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Key requirements of an IT tool based on last planner® system

Principales requerimientos de una herramienta TI basada en last planner® system

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Abstract

The Lean Production system, with its principles of industry efficiency and production systems, proposes a new way of working, starting in the automotive sector, but later adapting to other sectors, such as the construction industry, through Lean Construction and its various application systems, among which Last Planner® System (LPS) stands out. Based on the methodology of the LPS, various software applications have been proposed, which incorporate its main components and help companies in project planning and control. Despite its rise, currently the real requirements that construction companies have about IT tools based on LPS remain unknown, as how the main IT tools that apply LPS meet these needs. Given this scenario, this research identified and validated the requirements for IT tools based on the LPS methodology, along with evaluating how the main software applications in the market make compliance with these aspects.

Keywords: Last Planner ® System; LPS; Lean Construction; LPS Software; RII

Resumen

El sistema Lean Production, con sus principios de eficiencia de las industrias y los sistemas de producción, plantea una nueva forma de trabajo, iniciando en el sector automovilístico, pero más tarde adaptándose a otros sectores, como la industria de la construcción, a través de Lean Construction y sus diversos sistemas de aplicación, dentro de los que se destaca, Last Planner® System (LPS). En base a la metodología del LPS se han planteado diversos softwares, que incorporan sus componentes principales y ayudan a las empresas en la planificación y control de proyectos. A pesar de su auge, actualmente se desconocen los reales requerimientos que tienen las empresas constructoras acerca de las herramientas TI basadas en LPS, y a su vez, cómo las principales herramientas TI que aplican LPS satisfacen estas necesidades. Ante este escenario, esta investigación identificó y validó los requerimientos para herramientas TI basadas en la metodología LPS, junto con evaluar cómo los principales softwares del mercado hacen cumplimiento de éstos aspectos.

Palabras clave: Last Planner ® System; LPS; Lean Construction; Software LPS; RII

1. Introduction

Since the early 1990s, the global production system has been undergoing change, which began in the automotive sector, but later adapted to other sectors such as construction (Pons, 2014); (Koskela, 2000). Due to the need to improve the efficiency of industries and production systems, a new way of working, the Lean system, was born (Womack & Jones, 2008). Lean provides tools that contribute to greater integration between the different social agents and companies that intervene throughout the life cycle of a project, from managers to workers on site, which implies adopting a new approach to the integral management of the project (Pons, 2014).

In a Lean company, people represent a fundamental asset, generating a higher quality of work (Gil, 2017). In addition, this system encourages teamwork, improves communication, facilitates an overview of the entire process, helps in the early identification of errors, followed by effective and rapid problem solving, and leads to greater self-management (Womack & Jones, 2008). The comprehensive management of the entire project moves from the traditional hierarchical model of command and order to a collaborative and distributed authority system (Cuatrecasas, 2015). In this area, a new production philosophy for the construction industry has emerged, known as Lean Construction or construction without loss, which consists of applying the principles and tools of the Lean system throughout the entire life cycle of a construction project (Pons, 2014); from its conception to its execution and commissioning (Koskela, 1992). The Lean Construction philosophy has several tools for its implementation within a company, one of them being the Last Planner® System (LPS) (Ballard & Howell, 1997).

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LPS is a methodology for programming, monitoring and control of construction projects that focuses primarily on the execution of the works, but also has an initial planning component, prior to the start of the works (Ballard, 2000); (Ureta, 2018). LPS leads to a reduction in project variability, protection of executable work, optimization of workflows, improvement in loss identification, continuous improvement, collaborative work and integration of production and supply chains (Koskela et al., 2015). Given the many advantages of implementing LPS, which include achieving higher rates of productivity, quality, safety, customer satisfaction and reduced delivery times (Pons, 2014), is that many companies in the construction industry have dared to use this methodology, changing their traditional planning systems to a Lean system.

In recent years, there have been numerous contributions to the LPS, through the incorporation of information technology (IT) systems, which collaborate with the planning and management of a short-term project. For this reason, IT systems have been developed for project management based on the LPS methodology, incorporating the relevant components of this methodology (Ureta, 2018) and allowing an improvement in information flows and a better alignment between planning, operation and control, considering the project as a whole, i.e. the management of the project in the long term (Rodríguez et al., 2011). Although LPS has had a great boom in recent times, being applied mainly in large companies through various software offered by the market, currently it is unknown the real requirements that construction companies have about an IT tool based on Last Planner ® System. Also, it is unknown how the main IT applications that apply LPS meet the needs of enterprises. Therefore, the objective of this work is to identify the main requirements of an IT tool based on the LPS methodology, and observe how the main software in the market make compliance with these aspects.

2. Research methodology

The research methodology is shown in (Figure 1). It includes the work stages, research tools and activities carried out to achieve the objective of finding the functionalities that an IT based on LPS should have. In addition, the deliverables obtained in the course of the research are indicated.
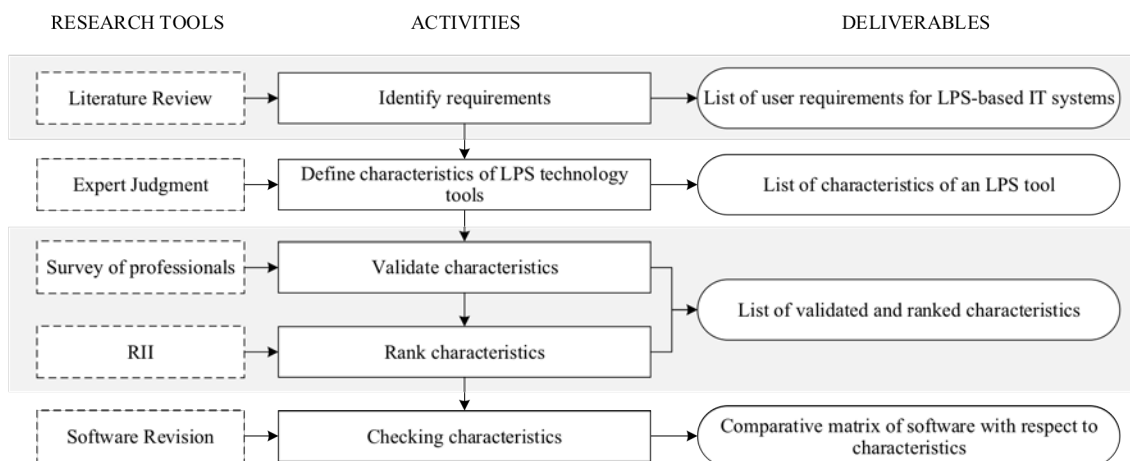

RESEARCH TOOLS	ACTIVITIES	DELIVERABLES
Literature Review	Identify requirements	List of user requirements for LPS-based IT systems
Expert Judgment	Define characteristics of LPS technology tools	List of characteristics of an LPS tool
Survey of professionals	Validate characteristics	List of validated and ranked characteristics
RII	Rank characteristics	
Software Revision	Checking characteristics	Comparative matrix of software with respect to characteristics

Figure 1. *Research methodology.*

In a first stage, through a literature review, the user requirements were identified for the formulation of IT systems based on Last Planner® System, obtaining a list with the main requirements identified. The search was carried out in the Google Scholar library, incorporating books, scientific articles and academic theses, between 1992 and 2018, based on the concepts of: Lean Production, Lean Construction, Last Planner® System, and LPS Software. In a second stage, a list with the main elements that a software based on the LPS methodology should have was obtained through expert judgment, based on a group discussion session. Eight experts were selected

meeting the following requirements: a) more than 15 years of practice in construction management, and b) experience as an implementer, consultant, researcher or university professor in Lean topics. In a third stage, from the list validated by the experts and the obtained from the literature, an online survey was made to 56 professionals practitioners or consultants of Last Planner® System, who had to qualify each element with a Likert type scale with a score from 1 to 5, according to the level of importance that they considered that element had for a LPS tool. From the results obtained from the survey, the Relative Importance Index (RII) was calculated, through which it was possible to create a ranking with the main elements that should contain an IT tool of LPS, obtaining a prioritized list. Finally, a verification to software found in the market was made, where it was analyzed if they count or not with the characteristics of the list obtained in the investigation, generating a comparative matrix.

3. Results and analysis

The technological advances of recent years allow the use of information technology (IT) to be extended to new applications to improve the effectiveness and efficiency of different fields and industries. Paradoxically, despite the important role of the construction sector in the national and global economy, the use of these technological advances in the construction industry is still quite modest. This poor use of technology by construction companies is well known and has been demonstrated in many studies, emphasizing that the technological reality of the construction industry is far from that of other sectors (Ureta, 2018).

3.1 User requirements

The Last Planner® System has been implemented in countries on all five continents for over 20 years and its evolution has been recorded in over 50 research papers published at the International Group of Lean Construction (IGLC) conferences (Cisterna, 2013). In addition, although the vast majority of publications report studies from the United States and Europe, the system has also had a wide and growing adoption in South America and particularly in Chile (Sabbatino, 2011). In addition, the number of components adopted has grown systematically over time; however, the degree of adoption of the various components has varied over the years and there are some components that have remained at an incipient degree of implementation (Lagos, 2017).

A widely accepted conclusion by the researchers of IGLC is that the focus of LPS implementation has been systematically short-term (Lagos, 2017). In fact, the most widely adopted components of the methodology have consistently been weekly planning, search for causes of non-compliance and measurement of the CFP (Alarcón & Calderón, 2003).

This problem turns out to be important since the non-use of the other components of LPS is highly correlated to the increase in the fulfillment of commitments and the improvement of project performance (Lagos et al., 2019).

The inclusion of IT systems to support the management of LPS presents an opportunity for the management improvement of such components (Alarcón & Calderón, 2003). (Choo y Tommelein, 2001) describe a list of requirements, obtained from the development and testing with users, for the formulation of IT systems based on LPS. These requirements seek to fix the necessary characteristics of such systems to facilitate their adoption and that their implementation be beneficial in construction projects. The requirements are based mainly on the characteristics of the applications to facilitate their use, understanding and integration with the methodology Last Planner®:

a) *Last Planner® procedure effective and simple: the software designed for the management of LPS must integrate all components of the methodology in a procedure that emulates the steps of the LPS planning and that is easy to follow by users.*

b) *Support for planning meetings: To do this, it must facilitate the collection of information and make it available to users as support for the planning meeting. Issues such as constraints, commitments and causes of non-compliance should be recorded in a simple and time-saving manner. In addition, it should be provided in the form of reports that have the most up-to-date information to contribute to the meeting.*

c) *Effective distribution of information: Delivery of updated information, either through printable reports, web formats or in the application itself, so that those responsible can easily and quickly access it.*

d) *Familiar data interface and structure: An order and structure of the information must be maintained, at the level of detail required by the users, to allow clear understanding of the information. In addition, the interface should be simple and clear in order to facilitate adoption. Some key points mentioned are the similarity with tools and reports already used by managers.*

e) *Interaction with existing systems: Many companies use computer systems for control and information management. The tools to be implemented must be able to interact with them to facilitate their adoption and use.*

f) *Registration of historical information: To promote the analysis of the evolution of the implementation and results, along with knowledge management.*

g) *Capacity to be systematically synchronized and updated: To ensure that planners always work with the latest information available.*

h) *To allow the collection of information at source: To allow the collection of information in several instances, without the need to re-enter it later. Also, to allow access to the information captured on subsequent occasions.*

i) *Integrity: It must be sustainable and reliable, which implies that it must function without system failures or errors in the information delivered.*

The requirements described are intended to minimize three of the most recurrent barriers to the adoption of IT systems and the LPS methodology: (1) the inclusion of mechanisms that facilitate communication and dissemination of information will facilitate the decentralization of planning and control (Ureta, 2018); (2) the use of tools that facilitate the registration, updating and visualization of information enables the decrease in time used in preparation, maximizing the time invested in planning and control (Alarcón & Calderón, 2003); and (3) the systematic recording of information, and its dissemination in the form of specialized reports, facilitates knowledge management and decision-making, which generates positive impacts on the degree of methodology adoption (Ureta, 2018). The need to obtain information quickly in order to keep a system updated and to have information in real time or when it is needed, lies in the fact that information is the basis for the planning process and, in addition, obtaining feedback from the operation ensures that better information is available in future planning processes (Ballard & Howell, 1998). If such feedback is not obtained in time, it will lead to a split between decisions made on the basis of planning and decisions to be made on the ground, based on the information of the field (Ureta, 2018).

3.2 Characteristics of an IT - LPS tool

In order to have clear the main elements that an IT tool must have to apply LPS, a survey was carried out, where it was sought to know which were the elements that the professionals that use daily LPS, consider more important and that should not be missing in a tool to apply LPS. The survey consisted in that each respondent had to indicate, first, the professional experience in LPS, and, second, the level of importance (1 to 5, where 5 is very important) for a 12-element LPS tool, which were the final result of a list that was made based on the literature and the expert panel.

The twelve elements covered by the survey are listed below:

1. *Reviewing commitments from the previous week and making commitments for the next week, i.e., allowing for the creation of a weekly plan.*
2. *Review and establish restrictions for each activity, specifying the person responsible and the date, and also specifying the causes of non-compliance.*
3. *Create or allow to enter a list of tasks in an intermediate plan and the global plan of the Project.*
4. *Deliver key indicators (e.g., CFP, RCP, etc).*
5. *Allow to create list and frequency of causes of non-compliance.*
6. *Allows to propose and control corrective actions to the causes of non-compliance.*
7. *Consolidate historical records of restrictions and causes of non-compliance affecting the Project.*
8. *To allow analysis of the historical compliance or non-compliance of those responsible for the activities.*
9. *Restrict the progress of tasks with restrictions and/or their inclusion in short-term periods.*
10. *Allow to create a list of weekly activities per project manager.*
11. *Enabling the creation and management of ITE.*
12. *Facilitate visual management of project information.*

The survey was conducted with 56 professionals from the construction industry, where most of the respondents have between 2 and 5 years of experience working with the Last Planner® System. The results obtained were analyzed with the Relative Importance Index (RII), an instrument validated to measure the level of importance of various attributes (Gunduz & Yahya, 2018), in this case, the elements of an LPS tool. The RII of each element was obtained through (equation 1).

$$RII = \frac{\sum W}{A \cdot N} \qquad (1)$$

Where W is the importance given to each factor by the respondents (1 to 5), A is the highest importance of each factor, in this case 5 and N is the total number of respondents, 56 for this analysis. The RII obtained for each of the elements that made up the survey is shown in (Table 1).

Table 1. RII of each element (own elaboration).

ELEMENTS	RII	RII (%)
2. Review and set activity restrictions	0,971	97%
1. Review and create weekly commitments	0,95	95%
10. Create weekly activities per manager	0,904	90%
4. Calculate key indicators CFP, PCR.	0,886	89%
12. Visual management	0,889	89%
3. Enter activities to intermediate and master plan	0,861	86%
5. Create CNC list	0,854	85%
6. Define corrective actions CNCs	0,821	82%
11. Creating and managing ITE	0,821	82%
7. Consolidate historical records of constraints and CNCs	0,804	80%
8. Analyze historical compliance of those responsible	0,771	77%
9. Restrict inclusion of activities with restrictions	0,743	74%

In (Table 1) it is possible to see that the most important element that an LPS-based tool must have is to review and establish restrictions for each activity, where the responsible party and date are specified, and also where the causes of non-compliance can be specified. However, it is important to note that the level of importance given to each of the factors is significant, since they are all above 70%.

3.3 Existing last llanner® system software
Currently, there are several software applications in the market based on the Last Planner® System methodology, which seek to make the implementation process of this project planning methodology much faster and more efficient for companies. Below is a brief description of the various tools based on LPS that were evaluated in this work. Finally, it is shown, in (Table 2), a matrix that allows the user of each software to identify which of these comply with the requirements and characteristics that through this work have been established as essential for an IT tool based on Last Planner® System.

3.3.1 ProPlanner® System
ProPlanner® is a software that belongs to Ipsum, a Chilean company founded in 2014, with the mission of contributing to the improvement of productivity in national and international industry, seeking to achieve both an economic and social impact, thus contributing to the creation of true "smart cities". This software is based on the Last Planner® System work methodology, and aims to help manage construction projects more quickly and easily. It consists of a web and mobile platform for the planning, control and management of engineering and construction projects, which allows, empowering the crews while gathering information from the ground. In addition, it allows you to save time because ProPlanner® automatically generates an endless number of spreadsheets in Microsoft Excel, avoiding the loss or distortion of information because everything converges in the same working ecosystem.

3.3.2 Impera

Impera is a project management and control program with 15 years of experience, created and developed by GEPUC using the vast experience of its professionals in the construction industry. It is based on the Last Planner® methodology, and aims to reduce variability, improve reliability and increase productivity, as well as incorporating digital transformation into projects.

3.3.3 COCOPLAN

COCOPLAN is a computer tool for management, monitoring and control of production on site, based on Last Planner® System that facilitates the implementation of the methodology in companies. It has a friendly interface, which helps the learning process to be fast, allowing the management and follow up of the general planning, or the Master Plan, updated weekly; of the detected restrictions that prevent the work flow and of the weekly planning, checking the weekly fulfillment of the tasks committed by the team. This program belongs to the company Thinks and has been created by professionals dedicated to Lean Construction after years of implementations, being used in more than 100 projects. The company provides consulting services for the implementation of the software and also offers a trial version.

3.3.4 Touchplan

Touchplan® is a planning and management technology optimized for construction project teams that helps to implement Last Planner® System. This program is rooted in the construction industry as a division of MOCA Systems, a software development firm.

3.3.5 V-Planner

VPlanner is a comprehensive solution for production planning and is compatible with Last Planner® System (LPS) workflows. This program solves two key problems when implementing LPS that require significant effort from the project team. The first is the alignment between short and long term project plans, and the second is the constant management of short term plans to identify and eliminate constraints that can affect the reliability of the workflow. VPlanner eliminates the redundant effort required to align the work that can be done on a project with the work that must be done for each work planning cycle.

3.3.6 Work Move Plan, Work Plan and DePlan

WorkPlan and DePlan are computer programs developed to guide production units in creating reliable work plans. They were born in response to the efforts that have been made in construction and design to implement the Last Planner® System. WorkPlan is a stand-alone program that helps develop weekly work plans, which allows you to export basic scheduling information. In addition, DePlan combines WorkPlan with the ADePT capability to represent design process models, perform matrix analysis of dependency structures, and develop design programs for general projects (Choo & Tommelein, 2001). WorkMovePlan, an extension of WorkPlan, includes capabilities for distributed planning and coordination, which allows production units to increase the reliability of their plans by sharing work package, scheduling information and constraint information (Choo & Tommelein, 2001).

3.3.7 BIM 360 Plan

BIM 360 Plan is a project management software that helps the collaboration between the different agents involved. Being a cloud-based software allows access to information anywhere, anytime and by anyone in the project. This production planning software in construction belongs to the company Autodesk, and is based on Last Planner® System. The software is created to take a mobile approach to production planning, to build reliable work plans using Lean Construction principles, and to reduce waste from overproduction, excess inventory, and rework.

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Table 2. *Comparative matrix of software based on LPS (own elaboration).*

CHARACTERISTICS	SOFTWARE								
	BIM 360 Plan	Impera	COCOPLAN	ProPlanner®	Touchplan	V-Planner	Work Move Plan	Work Plan	DePlan
1. Reviewing commitments from the previous week and making commitments for the next week, i.e. allowing you to create a weekly plan.	x	x	x		x	x	x	x	x
2. Review and establish restrictions for each activity, specifying the person responsible and the date, and also specifying the reasons for non-compliance.	x	x	x	x	x	x	x		
3. Create or allow to enter a list of tasks in an intermediate plan and hopefully the overall project work plan	x	x		x		x	x	x	
4. Delivering key indicators	x	x	x		x	x	x	x	
5. Allow to create list and frequency of causes of non-compliance	x	x							
6. Allows to propose and control corrective actions to the causes of non-compliance									
7. Consolidate historical records of restrictions and causes of non-compliance affecting the project	x		x						
8. To allow analysis of the historical compliance or non-compliance of those responsible for the activities			x	x					
9. Restrict the progress of tasks with restrictions and/or their inclusion in short-term periods	x	x		x					
10. Allow to create a list of weekly activities per project manager					x				
11. Enabling the creation and management of ITE									
12. Facilitate visual management of project information	x	x	x	x	x	x	x	x	x

As shown in (Table 2), the BIM 360 Plan platforms have 8 of the 12 features identified, followed by Impera which has 7 and COCOPLAN with 6. On the other hand, the ProPlanner®, Touchplan, V-Planner and Work Move Plan tools have only 5 features. Finally, Work Plan has 4 and DePlan only 2 features. Regarding the characteristics, the ones that are mostly repeated are: facilitating visual management of the project information (in all 9 software applications), reviewing commitments from the previous week and take commitments for next week, that is, allowing the creation of a weekly plan (in 8), reviewing and establishing restrictions for each activity, where you specify the responsible, and date, and also where you can specify the causes of noncompliance (in 7), and delivering key indicators (in 7). On the other hand, the tools of allowing to propose and control corrective actions to the causes of noncompliance and allowing to create and manage ITE have not been found in any of the 9 software applications explored.

4. Conclusions

Through a literature review, we were able to identify user requirements for the formulation of IT tools based on Last Planner® System. On the other hand, through an expert panel, the main elements that a software based on the LPS methodology should have were identified. Based on these, a list with the main requirements of an IT tool based on LPS was generated and subjected to validation through a survey of 56 professionals, whose results were analyzed by the Relative Importance Index (RII), obtaining a prioritization of the issues raised. The results show that the element with the highest level of importance is that of "Review and establish restrictions for each activity, where the person responsible and the date are specified, and also where the causes of non-compliance can be specified". In spite of this, all the aspects submitted for consultation have obtained an RII greater than 70%, which allows us to conclude that the 12 aspects identified are relevant, and therefore should be incorporated into an IT tool based on LPS.

In addition, it was possible to identify 9 software based on LPS available in the market, and to analyze if they have or not the 12 characteristics identified and validated previously. It is concluded that only 3 of them have 50% or more of the identified aspects (BIM 360 Plan with 8, Impera with 7 and COCOPLAN with 6), which denotes a low incorporation of the relevant characteristics identified, in the main IT tools offered to the industry. Regarding the characteristics, "Facilitate the visual management of the project information", "Review commitments from the previous week and take commitments for the next week, that is, allow the creation of a weekly plan", "Review and establish restrictions for each activity, where the responsible person and date are specified, and also where the causes of non-compliance can be specified", and "Deliver key indicators" are the characteristics that are mostly incorporated in the software. On the other hand, the tools for "Allow to propose and control corrective actions to the causes of noncompliance" and "Allow to create and manage ITE" are not present in any of the 9 software applications explored.

As future lines of research, the exploration and prioritization applied to real projects of the 12 LPS characteristics identified is proposed, in order to obtain a contrast with the perception of the professionals surveyed. In addition, it is proposed to consider the lack of some characteristics in the different software studied, as opportunities for improvement for the reformulation and strengthening of the tools offered to the industry.

5. Acknowledgements

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