LEAN CONSTRUCTION AND SUSTAINABILITY - COMPLEMENTARY PARADIGMS? A CASE STUDY

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ABSTRACT

In times when Sustainability is a major concern in public opinions all around the planet, it has become a constant issue for most Industries. The Construction Sector is not an exception to this trend, and efforts have been reported on seeking to adopt metrics that can measure Sustainability on site. On the other hand, the concept of Lean Construction (LC) is becoming a reality more and more present in this sector. Its effectiveness in controlling and eliminating wastes are becoming more and more acknowledged. Both concepts appear to have significant principles in common, hence this paper intends to examine and establish a relationship between LC and Sustainability, and assess their complementarity.

This paper portrays a case study where LC tools and techniques where applied on a construction site, in order to observe and assess the relationship and complementarity between those and the Sustainability Construction Index (SCI) developed by a major Portuguese Construction Company, Soares da Costa Construções, S.A. (SDC).

KEY WORDS

Lean Construction, Sustainable Development and sustainable metrics, Portugal, Sustainability

INTRODUCTION

The concept of sustainable development was coined in the 1987 Brundtland Report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987). This document is part of a sequence of initiatives that support a critical point of view of the development model adopted by industrialized countries and reproduced by developing nations. The report points out the incompatibility between sustainable development and the present patterns of production and spending. Following the publication of this report, other conferences were held in which other documents were created, but all with the same objective, to contribute to the sustainability of a nation.

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This goal sparked all sectors to the need of introducing the concept of sustainability and sustainable development.

In the business sector, a number of organizations have recently focused on Corporate Sustainability and Corporate Social Responsibility begins to emerge in a growing way, indicating the integration of the concept of sustainability by this sector. The first traces of sustainability logics in business companies have thus occurred by reporting environmental, social and even sustainability progress (Pinheiro, 2006).

The construction sector has not been indifferent to this process of integrating sustainability. It is, by nature, a sector that tends to be resource-intensive and a large-scale waste producer, which often produces significant impacts on the environment (Pinheiro, 2003).

This large-scale waste production needs to be taken seriously. According to Grohmann (1998), the amount of materials and manpower wasted in three construction sites allow the construction of another identical project, i.e., the waste would reach a rate of 33%. These wastes are reflected in the work costs that can cause a 6% increase in total cost (Pinto, 1995).

Against this backdrop, LC came to change the production management system in the construction sector. This concept aims at eliminating all types of wastes, such as costs, time, materials or equipment in order to reach a better final product, thus increasing customer value.

This paper aims at contributing to the assessment of the relationship and complementarities between Sustainability and LC concepts and principles. A review of previous literature of both areas of knowledge is carried out. Lean concepts and solutions are then presented and their possible contribution to Sustainability discussed. A case study is then portrayed where LC tools and techniques were applied on a construction site, in which practical observations were conducted, utilizing the Sustainability Construction Index (SCI) developed by a major Portuguese Construction Company. Finally, conclusions are drawn and future research is proposed.

LITERATURE REVIEW

SUSTAINABILITY IN BUSINESS SECTOR

According to Cepinha (2007), “All companies, regardless of the sector in which they operate, have a very important (moral) role in contributing to the sustainable development of the planet”, thus it is necessary to incorporate the concept of sustainability into planning systems corporate management.

Sustainability principles have been materializing in the form of voluntary certification systems, such as the LEED system in the USA, the BREEAM system in the UK and the LiderA system in Portugal. They share, as common basis, the Triple Bottom Line (TBL) approach; social, economic and environmental. To prove that a company fits the 3 principles of the TBL in its planning, variables have to be measured and the results compared. This resulted in the need to search for ways of linking sustainable performance to company value increase. The result of this demand has been the development, in 1999, of the Dow Jones Sustainability Index (DJSI).

This was the first global reference to impartially supervise the financial performance of sustainability leaders on a global scale (Dow Jones Sustainability Group Index, s/d). That same year, another index linked to sustainability was developed, called FTSE4Good. It influences investment decisions and defines how companies are evaluated (FTSE - The Index Company, s/d).

Aware of this trend, construction companies have been adopting existing sustainability indices or developing their own. In the Portuguese construction sector, Soares da Costa has, since 2008, been developing and implementing a tool that monitors the sustainable performance of their work sites, the Sustainability Construction Index (SCI). This tool was developed by a multidisciplinary team, composed by several elements with different functions inside the company, with the aim of monitoring the impacts of the works site and their performance minimizing negative impacts of economic, social and environmental activities, by seeking to transform good practices in common practices (Soares da Costa, 2010).

The SCI is divided into 3 indicators: Environmental Performance, Systems Management, and Economics and Value Chain, in which each is composed by subcategories as shown in the table 1.

Table 1: Indicators evaluated in SCI (adapted from Soares da Costa, 2010)

General Work Site Indicators	Workers on site; Worked Hours; Amount Budgeted for Environmental Planning and Management of Health and Safety
Environmental Performance Indicators	Total Energy Consumption; Total Water Consumption; Total Water Reuse; Total Waste Production, detailed by type of final destination; Material Reuse; Land Volume/Excavated Soils - Total, detailed by type of final destination
Systems Management Indicators	Accidents Indexes (Frequency and Severity); Awareness / Information / Training Environment; Awareness / Information / Education in Health and Safety at Work; Awareness / Information / Training on Quality; Costs Management and Environmental Management Health and Safety at Work ; Number of Environmental, Health and Safety and Quality Non-Conformances ; Number of Health and Safety at Work Non-Conformances ; Number of Quality Non-Conformances
Economics and Value Chain Indicators	Community Investments - Total; Local Suppliers - Volume of Purchases; Fines and Penalties – Financial amount; Internal Social Actions; Number of Workers' Claims; Monthly Value of Production

LEAN AND SUSTAINABILITY

From a positive perspective, the construction sector is one of the largest and important industrial sectors. But it is simultaneously of the largest polluters (Horvath, 2004, cited in: Bae and Kim, 2007). Therefore, the construction industry has a great potential for promoting sustainable development. One of the possible approaches to this promotion it is implementing LC principles through the introduction of social and environmental values as new targets to achieve, rather than focusing on just accidental benefits of LC to the environment (Bae and Kim, 2007).

Bae and Kim (2007) describe in their work how LC methods can contribute to the sustainability of a project. Table 2 summarizes these methods; more specifically it indicates which Lean tools can contribute to the sustainability of a project.

Table 2: Main contributions of Lean tools in sustainable development

Tools	Main contributions for sustainable development
JIT	Tool that may or may not be environmentally friendly; Reduces the amount of materials and materials' damages; Reduces the sources that cause the extra stock; However, the frequent stock transportation associated could cause increased emissions
5S	Visual tool that could help in sustainable construction; Used to maintain a workplace clean and organized
VSM	Visual tool that shows the processes (products and information); Allows for a better understanding of the generation of value streams and the steps which enclose waste; this tool can be used not only for economic purposes, but also for social and environmental ones, by adding environmental information to the map
Kaizen	"Continuous improvement", in Japanese; It has a key role in improving the current state towards sustainable development; All sustainability indicators could be improved by Kaizen

On a more conceptual level, Martinez et al., (2009) apply the principles of Morphologic Analysis and Cross-Impact Matrix, in order to find the relations between Lean and Sustainability concepts. This study developed a methodology of conceptual integration that has allowed sequentially disposing several construction activities in different scenarios within the life cycle of a construction project.

LEAN TOOLS

As the theory supporting Lean Thinking developed, a number of techniques that allowed its principles to be put into practice were created, developed and adapted. These Lean tools are numerous and their main objective is to certify on site what the theory itself says, i.e., eliminate waste and streamline processes and resources.

Seven of those Lean tools were considered particularly adequate for the materialization of the TBL and were looked at closely. They are listed and described below.

Value Stream Mapping (VSM)

This is a planning and communicating tool that enables to manage the material and information involved in the process. Rother and Shook (1998) presented standardized icons that make it easier to understand and apply this tool. It is composed of 5 steps (Queiroz et al., 2009): identify a product, draw the current VSM, proposals for improvement, create the future VSM and implement and monitor the changes.

This tool is very practice oriented and it is basic for the evaluation of where and how in the production process other Lean tools and techniques can be applied.

5S

This is a set of Japanese techniques consisting in 5 steps that aim to organize and standardize the work environment:

SEIRI (Sense of use): Distinguishes useful from not useful materials and tools, eliminating the unnecessary.

SEITON (Sense of organization): Refers to the organization of materials and tools. This organization aims at the identification and placement of tools, materials and equipment in the right spot, in order to allow a quick and easy access to them.

SEITO (Sense of cleaning): It consists of keeping the work area, surfaces and equipment clean and restoring and checking whenever it is necessary. It must be a daily procedure in order to achieve a working environment constantly clean and organized.

SEIKETSU (Sense of standardization): It seeks to define standard procedures to maintain the working environment clean and organized.

SHITSUKE (Sense of self-discipline): It has the aim of developing self-discipline by maintaining the utilization of all the steps mentioned above in a continuous way.

Just in Time (JIT)

The main objective of this tool is to produce the right amount at the right time with the right quality level (Chan, 2001). It is the ideal tool to fight one of the seven wastes identified in MUDA: Stock excess. MUDA is composed by seven types of wastes identified by Taiichi Ono including: overproduction, transportation, excess motion, waiting, inappropriate processing, stock excess and defects.

Last Planner and Percentage Plan Compete (PPC)

It essentially refers to the short and medium term planning and control, in which the main objective is to ensure, through various procedures and tools, that all the prerequisites and constraints of an activity are solved at its beginning, allowing the activity to be carried out without disruption and being completed according the planning (Peneirol, 2007).

The PPC is an index that calculates the percentage of activities completed each week, which should follow the Last Planner (Ballard and Howell, 1998c).

Map of Irregularities

This map was adapted from the Map of Fault proposed by Mendonça (2008) and it consists in completing the information obtained from the PPC, i.e., every time an activity is given as non-completed, the cause of failure is analyzed and recorded on this map. The map indicates the type of work and the week, in which the assessment is made, it identifies the activities that have not been completed, the detected failure and its consequences and finally the suggested resolution.

Subcontracting Relationship

In recent years, the practice of outsourcing has been increasing and it often encompasses for about 90% of the total project (Hinze and Tracey, 1994). Since close relationships between firms can improve the performance of the construction process, as well as eliminate waste and reduce efforts, evaluating this performance has become an important factor (Vrijhoef and Koskela, 2001).

Kaizen

This Japanese word's meaning is continuous improvement. It is based on the concept of a cyclical process which can involve people, materials or equipments which seeks to improve the processes performance involving all activities. Kaizen is a methodology that seeks to achieve perfection.

RESEARCH METHOD

This research study was carried out on a construction site from SDC, with the aim of establishing a relationship between LC and the company's SCI. To establish those relations, Lean tools were applied in construction processes in order to optimize them.

The site was directly observed during a period of 1 month, in which a data collection was carried out through direct observation, document analysis (made available by the company), meetings on site with the heads of the project.

The methodology used is based on the 5steps that compose the VSM:

- Identify a product or service that will be subject to the implementation of improvement proposals. In this study case, 3 processes were chosen: Plasterboard, steel and formwork material. These were the activities with the highest financial and workload weight.

- A current VSM was drawn for each of these 3 processes, describing all the steps that constitute each of the 3 processes, from the moment the order of the material is made to the collection of the waste that resulted from these processes.

- An analysis was carried out to the 3 current VSM, in order to identify weaknesses in the process and non-value-adding steps. Improvement proposals were made to eliminate the weaknesses and Lean tools were selected that best fit the proposed solution.

- The future VSM was then drawn based on the proposals made in the previous step, and providing the bases to implement these.

- Finally, the fifth step is based on the proposals' implementation and monitoring. During the implementation, difficulties that may arise must be taken into account, creating a new VSM in order to achieve continuous improvement.

The conclusions drawn were then validated through in depth interviews with the company's technical general director, its general production director and the senior officer that lead the development of the company's SCI, as well as the supervision of its implementation in the job sites. This validation strategy results from the particular characteristics observed in this case study and will be described and justified in the next section of this article.

MAIN RESULTS AND DISCUSSION

During the analysis made to the 3 current VSM, some steps of the processes were identified as already optimized. This situation was found not only in these 3 processes, but also in steps belonging to the planning and preparation of the work site. Following the Kaizen methodology, improvement proposals were made to some isolated weaknesses detected in the previous processes.

Interestingly enough, these optimized steps showed several characteristics that were compliant to Lean principles, indicating that optimization efforts had already been taken, intuitively utilizing Lean principles.

This observation led the authors to compare the SCI of this job with the overall average in the company. Although the data compiled by the company was still preliminary, this job's performance was found to be above average. This was in line with the observation that the job's staff put particular care in optimization issues.

Due to these particular characteristics there was little room left for further improvement in this specific project. This led the authors to carry out a reverse validation strategy. The improvement proposals were brought together in a set of tables, which were then presented to technical general director, its general production director and the senior officer that lead the development of the company's SCI. This was carried out in meetings held at the company's office in Lisbon, with two separate objectives: the improvement proposals were to be validated, and the optimized procedures which intuitively included Lean principles were to be analysed, in order to determine whether they were common procedure at the company or if they were only being applied in this specific job site.

The in depth interviews carried out determined that most of the optimized procedures were specific to this job site. This was due to the joint effect of three reasons: the owner was known for being strict about time or cost overruns and environment conscious, the contractor's staff on site were known inside the company for placing great interest in process optimization and the scarcity of space available for the staging area. Thus, it was concluded that having a demanding owner/client and rigorous deadlines and budgets is an important motivator for the adoption of Lean methods and tools.

Since the aim of this work was to establish a relation between Lean principles and Sustainability, table 3 below was prepared based on the information and results

obtained. This table identifies the processes/steps, the Lean term and the corresponding SCI metric, indicating also the possible relations between these two concepts.

Table 3: Parallelism between Lean and Sustainability

	Step	Lean Term	SCI metrics
Plasterboard	Material displacement for the application site	MUDA and 5S	Accidents Indexes (Frequency and Severity)
Formwork material	Placing of waste containers in the immediate vicinity of the shuttering/striking works	5S	Accidents Indexes (Frequency and Severity), Nonconforming HSW and Total Waste Production
Plasterboard	Send waste to appropriate location		
Steel	Option to buy pre cut and shaped steel	Eliminating activities in-situ	Total Waste Production
Plasterboard	Waste collection	5S	
Planning	Definition of durations and their maturities	Last Planner and PPC	Monthly Production Value
	Linking PPC to the Map of Irregularities	Kaizen	
Work planning and Site Management	Subcontractor hiring	Subcontractor relationship	

Table 3 was discussed with the senior officer in charge of the SCI development, in order to determine whether the measures portrayed procedures have any impact on the SCI metrics obtained for this job, when compared with the average SCI metrics in tall the job sites of the company. According to this responsible, due to the recent development of the SCI metrics, which started in 2008, it is not yet possible to determine whether these procedures have any impact on the SCI metrics at this stage. However, it is the company's objective to develop the SCI to the point of being able to determine which procedures impact it, and determine if it is a positive or negative impact.

The analysis made aimed at establishing a connecting bridge between Lean principles and Sustainability metrics. Each of these steps is analysed and presented bellow and they will be identified if they were an existing procedure present in the construction or an improvement proposal made.

In the first step (existing procedures), it was possible to establish the elimination of two types of wastes identified by MUDA (excessive transportation and handling) and the use of the 5S methodology (work area organized). From a Lean Thinking perspective, the benefit obtained was an increase of the workplace safety, which should lead to a decrease in the number of accidents. There is a SCI metric that counts

the number of work accidents, called Frequency Index. It was then possible to establish a relationship between this metric and a Lean procedure.

The second (proposal made) and third (existing procedure) steps correspond to the use of the 5S methodology. The benefits resulting from this procedure are an increased workplace safety and its easier reading by the workers, which translates into safer work conditions for manpower. These procedures should lead to a decrease of non-conformances, number of accidents and to a faster and more effective waste disposal. The SCI presents metrics that quantify those parameters: Non-conforming HST, Frequency Index and Production Waste (differentiated by type of final destination). Thus, a relationship was established between these procedures and metrics.

The fourth (proposal made) and fifth (existing procedure) steps correspond to the elimination of some in-situ activities and the use of the 5S methodology. The aim of the fourth step proposal was to eliminate the workspace problem, since the steel yard was located on top of a 2-story building. With this measure, the waste coming from the steel work would be also eliminated. Both procedures lead to a decrease in waste quantities and a faster and more efficient waste collection and disposal. SCI has a metric called Waste Production that quantifies the waste dispatch, reuse and disposal on site. Thus a relationship was identified between both metrics and procedures.

The last three steps correspond to the use of the Last Planner and PPC (existing procedure), Kaizen (proposal made) and Subcontractor Relationship (existing procedure). These three procedures lead, each in its own way, to a better work environment and better planning, increasing the productivity on site, with positive reflects on present and future work progress and development. Hence a relationship was established between them and the SCI metric, "Monthly production", which measures the monthly value produced.

CONCLUSIONS

In this work it was possible to conclude that there is a relationship between Lean and Sustainability. Through the application of Lean tools in the construction processes of a case study, it was possible to establish a parallelism between SCI metrics and Lean.

The proposed model was developed based on the VSM's 5 steps, since it was identified as having potential to contribute to sustainable development. Once the material flows were drawn and the non-value-adding steps identified, the future state VSM was created, which served as a basis to implement the proposed solutions. A relationship was then established between the proposals and the SCI metrics.

Quantifying this relationship depends on two important factors:

- A successful model implementation that requires time, initial investment and change efforts;
- A successful SCI implementation and consolidation that requires time and dedication from all players.

Being faced with a growing competition between companies in the construction sector and a growing awareness of the need to adopt a sustainable development within businesses is expected, with this model and with this established relationship, open new ideas and gateways between other Sustainability metrics and Lean.

FUTURE RESEARCH FIELDS

In order to complete this work, determining and quantifying the impact of Lean on SCI metrics, once both this index and the measures proposed in this study are fully implemented in the company and have become standard procedure. Once this stage is reached, a cost-benefit analysis of the implementation of the proposed measures would also be of great interest..

Another study of great importance should lead to the combination of Lean and Sustainability and their integration in the whole of the company's construction procedures, so that the whole construction process would be optimized both from a Lean perspective (minimizing waste, maximizing value to the customer) and in terms of Sustainability performance, maximizing the TBL.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the cooperation of Soares da Costa Construções, S.A., for providing access to their SCI and to the case study project, as well as assistance on several occasions in the course of this study.

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