Cano, S., Delgado, J., Botero, L., and Rubiano, O., 2015. Barriers and success factors in Lean Construction's implementation - Survey in pilot context. In: *Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction*. Perth, Australia, July 29-31, pp. 631-641, available at www.iglc.net.

BARRIERS AND SUCCESS FACTORS IN LEAN CONSTRUCTION IMPLEMENTATION - SURVEY IN PILOT CONTEXT

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ABSTRACT

The study identifies a set of barriers and critical success factors (CSF) involved in the implementation of Lean Construction (LC) through three phases: Literature's Collection, with analysis and obtained information processing; Characterization and classification of barriers and CSF associated with the implementation of LC; and Identification of barriers and CSF in construction companies in the Colombian context, based on their experiences in the implementation of LC. 83 academic articles published between 1998 and 2014 were examined, being identified 110 barriers and 51 CSF based on experiences of LC's application around the world. They were grouped into six "Master Factors": people, organizational structure, supply chain, external value chain, internal value chain and externalities. The obtained information from the data was analyzed using a cause-effect matrix and a structural analysis with MIC MAC method, and the most critical barriers and success factors were determined. Furthermore, the exploration in the pilot context demonstrated a common criticality in most of these factors, and it was shown that its appearance is related to the level of evolution of LC's application.

KEYWORDS

Barriers, Critical Success Factors, Lean Construction, Action learning, Commitment.

INTRODUCTION

To integrate LC philosophy in a construction organization, it is recommended to understand and anticipate situations (barriers) that might be opposed to a proper implementation, as well as taking hold of those (CSF) that can help ensure its success based on similar experiences in other contexts. A barrier prevents a step or an action,

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while a success factor is something that must occur — or that must not happen — to achieve the objectives, this factor becomes critical if its compliance is absolutely necessary for achieving those objectives. These situations are presented internally and externally in the organization and the project, and understanding them is of maximum importance to propose actions to contribute to forewarn their occurrence or to mitigate their impact in terms of barriers, and in another sense, to provide a guide towards strengthening those conditions that contribute to the successful implementation of LC using the CSF.

BARRIERS AND SUCCESS FACTORS IN LC

RESEARCH RETHOD

Primarily the search was conducted in the database of the International Group for Lean Construction - IGLC (www.iglc.net) with references from 1996 until the present year. This database presents a complete collection of publications in LC, thus this was the main reason to select it as the most important source for this research.

The bibliographic references were complemented with databases such as ScienceDirect, Emerald, and SpringerLink. Because the literature and research on the topic LC is huge, especially on the above databases, the search was delimited using keywords (filters) as: "barriers in the implementation", "obstacles", "difficulties", "hurdles", "hindrances", and "critical success factors". The search was directed to Google Scholar to finish this first stage of information gathering. The obtained articles were classified according to the publication year.

In the next phase of research, it was paid much attention to the quotations of authors and references of each article on the subject of barriers and success factors. The cited articles were looked again at the already suggested databases. This procedure was performed repeatedly and with each of the found articles, applying inclusion and exclusion criteria to complete the list for the study.

It was necessary to undertake an exclusion process of articles, which were not so relevant for this project. Exclusion criteria were: general publications and articles focusing on the implementation of Lean Manufacturing. Only documents in English and some in Spanish language were taken into account. The most important inclusion criterion was to select articles that clearly express the different obstacles or CSF that impact the implementation of LC, which have been documented in cases from different parts of world in construction projects.

DATA PROCESSING

Classification of the selected articles was done, summarizing the most important and relevant aspects to the research, especially the list of barriers and/or success factors identified by different authors. Furthermore it was took into account the author or authors, the country in which it was developed, the publication year, the identification method of factors, the used classification or categorization system, characterization of concepts, and the analysis and final discussions of each author.

When the total quantity of articles was revised, it was completed a list of critical factors of each of the collected publications. Afterwards it was consolidated a list that would group all barriers and success factors. For each factor was written the source

from which was obtained, the author who described it, and the quantity of different places where it has been also identified.

SEARCH RESULTS

During the literature review, it was identified 110 barriers and 51 CSF. The situations encountered were documented from 83 academic articles published between 1998 and 2014 (in this article only 26 references are presented), based on experiences in applying LC in the construction industry within countries such as China (Pheng and Shang, 2011; Shang, et al., 2014), United Kingdom (Bashir, et al., 2010; Sarhan and Fox, 2012; Sarhan and Fox, 2013), Vietnam (Khanh and Kim, 2013), Malaysia (Abdullah, et al., 2009; Jeni, Luthfi and Akasah, 2013; Marhani, et al., 2013), Mexico (Cervero-Romero, et al., 2013), Nigeria (Olatunji, 2008; Ahiakwo, et al., 2012), Dominican Republic (Senior and Rodriguez, 2012), Ghana (Ayarkwa, et al., 2005; Ayarkwa, Agyekum and Adinyira, 2011), Brazil (Viana, et al., 2010), Middle East (Alsehaimi, Tzortzopoulos and Koskela, 2009), Uganda (Alinaitwe, 2009), Germany (Johansen and Walter, 2007), USA (Haupt and Whiteman, 2004; Kim and Park, 2006; Hamzeh, 2011; Pekuri, et al., 2012), Singapore (Dulaimi and Tanamos, 2001), Chile (Alarcon and Diethelm, 2001; Alarcon and Seguel, 2002; Alarcon, et al., 2005), Finland (Pekuri, et al., 2012), and Lebanon (Gherbal et al., 2012).

CHARACTERIZATION AND CLASSIFICATION OF FACTORS

According to the definition and characteristics of each identified factor, the barriers are grouped into the Master Factors and categories, and improvement measures relating them to the identified CSF are presented.

MASTER FACTORS

People: Related to people who are involved or participate in construction projects. This group was separated into four categories: 1. Education and training, 2. Top Management, 3. Operation, and 4. Attitude and culture.

Organizational structure: aspects related to the structure of the organization, means or procedures necessary to achieve organizational goals, the flow or resource management, interrelated systems within the organization, among others. The categories of this group are: 1. Philosophy, 2. Resources, and 3. Structure.

Supply Chain: Supply chain involves all parties directly or indirectly to satisfy a customer. The aim of the supply chain is to maximize the global generated value. This consists of four categories: 1. Management, 2. Resources, 3. Technical aspects, and 4. Processes and systems.

Internal value chain: All processes, procedures and stages that include planning and control of project's development, in this case, of construction. There are three categories in this section: 1. Management, 2. Planning, and 3. Control.

External management and value chain: The value chain describes the full range of activities that are required to bring a product or service from conception, through the different stages of production, delivery to final consumers, and until final disposal after use.

Externalities: Those aspects that impact the project's development and as well as the LC's implementation as external factors. Three categories are distinguished: 1. Government, 2. Construction's nature, and 3. Other.

OVERCOMING WAYS

Ways to overcome barriers are influenced by local conditions of the industry, development and evolution of LC within construction companies (maturity), criticality and relevance of each of the identified situations, among others. A set of CSF is used as elements which are opposed to the identified barriers as an efficient manner to overcome or minimize their impact on the LC's implementation in construction projects.

People: Includes appropriate training and education, comprehensive understanding of the Lean philosophy, closer relationship between academia and industry, support and commitment from the top management, effective leadership, clear definition of roles, responsibilities, functions and levels of authority, selection and development of the right people, collaboration, inclusion of specializing in LC professionals, promises with commitment, motivated people to change, honesty and trust between project participants (transparency), discipline, respect for authority and deep aversion to waste.

Organizational structure: Comprises setting process goal in the short and long term, full implementation of the selected LC tools, incorporation of pilots testing, more focus and attention to customer needs, a holistic perspective, and solution of root problems. Management must provide adequate resources to support cultural transformation, have a mentality of order and active participation of all stakeholders in the organization. A balance of the interests of all participants, constitution of an improvement committee responsible for the implementation, incorporation of lessons learned, sharing information appropriately, improvement of coordination and cooperation, and reduction of hierarchical levels.

Supply Chain: Includes ensure an effective and open communication, establish closer and collaborative relations with suppliers, customers and consultants; to support the thinking transformation, working methods, promoting integration, coordination, and cooperation. Standardize and ensure complete and accurate designs. Establish an incentive system, awareness that the right process will produce the correct result.

Internal value chain: It aims to establish a better management of the production chain, employing an effective and open communication, better coordination and cooperation, a clear methodology and management processes. Establish a solid plan of action of extensive planning with enough anticipation.

External value chain: Comprises improvement of comprehension and understanding of the same administration and value chain, it is necessary to develop a system of training and education for those involved in its management.

Externalities: Includes an establishment of an adequate system of risk management that encourages more participation of all stakeholders, and an appropriate contractual agreement that balances the interests of all participants.

EXPLORATORY PILOT CONTEXT

A sample of 26 Colombian companies was studied. The LC's heads of the organizations were interviewed through personal meetings. The respondents work in organizations carrying out construction projects in the major Colombian cities, and have experience in implementing LC between 1 and 10 years. The built and applied instrument for data collection was an interview based on an exploratory survey conducive to know the process of implementing Lean in the organization. The objective was to identify problems or barriers encountered in this process, to determine the critical factors for successful implementation of LC, and to collect the final recommendations about the implementation process by interviewed. This instrument was validated through the evaluation by a panel of experts, who contributed to determine the final survey items which would lead to concise results. With the interviews it was able to identify a list of barriers and success factors in the Colombian context, and thus the common elements were related and analyzed with the list which was collected in the literature review.

From this exploratory test, it was identified that 56% of the barriers and 68% of the CSF of the list of obtained factors from literature, are presented in Colombian construction companies. In the local context were identified other barriers and CSF that have not been reported in the literature, some of them associated with the current conditions of the construction sector in Colombia. These are:

Barriers: 1. Difficulty in having appropriate people for LC's application. 2. Lack of identification and control of waste. 3. The results are not fast, and often only partially visible. 4. Poverty and social problems. 5. The own informality of local industry. 6. Lack of self-esteem and initiative on the part of individuals.

Success factors: 1. Making decisions in teams, collectivity. 2. Provision of capable and trained contractors in LC fundamental aspects in consistent with their field of work. 3. Reduction of labor turnover at all hierarchical levels - Continuity of workforce in projects. 4. Improvement of life's quality of workers. 5. Establishment of a continuous process of measuring losses. 6. Socialization, for the sector companies, of the individual results of the LC's application. 7. Destination of time to think and plan. 8. Generation of confidence in the philosophy and the principles. 9. Persistence in cleaning and order. 10. Work in the formality of the construction guild.

CRITICALITY ANALYSIS

Based on the gathered information, it was performed a descriptive exploratory analysis of the data, extracting the most significant and influential barriers and CSF in the projects and organizations. To identify relationships between the analyzed variables, some tools such as a cause-effect matrix and the MIC MAC structural analysis method were used, which are presented in the following subsection. The statistical treatment, to which were submitted the answers given by the respondents in the sample of visited companies in this investigation, led to obtain clear results that show not only the state in the maturity of the application of LC in companies of the Colombian context, but also the criticality of the identified factors, from a rigorous study of causalities and influences between them.

CAUSE-EFFECT MATRIX

The level of criticality or relevance of the obtained factors was determined from a cause-effect matrix, establishing causal relationships between the CSF and the barriers. In the top row of the matrix are aligned the outputs (the 110 barriers). In the left column are registered the inputs (the 51 CSF) (Hernandez and Reyes, 2007). To each output is given a priority factor, which is calculated with the frequency of each element in both contexts (identified in the literature and in the Colombian companies), the most frequent element is assigned with the highest priority factor (9 for the most frequent and 1 for the less frequent).

The matrix was completed by evaluating the relationship of each input with each output: if the input variable has no effect on the output variable was evaluated with zero (0), if the input variable has a small effect on the output variable was assigned with one (1), and thus, if the effect increases it might reach an assessment of ten (10) if the input variable drastically affected the output variable.

With the completed matrix the criticality is calculated by multiplying the relation values for priority factors. It estimated the total sum for each input and each output. Finally the cause-effect matrix is completed with all calculations, highlighting the most critical inputs and outputs based on the relationship among them and the priority factors. According to the score, the 10 most critical barriers and the 10 most critical success factors are listed below:

Critical barriers: 1. Cultural problems; 2. Lack of participation and integration of all stakeholders; 3. Lack of knowledge, understanding and awareness of Lean; 4. Resistance to change by managers; 5. Dichotomy design - construction; 6. Resistance to change by workers; 7. LC insufficient training; 8. poor and inadequate planning; 9. Lack of proper attitude; 10. Lack of commitment of continuous work.

Critical success factors: 1. Participation of all stakeholders; 2. Better coordination and cooperation; 3. Overcoming resistance to cultural change; 4. Change in the mindset of employees; 5. Motivated people to change; 6. Teamwork; 7. Development and selection of the right people; 8. Honesty and trust among participants - transparency; 9. Effective Leadership; 10. Training and appropriate education.

STRUCTURAL ANALYSIS

MIC MAC is a technical tool to describe a system using a matrix that connects components (Guzman, et al., 2005). It allows examining and identifying influential and dependent variables of the study. The MIC MAC structural analysis method is used to raise questions and make a collective reflection of the study group, reducing the complexity of the system to specific points, helping to identify the most influential and the most dependent variables.

Crossed-impact matrix and motricity – dependency analysis

For structural analysis are considered the factors with a high level of importance, relevance, or criticality which were identified in the cause-effect matrix; to establish what and how the influence and dependence of each critical variable is. For the analysis of motricity - dependency it is necessary to build a crossed impact matrix with double entry, one for the 10 critical barriers and other for the 10 CSF. In this matrix was analyzed the dependence of each variable, with respect to the others, from left to right and the motricity from top to bottom. This relationship is evaluated with

three when the degree or level of dependence or influence is high, with two if that level is moderate, with one if it is low, and zero if there is no dependence or influence. Finally the values in each row are added to determine the dependence of each factor (d) and the values of each column are added to determine their level of influence (m). With those totals, the percentage of dependence and influence can be obtained for each variable, which are shown below.

Barriers: lack of participation, integration and interest of all stakeholders is the most dependent barrier (19.8%), followed by poor planning (16.5%). On the other hand the less dependent barrier is insufficient training (1.1%), followed by lack of understanding and knowledge Lean (5.5%) and dichotomy design - construction (5.5%). Lack of proper human attitude and cultural problems are the most influential barriers (16.5%), followed by resistance to change by managers (14.3%). On the other hand the less influential critical barrier is poor and inadequate planning (3.3%), followed by the dichotomy design - construction (5.5%).

CSF: participation of all stakeholders and motivated people to change are the most dependent success factors (14.7%), followed by teamwork, better coordination and cooperation, and resistance to change by managers (13.8%). On the other hand the less dependent CSF is appropriate training (1.7%), followed by the development and selection of the right people (3.4%). In regard to motricity or influence effective leadership is the most influential CSF (15.5%), followed by development and selection the right people and change in the mindset of employees (12.9%). On the other hand the less influential critical factor of success is better coordination and cooperation (3.4%), followed by motivated people to change (6%).

Then appear four types of variables and are sorted to identify the essential ones or keys in the system: **Zone 1.** When the variables have low motricity and are little dependent: variables are little influenced by the others that constitute the system, they exert little influence on the other variables. **Zone 2.** When the variables have low motricity and are very dependent: variables are strongly influenced by the others that make up the system; they offer little influence on other variables. They are called outcome variables. **Zone 3.**When the variables have high motricity and are little dependent: variables exert strong influence on the others that make up the system, but they can be slightly affected. They are called independent or conditions variables; or variables of the power area. **Zone 4.** When the variables have high motricity and are very dependent: variables exert strong influence on the others that constitute the system; they are very influenced by other variables. They are called random variables or variables of the conflict zone. They are influenced by the conditioning variables and influence on outcome variables.

It is necessary to graph each of the analyzed critical factors in a motricity vs. dependence chart, with the previously obtained data in the crossed impact matrix, to determine in which zone they are located. In the Figure 1 are positioned each of the 10 critical barriers according to their respective values of influence and dependence. Similarly the 10 CSF are located in the Figure 2.

Barriers located in zones 3 and 4 are very critical (Zone 3: 1. Cultural problems; 3. Lack of knowledge, understanding and awareness of Lean; 4. Resistance to change by managers; and 6. Resistance to change by workers. Zone 4: 9. Lack of proper attitude), because they have high influence on the other barriers, and that fact could have a major negative impact on the Lean implementation; especially the more

independent variables (Zone 3, higher criticality). Barriers in zones 1 and 2 are not so critical over the others, because they present little influence.

The success factors most critical, namely, most important to increase the possibility of success in the Lean philosophy implementation, are the numbers 1, 3, 4, 7, 8, 9, and 10 (Zone 3: 7. Development and selection of the right people; 8. Honesty and trust among participants - transparency; 9. Effective leadership; 10. Training and appropriate education. Zone 4: 1. Participation of all stakeholders; 3. Overcoming resistance to cultural change; 4. Change in the mindset of employees), because they are located in zones 3 and 4 (although the ones in the area 3 could be the most critical).

This final map of criticality of the barriers and CSF, defines more clearly the target factors that guide the efforts and prioritize actions for efficient progress in the implementation of LC in construction systems in the Colombian context.

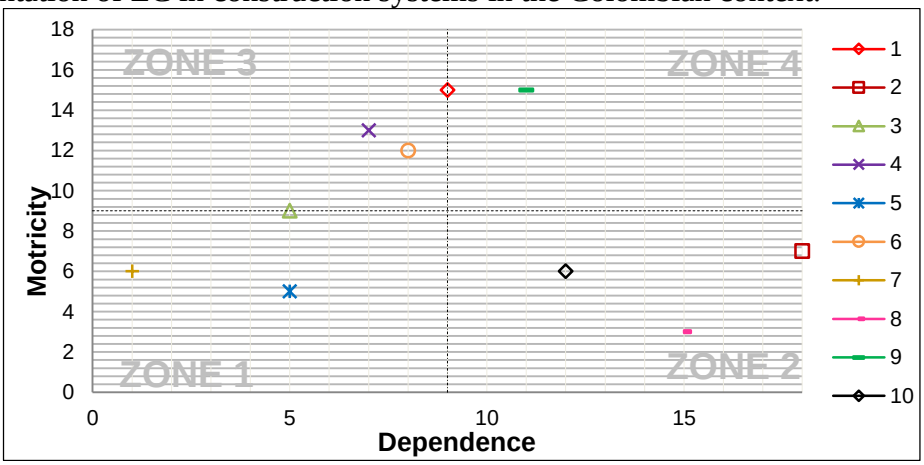

Figure 1: Graph of Motricity vs. Dependence of the 10 critical barriers. Enumerations correspond to the barriers identified in the cause-effect matrix (Source: own authorship).

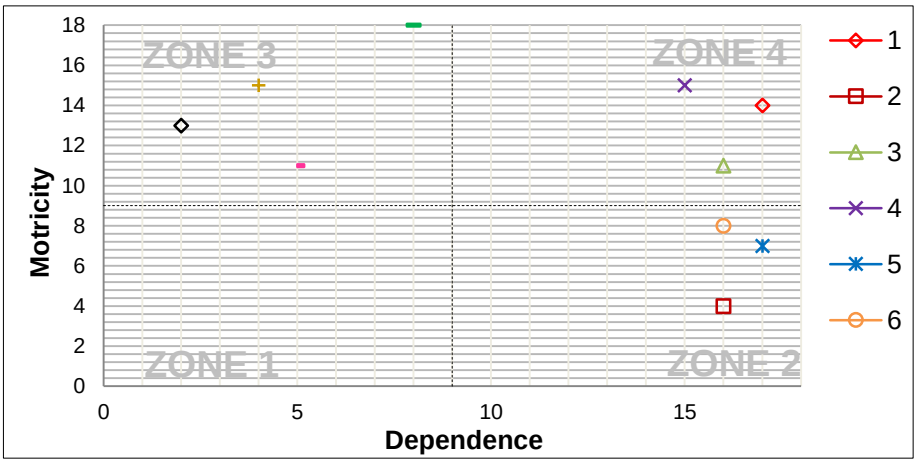

Figure 2: *Graph of Motricity vs. Dependence of the 10 CSF. Enumerations correspond to the CSF identified in the cause-effect matrix (Source: own authorship).*

CONCLUSIONS

Prior to the LC's implementation, knowing this wide set of barriers, it is advisable to provide a way to prevent their occurrence or mitigate their impact, based on

knowledge of the CSF to strengthen the LC's application. After the criticality analysis of the factors in the cause-effect matrix and the results in the MIC MAC analysis, it was identified that the most important and influential barrier is related to cultural problems and the most influential CSF is the development and selection of the right people. Two success factors were identified by several companies, showing their importance in the Colombian context and based on the local conditions: "reduction of turnover or continuity in the workforce" and "socialization of the results of the LC application". In the perspective of future works, this study can be extended to identify structural aspects to assess maturity in the LC application in construction projects.

ACKNOWLEDGMENTS

The authors express their gratefulness to construction companies who attended the interview and for their willingness to achieve the purpose of it.

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