TOWARDS ENHANCING CONSTRUCTION INDUSTRY WITH SIX SIGMA AND LEAN CONSTRUCTION

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Abstract

The civil construction environment is competitive, and their management seeks better business performance. In this context, this paper aims to investigate the six sigma, lean construction in the construction industry to enhance the business performance. Paper research was carried out related to these main topics. Six sigma methodology DMAIC six management flow applies quantitative and statistical methods. It researches the process and establishes defects and errors with analytical quality tools to examine issues causes, characterize common daily problems from the companies as mistakes, delays, and other improvements in the construction industry. Lean construction is another methodology to reduce the losses and quality improvement and eliminate waste in the construction flow. The researchers carried out exploratory and qualitative research to build the interpretations. Business performance is a pertinent subject to all companies, including the construction industry. With the combination of six sigma and lean construction being applying together in a complementary form, profitability, competitiveness, customer satisfaction, and quality could be achieved.

Key-Words: Six sigma; lean construction; business performance; construction industry; quality.

1. Introduction

The quality improvement interest is widespread in all companies, producers of products or services because managers realized the business performance is requested in the competitive world or local markets.

The condition of non-existent quality management procedures means time, money, and resources disbursements indicators. The audit of internal and external performance engineering and construction processes is an inquiry to improve the market competitiveness, adding a limit on non-value-adding activities. The organizations look to manufacturing industries to check their measuring effectiveness and control tools as six-sigma to attain these targets.

However, to attain acceptable quality levels in the construction industry has been trouble, the construction industry plays a relevant role in many economies. And a consequence of ineffective or non-existent quality management procedures, quantities of human and material resources are wasted each year.

The construction industry has quality improvement potential. Construction process improvement intends to produce a better account, lower cost, quality, and customer satisfaction.

And the quality is an essential question to companies, how achieve and maintain the quality level? There are so many tools to guarantee and sustain the quality company level. The construction industry could apply six sigma and lean construction. Lean construction is derivate from lean thinking and lean manufacturing. Six sigma is a methodology to reduce the variability using statistical tools. This paper's aim is how construction industry improvement could be endorsed aggregating six sigma and lean construction into the process.

2. Literature review

This topic is related to the main theoretical concepts that make up the article's scope. The sources are and papers published in several publications and classic literature with their relevant analyzes and contributions.

2.1 Six sigma in construction

From at least the last two decades, six sigma (6 σ) methodology emerged, providing a problem framework for organizational, advising leadership to apply new ways of understanding and solving their issues. Six sigma processes guide the importance of environmental sustainability to both profitability and customer satisfaction to improve their performance (KADRY, 2018).

As a historical chronological sequence for six sigma, in 1987, Motorola developed the six-sigma methodology and defined a goal of 3.4 parts per million (ppm) defects. In 1994 to produce high-level results, six sigma was introduced to improve work processes and expand all employees' skills. General Electric beginning in 1995, launched the six-sigma program (STEWART, SPENCER, 2006; KADRY, 2018).

According to Kadry (2018), the sigma means the statistical unit of measurement used to define the standard population deviation; and considering that defects occur under a normal distribution, this corresponds to almost two quality failures per million of parts manufactured. The six-sigma methodology challenge is to utilize management and quality tools sets in a systematic way to improve critical operational and business processes to reach 6σ performances.

Linderman et al. (2003) contribute affirming that six sigma an organized approach to achieving a committed team and better performance in construction processes. In this scenario of performance, Kadry (2018, p.6) affirms a single sigma improvement in a business process from one sigma level to the next one means into about something "about 10% net income improvement, a 20% margin improvement, and a 10 to 30% capital reduction".

Six sigma is a "well-structured continuous improvement methodology to reduce process variability and drive out waste within the business process using the effective application of statistical tools and techniques. It is a quality philosophy at the highest level, relating to all processes, and a quality measure at the lowest level" (TCHIDI; HE; LI, 2012, p.159; SHIBANI, 2016).

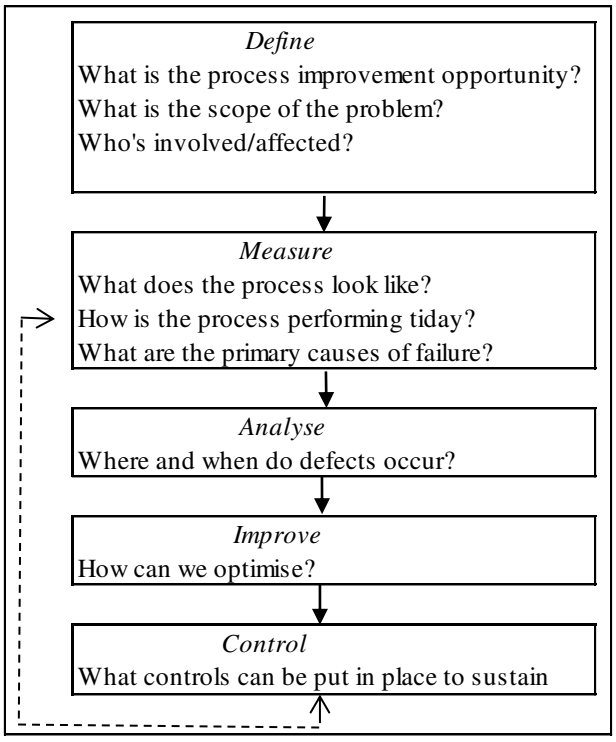
Following Tchidi, He, Li (2012), six sigma features enhance operational performance to improve customer satisfaction, conceive a product or service higher value, follow up schedules, quality, and cost. Second, Pyzdek (2003); and Stewart, Spencer (2006), six sigma

is a systematic procedure constituted by a five-step methodology call DMAIC (fig.1) (Define, Mesure, Analyze, Improve and Control).

As highlighted by Stewart, Spencer (2006), Tchidi, He, Li (2012), six sigma DMAIC management flow applies quantitative and statistical methods, researching the process and establishing defects and errors with analytical quality tools to examine issues causes. DMAIC process advises the organization to seek the whole process quality. The focus is on reducing input variability to reduce outputs. Variability, diminishing defects number or mistakes; DMAIC simplifies the process, acts as a road map for team advance (STEWART, SPENCER, 2006; PAUL; JIJU; BRYAN 2019).

Even though some quality management systems and philosophies are followed carried out by some organizations, the desired standard quality level is not always attained. Without a competent quality cost system in place, measuring the quality improvement is more complex; due to the fact, the product or service quality is not related to the final delivery but the complete business process. Besides this scenario, the complex made of materials used by the personnel qualification, customer satisfaction are components of the civil industry context (Tchidi; He; Li, 2012). In this contextualization, the six sigma is used by several construction industries (STEWART, SPENCER, 2006; TCHIDI; HE; LI, 2012).

Figure 1 Methodology DMAIC



Source: Stewart, Spencer (2006, p. 342)

Another feature of six-sigma is a focused management people system, which intends to increase customer satisfaction increment, decrease needy quality causes and variation, and

reduce costs. Also, the target is detected and correct mistakes, process variation process to eradicate defects in all transactions; the traditional quality programs are oriented on catch and correct mistakes. (STEWART, SPENCER, 2006).

Furthermore, Oguz et al. (2012) related the construction projects generally have delay for some reasons, as the vulnerability of equipment, materials, late delivery. As well orders modified, tool malfunctions, not good uses from crew, natural and environmental effects, accidents are some factors that contribute to production industry wastes. It is decisive to maintain a construction flow for materials and work because otherwise is a loss of time and money on inventory, space, and time.

Six sigma has been applied in the manufacturing industry and in a significant manner in several companies seeking opportunities. The relevant changes are achieved in the manufacturing scenario. Because the projects associate design and development for a new product or service; or modernize one. On the other hand, six sigma construction industry improvement reached micro-opportunities; this condition implies that six sigma projects would be small-scale and relate to given an account sub-task in a macro-opportunity (STEWART, SPENCER, 2006).

2.2 Lean construction

Koskela et al. (2002) affirm that the early industrial engineering framework introduced production as flow, and it was only developed from the 1940s in Japan to eliminate wastage flow processes.

Lean can be applied efficiently in all business processes, and lean gives a critical administrative support process as buying or productive (Liker, 2004). The theory of production, including transformation and value (TFV), was proposed.by Koskela (Koskela et al 2002; Aziz, Hafez, 2013). And flow and value serve as a framework for the definition of lean construction. Al-Omar (2012, p.107) affirms that lean construction "keeps an eye on the value-added (VA) element of the construction process (conversion) as well as the None-Value-Added (NVA) elements (flow, delay, and errors). A lean delivery emphasizes a cost-effective and on-time handover with no delays or rejects or quality issues".

According to Koskela (1992), eleven principles guide an essential improvement to lean construction; and these must be managed in an integrated way of the processes:

a) Reduce activities that do not add value;
b) Improve product value through consideration of customer needs;
c) Reduce variability;
d) Reduce cycle time;
e) Simplify by reducing the number of steps and parts;
f) Increase the flexibility of the product;
g) Increase the transparency of the process;
h) Focus control in the overall process;
i) Introduce continuous improvement to the process;
j) Balance the progress in the flow with the upgrades of the conversions;

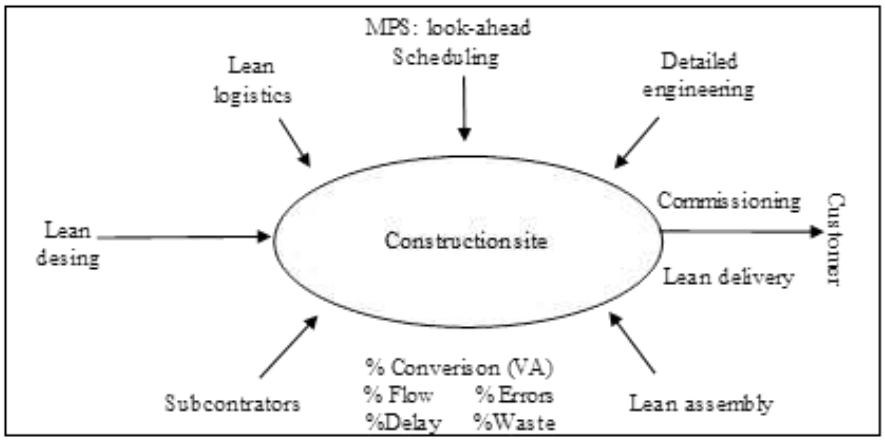
k) Benchmark.

Oliveira, Pereira (2014, p.3) emphasize that lean construction "differs from the traditional model because it attaches importance to flow and conversion activities. Conversion activities are considered activities that add value to the product, while flow activities do not always add up".

Al-Omar (2012) highlighted that lean construction is focused on delivering value by production management projects. And lean construction follows the lean principles and lean thinking to improve a new way to manage construction projects, reducing waste, increasing value, and seeking perfection. It is essential to mention, could apply lean philosophy in all productive systems of products or services. It is constantly combating the seven classics wastes: "defects (errors), delays, overprocessing, overproduction, excess inventory, unnecessary transport and convenience of materials and equipment, and unnecessary motions and movement of people" (AL-OMAR, 2012, p.106).

At first glance, we can think only about lean design, lean supply, lean assembly, lean production, and lean delivery system at the principal modules of project delivery; but also think about the interaction at the construction site and the environment construction (fig.2).

Figure 2 - Lean construction environment



Source: Al-Omar (2012. p.107)

Al-Omar (2012) informed that a lean delivery determines on-time handover and cost-effectiveness without rejecting quality problems or delays.

The same concept about lean construction is applying new management construction, with clear objectives for specific delivery processes and maximizing project performance and customer satisfaction. It is a way to think, design, and make things different, optimizing production system performance against performance (AZIZ, HAFEZ, 2013).

The construction managed under lean construction orientation has delivery process objectives, look for maxim project performance for the customer, designs process and products, the practice of life project with production control AZIZ, HAFEZ, 2013).

Marhani; Jaapar; Barai (2012 p.90) summarizes the last 30 years of the evolution of lean construction (table 1) concept evolution and methodology.

Table 1 Evolution of lean construction

Author	Contribution
Koskela (1992)	Advantages of the new production philosophy in terms of productivity, quality, and indicators were solid enough in practice in order to enhance the rapid diffusion of the new principles
Howell (1999)	Lean construction is much like the current practice as the goal of better meeting customer needs while using less of everything
Lukowski (2010)	Lean construction is the practical application of lean manufacturing principles, or lean thinking, to the building environment
Yahya and Mohamad (2011)	Lean construction is about managing and improving the construction process to profitability deliver what the customer needs by eliminating waste in the construction flow by using the right principle, resources and measure to deliver things right first time

Source: Marhani; Jaapar; Barai (2012, p.90)

As Aziz, Hafez (2013, p.680) affirms, "the first goal of lean construction must be to fully understand the physics of production, the effects of dependence and variation along supply and assembly chains. In lean construction as in much of manufacturing as planning, control".

And Ahmed; Sobuz (2020) affirm that adopting lean principles generates innovation on construction projects as a systematic way of work, promotes best practices of lean principles, better corporate image, productivity, competitive advantage, and adequate customer expectation and compliance.

2.3 Business performance

Regarding business performance, it is necessary first of all to understand the meaning of performance. It means "to perform a task with regularity, method, and application, run it, properly achieve its fulfillment, i.e., give effect to a duty, fulfill a promise and carry out the provisions of a contract or order."

The performance "means the completion of work, an action of a work or an exploit and how an organization reached the objectives that were referred to him (MILI; SNOUSSI, 2018, p.77).

Mili, Snoussi (2018) confirms that established practices work and six sigma practices achieve quality performance, approaching a higher business performance. The elemental argument for the apparent positive financial effects of the six sigma application is "that it generates new knowledge, learning, and adjustment of capabilities within the company. Briefly, 6-σis a notion that offers both a structure and stimulates a culture that favorites problem/opportunity recognition, process analysis, and the conception of continued developments" (MILI; SNOUSSI, 2018, p.76).

It is essential to highlight that business performance (BP) amounts to a central measurement that allows managers to earn and control the strategies. The focal point is that the performance measurement should be an overall management item system that encloses numerous fundamental elements that conceive a performance management system. Some types of performance measurement are the general Balanced Scorecard Model (BSC), the European Foundation for Quality Management Excellence Model (EFQM), and the Performance Pyramid System (PPS) (MILI; SNOUSSI, 2018).

Six-sigma can be defined under a business, and statistical perspectives: the first one defined six-sigma as a strategy apply to enhance profitability, diminished quality costs and intensify operations to overcome customer's expectations (STEWART, SPENCER, 2006).

For Sánchez-Rebull (2020, p. 1119) et al., six sigma is a "philosophy that pursues excellence, offering reliable products or services." Also, enlarge the opportunities for business efficiency and product defect reduction, customer satisfaction, and contribute to the variability of reduction in the process. It helps to solve strategic problems.

Six sigma tends to make better the business processes, studying and diminishing the process deviation; and as minor process variation, better quality performance "by allowing the process to get more consistent results in terms of quality, lead times, yield rates, and so on (MILI; SNOUSSI, 2018).

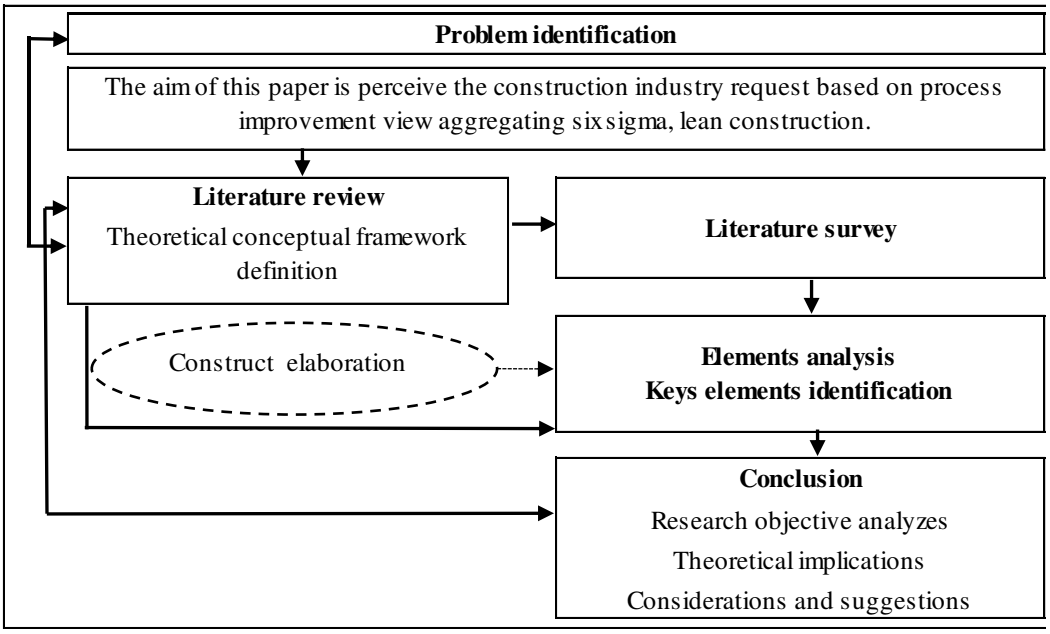
The industry condition draws attention to the less structured frameworks to define process improvement initiatives and reach total quality. This condition implies on the guidelines lack, and benefits cannot be coordinated or repeated, and improvements are isolated. However, in the construction industry, the improvement process varies for construction firms, customers' requirements fluctuate; therefore, variation is not eliminated, yet it can be handled (STEWART, SPENCER, 2006).

Sánchez-Rebull (2020) pointed out the importance of cash flow because the disposal of funds through current profitability is related to the lower debt ratio. This likelihood is a good relation between cash flow volatility and debt cost. The absence of a positive balance cash flow can bring issues due to not achieving profits or presenting losses, bringing a company to collapse.

3. Method

The central idea is to study and comprehend the literature survey. The researchers carried out exploratory and qualitative research. According to Oliveira (2010), the qualitative path permits the review presentation and fact analysis and descriptions. When we cannot quantify information on a given subject, on observed phenomena, interpreting is necessary (Triviños,1987). The extraction purpose Web of Science and the Scopus database was used to select the papers, and the methodology flow chart is presented in figure 3.

Figure 3 Methodology flow chart



Source: The Authors (2021)

The string parameters search followed some parameters as representatives' journals, books, language limit to English, and 2000 until 2021. The search string delineates to retrieve papers from databases were: ("construction industry") and ("six sigma") and ("construction management") and ("lean construction"), and ("process improvement") and ("total quality management"). These combinations should be present in either the title, keywords, and the abstract of each document.

4. Analysis and results

Based on the literature review, several positive aspects could be perceived on the scenario of the civil construction industry, six sigma, lean construction, and business performance.

Six sigma and lean construction could be applied together and enhance the company's results, using a methodology to provide new forms to understand and solve an issue and the importance of environmental sustainability to profitability and customer satisfaction.

Six sigma reduces process variability and drives out waste by applying statistical tools and techniques and helps operational performance. It conceives a product or service of higher value, follow-up schedules, quality, and cost with the input reduction variability to reduce outputs variabilities, diminishing defects number or mistakes. Further, six sigma organize to achieve a committed team and better performance in construction processes.

On the other side, lean construction seeks the value-added element of the construction process and identifies the none value-added elements as errors, delay, and problem flow. The value-added is obtained by conversion. A lean construction delivery emphasizes no delays, rejects, quality issues, and a cost-effective and on-time handover.

Lean construction follows lean principles and lean thinking to promote a new way to manage construction projects, waste reduction, increase value, and look for perfection.

Performance is to perform a task with regularity, method, and application, deliver the promise of a contract or order. Established six sigma practices in a company help achieve quality performance, approaching a higher business performance. It is a positive financial effect that generates knowledge, learning, and adjustment capabilities within the company.

The business performance amounts to a central measurement that allows managers to earn and control the strategies. Six-sigma can enhance profitability, diminished quality costs, and intensify operations to overcome customer's expectations.

Six sigma is a philosophy that seeks excellence, offering reliable products or services, enlarge business efficiency and, product defect reduction, contributing to strategy.

All these aspects analyzed about six sigma, lean construction and business performance indicate that the synergy between them is fundamental for the construction industry to reach better results, attend customer expectations, be more competitive on the market, and differentiate from competitors.

5.Conclusions

The competitive business environment is under stakeholders, shareholders pressure to improve the organizational performance; not achieve the improvement could mean failure or profits losses. There are various business process techniques to improve operational, financial, and strategic performance efficacies.

The primary outcome is the overview of six sigma, lean construction, and business performance; these three aspects can interact and yield good results to the construction industry.

The second outcome and endorsement from this study are the monitoring construction activities and case study, applying DMAIC techniques in teamwork, and mechanized process improvements at construction industry procedures.

The third outcome is six-sigma structure provides a procedure for data collection during the construction processes and attributing quality and process improvements.

The fourth outcome is related to lean construction, a managed way to improve the construction process, achieve profitability, and eliminate waste in the construction flow.

The last outcome, but less important, is driven to the academic community and professionals from the construction industry to elaborate on lean six sigma and lean construction for every company size. The impact will be felt throughout the civil chain construction industry, with minor losses, more quality, fewer errors, more profitability, and customer expectation achieved. The authors do recommend more researchers about the subject to conduct qualitative and quantitative results.

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