through interviews and visits, the characterization of the company has been made, in order to identify needs that would have to be covered by the lean checklist tool, according to company history, particularities, management team, the implementation phases of construction sites projects and other relevant aspects.

After that, all guidelines for lean evaluation were formulated, including frequency of audits, evaluation criteria and aspects to be analyzed. This activity was totally dependent on the two previous activities, once the preparation of lean audit proposal is based on literature review and characterization of the case study.

Once the proposal of lean audits was validated by the top management team, the application of these audits on construction sites was started, as established periodicity, finally compiling to a panel of lean evolution of audit results over time in all construction sites, in order to compare them qualitatively and serve as a tool for strategic decision-making by the management team of the company.

### **C. Rolim Engenharia Company**

Founded in 1975, C. Rolim Engenharia's area of expertise now, after recent strategic definition, is exclusively property incorporation, specifically looking forward to Classes A and B, even though it already built industrial and commercial divisions in the past. C. Rolim already has more than 530.000m<sup>2</sup> of constructed area and 172.000m<sup>2</sup> under construction, fragmented into more than 12 buildings and 500 private units. About its effective people, C. Rolim already has 880 employees of its own in construction itself and 54 employees in the administrative team of construction sites or central office, being 16 civil engineers or under engineering graduation.

The lean journey in this company started in 2004, when its top managers attended the 1<sup>st</sup> 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 process 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. Thus, since 2004 C. Rolim Engenharia innovates with its lean philosophy.

However, before getting through internalization of the concepts and application of tools, it was necessary to stabilize the production through a good planning system. The planning methodology was formerly based on the theory of PMI (Project Management Institute) and it was replaced by the methodology of planning and production management in hierarchical levels (Ballard 2000, Formoso 2001). This new concept allowed the company to have more clarity in its decisions and routine of the construction site, providing the stability required for a change in the management philosophy.

Over these seven years, the company has been using many lean tools: kanbans for inventory and mortar, ANDON, supply scheduling, material flow's kanban, poka-yokes, 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.

Thus, the managers who were interviewed identify that in a lean periodic audit process for the company, all of these conditions must be analyzed, because they are the ones motivating and increasing the production and “lean” manpower at construction site, as they need some more qualified education to absorb the concepts of lean philosophy.

## LEAN AUDITS

Once this lean issue was contextualized and the company was characterized, the next step for preparing the lean checklist was started. Based on existing lean evaluating performance tools (Carvalho 2008) and in order to consider both lean production principles (Womack et al. 1990) and lean construction principles (Koskela 1992), the technical crew (top managers of C. Rolim Engenharia and a graduate student) designed the lean checklist divided into seven issues. It is very important to have in mind that this lean checklist was designed specifically for the company of this case study, i.e., the checklist approach considers the lean journey of the company and its goals and targets on lean evolution.

The seven issues of the checklist are: Planning and Production Management, Kanbans, Jidoka, Flows, Production, Transparency and Cleaning, Organizing and Safety. Each one includes general questions and specific features of the company about this theme (Valente 2011). In a table 1, it is shown below the references that were consulted and followed to a better understanding of the subject and aspects to be evaluated in each issue. For the little available space in this article, the final and complete version of the lean checklist is online<sup>5</sup> on C. Rolim Engenharia’s website.

Table 1 – References for lean checklist preparation (Table 4.1 in Valente 2011)

Lean Checklist Issue	References
Planning and Production Management	Oliveira, K. A. Z. 1999 Formoso 2001
Kanbans	Heineck and Machado 2001
Jidoka	Novaes 2008
Flows	Alves 2000 Mourão 2007
Production	Koskela 2000 Mourão 2007
Transparency	Barros Neto et al 2005
Cleaning, Organizing and Safety	-

Given that, the purpose of this lean audit is that it is held periodically throughout the execution of the building, and to space its audits satisfactorily for perception of changes and improvements, this lean audit proposal happened monthly. It was agreed between top management and construction site managers that lean audits would occur at the end of each month of the year.

<sup>5</sup> <http://www.crolim.com.br/leanchecklist.htm>

The lean audit requirements involve both qualitative and quantitative aspects, in order to inform the top managers all relevant observations, because they do not have enough time to walk through all of construction site periodically, making it harder to identify difficulties and evolutions. However, it is clear that, for each question of each issue, there is a qualitative evaluation of this aspect, which will be analyzed through some criteria.

Five evaluation criteria were adopted for each one of the proposed items in the lean checklist: None at Work, corresponding to zero points; Poor, corresponding to 1 point; Good, corresponding to 2 points; Excellent, corresponding to 3 points; and Not Applicable, when the item of the issue is excluded from the whole analysis. This scale was divided in only four parts, so that it's simple, easy and leaves no doubt for the auditor to conclude on which level that tool or technique evaluated is. More than that, given the particularities of each phase of the construction site, it was necessary to include the criteria that the tool or the technique was not applicable to that moment.

The total score is the maximum sum of all items which can be applied at that moment of the construction site. That is, the sum total for the first block, which has ten items, is 30 points. Likewise, the sum total for the second block, which has six items is 18 points. However, if from these six items, two of them do not apply to the current stage of the construction site, then the sum total of points for this block is 12 points. Complementing the previous example, if from these four items that can be analyzed in the construction site, two of them are rated as Good and the other two, as Excellent, so the total points will be only 10 of the possible 12 points, or 83% of the total. And, like the example given, it happens to all other blocks. Table 2, below, illustrates the example more clearly.

Table 2 – Example of lean audit calculation of points (Table 4.2 in Valente 2011)

Block:	Questions Related:	Not Applicable:	Grade:
Planning and Production Management	The Line of Balance is being monitored monthly? Who is responsible for this monitoring?		3
	Thermometer and X-ray are updated and displayed in the technical room? What is the current value of the thermometer?		3
	The Look Ahead Plan is being updated and monitored monthly? Who is responsible for this monitoring? The restrictions are properly listed?		3
	The IRR is updated and displayed in the technical room?		3
	The Last Planner is updated to the current week? The previous records are properly stored? Who is responsible for this monitoring?		3
	The PPC is updated to the current week (about the previous week)?		3
	The data from the PPC and the causes of non-compliance of activities are being tabulated and analyzed for continuous improvement?		3
	There are improvements made from the analysis of the causes of the problems occurred? What are they? The recurrence of the problems decreased with the improvements adopted?		3

	Those responsible for Planning and Production Management have enough time for planning activities and improvement?		3
	The Schedule of Supplies based in Long / Medium / Short Time is updated?		3
Block Total:		0	30
% Achieved			100%
Kanbans	The Minimum Inventory's Kanbans are properly calculated and marked?	x	
	Who manages the Mortar's Kanbans? The tasks are properly distributed among its leaders?		3
	The Mortar's Kanbans are being placed on the central manager of mortar kanbans one day before use?		3
	The requested features from the Mortar's Kanbans are being distributed to the teams before they start their work at the pavements?		2
	The workplace is clean, neat and organized (clean and well maintained kanban manager, clock and table features in a visible place)?		2
	The Materials Kanbans are fully operational? For which materials, specifically?	x	
Block Total		6	10
% Achieved			83%

The lean checklist tool was applied to the manager of the construction site, who has strategic knowledge as well as tactical and operational knowledge of the construction site. Also, people directly linked to production were asked, such as the worker of concrete mixer, for items related to mortar's kanban and the storekeeper, for items related to the organization of inventory and warehouse.

Finally, the lean diagnosis generated from the compilation of this checklist contains the percentage achieved by the construction site of as many points as possible from all blocks, and this is the main result of the audit. In order to assist strategic decision making, all relevant information regarding the aspects analyzed are posted on the observation camp of the lean diagnosis.

## RESULTS

Now, it is analyzed the general percentages of each of the four construction sites included in this case study, over the months that they were audited. It is important to remember that the calculation of the general percentage is similar to the calculation of the percentage of the block; it means that the non-applicable items are excluded and the division between the total obtained points and the total applicable points leads, finally, to the total percentage. The line graph that is shown below represents the evolution of the construction sites between June and October 2011.

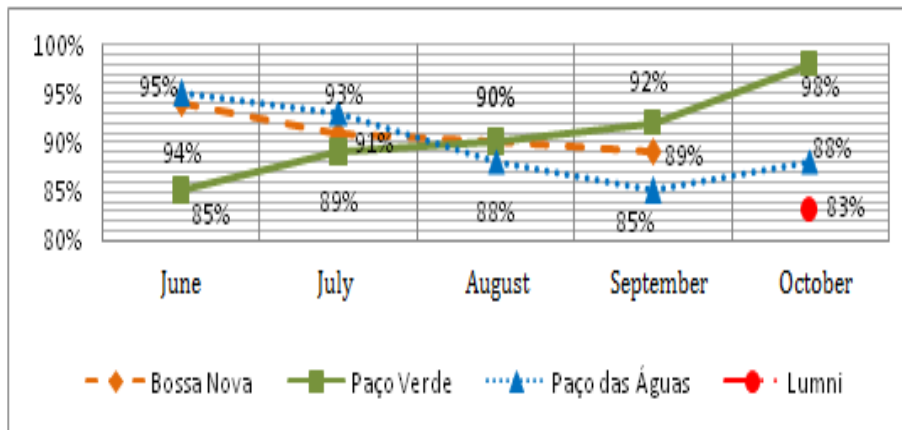


Figure 1 – Lean Evolution Panel - C. Rolim Engenharia (Figure 5.6 in Valente 2011)

Initially, only with a view to the axis of ordinate of the graph, it is noted the good overall results, since no audit resulted in a percentage lower than 80%. In fact, the lowest result found was for Lumni, that deserves some reservations to the fact that it just had one audit, i.e., there was no earlier scenario that could provide improvements such as it happened to the other construction sites, besides the fact that this initial phase of the construction site prevents many of lean tools and techniques to be applicable, making those that are applicable more significant and representative in the final result of the audit, because more items are not applicable and the total applicable points is much lower than the total points of the lean checklist.

The orange dashed line, corresponding to the Bossa Nova construction site, is descending towards to the months of the audit and its results decrease from 94% to 89%, in the month of September. In this case, it is important to highlight that the construction site is in its final phase and the building is almost finished, and over this last six months of work, more and more lean tools and techniques no longer are used because there is a growing demobilization of tools, equipment and production teams. So, it is expected that, as the construction is going to finish, this lean percentage decreases. However, it is also important to note that even the last and lowest percentage of 89% is a good result in comparison of results obtained in the graph.

For Paço Verde construction site, the green line shows its evolution and continuing consolidation of practices, lean tools and techniques over time. The line is up and jumps from 85% to 98% in just five months. It is a fact that the timing of the construction site, with more than one year for finishing, i.e., relatively slack, and with the concrete structure almost finished and production teams working and taking place in almost all floors, it provides the application of nearly all items of the checklist, avoiding that the results depend significantly on some items, while others are not applicable. It is possible to predict, based on the results of Bossa Nova, that this line will remain at its high level for some months, and approaching to the end of the project, it will suffer a new downward slope, as seen in the above paragraph.

For Paço das Águas construction site, with more than two years for finishing, it is noticed that the dotted blue line at first decreases from the value of 95% to 85%, and then ascends to his final result of 88% in October. This first moment of decline can be explained by the fact that many of the tools that were not applicable to the

construction site (at the origin of the line) become fully evaluable (at its most intermediate), and in some cases, poorly. This happened, for example, with the ANDON and the materials' and ceramics' panels, within the last two months of evaluation. For the second moment of the line, of ascension now, it is possible to see an evolution about many of the blocks of evaluation, such as PPM, Kanban, Flow and Production, showing how the audit results are being analyzed by management team of the construction site for continuous improvements in each block.

Interestingly, if it is compared the second moment of ascension of Paço das Águas with the first two results of the audits of Paço Verde, it is possible to identify a similarity, which may suggest that the continuity of the line of Paço das Águas in the next months is similar to the line described now for Paço Verde.

Thus, after analyzing all the results, the lines of evolution, and having in mind that the phases of all construction sites analyzed are complementary to one another, it is possible to relate the phase of the construction with the degree of implementation and consolidation of the lean tools and techniques of the company under study, it means it may imply a behavior model of lean evolution over the entire time of construction of a single building. This is due to the fact that, if aligned the audit results in chronological order in advance of the construction, i.e., starting with the result of Lumni, being followed through Paço das Águas results, passing through Paço Verde results and finishing with Bossa Nova results, there is a schematic overview of the 36 months of execution of a standard construction site of the company. This suggestion is presented below on Figure 2.

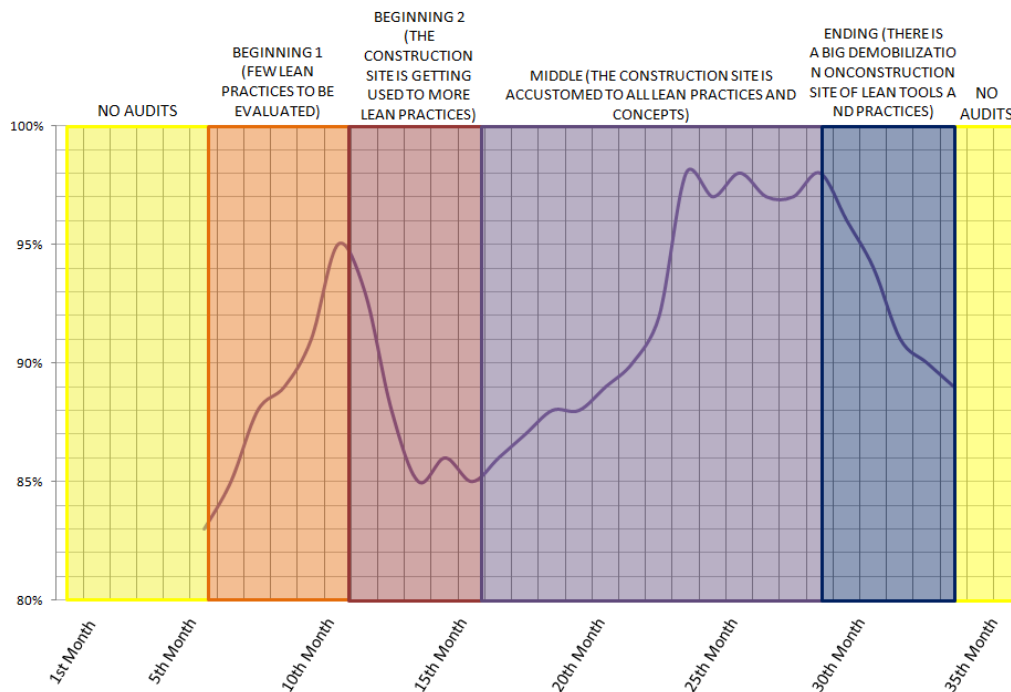


Figure 2 – Suggestion of lean evolution results in a single construction site over all time of execution (Adapted from Figure 5.7 in Valente 2011)



Anyway, it is first necessary to analyze a construction site through lean audits over all time of construction, so that this suggestion can be criticized or validated for future use.

## **CONCLUSIONS**

It is concluded that the goals were achieved. First, the results showed that proposed guidelines for internal lean audits on construction sites (lean checklist tool, timing of application and evaluation criteria) are applicable, given the limitations discussed, for all phases of the construction, and demonstrate the performance and points to improve in the various lean aspects analyzed. Furthermore, it was identified that the audit results are used by managers of the construction site and top managers of the company as a diagnosis of what should be improved in the construction site for the next audit, positively impacting the process of decision-making both tactical and operational, as well as strategic decisions.

It was also possible to suggest how the results of the audits would behave for all the months of execution of a single construction site, in view of the results obtained for the four construction sites evaluated. And finally, it was noted that the comparison between construction sites in different phases of execution, from the Lean Evolution Panel, is not indicated because the overall results may be similar, but only these results, it is not possible to know which tools are actually being applied or not in the construction sites, or how much better in one specific item is one construction site towards another one.

About the limitations of research, it is important to note that this work is a case study, and has not pretensions of coverage to other companies and their results cannot be taken by other companies.

As ideas for further work, it is suggested for: lean audits to be applied over the entire development and execution time of the same construction site, so that it may be possible to criticize, validate and compare the graphical suggestion of lean evolution proposed, certifying it as a satisfactory model of control and comparison of results or rejecting its conception; this proposed lean internal audit to be formatted in a way that it can cover different companies, in other words, that the peculiarities of the case study company give space to more general characteristics of the blocks of lean aspects, in order to verify the degree of lean introduction, implementation and consolidation in companies; and, finally, this proposed lean internal audit to be performed in different construction sites in the same phase of execution, so that it can compare them directly, which could not happen in this work.

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