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MATURITY ASSESSMENT OF THE INTEGRATION BETWEEN LEAN SERVICE AND LEAN CONSTRUCTION IN BRAZILIAN POPULAR HOUSING PROJECTS[1]

AVALIAÇÃO DA MATURIDADE DA INTEGRAÇÃO ENTRE LEAN SERVICE E LEAN CONSTRUCTION EM PROJETOS DE HABITAÇÃO POPULAR NO BRASIL

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Abstract: This paper assessed the maturity of Lean Construction (LC) in a Brazilian affordable housing company, focusing on two main objectives: to identify the strengths and weaknesses in adopting LC concepts and to analyse the practical implications of this diagnosis to support a performance-oriented development program. The research design included a literature review and contextual analysis to select an appropriate maturity assessment model, followed by empirical data collection and content analysis grounded in established LC theory. The results indicate the company's current level of LC maturity, with main weaknesses in product design flexibility and understanding customer requirements, as well as notable strengths in reducing process variability. These results highlight how maturity assessment can expose critical factors that influence the effectiveness of Lean practices, particularly when aligned with performance measurement perspectives. The insights derived from this analysis are expected to inform the planning and implementation of Fábrica Azul's development program, guiding strategic improvements and aligning operational practices with Lean principles. This study's originality lies in applying a maturity model in the context of Brazilian affordable housing, combined with stakeholder value considerations and a literature-based interpretation of the results. Overall, this work contributed to the field by demonstrating how maturity assessment, when integrated with performance evaluation, can serve as a powerful diagnostic and planning tool to enhance the sustainable adoption of Lean Construction.

Keywords: Lean Construction. Lean Service. Maturity Evaluation.

Resumo: Este artigo avaliou a maturidade da Lean Construction (LC) em uma empresa brasileira de habitação popular, com foco em dois objetivos principais: identificar os pontos fortes e fracos na adoção dos conceitos de LC e analisar as implicações práticas desse diagnóstico para apoiar um programa de desenvolvimento orientado a resultados. O projeto de pesquisa incluiu uma revisão bibliográfica e análise contextual para selecionar um modelo de avaliação de maturidade apropriado, seguida de coleta de dados empíricos e análise de conteúdo fundamentada na teoria consolidada da

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LC. Os resultados indicam o nível atual de maturidade da LC na empresa, com principais fragilidades na flexibilidade do projeto do produto e na compreensão das necessidades do cliente, bem como pontos fortes notáveis na redução da variabilidade do processo. Esses resultados destacam como a avaliação de maturidade pode expor fatores críticos que influenciam a eficácia das práticas Lean, particularmente quando alinhadas com perspectivas de mensuração de desempenho. Espera-se que os insights derivados desta análise informem o planejamento e a implementação do programa de desenvolvimento da Fábrica Azul, orientando melhorias estratégicas e alinhando as práticas operacionais aos princípios Lean. A originalidade deste estudo reside na aplicação de um modelo de maturidade no contexto da habitação popular brasileira, combinada com considerações sobre o valor para as partes interessadas e uma interpretação dos resultados baseada na literatura. De modo geral, este trabalho contribuiu para a área ao demonstrar como a avaliação da maturidade, quando integrada à avaliação de desempenho, pode servir como uma poderosa ferramenta de diagnóstico e planejamento para aprimorar a adoção sustentável da Construção Enxuta.

Palavras-chave: Construção Enxuta. Serviço Enxuto. Avaliação de Maturidade.

1 INTRODUCTION

The construction industry is an important part of the Brazilian economy and has a significant share in the country's Gross Domestic Product (GDP) (Ajayi and Oyedele, 2018; Nunes *et al.*, 2020a; Souza *et al.*, 2022). The strong relationship between the variations of the Construction GDP and the national GDP (The World Bank, 2025). In general, when the GDP variation is positive in the sector, it is also positive in the country, and vice versa; and when the GDP variation is negative in one of these economic spheres, it is usually also negative in the other. Construction activities promote changes in other sectors of the Brazilian economy and present an important role in generating jobs on a large scale (Alaloul *et al.*, 2021; Nunes *et al.*, 2020b). The housing building subsector is driven by government incentives from the "Green and Yellow House Program" and the "Growth Acceleration Program" (Ribeiro *et al.*, 2021; Silva *et al.*, 2022).

Despite the favorable economic scenario, the Brazilian construction sector presents chronic operational problems, which directly impact the composition of the result. In this alignment, with greater relevance, the low number of people, which has impacts on low productivity, waste, and the rework rate (Freitas *et al.*, 2018; Goh and Goh, 2019); Team management style, which is related to low performance and work overload (Brandalise *et al.*, 2021a; Kissi *et al.*, 2019); Inefficiency in purchasing management, with discontinuity of inputs at the construction site, generating idleness of people (El Daouk, 2023); The culture of lack of training for the team, whether for

risk prevention in the activity, or a specific qualification is not encouraged, and it has been found that there are impacts on the rates of work accidents and turnover (Gallon *et al.*, 2021; Meirelles and Pinheiro, 2021); Finally, it is understood that there is no application of planning and monitoring techniques, generating points of low performance (waste and rework) (Freitag *et al.*, 2020).

Such problems can be mitigated with a strategic approach based on methodologies recognized in the literature (Ghosh *et al.*, 2020; Helmold, 2020; Vaagen and Ballard, 2021). The traditional production model is focused on execution, limiting construction planning and management because there is no global view of the production processes (Brandalise *et al.*, 2021b).

Given this scenario, Lean Thinking is a practical proposal to improve the constructive mindset (Psomas and Antony, 2019; Tortorella *et al.*, 2021; Yadav *et al.*, 2020). Lean Manufacturing tools are applicable to the construction context, with the following applications evidenced in the literature (Table 1).

Table 1 – Alignment between tools and authors

Lean Tool	Description	References
Kanban	Demand-driven system and visual control of process flow	(Zeng *et al.*, 2024); (Vaagen and Ballard, 2021)
Manufacturing Cells	Organization of a suitable physical arrangement at the production site	(Chiarini *et al.*, 2018)
Last Planner System	Detailed operational planning in the short and medium term, considering deadlines and resource availability	(Aquila *et al.*, 2023) (Knospe *et al.*, 2023)
Poka Yoke	Quality assurance through inspection systems to prevent human errors	(Tommelein *et al.*, 2022); (Loyd *et al.*, 2020)
Heijunka	Production leveling to efficiently respond to demand changes	(Jiménez García *et al.*, 2025); (Yusuf *et al.*, 2025)
Gemba Walk	Continuous improvement by gaining new knowledge through direct observation at the production site	(Stolarska-Szeląg, 2022); (Micieta *et al.*, 2021)
Value Stream Mapping	Mapping the value stream to illustrate, analyze, and improve the flow of a product or service	(Kashyap *et al.*, 2025) (2020); (Ramani and KSD, 2021)

Source: Authors (2025).

Performance management of the Lean application in Construction companies to measure productivity and operational efficiency contributes to adding value to the product or service delivered to the customer (Rodegheri and Serra, 2020; Shafiq *et*

al., 2019). Measuring productivity in a production system is essential to ensure more efficient results and quality products (Mano *et al.*, 2020).

Among the objectives of this paper, the following stand out: the assessment of the maturity of LC in a construction company of affordable housing in Brazil, identifying the strengths and weaknesses in the concepts of LC, and the discussion of the practical implications of the initial assessment of the company through the analysis of empirical data based on a theoretical framework selected to guide the internal development program of LC, called “Blue Factory”.

2 LITERATURE REVIEW

Converso *et al.* (2025) offers a contemporary reaffirmation of Ohno and Liker's taxonomy of waste, contextualizing waste classifications in modern business environments. Identifying and systematically eliminating these wastes is essential to maintain the efficiency and competitiveness of processes in a highly competitive scenario and can be a competitive differentiator.

These basic elements have been applied to the LC Philosophy, reinforcing the operational relevance of each type of waste and seeking to adapt it to customized production in order to deliver perceived value to the customer.

Johansson *et al.* (2024) describes an updated guide on methods to identify waste in real-world processes, how to approach it strategically, and how to generate learning opportunities in each event. This dynamic can be a link between theoretical understanding and improvement applied to processes, especially useful in hybrid and service-oriented production models.

Integrating digital resources supports early waste detection, predictive maintenance, and more agile workflows, addressing the limitations of classic Lean structures (Alagarsamy *et al.*, 2025). This perspective not only validates the fundamental principles of Lean but also points to a synergistic future between lean and smart manufacturing (Masoud *et al.*, 2025), favoring a permeable environment for the generation of specific and applied knowledge and the level of business maturity.

In view of material waste and labor idleness in Construction, LC emerged to ensure fluidity and operational efficiency. This concept is inspired by Lean Manufacturing, which has had widely accepted results in Western manufacturing (Aquila *et al.*, 2023; Gao and Low, 2014).

LC is structured in 11 principles (Koskela, 1992). These aim to promote the maximization of business objectives and mitigate factors that may impact the performance of activities and processes, avoiding discontinuity in the flow (Bernardes, 2021; Carvalho and Scheer, 2017; Gontijo *et al.*, 2018).

Converso *et al.* (2025) revisit the classical concept of waste in Lean by contextualizing it within service-oriented environments. Their identification of 22 service-specific wastes broadens the scope of non-value-adding activities, reinforcing the role of waste elimination in improving competitiveness. (Moradi and Sormunen, 2024) highlight the importance of understanding customer requirements in enhancing value delivery. Their study emphasizes that aligning construction outputs with user expectations is a strategic imperative in integrated Lean-BIM sustainability initiatives. Garces *et al.* (2025) identify variability as a significant inhibitor of performance and flow stability in construction.

They argue that Lean strategies help reduce inconsistencies, fostering more predictable and efficient processes. Mirdha and Calahorra-Jimenez (2025) focus on reducing activity cycle times by streamlining the pre-construction phase. Their Lean-based methodology demonstrates how early-stage planning minimizes delays and cost overruns.

Pipaliya and Malek (2024) advocate simplifying construction processes through Lean-digital integration. They show that automation and data use improve productivity and process clarity by reducing unnecessary steps. Najafi *et al.* (2024) emphasize output flexibility as the key to project adaptability. Their perspective suggests that Lean fosters responsive systems that adjust to changing project and client needs.

Daneshgari and Moore (2024) promote transparency as essential for collaborative construction. Through Agile-Lean convergence, they show that visual tools and shared platforms improve stakeholder communication. Pérez *et al.* (2023) present location-based sampling as a method for process control. This technique,

aligned with Lean principles, enhances real-time visibility and coordination across project activities.

Asadian *et al.* (2023) discuss how mature trade contractors institutionalize continuous improvement. They find consistent feedback loops crucial for learning and long-term Lean adoption. Drevland and Lohne (2023) stress balancing flow and conversion improvements. Rather than opposing elements, they argue that these aspects should be treated as interdependent pillars of Lean execution.

Moradi and Sormunen (2024) rethought the benchmarking approach in Lean with a contemporary perspective, linking it to performance comparison and learning between projects. Their approach encourages methodological reflection and proactive process enhancement (Table 2).

Table 2 – Alignment between LC principles and references

Lean Construction Principle	References
Reduction of activities that do not add value	(Converso *et al.*, 2025)
Increase output value through understanding customer requirements	(Moradi and Sormunen, 2024)
Reduction of variability	(Garces *et al.*, 2025)
Reduction of the cycle time of the activities	(Mirdha and Calahorra-Jimenez, 2025)
Simplification of processes through the reduction of steps	(Pipaliya and Malek, 2024)
Increased output flexibility	(Najafi *et al.*, 2024)
Increased transparency in the process	(Daneshgari and Moore, 2024)
Focus on the control of the complete process	(Pérez *et al.*, 2023)
Incorporation of continuous improvement in the processes	(Asadian *et al.*, 2023)
Balance between the flow improvement and the conversion improvement	(Drevland and Lohne, 2023)
Benchmarking	(Moradi and Sormunen, 2024)

Source: Authors (2025).

This exploration of the literature demonstrates that Lean learning continues to be a challenge for organizations from a cultural perspective. The contributions reinforce the importance of applying the basic principles to contemporary challenges (digitalization, sustainability, and collaborative project delivery). These perspectives validate the relevance of seeking a more solid corporate cultural approach to these principles LC and offer concrete support for their strategic application in complex environments and scenarios.

3 METHODOLOGY

The first stage of this paper included a literature review and an analysis of the company's context to study the models for assessing LC maturity and select the most appropriate one. The goal was to understand the current status and reinforce the implementation of the Lean philosophy in the company's culture.

Given the above, the DOLC evaluation method was followed, based on the questionnaire proposed by (de Carvalho, 2008) and reapplied by (Carvalho and Scheer, 2017), which met the aforementioned criteria: (i) the model was created to evaluate companies that are in the initial phase of implementing the Lean philosophy; (ii) data collection is in the form of a questionnaire, which can be done electronically; (iii) the research instrument was developed to demonstrate the perception of the six main focus groups in a value chain (Management, Engineering, Workers, Suppliers, Designers and Customers).

After structuring the assessment, data collection began. This made it possible to describe the profiles of the respective interviewees in each group. Therefore, six questionnaires, divided into six sections, each containing about 30 questions, and directed to the respective profiles, were obtained to stratify the perception of these profiles (it was an adaptation of these concepts in the form of objective questions that could extract information about the strengths and weaknesses of lean philosophy in buildings).

Based on content analysis (Bardin, 2011), this made it possible to facilitate the discussion of results involving theory and practice in research applied to organizations (Alcadipani, 2023), seeking to highlight the practical implications of performance in each principle of LC.

4 STUDY OF MATURITY MODELS IN LEAN CONSTRUCTION

Rodegheri and Serra (2020) identified the most appropriate model to characterize the level of LC culture in small and medium-sized companies in the Brazilian Civil Construction sector, following a benchmark with the principles (Shingo Institute, 2022).

The authors highlighted five assessment tools, such as:

I. Lean Construction Maturity Model (LCMM), (Nesensohn, 2014);
II. Maturity Model for Development of Lean Construction Principles (MMDLCP), (Becerra, 2016);
III. LCI Lean IPD Health and Maturity Assessment Tool (LCI Lean IPD), (Lean Construction Institute, 2025);
IV. Degree of Lean Construction (DOLC),(Carvalho and Scheer, 2017).

The choice of the model is justified because the tool was created to evaluate companies that wish to implement LC but do not understand their current stage in relation to the basic concepts of the proposed philosophy. In addition, the tool contemplates the perspective of six relevant stakeholders in the construction value chain (de Carvalho, 2008).

Monte (2017) argues that it is important to briefly define each focus group's profile before applying the questionnaires (Table 3).

Table 3 – Profile Analysis

Stakeholder	Description
Board	A company director with autonomy to make operational decisions.
Engineering	Resident civil engineer or senior engineer.
Workers	The most educated as possible is recommended, usually the master builder.
Suppliers	Supplier of expression in the demand for materials of the ABC curve.
Designers	Professionals involved with the development of the final project of the work.
Customers	These are obligatorily end customers of the researched enterprises.

Source: Authors (2025).

After the initial approach, the results were obtained, distributed according to the respective categories, and by a focus group to facilitate understanding (Table 4).

Table 4 - Distribution of questions by category and focus group

Koskela Principles	**Board**	**Engineering**	**Workers**	**Suppliers**	**Designers**	**Customers**	**∑ questions principles**
1	4	4	3	4	6	5	26
2	3	3	2	3	7	4	22
3	4	4	3	4	3	2	20
4	3	3	4	4	4	1	19
5	5	3	2	4	3	3	20
6	3	2	2	4	3	3	17
7	3	3	4	4	2	7	23

8	4	3	2	2	2	1	14
9	4	3	3	4	4	4	22
10	5	4	2	2	1	1	15
11	1	1	1	1	1	1	6
∑ questions focus group	39	33	28	36	36	32	204

Source: Adapted from Carvalho (2008).

Questionnaire grades range from 0 to 3, and they are composed of four levels of evaluation from an even scale (Table 5).

Table 5 – Classification levels Maturity

Level	Description
0	The principle does not exist, and its implementation has a significant inconsistency
1	The principle exists, but small inconsistencies were identified in its implementation
2	The principle was thoroughly and effectively implemented
3	The principle has been implemented fully, and execution has improved over the past 12 months

Source: Authors (2025).

Due to the variation in the scale of grades attributed to the questions, it was necessary to parameterize the results in arithmetic mean for each focal group defined in the evaluation model to systematize the analysis (Equation 1).

$$Evaluation\ grade = \frac{x1 + x2 + \ldots + xn}{n} = \frac{\sum i = 1n\ xi}{n} \quad (1)$$

x_1, x_2, x_n: value assigned from the perspective of each focus group for each question;
n: number of questions applied.

The simple percentage assessment is not a consistent metric for measuring the maturity level of Lean Construction companies in the construction sector. Therefore, the results obtained through the arithmetic mean should be analyzed using a range of percentage values to measure the level of application (Table 6).

Table 6 - Classification of maturity level in Lean Construction

Maturity level	Sublevel	Value range (%)	DOLC description
A	AAA	95% to 100%	Excellent level of Lean Construction – Search for perfection.
	AA	90% to 94%	
	A	85% to 89%	

B	BBB	80% to 84%	Good level of Lean Construction – Awareness and lean learning.
	BB	75% to 79%	
	B	70% to 74%	
C	CCC	65% to 69%	Low level of Lean Construction – Focus on quality but low lean knowledge.
	CC	60% to 64%	
	C	55% to 59%	
D	DDD	50% to 54%	No use of Lean Construction – Low focus on improvements.
	DD	45% to 49%	
	D	0% to 44%	

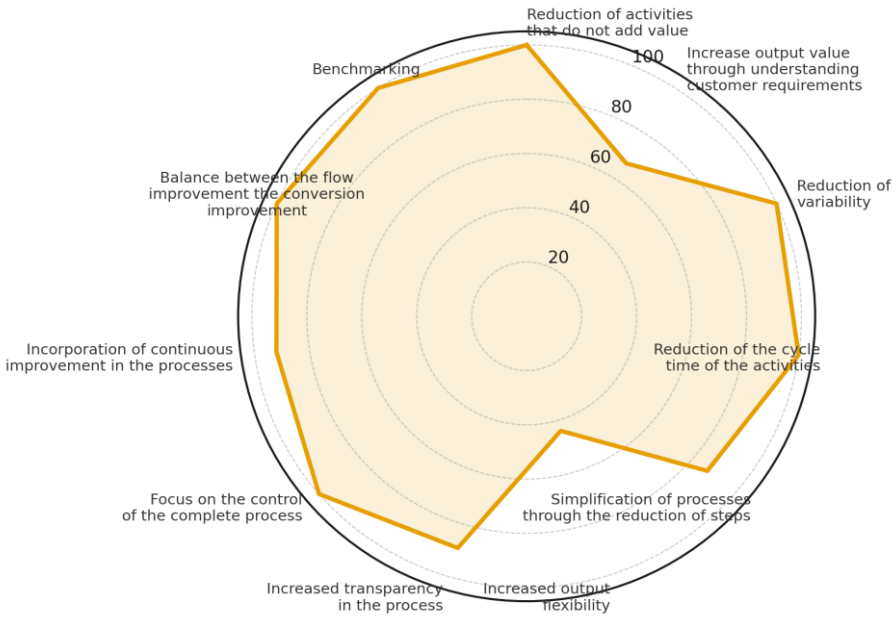
Source: Adapted from Carvalho and Scheer (2017)

6 FINDINGS AND DISCUSSIONS

a. Board of Directors Perspective

From the perspective of the Board of Directors, the rating obtained was "A", the thinking of the Technical Director. However, this was not evident in the other focus groups (Figure 1).

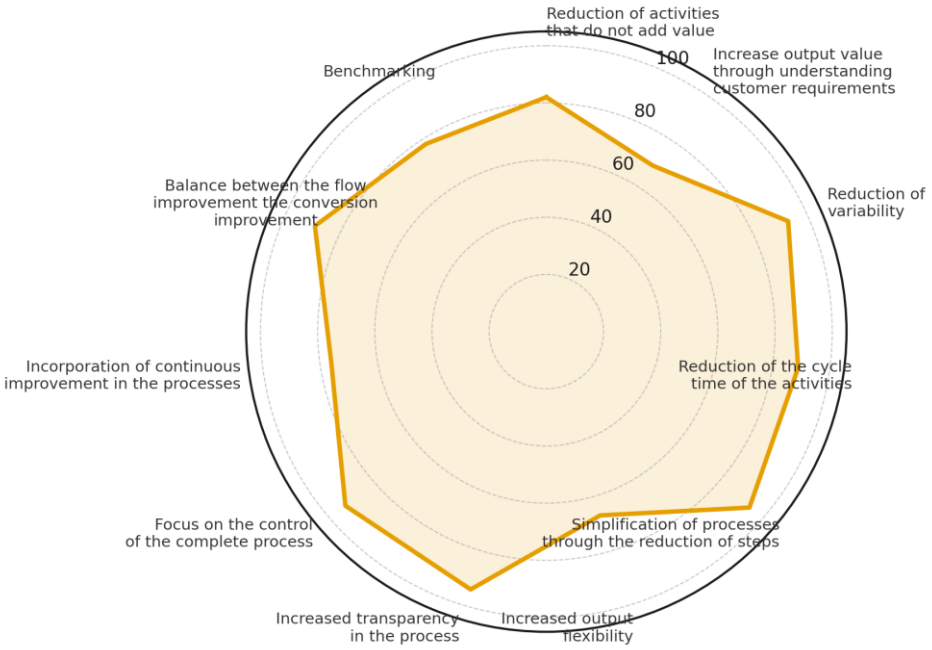
Figure 1 - Board of Directors perspective on radar chart



b. Engineering Department's Perspective

From the engineering department's perspective, the rating was "BBB," expressed by the evaluation of six professionals. The low performance obtained in the principles is due to the low flexibility in construction, justified by the business strategy of following standardization in projects to ensure agility in construction and reduce costs (Figure 2).

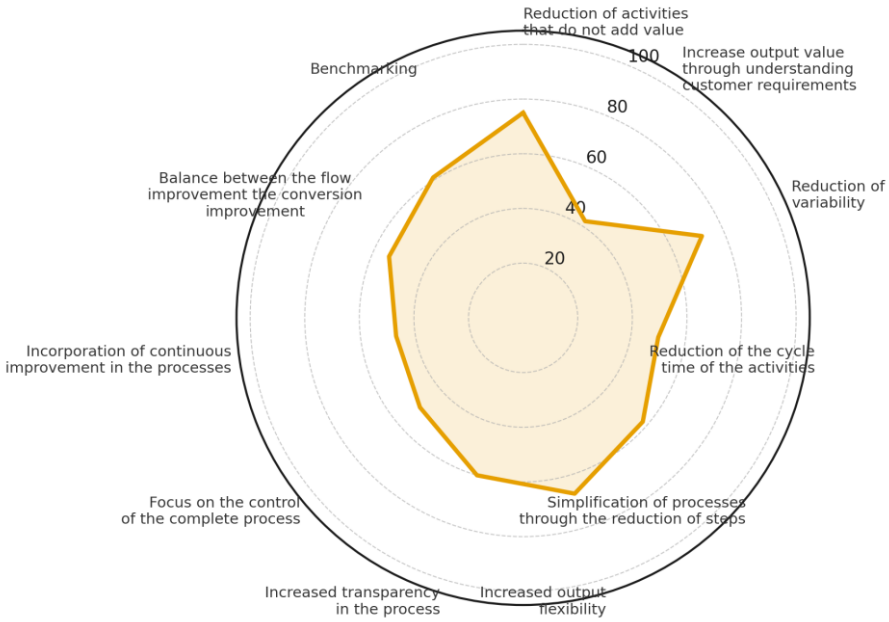
Figure 2 - Engineering Department's perspective on radar chart



c. Workers' Perspective

The score obtained from the workers' perspective was "C," which reflects the thinking of four interviewees who hold construction management positions. The weaknesses stand out: a low understanding of customer requirements, a low incorporation of continuous improvement, a low reduction of cycle time, a low focus on complete process control, and an imbalance between flow and conversion improvements (Figure 3).

Figure 3 - Workers' perspective on a radar chart

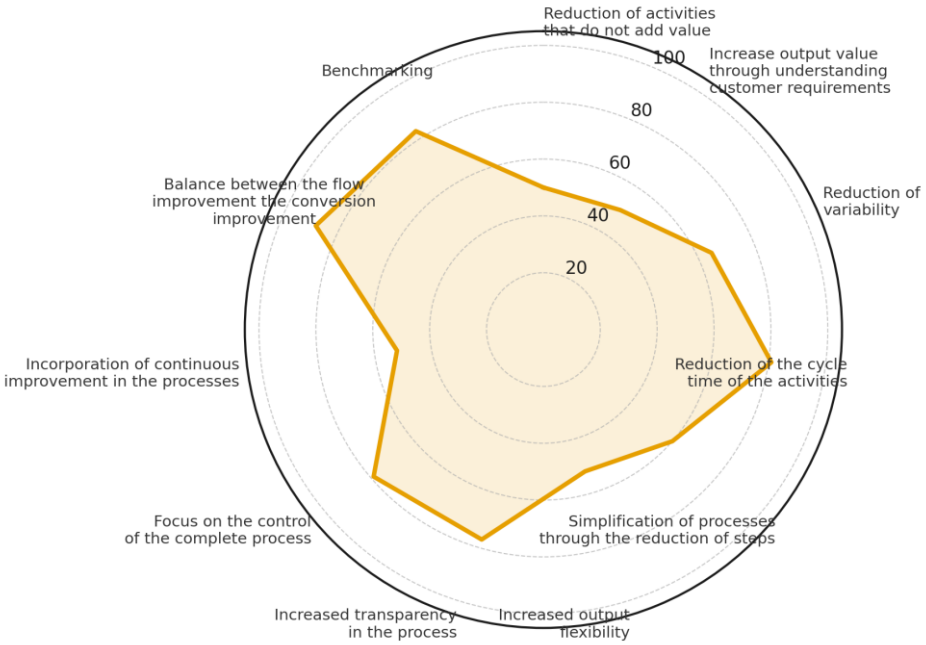


d. Suppliers' Perspective

Based on a sample of four sales representatives from companies that supply electrical, hydraulic, and concrete materials, which are basic inputs in the ABC curve. The level of maturity from the suppliers' perspective indicates that the Company has a low level, "CCC". The first statement in the questionnaire should have received the maximum score, considering that all materials delivered by the suppliers analyzed have standardized dimensions and are modular. The second statement is inconsistent, considering that unloading is the responsibility of the suppliers and their equipment in all cases analyzed.

The third statement also appears inconsistent in the cases analyzed, as the materials are delivered in other packaging or storage devices. This points to expected behavior, where organizational levels classified as operational tend to lower classifications due to a poor organizational climate (Figure 4).

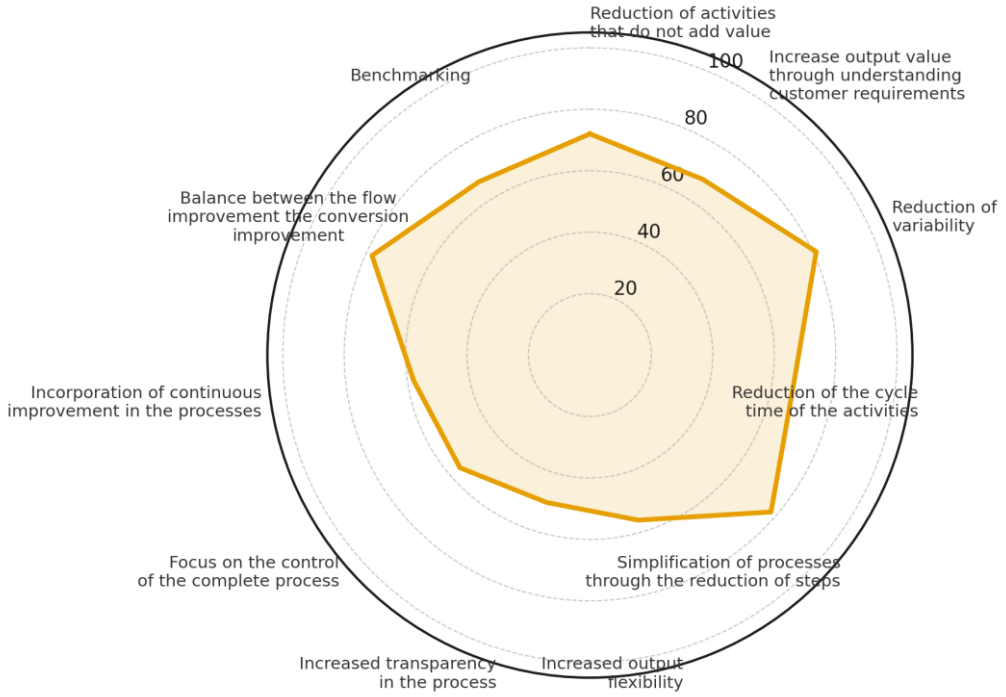
Figure 4 - Suppliers' perspective on radar chart



e. Designers' Perspective

The sample consisted of three interviewees who held the position of Project Analyst and were given a "CCC" rating. The low performance was justified by the inflexibility in the design of the housing units, the lack of technical visits to the project and construction, and the project team not feeling invited to contribute innovations to support the company's development together with the Products Department (Figure 5).

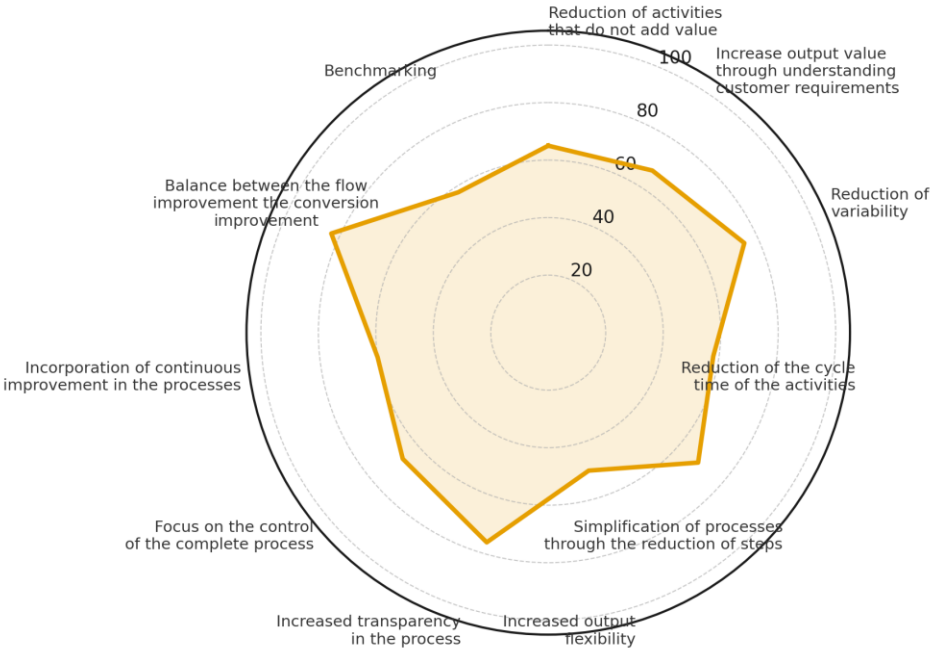
Figure 5 - Designers' perspective on radar chart



f. Customers' Perspective

The result, from the customers' perspective, was "CCC". This index reflects the position of four owners of housing units built by the company. For them, the company has a low level of LC due to the failure in communication (Figure 6).

Figure 6 - Customers' perspective on radar chart

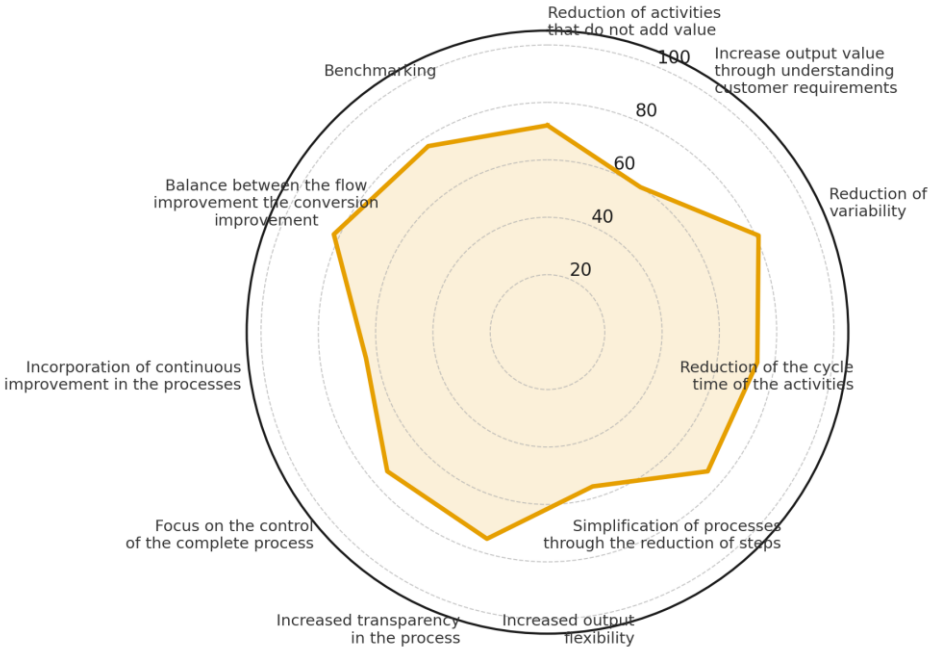


g. Company Overview

The stakeholder rating was "B," reflecting the opinion of the twenty-two interviewees. Notably, no principle performed very well, eight performed well, two performed poorly and one was classified as not using lean knowledge.

The survey highlighted the weaknesses of the company's current level of LC maturity and provided empirical data for developing strategic plans. The objective was to eliminate the weaknesses identified and enhance the strengths. The results were relatively good but still far from the culture in which the company intends to implement the Blue Factory program in its buildings (Figure 7).

Figure 7 - Company overview on radar chart



5 CONCLUSIONS

The maturity assessment revealed critical weaknesses, including low production flexibility, limited understanding of customer needs, and poor incorporation of continuous improvement practices. These issues can lead to strategic losses, such as reduced competitiveness, cultural resistance to change, increased variability, and wasted resources. However, the company demonstrated promising flow-conversion balance, variability reduction, and benchmarking strengths. These strengths contribute positively to operational performance, with potential gains in efficiency, cost reduction, and knowledge transfer.

The study's main contribution was to provide an initial diagnosis to support strategic decisions and lean transformation within the company. Its main limitation was the geographic concentration of participants in the Southeast region, which excluded regional variability among the company's national operations. Future research should explore post-implementation reassessment and apply the maturity

model to comparable organizations to identify industry- specific critical success factors.

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