

# Lean Construction and Green Building: Gaps between knowledge and adoption in the Brazilian Building Construction

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**Abstract--** This article aims to identify the relation between concepts and techniques of Lean Construction philosophy for the benefit of Green Building. It aims to evaluate construction companies of Rio de Janeiro to measure how much it is known and how much Lean and Green philosophies are combined in the project life cycle. The main results reveal gaps between knowledge and the adoption of these two philosophies in the development of a same project. One of the main conclusions is that Lean Construction and Green Building concepts need to be aligned in a project life cycle and used in a systematic way by construction companies

**Index Term--** Lean Construction, Green Building, Building Construction.

## I. Introduction

Recognized as one of the most important sectors for the economy of a country, building construction is also considered the sector of human activities that consumes the most natural resources and uses energy intensively, generating considerable negative impacts on the environment [23].

The productive network of building construction, due to the volumes that it handles and uses, is a strong concern for the sustainability of the planet [6]. In the building construction sector, sustainability involves building systems that promote integration with the environment. This means that sustainable buildings must be designed and planned from various premises [11]. One of these premises is technological progress, which can be seen as the increase in the technical level of knowledge applied to production. This increase is expressed in various ways, such as dissemination of new construction processes, technical progress incorporated into capital goods and a higher qualification of labor [10].

The concern with sustainability in buildings aims to eliminate the negative social and environmental impacts of the entire life cycle of the project [11]. Although the origin of Lean Construction is not related to the defense of sustainability, several authors agree that the Lean and Green philosophies are intersected in a common principle: the elimination of waste [2,12,14,20,22]. However, if considered alone, they may create serious conceptual and practical mistakes [12].

Lean production focuses on eliminating waste and maximizing productivity [2]. It is considered as one of the most correct philosophies for building construction because it considers, through its tools, not only the control of waste, but also the anticipation of project uncertainties [22].

The disposal of waste and the improvement in productivity that can be achieved through the application of Lean concepts are greatly discussed. However, as the concern for the

environment is becoming increasingly important to the construction culture, there is a need to investigate the applicability of Lean concepts to achieve an environmental sustainability [2].

This concern exists because the Lean philosophy does not have a clear and conscious direct concern for the ecological context of sustainability [12]. It takes into account that, in practice, Lean techniques can be applied with a local success to a non-sustainable project, or otherwise, a well-equipped project may continue to be developed with less technology, without privileging the value stream in detriment of the elimination of any form of waste based on the Lean Construction philosophy [12].

In this context, this study aims to identify the relation between concepts and techniques of Lean Construction philosophy for the benefit of sustainability in the development of buildings by evaluating the construction companies of Rio de Janeiro in order to measure the degree of knowledge and to what extent the Lean and Green philosophies are used in isolation and together in project life cycles.

## II. THEORY

### *Lean Construction*

The term Lean was created at the MIT (Massachusetts Institute of Technology) to name the new production system. The model was related to the concept and vision of waste in all stages of the process, in leadership and in commitment of employees [24].

This new production system began in Toyota Motors factories in the 1950s. It was called Toyota Production System (TPS) [5]. TPS brought to the automotive industry and later to other industries practices that aim to reduce process variability and to pursuit value creation for customers by eliminating waste. It was based on two pillars: Just in Time and Jidoka [5,7,21].

The transfer and adaptation of the concepts and principles of the Toyota Production System for building construction arises in the early 1990s. The major landmark was the publication of the work "Application of the new production philosophy in the construction industry" by the Finnish author Lauri Koskela [4,7,16]. In this report, Koskela challenges construction professionals to break their management paradigms and adapt techniques and tools developed successfully in the TPS [15].

Koskela [17] defines the production as a flow of materials and/or information from raw materials to finished products. Lean Construction emphasizes the importance of the production process flow based on three concepts. The first concept is the vision of transforming raw materials (input) into

products (output), in which the production management equalizes the total decomposition of transformation into elementary transformations by task, pursuing minimal cost and maximum efficiency [9]. The second concept refers to the flow in waiting, inspecting and moving to the next stage, in which the management of production seeks to reduce this variability in the production flow [18]. The third key concept refers to meeting customer needs, in which the management of production seeks to translate the needs of the customers into products or services [18].

Lean Construction is determined by a set of interconnected principles that should be applied in an integrated manner in management processes to obtain the expected results [17]. These principles are basically Reduce the amount of activities that do not add value; Increase the value of the product by considering the customers' needs; Reduce process variability; Reduce cycle time; Simplify by reducing the number of steps or parts; Increase output flexibility; Increase the transparency of the process; Focus on the control of the global process; Introduce a continuous improvement into the process; Maintain a balance of improvements in flows and conversions; Benchmarking [17].

### B. Green Building

Green Building aims to adopt a high-performance delivery system of green building aiming to ensure that the project is profitably designed, built and delivered for operation [2].

According to the concepts disclosed by the US Green Building Council, benefits such as reducing water and energy consumption, increasing productivity, positive marketing, health benefit of its users and environment benefits are comfort and capital factors in a sustainable building [3].

The benefits can be seen as Reduction of investment and operating costs; Image, differentiation and improvement of the product; Risk reduction; More user productivity and health; New business opportunities; and Satisfaction for doing the right thing [3].

For the Brazilian government, entrepreneurs are betting on green certifications for buildings. However, many buildings labeled green reflect only efforts to reduce embodied energy and are, in many other respects, conventional, both in appearance and construction processes [8].

### C. Lean Construction vs. Green Building

In the early 1990s, Koskela [17] already identified the relation between Lean Construction and Green Building by the reduction and removal of waste. For him, by using material resources efficiently the sustainable management of waste could be increased. However, waste was seldom considered by project managers, thus becoming the leading cause of loss of efficiency and productivity.

One can understand that the action developed by Lean Construction is in defense of sustainability because this philosophy promotes the global reduction of waste

(environmental sustainability) and adds at the same time a greater value to projects from the perspective of their owners, improving GDP and per capita income of workers (economic and social sustainability) [12].

It is necessary to identify the actions for integration at all steps of the project life cycle. In order to be a sustainable building, it is important to assess where the construction is, and plan all stages in order to reduce the aggression to the environment before, during and after the construction [26].

Costa [13] states that the more efficient it is to the compatibility of smaller projects, the less the rework and the greater the waste reduction in the project. Within this perspective, a project, in a broad sense, allows determining which solutions are actually interesting from an environmental, economic and social point of view for each of these stages [14].

In a US study comparing different types of buildings with several environmental standards, it was found that there was no correlation between the cost of the buildings and their environmental performance. The major problems identified concerned the pre-construction and construction stages, with delays in materials supply, poorly defined projects, irregularities in subcontracts, defects after construction etc. [14] The principles of lean construction work directly to address deficiencies, such as those identified in the study, through professional building, in which project changes are made to improve the energy efficiency of the building [14].

The impact of the construction process on the environment can be reduced in the following ways [2]:

1. By strengthening and improving process efficiency.
2. By conserving water, energy and other resources during the construction process.
3. By reducing the amount of waste during the construction process and minimizing other activities that may lead to lower costs and maximize the productivity of a project.

A study conducted in Indonesia to implement the concepts of sustainable construction demonstrated in its conclusion the importance of Lean concepts to support the construction operation and the development of a construction supply chain that meets the demands of green projects [1].

Another study compared the investments in sustainability from cost reduction of waste using Lean Construction. The economy provided by Lean construction represented a relative cost reduction of 0.19% on waste materials, generating 14% cost savings on green certificates [25].

### III. RESEARCH METHODOLOGY

This research is exploratory. The objective is to conduct a survey of relevant information on the subject to assist in the formulation of the problem to be solved.

The case study focused on evaluating through a survey construction companies operating in Rio de Janeiro that declared supporting sustainability in construction in their marketing on the Internet. It also aims to measure the level of knowledge and the use of the two concepts (Lean and Green). In this method, the researcher usually evaluates a significant

sample of the problem under investigation in order to draw conclusions about this sample [19].

The classification of data is qualitative. Data were collected through a questionnaire consisting of a series of questions on the topic researched. Three of them to identify the companies profiles and the others were related to specific issues of the subjects researched. It was used the Likert index. The sample population was based on a list of construction companies operating in Rio de Janeiro on the website "Brazilian Constructions Companies" available at <http://www.construtorasbrasil.com.br/construtoras/rio-de-janeiro/>, accessed on August 31, 2015, in which 54 construction companies that operate in the capital of the state of Rio de Janeiro are listed.

Among the 54 construction companies, it was investigated which of them declared supporting or adopting sustainable buildings in their websites on the Internet. From this list, 32 construction companies were selected.

The sampling was classified as non-probabilistic. Therefore, questionnaires were sent to each of the construction companies by e-mail.

In the exploratory analysis of qualitative data, the usual measure is the mode. Thus, the results will be represented by bar graphs or circular diagrams [19].

The research was conducted between September and November 2015, and the return rate was 81% of all questionnaires sent, namely 26 responses.

#### IV. CASE STUDY

##### A. Overview

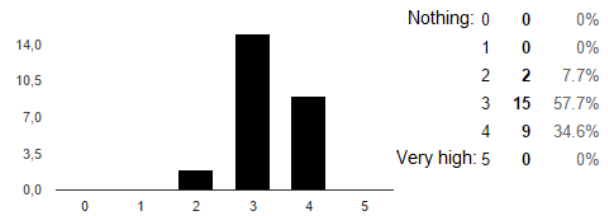
The research focuses on construction companies operating in Rio de Janeiro, the capital of the state of Rio de Janeiro, Brazil. Rio de Janeiro has a significant importance in the national and international scenario. It is the second largest city in Brazil and one of the main economic, cultural and financial centers, representing the second largest GDP in the country.

Among the 26 companies surveyed, 73% operate for over 10 years in the construction industry, and over 84% have between 100 and 499 employees.

The questionnaire sought to measure the degree of knowledge and the use of Lean Construction and Green Building techniques. Scenarios were designed to identify the development of green projects under construction in a conventional manner as well as projects developed with Lean techniques for non-sustainable buildings. The questions also sought to measure at which phase the two techniques were best intersected in project life cycles.

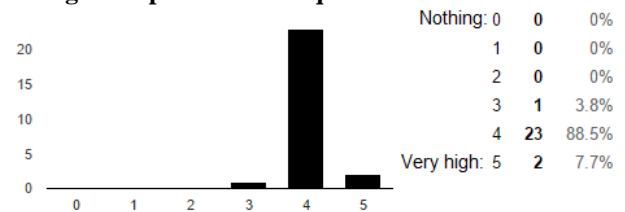
##### B. Results of the Survey evaluation.

##### 1) To what extent does the company know about Lean Construction concepts and techniques?



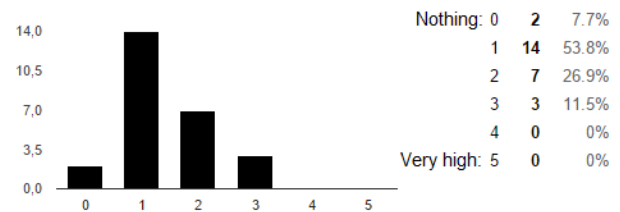
The results show a medium to high knowledge of Lean Construction concepts and techniques, the sum of the two greatest representativities reaching 92%.

##### 2) To what extent does the company know about Green Building concepts and techniques?



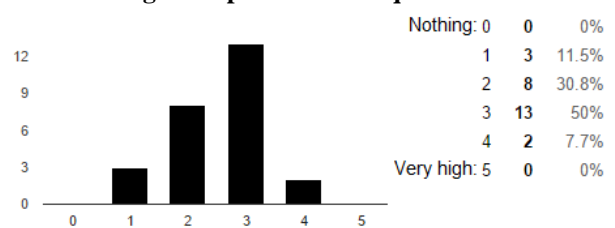
The results show a predominantly high knowledge about the concepts and techniques of sustainable construction.

##### 3) To what extent does the company systematically use Lean Construction concepts and techniques?



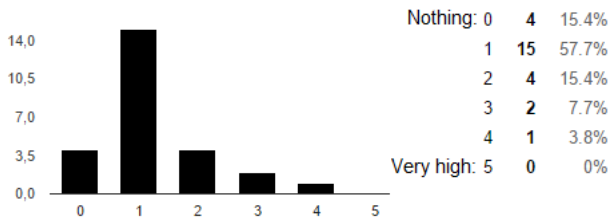
Regarding the use of the concepts and techniques of Lean Construction, most companies state a very low level of use. The levels very low and low sum approximate 80% among those surveyed.

##### 4) To what extent does the company systematically use Green Building concepts and techniques?



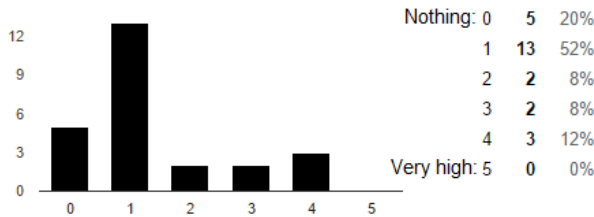
Regarding the use of the concepts and techniques of Green Building, the greatest plurality represents a medium level. Summing the two greatest representativities, the survey shows a medium to low use, approximately 80% of construction companies.

##### 5) How often does the company develop projects using Lean Construction concepts in a sustainable project?



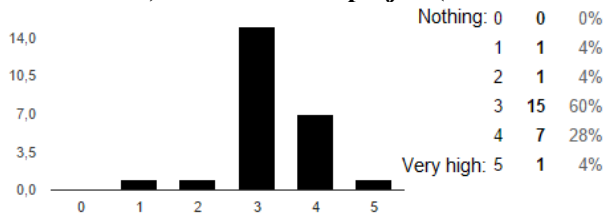
The use of Lean Construction concepts in sustainable projects results in a very low adoption rate. Summing those that claim not to use them, up to the Grade 2, which represents a low level of use, this representation is approximately 90%.

**6) How often does the company develop projects using Lean Construction concepts in a non-sustainable project (Conventional Project)?**



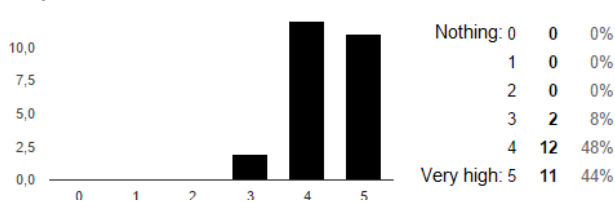
The use of Lean Construction concepts in non-sustainable projects still results in a predominantly very low adoption rate. Summing those that claim not to use them, up to the Grade 2, which represents a low level of use, this representation is approximately 80%.

**7) How often does the company develop projects using traditional construction concepts (without using Lean Construction) in a sustainable project (Green Building)?**



The use of conventional construction methods, without using Lean Construction concepts in sustainable projects, results in a medium to high level of use, summing 88% for the two representativities.

**8) How often does the company develop projects using traditional construction concepts (without using Lean Construction) in a non-sustainable project (Conventional Project)?**



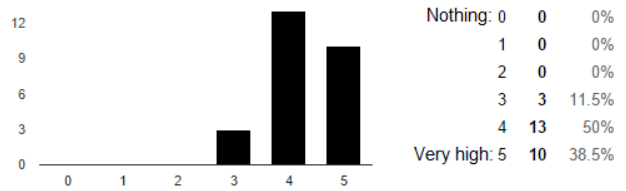
The use of conventional construction processes, without using Lean Construction concepts in non-sustainable projects, results in a high and very high frequency of use, summing 92% for the two representativities.

**9) At which phase of the development life cycle can Lean Construction techniques be better applied in Green Building projects?**



In question 9, respondents could indicate more than one answer to evaluate at which stage of the project life cycle lean construction techniques could be better applied in sustainable projects. The results indicate that the "pre-construction" phase, with 80% of indications, and the "construction" phase, with 100% of indications, are seen as the most appropriate to combine the two philosophies (Lean and Green) within the life cycle of a project.

**10) To what extent can Lean Construction and Green Building concepts and techniques, applied together on a project, make the construction industry more efficient?**



Of the surveyed construction companies, approximately 88% consider using the concepts and techniques of the two philosophies combined (Lean and Green) at a high to very high level in favor of a better efficiency in the construction industry.

**V. CONCLUSIONS**

This research sought to identify gaps between what is known and to what extent the techniques Lean Construction and Green Building are used within a same project. Although several authors agree on a common agenda between Lean Construction and Green Building, there was a need to investigate the applicability of the two concepts.

Thus, this study evaluated 26 construction companies operating in Rio de Janeiro. The results showed that a very low number of construction companies use both concepts combined in the construction of a project. Even the small number of construction companies that apply the two techniques combined in a same project do not use them systematically.

Most of the companies build using conventional construction processes for conventional and sustainable buildings. When it comes to conventional production in non-sustainable buildings, this number is even higher.

Within the conceptual perspective, the vast majority states that it is possible to achieve sustainability in a project by following Lean principles.

Within the project life cycle, the "pre-construction" and "construction" stages were recognized as the most suitable to intertwine both concepts (Lean and Green).



To improve the efficiency of building construction, the adoption of construction systems, such as Lean Construction and Green Building concepts, need to be aligned in a project life cycle and used in a systematic way by construction companies.

The dissemination of the techniques and concepts of the two philosophies need to be presented to construction companies in order to justify the value of their applicability to encourage projects owners to seek resources for its adoption.

The research does not seek to generalize the results, enabling the development of further studies and evaluations in favor of contributing to eliminate doubts and to give examples of good practices to be tested in new sustainable projects.

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