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Evaluation Of Lean Knowledge And Practices In The Civil Construction Of The South Region Of Santa Catarina

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Abstract:
Background*: The construction industry environment has been marked by changes, which challenges professionals to learn new management tools that promote sustainability in the execution of works. Lean Construction treats the change of traditions and behaviors as necessary conditions for its implementation, and it is based on a culture of problem-solving and continuous improvement. The objective of this study is to investigate the knowledge of construction professionals about the Lean production philosophy in the construction industry of Criciúma - SC*
Materials and Methods*: The research was conducted with engineers who work in the largest construction companies in the region. To identify knowledge about the research topic, a questionnaire was developed containing open-ended questions to learn about the respondent's profile and closed-ended questions based on the 11 Lean Construction principles. The survey was sent to the engineers, obtaining a sufficient number of responses to generate statistical sufficiency.*
Results*: The results showed the level of knowledge of the sample regarding the 11 principles, in order to exhibit the situation of the far south region of Santa Catarina regarding lean thinking in the construction sector. Finally, the study identified opportunities for improvement and legitimized whether Lean Construction is being considered a culture within organizations, and if it is widely known by engineers.*
Conclusion: *The investigation of knowledge about the lean production philosophy with professionals in the field, based on the selected sample, was identified and analyzed in such a way that, in general, it presented about 43% applicability. It is known that, for the effective implementation of lean construction concepts in the production system, factors such as the commitment of top management to implement them; focus on measurable and viable improvements, through appropriate lean performance indicators; the involvement and commitment of employees, who must know and understand the principles; and finally, knowledge of the current state are ideal to set goals for the future.*
Key Word*: Lean Construction. Management tools. Continuous improvement. Sustainability.*

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I. Introduction

The construction industry is a basic industrial sector for the development of the country, as any other activity is subject to it, whether it be renovations, new constructions, or necessary adjustments. The Annual Survey of the Civil Construction Industry (PAIC) of 2016 showed that the number of active companies was 127.332 and that in the same year, construction works and/or services were carried out that totaled R$ 292.070,21 in revenue for the companies.

Sustainable aspects are also observed. SEBRAE estimates that of the total solid waste generated from human activities, more than 50% comes from the construction industry, and 70% of construction waste comes from renovations, demolitions, and small works, with the remaining 30% from formal construction (SIGOR, 2018). Therefore, it is necessary to adopt attitudes to strengthen the idea of sustainability, both in large and small companies, so that construction waste is managed in a way that ensures that it exists in the smallest possible quantity and that processes for reusing and recycling waste are well-structured.

Although the construction industry in Brazil is considered precarious, managers seek ways of growth based on competitiveness in the segment and improvements in the quality of services provided, through management tools. According to Beuren, Floriani, and Hein (2014), for companies to be considered competitive

in the market, they need to offer customers new solutions, relying on innovations, better quality products, adequate prices, and rewarding returns.

The construction of buildings is part of a sector responsible for a market share that has constantly grown, composed mostly of micro and small companies. In Brazil, the Civil Construction Industry Subsector of Buildings (ICCSE) is considered fragmented because no company has a significant impact capable of strongly influencing the industry's results (PORTER, 2000).

The studies by Barros Neto (1999) point out that specializing in a market niche, facilitating payment methods, or offering the customer a maintenance service for a longer period compared to the competitor are attitudes that can help in this market fragmentation.

According to the classification of Construbusiness of 1999, SEBRAE, 2005, and Villela, 2007, the construction industry is organized into the sectors of: construction materials, capital goods, buildings, heavy construction, industrial assembly, and various services. Branco (2006) categorized the typology of the subsector buildings as shown in Chart 1.

Chart no 1: Building sector subdivisions

Tipology	Description
Commercial and financial buildings	Characterized by buildings intended for commercial purposes, such as shops, supermarkets, shopping centers, and banks.
Residential buildings	Intended for residential purposes, either single-family or collective, arranged in vertical or horizontal forms, such as houses, housing complexes, apartment blocks, etc.
Urban facilities	Consisting of buildings intended for the social well-being of their users, being primarily characterized by public buildings built with government support, such as constructions intended for sports, health, leisure, transportation, culture, and supply.

Companies operating in the building sector face problems, one of which relates to the customer, as the acquired product has a high value and is a large part of consumers' income. This makes the product choice very careful and demanding. The other problem is the certain dependence and subordination to the government due to the existence of financing, as its performance is highly dependent on economic policies (MUNIZ, 2006).

The production processes currently used in the sector will have to adapt to the new paradigm established by the need to seek more sustainable development alternatives (DANTAS et al., 2015). The knowledge developed in Production Engineering, regarding the evolution of productive systems, resources, causes and effects, can be employed in the field of Civil Engineering, alongside Lean Construction, capable of mediating existing difficulties in project management through tools and methods capable of changing the course of the construction industry.

In addition, an increase in productivity in the sector is necessary. The past years have been characterized by high production levels, although productivity and production are closely linked. An economic sector is considered competitive if it is done efficiently, employing fewer resources to achieve the same production (ALVARENGA; SILVA; MELLO, 2017).

Faced with this reality, considering durable and high-value-added products, it is essential to recognize the need to implement management tools that can combine sector-specific problems and improve the results achieved on site. Among the existing alternatives, Lean Construction philosophy stands out.

Derived from the Toyota Production System, Lean Manufacturing concepts were adapted to the Construction Industry in the early 1990s, differing only due to the peculiarities of the construction process. Koskela was the precursor of the theme, from the publication of his work "Application of the New Production Philosophy to Construction," where he applied Lean concepts on construction sites and defined the new philosophy as a way of managing production. The set of principles is presented in Chart 2.

Chart no 2: Lean construction principles

Principles	Descrição
Reduce activities that do not add value	Activities that do not add value are considered those that are not part of the customer's requirements, for example, the consumption of time, resources, and space.
Increasing the value of the product considering customer needs.	For the customer, value means meeting all the requirements requested in all stages of the project
Reduce variability	Standardized products and services are better accepted by the customer, and those products and services that have great variability tend to increase non-value-added activities.
Reducing production cycle time.	Also known as Just in Time. The goal is to minimize the cycle time as it directly affects productivity. Cycle time is the sum of transportation, waiting, processing, and inspection.
Reducing the number of steps or parts	By reducing the number of steps or parts in a process, there is a tendency to decrease the number of non-value-adding activities.
Increase flexibility in product execution	Offering different customization features to customers without substantially increasing costs.

Increasing process transparency	Atender à este requisito, pode reduzir a ocorrência de problemas, já que auxiliam na identificação de erros
Focar no processo global	Can help reduce the occurrence of problems by aiding in the identification of errors.
Introduce continuous improvement in the process.	Identifying the causes of problems, defining priorities and goals, and standardizing procedures are all actions that help to add value and eliminate waste.
Maintaining the balance between improvements in flows and conversions.	All process activities start with continuity. Improvements should be applied to the entire process, and it is of no use if a single activity does not follow the speed and functionality of the process.
Benchmarking	To take on the best practices from another company considered a market leader as a learning experience, transforming and adapting them to your own company.

The concepts presented in Chart 2 were developed and well-received by the scientific community, so much so that the International Group for Lean Construction (IGLC) was created with the goal of disseminating these practices worldwide to aid in continuous process improvement. These principles embody the philosophies of Total Quality Management (TQM) and Just In Time (JIT), both known for managing quality through minimal errors, with a focus on delivering the best possible product to the customer, while seeking maximum efficiency, minimal waste, and promoting quality production (LORENZON; MARTINS, 2006).

During the adaptation of Lean concepts to the construction industry, Koskela (1992) identified deficiencies in the process, with the main one being the disregard for the actions that form the physical flow between conversion activities, known as flow activities (PFAFFENZELLER et al., 2015). Thus, flow activities refer to the movement, waiting, and inspection of materials within a production cycle, also known as non-value-adding activities.

These actions contribute to process losses, an increase in final cost, and waste of material, time, and consequently, labor. Therefore, it is important for workers to be well-directed so that they do not perform unnecessary operations, for the layout of the work environment to facilitate logistics and necessary movement, and for production to be leveled and synchronized to avoid work-in-progress waiting. These practices are usually implicit in the process, and are difficult to identify, causing problems and hindering production management (FORMOSO, 2002).

The production process in a construction site is the conversion of inputs into outputs, which can be composed of subprocesses that will make up the building. The set of operations in which every input that enters (inputs) results in an output called the final product (outputs) has been defined as the activities that add value. Efforts in the transformation must be exclusively focused on minimizing costs, considering processes and subprocesses as a single entity, thus reducing expenses as a whole. As a result, the final value of the product is defined by its inputs (KOSKELA, 1992).

In the traditional management model, the final cost is related to the costs of each of the subprocesses, labor, and materials. According to Formoso (2002), an optimization focused on specific subprocesses will hardly result in an improvement of the entire production system, and not considering customer requirements, even in a highly efficient production, can generate inadequate products with low market value.

In general, the study involves the Lean knowledge developed by Koskela (1992) applied to the stages involved in the construction process. Thus, it aimed to investigate the knowledge of civil engineers about the Lean production philosophy in the construction industry in Criciúma. To achieve the general objective, the following specific objectives were listed: to study the principles and tools of Lean Construction; to select a sample with knowledge and/or formation related to construction sites; to identify the knowledge of the sample; to analyze the knowledge and applicability of Lean Construction tools. This study is of great value in drawing attention to both companies and the academic community of universities, who are responsible for disseminating knowledge about new production systems, as they can take solutions for themselves, resume instructions on the subject, and apply them to achieve improvement goals.

II. Material And Methods

The method adopted for the research development follows a qualitative and quantitative approach, with qualitative analyses being performed for the development of the questionnaire and data collection through an applied survey, and quantitative for the treatment of the obtained data, with the objective of evaluating the degree of knowledge of Lean practices in the management of works with engineers working or operating in related areas of the construction industry, from companies in the extreme southern region of Santa Catarina.

It is classified as a descriptive study, where initially a greater proximity to the subject was sought through bibliographic research, exploring the problem topic, followed by the collection of information that was statistically evaluated through the application of a questionnaire, in order to better understand the observed problem and subsequently providing additional information on the subject.

To conduct the questionnaire, the participation criterion established was that the interviewees have completed higher education in Civil Engineering or related fields and have worked or currently work in the

construction industry. Initially, a pilot test was conducted, and adjustments were made based on feedback to improve respondent understanding. After the questionnaires were developed and the pilot test was conducted, the research was divided into two stages. The first stage involved individually sending the survey via GoogleForms to the largest construction companies in Criciúma, Santa Catarina, resulting in 29 responses. The second stage was conducted in person at a lecture on Lean Construction concepts for engineers participating in the Southern Santa Catarina Association of Engineers and Architects (ASCEA), followed by the delivery of questionnaires for data collection, resulting in a total of 43 responses.

Initially, the survey sought to identify the respondent's profile, such as age, academic background, and years of experience in the construction industry. Then, the survey included a total of 27 closed-ended questions covering each of the 11 Lean Construction principles proposed by Koskela (1992). The Likert scale of 1 to 5 was used sequentially to develop the alternatives, with "Strongly Disagree" and "Strongly Agree" being the options presented, indicating the possible conclusions. These scales allow the respondent to express their opinion in terms of complete or partial agreement when presented with a statement. For the researcher, this type of scale plays an important role in data analysis because it allows for the establishment of perception gradients (CUNHA et al., 2010).

The questionnaires were applied from March 7, 2019, to August 27, 2019. The IBM SPSS Statistics software was used for data tabulation, which according to Meirelles (2014), assists in collecting, analyzing, and interpreting research data.

III. Result

The questionnaire was applied to a sample composed of construction area managers from the southernmost region of Santa Catarina, Table 1 shows the median time of work in the area of 10 years. It was also obtained that 86% of the sample is linked to the Civil Construction Industries - Buildings Subsector (ICCSE), with a predominant academic background in Civil Engineering, corresponding to 93% of the total.

Table no 1: Profile of respondents surveyed regarding knowledge of Lean Construction in the ICCSE of southern Santa Catarina.

	Median (AIQ), n (%) n = 43
Age (years)	35,00 (30,00 – 42,00)
Years of work experience in the field	10,00 (5,00 – 18,00)
Sector of work	
Work in the ICCSE	37 (86,0)
Do not work in the ICCSE	6 (14,0)
Academic background	
Civil Engineering	40 (93,0)
Architecture	1 (2,3)
Chemical Engineering	1 (2,3)
Mechanical Engineering	1 (2,3)
Academic institution	
University of Extremo Sul Catarinense (UNESC)	18 (41,9)
University of Southern Santa Catarina (UNISUL)	6 (14,0)
Other Institutions	6 (14,0)
Federal University of Santa Catarina (UFSC)	5 (11,6)
Superior School of Criciúma (ESUCRI)	5 (11,6)
Pontifical Catholic University (PUC)	2 (4,7)
University of São Paulo (USP)	1 (2,3)

The questions related to the profile served to identify the individual in relation to age, experience in the construction industry, and whether they are currently part of this market. Among the interviewees who work in the sector, the median experience time is 10 years. The average age of the survey participants was 35 years. 93% of the interviewees have a degree in Civil Engineering and 7% are graduates in areas directly or indirectly related to the field. Furthermore, of the interviewees, 72% have a degree from private institutions, 14% from public institutions, and 14% not mentioned.

Starting from this first section of the questionnaire, we move on to sections of questions related to Lean Construction principles, in which respondents should express their level of agreement with each statement, all of which are related to one of the 11 principles. The first section focused on the first three concepts, as shown in Table 2.

Table no 2: Degree of agreement of respondents regarding the occurrence of the application of the first three principles of Lean Construction in the ICCSE of the southernmost region of Santa Catarina.

	Escale Likert †, n (%)				
	1	2	3	4	5
	n= 77	n = 107	n = 110	n = 116	n = 102
Reduction of non-value-added activities (n=43)					
Job site safety	2 (4,6)	10 (4,3)	19 (44,2)	7 (16,3)	5 (11,6)
Design projects to optimize space and flows	0 (0,0)	10 (23,3)	8 (18,6)	12 (27,9)	13 (30,2)
Employee training (n=42)	9 (21,4)	10 (23,8)	12 (28,6)	8 (19,0)	3 (7,1)
Increase value by considering customer needs (n=43)					
Process mapping (n=42)	2 (4,8)	7 (16,7)	11 (26,2)	13 (31,0)	9 (21,4)
Research to meet customer needs	5 (11,6)	8 (18,6)	9 (20,9)	18 (41,9)	3 (7,0)
Flexibility for modifications during construction	3 (7,0)	4 (9,3)	9 (20,9)	14 (32,6)	13 (30,2)
Weekly communication between designers and engineers	9 (20,9)	12 (27,9)	9 (20,9)	10 (23,3)	3 (7,0)
Post-occupancy research conducted for all projects	7 (16,3)	9 (20,9)	6 (14,0)	11 (25,6)	9 (20,9)
Reduction of variability (n=43)					
Company is certified in PBQP-H or ISO 9001	8 (18,6)	7 (16,3)	8 (18,6)	5 (11,6)	15 (34,9)
Procedures are standardized with work instructions	3 (7,0)	6 (14,0)	8 (18,6)	10 (23,3)	16 (37,2)
Employee training conducted (n=42)	17 (40,5)	13 (31,0)	7 (16,7)	2 (4,8)	3 (7,1)
Calibration and measuring equipment available on job sites	12 (27,9)	11 (25,6)	4 (9,3)	6 (14,0)	10 (23,3)

PBQP-H - Brazilian Program for Quality and Productivity in the Habitat.
† Likert scale of satisfaction where (1) total disagreement, (2) disagreement, (3) neutral, (4) agreement, (5) total agreement.
†† Scale of training frequency where (1) annually, (2) biannually, (3) monthly, (4) biweekly, (5) weekly.

Regarding the first principle proposed by Koskela, the reduction of non-value-adding activities initially addressed safety on the construction site, where 27.9% agreed that the construction sites of their works are safe, 8.9% disagreed that there is safety, and 44.2% did not know how to express an opinion. Regarding projects designed with better use of spaces and flows, 58.1% of respondents agreed that the construction site is planned to obtain the best use of spaces and reduce flow, 23.3% disagreed, and 18.6% were neutral. If there is training for employees, 26.1% agree that employees are formally trained through courses to reduce waste on the construction site, 45.2% disagree that employee training is carried out, and 28.6% did not express an opinion.

The second principle is to increase value by considering customer needs, which addressed 5 questions. The first question relates to process mapping, where 52.4% agree that all construction processes are mapped, 21.5% disagree, and 26.2% did not express an opinion. Regarding research to meet customer needs, 48.9% agree that research is frequently conducted to meet customer needs, 30.2% disagree with the existence of research, and 20.9% showed neutrality. About the possibility of changes during construction, 62.8% agree that ongoing construction projects allow changes to meet customer needs, 16.3% disagree, and 20.9% did not express an opinion. Communication between designers and engineers occurs weekly, 30.3% agree that communication between designers and construction managers occurs weekly, 48.8% disagree, and 23.3% did not express an opinion. Regarding post-occupancy surveys on construction sites, 46.5% of cases have a post-occupancy satisfaction survey, 37.2% do not, and 14% did not know how to answer.

In the third principle, the reduction of variability was observed regarding certifications such as PBQP-H or ISO 9001, where 46.5% agree that quality concepts are applied, 34.9% do not apply, and 18.6% did not express an opinion. Standardization and work instructions, 60.5% agree that processes have standard procedures and work instructions, 21% disagree, and 18.6% did not express an opinion. Regarding the frequency of training with employees, it occurs weekly for 7%; biweekly for 4.8%; monthly for 16.7%; every six months for 31%; annually for 40.5%. Calibration and measurement equipment on construction sites, 37% agree that calibrated measurement equipment is distributed on construction sites, 53.5% do not have this equipment, and 9.3% do not have the information.

Table 3 presents the continuation of the fourth, fifth, and sixth principles of Lean Construction.

Table no 3: Degree of agreement of respondents regarding the occurrence of applications of the fourth to the sixth principle of Lean Construction, in the ICCSE of the extreme south of Santa Catarina.

	Escala Likert †, n (%)				
	1	2	3	4	5
	n = 36	n = 46	n = 86	n = 77	n = 55
Reduction of production cycle times (n = 43)					
Knowledge of cycle times of processes	4 (9,3)	10 (23,3)	13 (30,2)	10 (23,3)	6 (14,0)
Use of support systems (cranes) and palletized construction materials	7 (16,3)	9 (20,9)	9 (20,9)	4 (9,3)	14 (32,6)
Cross-functional work teams	5 (11,6)	7 (16,3)	7 (16,3)	11 (25,6)	12 (27,9)
Reduction of the number of steps and parts (n = 43)					
Use of prefabricated elements	5 (11,6)	5 (11,6)	14 (32,6)	11 (25,6)	8 (18,6)
Simple and efficient material procurement process	3 (7,0)	4 (9,3)	16 (37,2)	16 (37,2)	4 (9,3)
Increase in product execution flexibility (n=43)					
Reduction in batch size	2 (4,7)	6 (14,0)	18 (41,9)	10 (23,3)	7 (16,3)
Flexibility to adapt projects during execution	10 (23,3)	5 (11,6)	9 (20,9)	15 (34,9)	4 (9,3)

A Likert scale of satisfaction regarding items where (1) total disagreement, (2) disagreement, (3) neutrality, (4) agreement, (5) total agreement.

Principle 4 refers to the reduction of production cycle times and addressed 3 questions. The first one is about the knowledge of process cycle times. 37.3% of those who responded agree that process cycle times are known, 32.6% do not agree or do not know the cycle time, and 30.2% did not know how to answer. The use of support (crane) and palletized construction materials. 41.9% agree that support systems (cranes) and standardization (pallets) are used for material handling, 37.2% do not agree or do not use them, and 20.9% do not know the information. Versatility (steel fixers, carpenters, bricklayers, tilers, electricians) in work teams. 53.5% agree that work teams are versatile, 27.9% do not agree, and 16.3% did not know how to answer.

The reduction in the number of steps and parts addressed the use of prefabricated elements, where 44.2% use prefabricated elements, 23.2% do not use them, and 32.6% did not know how to answer. Simplicity and efficiency in the material purchasing process, 46.5% agree that the material purchasing process is simple and efficient, 16.3% do not agree, and 37.2% were neutral.

Principle 6 refers to questions regarding increasing flexibility in product execution, where reducing batch size was the first item questioned, with 39.6% agreement. Therefore, they seek to reduce batch sizes. 18.7% do not seek to reduce them, and 41.9% did not know how to express an opinion. Flexibility for project adaptation during execution, 44.2% agree that the internal layout of apartments can be modified during construction (walls, electrical installations, windows, etc.), 34.9% do not agree, and 20.9% did not know how to answer.

Table 4 provides information on the degree of agreement on questions related to the seventh, eighth, ninth, tenth, and eleventh principles.

Table no 4: Degree of agreement of respondents regarding the occurrence of the applications of the seventh to eleventh principle of Lean Construction, in ICCSE of the southernmost part of Santa Catarina.

	Escale Likert †, n (%)				
	1	2	3	4	5
	n = 65	n = 50	n = 72	n = 67	n = 46
Increase in process transparency (n = 43)					
Existence of indicators for visual management:	9 (20,9)	8 (18,6)	11 (25,6)	11 (25,6)	4 (9,3)
Use of Lean tools:	26 (60,5)	11 (25,6)	5 (11,6)	1 (2,3)	0 (0,0)
Clean and easily accessible work area:	3 (7,0)	5 (11,6)	13 (30,2)	16 (37,2)	6 (14,0)
Focus on the overall process (n = 43)					
Short, medium, and long-term construction planning.	4 (9,3)	7 (16,3)	11 (25,6)	11 (25,6)	10 (23,3)
Introduction of continuous improvement in the process (n = 43)					
Existence of continuous improvement programs.	10 (23,3)	7 (16,3)	7 (16,3)	11 (25,6)	8 (18,6)
Recording and discussion of non-conformities found.	4 (9,3)	5 (11,6)	14 (32,6)	11 (25,6)	9 (20,9)
Balance between improvements in flows and conversions (n = 43)					
Volume of waste generated on the construction site †† (n = 42)	9 (20,9)	7 (16,3)	11 (25,6)	6 (14,0)	9 (20,9)
	Visits to other companies by employees. †††, n (%)				
		1	2	3	
Principle of best practices (n = 42)		16 (38,1)	10 (23,8)	16 (38,1)	
Benchmarking					

† Escala Likert de Satisfação quanto aos itens onde (1) discordância total, (2) discordância, (3) nulidade, (4) concordância, (5) concordância total.

†† Escala de volume de resíduo gerado por coletor de entulho onde (1) mais de um por semana, (2) um por semana, (3) um a cada quinze dias, (4) um por mês, (5) menos de um por mês.

††† Escala de afirmação de frequência de visitas para identificação das melhores práticas onde (1) Não, não há necessidade, (2) Sim, uma vez que precisam buscar ferramentas ou equipamentos de trabalho, (3) Sim, sempre que possível, com intuito de verificar as novas práticas adequadas.

The seventh principle refers to increasing transparency in the process, which includes the existence of indicators for visual management. 34.9% agreed that they have visual management with indicators such as productivity level and number of rejected parts, 39.4% do not have or use these visual management methods, and 25.6% did not know how to respond. Regarding the use of Lean tools, 2.3% claimed to use the existing tools, 86.1% do not use them, and 11.6% did not have an opinion. As for the workplace, 51.2% agreed that the workplace is clean, clear, and easy to move around in, 18.6% disagreed, and the remaining 30.2% did not know.

Principle 8, which focuses on the overall process, addressed the issue of short-, medium-, and long-term planning. 48.9% agreed that the planning of the construction occurs in the short, medium, and long term, 25.6% did not agree, and the other 25.6% did not have an opinion.

The introduction of continuous improvement in the process questioned the existence of continuous improvement programs. 44.2% of those who responded agreed that there is a continuous improvement program in their construction projects, 39.6% claimed not to have one, and 16.3% did not know how to respond. Regarding the registration and discussion of non-conformities found, 46.5% register and discuss the existing non-conformities, 20.9% do not act in this format, and 32.6% did not have an opinion.

In the principle of balance between improvements in flows and conversions, only the volume of waste commonly generated in the construction project was addressed. 20.9% answered that they generate more than one container of debris per week, 16.3% considered one container per week, 25.6% one container every 15 days, 14% one container per month, and 20.9% less than one container per month.

Benchmarking is a process of comparing competitors' best practices. Regarding the principle of best practices, 38.1% responded that there is no need to visit other construction projects, 23.8% responded that they visit other projects within their own company to search for tools, and 38.1% responded that they do benchmarking whenever possible to verify new practices adopted.

Table 5 summarizes the results to display the degree of agreement of each principle, facilitating the visualization of which principles currently have greater or lesser applicability in construction companies.

Table no 5: Lean Construction Principles and their agreement percentages.

Lean Construction Principles	Negation agreement	Neutral	Positive agreement
1 – Reduce non-value added activities	32,0%	30,5%	37,5%
2 – Increase value considering customer needs	31,0%	20,7%	48,4%
3 – Reduce variability	36,4%	15,5%	48,1%
4 – Reduce production cycle times	32,8%	22,7%	44,5%
5 – Simplify and reduce the number of steps and parts	19,8%	34,9%	45,3%
6 – Increase flexibility in product execution	26,7%	31,4%	41,9%
7 – Increase process transparency	48,1%	22,5%	29,5%
8 – Focus on the global process	25,6%	25,6%	48,8%
9 – Introduce continuous improvement in the process	30,2%	24,4%	45,3%
11 – *Benchmarking*	**No** 61,9%		**Yes** 38,1%

According to Table 5, it can be seen that the most applicable principles today are "Increasing value considering customer needs" with 48.4% agreement, "Reducing variability" with 48.1%, and "Focusing on the global process" with 48.8% utilization. In contrast, the least used principles are "Increasing process transparency" in which only 29.5% execute, "Reducing activities that do not add value" with 37.5% agreement, and "Benchmarking" with 61.9% not practicing.

Regarding the most applicable principles, it was initially perceived that customer desires are already key points observed by construction companies and professionals. The market is changing, and the industry is understanding that the customer is becoming increasingly demanding, willing to pay for what they want and the differential offered, which requires flexibility and planning from the service and product providers. Another point observed was regarding the standardization of procedures, which reduces the variability of final products. Formoso (2002) reports that standardized products and services are better accepted by customers, and those products and services that have great variability tend to increase the portion of activities that do not add value.

Principle 7 was the most unfavorable as it was questioned about the presence of visual management indicators, circulation, cleanliness at the workplace, and the use of lean tools, where only 2.3% said they use existing tools, against 86.1% who do not use them. There was a discrepancy in this point, since the study, in general, involves the applicability of lean practices in construction, and precisely in one question, this number was very low compared to the study that revealed relatively good results regarding the knowledge and applicability of these tools.

Regarding the principles with less acceptance, activities that do not add value are considered those that are not part of customer requirements, such as the consumption of time, resources, and space (KOSKELA, 1992), safety on the construction site, and employee training end up impacting this principle. Being more exposed to danger and lack of qualification can contribute to the consumption of time and resources. 8.9% of respondents do not agree that construction sites are safe, and only 26.1% said that training is carried out with workers.

Benchmarking is directly related to improvement and is another principle that deserves attention, as it presented a relatively low level of application. Using the benchmarking tool is ideal to enhance continuous improvement among enterprises.

It is worth noting that Table 5 does not include the questions related to the third principle, which deals with the frequency of post-occupancy surveys, and the tenth principle, not present in the table, as it solely addresses the frequency of the volume of waste generated on construction sites. The response format for these questions is not positive or negative agreements, but rather about the frequency with which certain events occur.

It is important to highlight that regarding employee training, 40.5% of those interviewed reported that training occurs only annually and 31% biannually. This is a point that needs to be viewed with attention, as the construction industry sector needs qualified personnel to ensure that the delivered product is of good quality. Therefore, it is essential to bring up another point addressed in the survey, regarding the versatility of work teams, where 53% of respondents positively agreed with this statement. This is, in fact, a good result, and it is of great value that these teams remain updated regarding new knowledge developed concerning their activities such as reinforcing, carpentry, electricity, and others.

Concerning the volume of waste generated during the execution of construction works, it is necessary that a rubble collector picks up the waste with a certain frequency. It is expected that the quantity is as low as possible to sustain the idea of sustainability and waste reduction. In this matter, the answers were quite dispersed, with 20.9% responding that this occurs less than once a month, 25.6% every fifteen days, and 20.9% more than once a week.

IV. Conclusion

The research aimed to focus on the importance of measuring the level of progress in the implementation of the lean philosophy, in order to obtain data related to the best practices and principles that need improvement. According to the data from the survey conducted with 43 respondents, it was verified which of the 11 principles are currently more present in the construction industry in the far south of Santa Catarina, and those with a lower degree of agreement are the ones that deserve more attention for the evolution of Lean Construction.

Thus, the investigation of knowledge about the lean production philosophy with professionals in the field, based on the selected sample, identified and analyzed knowledge that, in general, presented about 43% applicability. It is known that for the effective implementation of lean construction concepts in the production system, factors such as commitment from top management to implement them, focus on measurable and viable improvements through appropriate lean performance indicators, involvement and commitment of employees who must know and understand the principles, and finally, knowledge of the current state are ideal for setting goals for the future.

Although the data was carefully evaluated, it is necessary to recognize that there were weaknesses in the study regarding the sample size, due to the difficulty of distributing the questionnaires via GoogleForms. Therefore, it is recommended that other studies contribute to the sampling procedure to improve the study. Another suggestion for the progress of the research is to make a comparison of this engineering knowledge with the knowledge of academic Civil Engineering students in the far south of Santa Catarina, to understand and chart a horizon of how the applicability of Lean concepts can behave in the future.

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