Lean Construction:

Lean Practices Maturity Model Proposal

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Extended Abstract

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1. Introduction

Given the problems facing the Architecture, Engineering and Construction industry, this presents a chance to study the issues that currently are present in construction, and to understand what possible opportunities for improvement exist. Lean Construction might be able to offer solutions to these problems, since its main goal is to do more with less, improve effectiveness, and reduce waste in production overall.

In this work we hope to accomplish two main goals. Firstly we want to study the current state of the issues that plague the construction industry in Portugal, and then, update those issues to the current days, while also taking into account the previous studies. This will be achieved by making a comparison between earlier studies.

To update the previous studies, we studied the data gathering and analysis methods used by the older studies. Based on the methods we found, we decided it would be best to arrange a meeting between industry professionals, and discuss on the spot, which issues are the direst. Previous studies had used inquiries and interviews, but an open discussion provides better results, since we are able to have all the professionals in the same spot.

This approach allows us to focus the group on the main goal, which is to find issues that can be solved by the application of Lean practices. One major problem with the historical data, is that the issues mentioned there can't be solved, for instance, bad weather, bad soil conditions, delays from government officials.

Secondly, we created a proposal for a Maturity Model, one that evaluates the current practices of a construction organization. The practices that are taken into account vary from operational processes that share similarities to ones suggested by Lean Construction, to soft skills. For example, if the organization is committed to implement new practices, or if there is training of the people involved in the application on new practices, among other parameters that can be taken into consideration.

Based on the results of the evaluation, the model will prioritize a set number of practices to mitigate the weak points of the organization. It will take into account which areas the organization is doing it's worst, and will push practices that improve on such areas.

All this work was developed with the help of the Lean Work Group. This group was an initiative by the PTPC (Portuguese Construction Technological Platform), to study and spread the knowledge of *Lean* practices in the construction industry. The results achieved were shared with the Lean Work Group, which then presented some of the results in a Seminar held at the National Laboratory for Civil Engineering (LNEC).

2. Problems and opportunities in the Portuguese AEC industry

To study the problems in the construction industry, we started by looking at what other studies had already done. We chose studies that tackled and displayed the problems present in the industry in their respective year. We focused our attention searching for recent studies, so that we get a view of the current situation as well as the evolution of the problems since the crisis began. With this being said we compiled a list of studies that suited our needs and proceeded to evaluate them.

The studies used in our analysis of the Portuguese industry problems are (Couto, 2006; Branco, 2007; Cabrita, 2008; André, 2010; Martins, 2011; Cruz, 2012; Silva, 2014).

These studies focus on the current problems of the construction industry, and all of them follow a similar structure of analysis to one another, which makes comparing them quite a manageable task. The backbone of the methodology of analysis of these studies is the PhD thesis by Couto, (2006). Most studies base their analysis on this study, since it's the most comprehensive of the lot.

The methodology used by the studies to reach their conclusions can be seen in following Table 1. It shows all the relevant analysis and data collection methods of each study.

Table 1 – Evaluation tools and methods used by each study

Evaluation Methods	**Couto**	**Branco**	**Cabrita**	**André**	**Martins**	**Cruz**	**Silva**
	2006	2007	2008	2010	2011	2012	2014
Is it based on a pre-existing industry issue list?							
Pre-existing issues list	X	X	X	X	X	X	X
What data collection methods were used?							
Interview	X				X		
Inquiries	X	X	X	X	X	X	X
Construction oversight		X	X	X			
Quantitative analysis (a value is attributed to an issue)							
Likert Scale		X	X	X	X	X	X
→ Frequency (Probability)	X	X	X	X	X	X	X
→ Severity (Impact)	X	X	X	X	X	X	X
→ Cost					X		
→ Importance F7xS (aka. Relevance)	X	X			X		X
Qualitative analysis (opinion on the subject matter)							
Inefficiencies	X						
Results	X		X				X
Indicators (Control Methods)	X				X		
Statistical analysis (for validation of the results, and sample size)							
Spearman Test (correlation)	X				X		X
Kendall Test	X						

Despite there being a lot of similarities between the data collection and analysis methods, the same cannot be said about the sample size. Some are quite large, while other are limited only to one organization, so the feedback was given only by the employers working there. The Table 2 shows the sample size and typology of the inquired for each study.

Table 2 – Sample Size and typology of the inquired for each study

Studies	Inquired					
	Private Developer	Public Developer	Designers	Contractor	Employees	Total
Couto, 2006	17	62	26	59		164
Interviewed →	5	18	8	8		39
Branco, 2007					20	20
Cabrita, 2008					13	13
André, 2010					17	17
Martins, 2011	8	10	13			31
Cruz, 2012		8	11	13		32
Silva, 2014				343		343

The main goal of this chapter was to collect data from older studies, and to compare them to the data that was collected during a group workshop that took place in November 2015, in the LNEC installations (National Laboratory for Civil Engineering).

Several entities were asked to give their feedback on the problems facing their work. These entities present comprised mostly of contractors, but there were also designers, developers and the oversight branch of construction. On this workshop a discussion was opened to collect a new list of inefficiencies.

Table 3 shows the compilation of the results obtained from the workshop, as well as comparing them to the older studies found. The red T, in the results column, shows which problems the group mentioned as being the most serious currently in construction.

Note that equipment is mentioned for the first time. This is because the organizations that came to this conclusion are organizations that use *Lean Construction* practices, for them the traditional way equipment is used is very low efficiency, with no attention given to repair times, or scheduled repairs. Also no attention is given to preemptive repair, to avoid major breakdowns in the future, something that *Lean* focuses on heavily. These organizations would help shape a more *Lean* view of the issues discussed in the group.

With the compilation of Inefficiencies done, we then identified the opportunities presented by *Lean Construction*. We compiled a list of *Lean* practices that was first presented to the group for analysis. Some of the *Lean* practices initially presented were not suitable for application in the construction industry. Also it was discussed if the applicability of the selected practices could have an impact in the problems that have been presented. Only practices that were applicable to construction, and that could affect the problems found were selected.

The results of both the gathering of inefficiencies of the national construction industry, and the final *Lean* practices list that the group deemed usable in the industry are presented in Table 3 and Table 4, respectively.

Table 3 – Compilation of inefficiencies results

Inefficiencies	Couto 2006	Branco 2007	Cabrita 2008	André 2010	Martins 2011	Cruz 2012	Silva 2014	Group results 2015
Developers								
Frequent change requests	X	X	X		X	X	X	
Delays on decisions by the developers		X	X	X	X	X	X	T
Unrealistic date setting	X	X		X	X		X	T
Communication failures			X		X		X	T
Interferences and suspension of work		X		X			X	
Bad proposal selection criteria	X			X		X		T
Delays on the workplace availability		X				X		
Designers								
Lacking information before design	X	X		X		X	X	T
Errors and divergences on designs	X			X		X		T
Delays on design production	X				X			
Lack of communication in design phase	X		X					T
Project/design complexity		X	X					
Delays on oversight and revision of work				X	X			
Work overload					X			T
Oversight								
Delays on review and approval of work		X		X			X	
Delays on oversight and trials		X		X				
Lack of experience		X						T
Workforce								
Lack of qualified workforce	X		X	X			X	T
Low productivity	X		X	X			X	
Lack of workers				X	X			
Equipment								
Equipment breakdown								**Mentioned**
Lack of equipment								**Mentioned**
Low productivity and efficiency								**Mentioned**
Materials								
Delay on material delivery		X	X				X	
Delays on material production			X				X	
Late search of needed materials		X						
Other issues								
Municipal and exterior paperwork delays	X	X	X	X	X	X	X	
Climacteric conditions		X	X	X	X	X		
Lack of finance					X	X	X	
Bad soil and terrain conditions		X		X		X		

Table 4 – Selection of practices and techniques

***Lean* practices and techniques**	
Big Room	Integrated Project Delivery
5S	Virtual Design & Construction (BIM)
Last Planner System	Standard Works
Kaizen Events	Spaghetti Chart
A3 Report	Gemba Walk
Visual Control	SMED
Value Stream Mapping	Logistic train
Briefing Room	Root Cause Analysis
Kanbans	Value Engineering
Poke Yoke	KPI
Heijunka	TPM

3. Maturity Model Proposal

The goal of this chapter is to create a tool that allows organizations to self-evaluate their current practices against a set list of Lean practices that were established with the help of the Lean Work Group. The model can also be used as a basis for further improvement and development of maturity evaluation.

The main objective of a Maturity Model is to evaluate an organization, the purpose of this evaluation is to measure how well the practices inside an organization are implemented and applied. There are several factors that come into account when you evaluate an organizations practices (Nesensohn, et al., 2014). We will base our proposal on existing models. Maturity Models started being applied in the software industry, with one of the most well-known models having been developed by the Carnegie Melon University, this model is known as CMMI. We present in Table 5 a number of Maturity Models that were used for the elaboration of our own model.

Table 5 – Maturity Models

Maturity Models
Capability Maturity Model Integrated (CMMI)
Organizational Project Management Maturity Model (OPM3)
Berkley Project Management Process Maturity Model
Portfolio, Program and Project Management Maturity Model (P3M3)
Standardized Process Improvement for Construction Enterprises (SPICE)

One model that will be heavily taken into consideration is the SPICE model. This model is an adaption of the CMMI to the construction industry, being developed by the Center for Information Technology in Construction, University of Saltford, in the UK.

After studying maturity models, we established a basic framework that shows how our own maturity model will work. In Image 1 we can see all the steps, tools, and outputs of the maturity model.

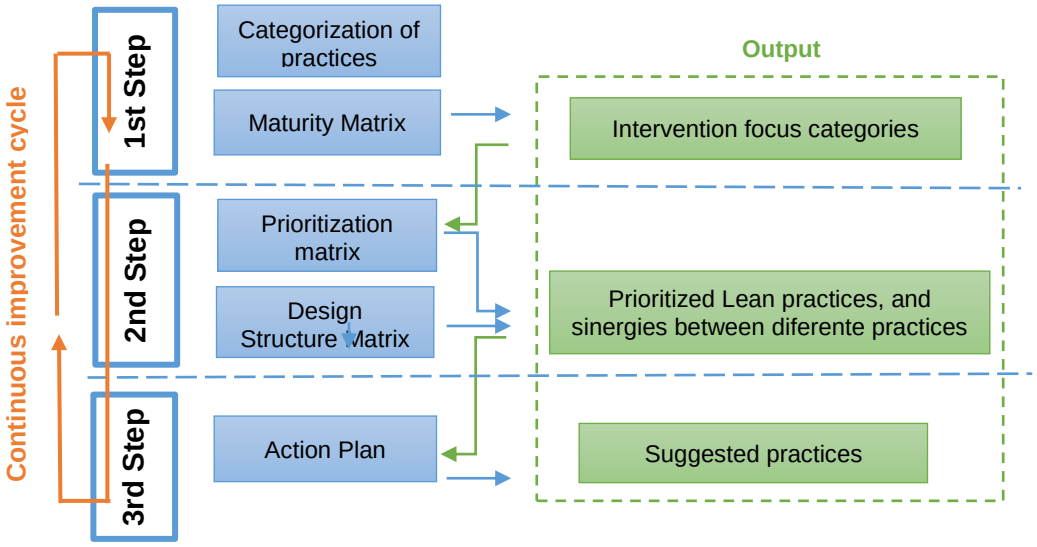

Image 1 – Basic function framework of the proposed maturity model

Step 1: Evaluation of current practices

The first step is to evaluate the current practices of the organization. The first approach of the majority of the models is to have the organization answers an inquiry about their own practices. With this in mind we set to make our very own inquiry. The questions were built based around each practice, how they work, what they require, and what they set to achieve. To relate the questions with the practices we had to create categories that represent the field of use of each practice (Etges, et al., 2012). Table 6 shows the suggested categories.

Table 6 – Categories that relate fields of use

Categories	
1. Human Resources and autonomous work	6. “Pull” production
2. Continuous improvement	7. Layout and flow of work and movement
3. Standard Work	8. Information and communication technologies
4. Production Planning and control	9. Visual control, benchmarking, and performance metrics
5. Design Planning and control	

Each practice has a set number of questions depending on how difficult it is to implement that practice, this was done with the help of the group. Hard to implement practices have 10 questions, medium have 5 and easy have 3, with the answers to each question being Yes or No. A positive answer grants 1 point to the respective category.

A second inquiry was created, this was suggested by the group, that found that evaluating only practices was insufficient. The same happens in Maturity Models, they take into account Process Enablers, are soft skills that help ensure a correct implementation of new practices, and also guarantee that a practice will keep being used correctly, and not forgotten (Maasouman, 2014). We created another inquiry that evaluated the Process Enablers presented in Table 7.

Table 7 – Process Enablers used in our proposal

Process Enablers
Commitment and leadership
Implementation capacity
Comprehension and understanding of the activities
Process evaluation
Results verification

Each process enabler has 4 questions, with 5 possible answers. The answers to each question score the following values, 0, 5, 10, 20 and 25. A process enabler is fully mature when a score of 100 can be achieved. Each category will be scored by the 5 process enablers suggested, since they are essential for implementation no matter the category, this also follows the example of the other Maturity Models.

At this point we have the results of the evaluation of the practices and process enablers. We are left with a practices score for each category, and each category has 5 scores for each process enablers. Now it’s time to build the tools that look at what practices to prioritize, and what synergies exists between the application of each practices.

Step 2: Prioritization of practices and synergies

Several members of the Lean Work Group mentioned that some practices would benefit greatly from the simultaneous application of other practices (Tuholski & Tommelein, 2008). Based on this we set to build a DSM (Design Structure Matrix), these matrixes are a tool that show correlation between the practices and how they relate to each other. In Image 2, we can see a glimpse of the full DSM.

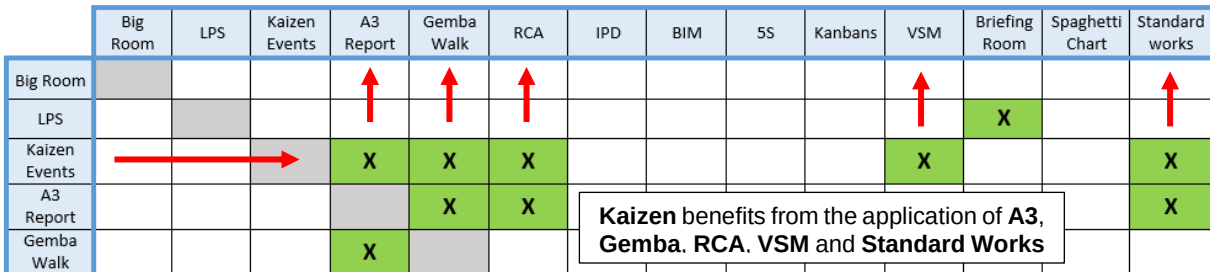

Image 2 – Sample Reading of the DSM created

The DSM should be able to transmit, to the organization, the message that some practices would greatly benefit from the application of others, rather than solo implementation of practices.

The prioritization of practices is based on the assumption that cost and time might affect the number of practices that an organization is capable of implementing. We need to take into account the benefits that a practice can bring versus the difficulty of implementation (Gosenheimer, 2012).

We had already gathered from the Lean Work Group, the difficulty of implementation of each practice and the expected reward from its application. With this information we were able to build a matrix that would prioritize the practices with the least difficulty and highest reward for implementation.

Based on how prioritization matrixes are created we followed the same set of logic and created the following score values to be used in the creation of the matrix, as seen in Table 8.

Table 8 – Score of criteria

Criteria	Weight	Score
Reward	4	High = 5; Medium = 4, Low = 1
Complexity	3	High = 1; Medium = 4, Low = 5

The values for each cell are calculated by using the formula presented.

$$Practice\ Score = Comp.\times Comp.Weight + Rew.\times Rew.Weight$$

We can see in Table 9 the final table with all cell values calculated, this matrix will prioritize the most effective practices first, choosing the ones that are higher reward vs. low implementation complexity.

Table 9 – Prioritization of practices by complexity and reward

Reward	High	23	**32**	**35**	
	Medium	19	**28**	**31**	
	Low	7	16	19	
		High	Medium	Low	Complexity

This matrix allows us to prioritize practices so that in Step 3 we suggest the most effective practices first.

Step 3: Action Plan and suggestion of practices

The action plan is the culmination of all the tools and inquiries that were elaborated in the previous steps. Here you should be able to see an organizations weak points, as well as a suggestion of practices for the categories that were lacking maturity.

The first results presented in the action plan, show in which categories the organization has practices that are relatively far from the ideals of Lean Construction. At the same time it shows the scores of the process enablers for each category. A sample of possible results is shown in Image 3.

		Process Enablers				
Categories	Category Score (in descending order)	Commitment and leadership	Implementation capacity	Comprehension and understanding of the activities	Process evaluation	Results Verification
1. Human Resources and autonomous work	50	75	85	70	35	45
6. "Pull" production	56	10	5	35	40	10
3. Standard Work	58	25	5	20	5	50
4. Production Planning and control	62	45	25	45	25	25
5. Design Planning and control	63	25	10	25	10	5
9. Visual control, benchmarking, and performance metrics	71	0	5	0	25	25
2. Continuous improvement	76	25	0	5	50	0
7. Layout and flow of work and movement	79	25	0	25	0	45
8. Information and communication technologies	100	25	10	50	10	0

Image 3 – Maturity results for each category and process enabler

Based on these values the action plan will show the suggested list of practices for a given number of weak categories. The practices are shown in descending order, with the most important practices showing up first. You can also see that the model adjusts its suggestion depending on how many categories you want to improve by implementing Lean practices. A sample is provided in Image 4.

Practices suggested for the worst category	Practices suggested for the 2 worst categories	Practices suggested for the 3 worst categories
		Heijunka
		A3 Report
		Kanban
		Kaizen Events
	Heijunka	5S
	Kanban	LPS
	LPS	IPD
	IPD	BIM
IPD	BIM	Logistic Train
BIM	Logistic Train	Big Room
Big Room	Big Room	Briefing Room
Briefing Room	Briefing Room	Standard Works

Image 4 – Sample of Maturity Model suggestion

4. Conclusions

The work started by older studies, of collecting and compiling the inefficiencies of the Portuguese Construction industry, has been updated in this work. This time we had the opportunity to include entities that provided us with a Lean perspective on the whole inefficiencies debacle, bringing new insight to the study of inefficiencies.

Given all of the inefficiencies provided and collected, there is a clear necessity in the current Portuguese Construction industry for improvement of production and overall operating and planning processes. The inefficiencies related to equipment were mentioned for the first time in any of the studies covered, this was due to the fact that the people mentioning this problem were Lean practitioners, for them equipment, if managed in the traditional way, is not effective at all and contributes a great deal to overall waste generated.

With the help of the Lean Work Group, we were able to gather a series of practices that through consensus, were deemed applicable to the Portuguese Construction Industry. These practices would later on be used to create our maturity model.

The elaboration of the maturity model, enabled us to start developing a tool that might be used by organizations to get an idea of what their current standing in Lean Construction is. This is one of many stepping stones that an organization must go through. The current model developed, through an inquiry, tries to figure out if there are practices being applied in an organization that are similar to those described by the Lean Construction practitioners, it also tries to evaluate, to a certain extent, the maturity of the culture behind the organization. It is this backbone that allows an organization to successfully implement new practices and to assure that they can continue to be used and also improved as they are used, time and time again

Based on the evaluation the maturity model with present the weak points of an organization. It will point out which categories of practices are the weakest, and will also show what aspects of the culture are missing or fragile. It then gives suggestions on which practices can be implemented where.

In the future, the inefficiencies can keep being updated to see if there are any changes in the industry, may they be positive or negative. The list of practices can be added upon, as there is always room for more Lean practices that are applicable to the Construction Industry. The Maturity Model that has been presented can be built upon, it can be used as a basis for a more developed and comprehensive model to be developed. The maturity model can be adapted to incorporate several levels of maturity, changing its questions and practices with each one, this is what models like CMMI do and is the next logical step for a maturity model to take. It could also take more factors into consideration, like financial results, performance indicators.

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