RAPID LEAN CONSTRUCTION-QUALITY RATING MODEL (LCR)

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ABSTRACT

The rapid Lean Construction-quality 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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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.
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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 leaness 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

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\(^1\) 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-Q 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 environment.

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

investigates the 9 variables of leaness 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).

Proceeding to develop- & content of the rapid LC-quality Rating
model

1. Brain-storming & literature
+ 4 existing evaluation models:
Rapid Plant Assessment
Benchmark model ProBRAL 2007
Questionnaire UFPR

2. Evaluation Sheet in 6 categories (in Excel):
(for construction project, ~ 3x projects - company evaluation)

3. Visualisation of
results

4. Categorization
into degree of pursuing
leanness: from D = 0 to
AAA (100%)

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

Table 1: Evaluation sheet for construction visits, data input, Rapid LC-Quality Rating Model.
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**Category** | **Nr** | **Evaluation point (continued)**
---|---|---
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)
Organizational / 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.
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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.

![Rapid LC-Quality Rating Model](image)

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 scheme\(^1\). 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.

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\(^1\) 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:

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

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 wastefulness 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

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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.

REFERENCES
Womack, J.P., Jones, D.T. and Roos, J. (1990), The machine that changed the world, Mcmillan, New York, N.Y.