

RAPID LEAN CONSTRUCTION-QUALITY RATING MODEL (LCR)

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ABSTRACT

The *rapid Lean Construction-quality⁸ Rating model* (LCR) is a unique and easy model to evaluate the quality and degree of leanness related to the pursuit of the lean-philosophy in a construction project. A standardized framework enables to combine qualitative evaluation through observation together with quantitative analysis.

A categorized evaluation scheme is proposed within the same model, to easily visualize and interpret the rating results. The degree of LC-application is hereby distinguished between *d*-projects (low level, projects without any LC knowledge, low quality and highly wasteful) and *aaa* - projects (high level). This standardized rating model can be applied to all kinds of construction projects and within different geographic contexts. One hour of construction site visit and another half-hour for the analysis is required to undertake the rating. The model further suggests applying the rating model on three or more construction projects of one company. This should allow carrying the evaluation forward from a project to a company level.

KEY WORDS

rating model, lean construction, qualitative and quantitative analysis, classification of projects

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⁸ LC = Lean Construction. The term “LC-quality” was added to widen the application scope from pure Lean-Construction terminology. In this way people without Lean-Construction knowledge can implicate the content- and better understand the focus of this model.

INTRODUCTION

Evaluating the quality- and application status of high abstract principles of Lean Construction (LC)¹ in construction projects or companies is mostly restricted to qualitative measures. Indeed, principles of lean-manufacturing such as detection of value, defining the value-stream, creation of flow and pull in processes and strive for perfection through continuous improvement (Womack & Jones, 1996) are less tangible and difficult to measure in the construction environment.

In this research an attempt was made to provide a tool for a quick assessment of a construction project regarding to the use of lean production. The objective of this new rating model is to provide a rapid quantitative assessment of the degree of pursuing leanness in a construction environment. This is based on a one-page questionnaire framework that should be conducted together with a site visit.

RESEARCH FRAMEWORK

BACKGROUND AND OBJECTIVE OF THE RAPID-LC-QUALITY RATING MODEL (LCR)

A research exchange program (PROBRAL) between the University of Karlsruhe (TH), Germany, and the Universidade Federal do Paraná

(UFPR) at Curitiba, Brazil, focus on the application of Lean-Construction (LC) in Germany and Brazil. Researchers conducted in 2007 several construction-site visits in both countries with main emphasis on high-rise buildings. Some creative applications of LC-methods were detected through a qualitative analysis, interviewing construction employees and managers. Projects were compared with each others, the results were reported, visually explained (supported by photos) and a benchmarking of LC-practices was conducted. The difficulty is to define "the benchmark".

A scientific rating framework was missing in literature and practice for Lean-Construction and the limitations for comparability of construction projects in different countries were also not clear. The construction industry in Germany is in general more mechanized and standardized than the Brazilian construction industry. South American constructions on the other hand often imply more flexibility to adapt and optimize processes and organizations towards lean-principles and a more intensive use of social strategies to improve production. Previous investigations also showed that several companies apply parts of LC-principles without knowing anything about the lean-philosophy.

Therefore a sound and stable conceptual framework was required and developed to provide also quantitatively a distinction of the different stages of applying LC within construction projects in both countries. The target for this model was to be rapidly applicable (within an one-hour site visit), to provide a quick and visual overview of the status of the results and to categorize the project in order to provide an agenda for

¹ Lean Construction (LC) is derived originally from the Toyota Production System and the principles of lean-thinking defined by Womack, Jones and Roos (1990). Koskela (1992) provides the first translation of this philosophy of process- and quality-value oriented principles into the context of construction.

improvement. Furthermore, the model should be flexible enough to be applied by different researchers and applicable to different construction environments (whether in Germany or Brazil) and to different construction types, such as high-rise buildings, infrastructure projects (e.g. highway construction) and small-house constructions.

The LCR model also helps interviewers to quickly identify and explain the actual use of main principles of lean construction in practice. The result of this rapid assessment should also serve financial analysts as a supporting tool to rate construction-project risks and credit management, by providing insights into the companies' value-, quality- and improvement focus within the production process.

DEVELOPMENT CONCEPT OF THE RAPID LC- QUALITY RATING MODEL (LCR)

Before developing the model, a brainstorming between researchers of both countries and literature research was conducted, about the main lean-construction principles and the question of how these principles can be quantitatively evaluated within construction projects through site visits by external researchers. Two different former framework-models were selected from literature and partly incorporated into the LCR-Model:

- The Rapid Plant Assessment, (Goodson, 2002). This model provides a quick rating method to evaluate production of manufacturing companies.
- A model for evaluating the degree of leanness of manufacturing firms, (Soriano-Meier, Forrester, 2001). This

model itself is based on a model developed by Boyer (1996) and another model by Karlsson and Ahlström (1996).

The Rapid Plant Assessment (RPA) Analysis was developed in the 1990th. It is based on a manufacturing plant visit with a team of analyzing people. The analysis contains two evaluation modules, the RPA evaluation formula containing 11 categories and an additional questionnaire with 20 closed questions. The questions shall facilitate the rating within the categories. The eleven evaluation categories are: (1) client satisfaction, (2) safety, environment, orderliness, (3) optical management system, (4) planning system, (5) space utilization, material flow (6) stock management and work-process, (7) teamwork and motivation, (8) status and maintenance of machines, (9) dealing with complexity, (10) integration of suppliers, (11) effort to reach quality. The main focus of RPA is to provide to financial analysts an additional and simple evaluation tool to rate the production quality of a manufacturing firm. It is not adapted to project or construction environment².

The model of Soriano and Forrester (2001) for "evaluating the degree of leanness of manufacturing firms is based on a definition of 9 variables of leanness. Two different questionnaires are used, one for operations managers (engineers) and one for top management (CEOs). The operations managers questionnaires

² Further suggested reading: Goodson, E., (2002) Eine Fabrik unter die Lupe nehmen – schnell und effizient, (Rapid-Plant-Assessment) Harvard Business; Peppmeier and Schuppener (2003), Rating von Industrieunternehmen und Beurteilung der Fertigung, Betriebswirtschaftliche Blätter.

investigates the 9 variables of leanness with a rating scale from 1 to 7. The top-manager questionnaire shall investigate the managerial commitment to lean production, based on the concept of Boyer, (1996). It consists of (1) the commitment to Just-In-Time, (2) Total Quality Management, (3) quality leadership, (4) group problem solving, (5) training and (6) worker empowerment. This model is focusing on the stationary manufacturing industry but not on project management or construction industry (Further suggested reading: Soriano-Meier, H., Forrester, P.L. (2002) A model for evaluating the

degree of leanness of manufacturing firms, Journal of Integrated Manufacturing Systems).

The Rapid-LC quality Rating model (LCR) also partly incorporates a former detailed questionnaire on quality issues in construction projects, developed at UFPR (GRUPOTIC, 2007) and the benchmark of Lean-Construction principles elaborated within the PROBRAL program (Hofacker, Kirsch, Gehbauer, 2007). Figure 1 describes the proceeding for the development as well as the concept and contents of the Rapid LC-Quality Rating Model (LCR).

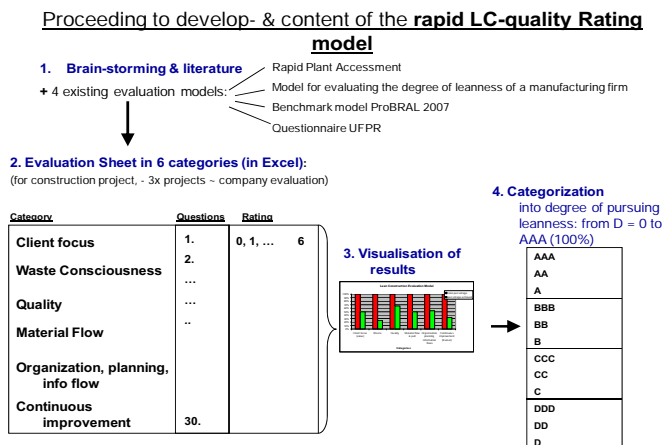


Figure 1: Proceeding of the LCR model development (1), and concept of the LCR model (2.-4.).

The five lean-principles as defined by Womack and Jones (1996) and Koskela's eleven LC-principles (Koskela, 1992) were taken into account to derive the contents of the questionnaire. These principles were crossed with questions applicable to the reality of construction sites. However, for applicability reasons, these lean-principles within the

questionnaire were split into six main categories, precised by 30 categorized questions. These six main categories are client focus (1), waste consciousness (2), quality (3), material flow (4), organization, planning, info-flow (5) and continuous improvement (6).

Each of the 30 question has a rating possibility with a rating-value

selectable from 0, (meaning not applied/very bad/ very low), up to the value 6, (as very good /very high /fully applied). The assessment of the rating scheme is derived from literature and the model of Soriano and Forrester (2001). Their scale was slightly modified from a assessment range from 1..7 to a range from 0..6, where the 0 denotes a complete absence of this point. The rating assessment was further calibrated and validated by applying the LCR-model on various construction sites and its results were discussed with researchers of both countries.

ASSESSMENT OF THE MODEL, THIRTY RATING QUESTIONS

Table 1 describes the 30 evaluation points, linked to the respective categories. For each of the evaluation points an additional explanation is elaborated, describing the examples and the meaning of the extreme values 0 and 6 (The content meaning of each extreme value can be downloaded together with the LCR model at <http://www.tmb.uni-karlsruhe.de/Hofacker.php>.)

Table 1: Evaluation sheet for construction visits, data input, Rapid LC-Quality Rating Model.

Category	Nr	Evaluation point	0...6
Client Focus	1.	Client focus, in terms of sales, marketing & strategy focus, detecting what is value for the client (& how well is this perceivable for the visitor)	
	2.	Regular client communication & flexibility to adapt to change requests	
	3.	Project flexibility and communication between project-designers and construction management (during execution)	
	4.	Cleanliness of the construction site (5S), orderliness, client-focus through cleanness and project-visualization in the engineers offices	
Waste Consciousness	5.	Waste of construction materials: detection of waste and consciousness on site	
	6.	Actions, knowledge & incentives to eliminate waste (overproduction, waiting time, unnecessary transport, rework, etc)	
	7.	Disposal (waste) management (recycling, separation of construction	
	8.	Space utilization: how efficient is the space utilized (material at clearly dedicated areas, small parts orderly gathered, as few space utilized as	
	9.	Wasted time (transportation time reduction, waiting time, usage of equipment and transport standardizations)	
Quality	10.	Regular quality control of construction materials (e.g. concrete certification-strength control)	
	11.	General quality certification existing for the project / company (e.g. ISO	
	12.	Visually perceived quality of the construction execution (variability to	
	13.	Safety on the construction site	
	14.	Root cause analysis for rework executed (5W)	
	15.	Standardization of processes	
	16.	Visual management systems (clear signs, self-explaining and quality controlling systems)	
	17.	Degree of mechanization (technical machining) to obtain a standard quality & performance, facilitating smooth and efficient construction processes	

Category	Nr	Evaluation point (continued)	0...6
Material flow & pull	18.	Kanban card system (existence and well operated)	
	19.	Just-In-Time concepts applied (measurable e.g. in the amount of stock, e.g. stocks > 1 week, no JIT)	
	20.	Use of ready-mixed concrete and efficient material flow on the construction site (e.g. manual in situ concrete = 0)	
	21.	Ordering system and time to get main material (concrete, steel, bricks) from suppliers (1 day = very good, 1 week = ok, > 2 weeks, bad (0))	
	22.	Use of transportation support systems (crane) integrating horizontal and vertical transportation, and standardization of transport (e.g. standard pallets)	
Organization/ planning / info flow	23.	How is the top management aware, convinced and supporting in the application of lean-construction?	
	24.	Motivation and self-responsibility of employees (are there actions, methods to promote this?)	
	25.	Multi-functional teams (how flexible are the employees to work on different work areas)	
	26.	Last Planner System applied with daily hurdle meetings (6). (or classical structural production planning 0)	
	27.	Communication tools (e.g. Andon applied)	
	28.	Is there a vertical and horizontal information system applied	
Continuous improvement, Kaizen	29.	How is the company striving for perfection, and how is a learning process from project to project applied?	
	30.	Is there continuous education for the employees (e.g. quality, further specialization, lean, etc)	

To keep the model simple and its results easily understandable, all questions are weighted equally with the same importance (factor = 1).

LCR MODEL UTILIZATION

DATA COLLECTION WITH THE LCR MODEL AND LIMITATION OF BIAS

To conduct application of the LCR model adequately, there are several necessary prerequisites. The interviews need to be well prepared before the site visit therefore project and company information should be gathered beforehand.

Site visits and interviews should be conducted with two or more interviewing people, in order to reduce bias and to facilitate observation and questioning.

The 30 rating points should be known from memory. The evaluation model should not be filled out during the site visit and questioning. This

facilitates better observation and creates a better atmosphere of confidence between the interviewers and interviewee. One hour of site visit is considered as enough to be able to rate the project according to the LCR Model. The two or more interviewers shall independently fill out the questionnaire directly after the visit. Afterwards the results of the external observers are compared, discussed, merged and the interviewers need to agree on a final version. It is also recommended that the same researchers apply the LCR-Model to as many projects as possible to get more experiences and a clearer rating notion. In this way bias shall be reduced as much as possible.

EVALUATION OF THE MODEL

For each of the six categories are calculated the percentages between total achievable- and achieved rating points. The results are visualized

within a graph. In this way it is easy to visually understand the current strengths and weaknesses of the production process within the respective project. Figure 2 shows an example of an investigated construction project. Once having a large number of study cases conducted, we can further distinguish real values

on benchmarks. Benchmarking based on the LCR-results can be used internally for different construction projects of one company, or externally to compare the pursuit of leanness between projects of different companies or even globally between different countries.

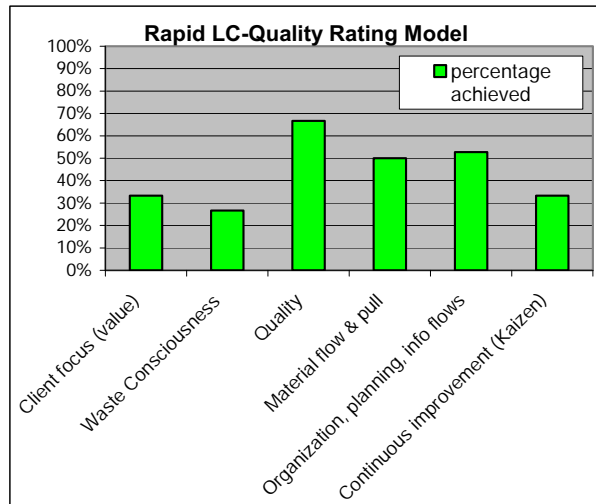


Figure 2, Example: result-graph showing the rating results for a certain construction project related to the pursuit of the six categories of the rapid-LC-quality Rating model (LCR)

FINAL LCR- MODEL OUTCOME: PROJECT CLASSIFICATION

The LCR model groups the results of the 6 above mentioned categories together and suggests an easy understandable classification scheme¹. The achieved total percentage is calculated by adding all achieved scores, divided by the maximum

possible score (180 points, based on the 30 questions). This total percentage is used for the classification. A project with the lowest classification is defined as LC-*d* project, while the highest possible score is classified as LC- *aaa*. Table 2 describes the LCR classification.

¹ This scheme has the same logic as in financial risk classification for credit management. However, the LCR-model uses small-letters and the *LC*-abbreviation to differ from financial company rating

However it must be remarked that lean-construction is not a static issue and this classification describes one “picture” status of a project. Therefore the reader and applicant of the LCR-

model shall relate the “degree of leanness” as a continuously developing process towards continuous improvement, in terms of pursuing leanness.

Table 2: LCR classification and macro-interpretation of results:

Result	% achieved	step	Interpretation of class
LC aaa	95% to 100%	6	} (strive for perfection in quality improvements and LC application)
LC aa	89% to 94%	6	
LC a	81% to 88%	8	
LC bbb	73% to 80%	8	} (high quality focus and lean-learning within the main project / company levels)
LC bb	64% to 72%	9	
LC b	55% to 63%	9	
LC ccc	46% to 54%	9	} (quality consciousness, but low/no lean-construction knowledge)
LC cc	37% to 45%	9	
LC c	28% to 36%	9	
LC ddd	19% to 27%	9	} (low quality and low improvement focus, wasteful)
LC dd	10% to 18%	9	
LC d	0 to 9%	10	

The steps in percentages between each class and sub-class are not equally divided. The range is between 6 percentage steps at the top-end and 10 steps at the lower end. The model was calibrated in this way, due to application to several construction sites in Brazil and additional discussions with the researchers from Karlsruhe and Curitiba.

The LC-a class (from a to aaa) is defined as the top-end of quality focus, strive for perfection in the six categories, so to say “the leaders of continuous improvement and pursuing the ideals of a lean construction project”. Apparently this is a very high target. Today there are expected to be

very few construction projects and companies classified within the *LC-a* classes, as the topic of Lean Construction is relatively new and due to the wastefulness¹ and complexity within the construction environment.

Projects and companies in the *LC-b* class (from b to bbb) have already a high quality focus. They evidence efforts to learn and improve. Furthermore application of the lean construction philosophy is found in the

¹ The seven types of waste : overproduction, waiting time, transportation, over-processing, inventory, rework, unnecessary motion (Womack and Jones, 1996).

whole construction project (or the main company organization levels).

LC-c class (from c to ccc) are projects with a considerable quality consciousness but low, or no lean construction knowledge. Most of the current construction projects are expected to be found in the *LC-c* classification group because lean management aspects are still unknown to most of the construction companies. The very low classification group *LC-d* (from d to ddd) includes projects with a low quality focus, very low improvement focus and a lot of waste in the production process.

FUTURE OUTLOOK AND CONCLUSION

The objectives for the development of this rating model were to keep the LCR model on a macro scale and to provide a complete framework for the evaluation, visualization of results and classification into standardized LCR classes. An applicant of the LCR model can quickly obtain a standardized notion of the quality and application degree of Lean-Construction principles. This clearly reflects whether a construction project or company is in line (or not) with a precise strategy focus on value generation and waste reduction.

The LCR model does hardly consider the degree of mechanization in construction, financial indicators or key performance indicators (e.g. on-time). However these indicators must also be taken into account when evaluating the "health" of construction projects. Therefore the model does not replace financial ratings for projects. A suggested further research topic is to evidence whether and how there are correlations between financial results

of companies and the LCR-classification.

We ask researchers to apply the model in many different contexts and different countries, to publish their results and provide improvement suggestions. In this way we can establish real, sound and stable international benchmarks on the status of LC-quality of certain construction segments. The model in Excel is available as a free download at: <http://www.tmb.uni-karlsruhe.de/Hofacker.php>.

Furthermore we're building a platform with the possibility to upload the results and to create a larger database for benchmarking and research within this PROBRAL Project's results. The link for this platform will be published at the same site above.

The LCR model should also be promoted to financial analysts for construction projects, as it provides good insights into the quality, value-creation and sustainability of the production process in construction projects.

If the LCR-model is applied three or more times on construction projects of the same enterprise, the rating may be generalized from project to the company level. The suggestion for this generalization is based on discussions between researchers and operational people in the construction industry. The intention is to provide a minimum required data sample to allow such generalization and on the other hand to maintain sufficient applicability to the reality of construction. However, the validity for this generalization must be further approved by wider application of the LCR-model.

Construction companies should be interested and request to get an external rating with the LCR model,

which will help them to visually understand some main areas for improvement and in this way in the future they could compare their LC-quality status with national and international benchmarks.

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