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Collaborative work tools in Spanish construction sector. Best practice proposal to implement Last Planner System (LPS).

Herramientas de trabajo colaborativo en el sector de la construcción español. Buenas prácticas para la implementación de la metodología "Último Planificador (LPS)".

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ABSTRACT

The innovation that the construction sector requires is more than simply implementing technology, instead it is necessary to digitize the sector and promote collaborative work among stakeholders, in order to improve on-site management. Many countries around the world have incorporated tools to facilitate collaborative work in their processes. In the US particularly, there are many companies which are implementing the LPS methodology, and they are even applying this concept to the execution of works, supplementing it with BIM tools. In Spain, however, the implementation of such tools is relatively recent. By using a survey, this article seeks to determine the level of knowledge that stakeholders involved in the Spanish construction sector have about the collaborative work model, specifically BIM and LPS tools. Furthermore, a group of experts proposes a selection of Best Practices (BP) for the application of these tools to a case study in Madrid (Spain).

Keywords: Collaborative work; Lean Construction; Last Planner System; Best Practices; BIM environment.

RESUMEN

La innovación que requiere el sector de la construcción es más que simplemente implementar tecnología, es necesario digitalizar el sector y promover el trabajo colaborativo entre las partes interesadas. Muchos países de todo el mundo han incorporado herramientas para facilitar el trabajo colaborativo en sus procesos. En US en particular, son muchas las empresas que están implementando la metodología LPS y están aplicándolas en la construcción junto con las herramientas BIM. En España, sin embargo, la implementación de estas herramientas es relativamente reciente. A través de una encuesta, este artículo busca determinar el nivel de conocimiento que los interesados involucrados en el sector de la construcción español tienen sobre el modelo de trabajo colaborativo, especialmente de las herramientas BIM y LPS. Además, un grupo de expertos propone una selección de Mejores Prácticas (BP) para la aplicación de estas herramientas a un caso de estudio en Madrid (España).

Palabras clave: Trabajo colaborativo; Lean Construction; Last Planner System; Buenas prácticas; Entorno BIM.

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1. INTRODUCTION

The productivity of the construction sector is historically lower than other industrial sectors, in all countries, independently of whether we are talking about times of crisis or times of economic boom (1).

In Spain, in 2007, the average productivity per hour worked was 28 euros for the national economy as a whole and 23 euros for construction (2). The McKinsey study (3) even points out that the level of productivity in the construction sector is on a par with that which existed 80 years previously.

Furthermore, the recovery experienced by the construction sector in recent years has not led to an increase in its productivity. This is due to the fact that in general, construction has always grown by accumulating production factors, particularly employment and inactive capital, and not by developing new technological processes, since the development of such new processes is complex due to two characteristics of the sector: the size of the constructions companies and the low level of education of the agents involved (1).

Where the latter question is concerned, it must be noted that despite the fact that the crisis has led to an increased skill level in the sector, this is still a long way off reaching the levels of countries such as Germany, the United Kingdom, Holland and France.

In any event, progressive innovation in products and materials is changing the construction process by introducing new and greater training requirements and, more generally, demanding more qualifications and professional skills in the sector. As such, the sector should consider moving forward via a growth path in which technological capital and the knowledge-based economy have a greater presence, thus encouraging medium and long-term growth in productivity (1).

Innovating in the construction industry is a key factor for closing the gap which exists with regard to productivity between this activity and the rest of the country's economy. According to the latest Spanish Statistical Office Innovation Survey (2016) (4), out of all that is spent on innovation by companies, the construction sector is that which invests the least in innovation, just 1.1%.

In any case, the innovation that the sector needs is more than simply implementing technology, such as replacing manual processes by robotic processes; instead, it requires the digitization of the sector and the promotion of collaborative work among stakeholders, both in the early stages and during the execution of works, in order to improve on-site management (5, 6).

Where digitization is concerned, it is important to note that the McKinsey study (3) states that construction is the sector which has one of the lowest digitization indexes worldwide, even lagging behind sectors such as agriculture, and it suggests that sustainability and the digitization of the sector are key to the future.

The market currently offers numerous tools for designing digital models, but the BIM environment software is the most commonly used. BIM and the integrative process with other disciplines is the differentiating factor with regard to the previous model. This type of software is driving the digitization of construction and facilitating the introduction of other innovative technologies, such as robotics, drones, augmented reality and 3D printing, enabling the sector to join the fourth industrial revolution, giving rise to construction 4.0. and making it possible to build more cheaply, more quickly and consuming fewer resources. Numerous studies were found which confirmed that the BIM environment is the tool which is facilitating the integration of new technologies in construction and making it possible to improve efficiency and competitiveness (7, 8). As such, the sector should incentivize the use of digital technology, both remotely and on-site, by using digital models for virtual design.

Where collaborative work is concerned, it is clear that construction should cease to be something linear and become a cycle in which all of the stakeholders involved work in a more coordinated and collaborative way. They must all have access to the full project lifecycle, sharing the same data history when performing their respective tasks (6). In this respect, studies have been found which analyze the improved efficiency of collaborative work by using the LEAN principles, as well as studies which analyze the use of one of the most commonly used Lean tools for the implementation of this philosophy, Last Planner System (LPS), a collaborative planning methodology for project management and planning.(9-13)

Lean is a production philosophy, the objectives of which are continuous improvement, minimizing losses and maximizing the value of the end product, designing together with the customer, improving the overall profitability of the project and eliminating waste (fig.1). Furthermore, with Lean the efficiency of the planning and control systems are measured and improved (14).

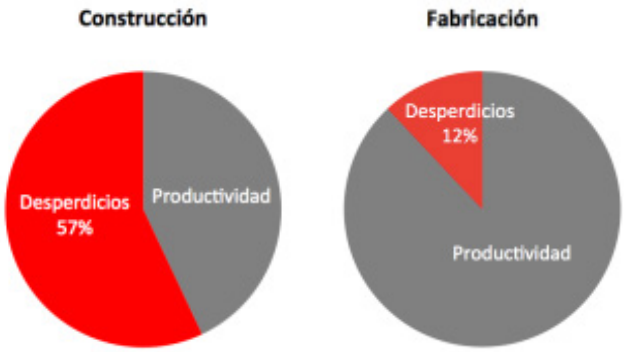

Figure 1. Percentage of time wasted in manufacturing and construction (14)

This concept was transferred to the construction sector between 1992 and 1993, however, in Spain there was no dissemination or real interest until 2010, this being thanks to the creation of the Spanish Group for Lean Construction (15).

The results of Lean Construction are reflected by a cost reduction, increased quality and a reduction in the building delivery time, as well as better value being offered to the customer, considering their needs and evaluating the impact on society and on the environment. Some of the inefficiencies ("waste" or shedding) which can occur in construction and which could be avoided by working with Lean Construction are: waiting times; periods of inactivity; unnecessary travel; accumulation of materials in unsuitable places (generation of storage areas and

unnecessary inventories) and delays due to a failure to comply with the specifications or design changes. As such, there are many companies which, particularly in the USA, are implementing the Lean Construction methodology (14).

Meanwhile, studies were also found which analyze the synergy of LPS and BIM together (16-20) and even studies which analyze case studies where these tools have been used (21-23). These studies conclude that the use of both tools would lead to a true revolution and an evolutionary leap which would contribute towards increasing the success of the projects managed in accordance with the project management best practices that have been being applied in recent decades.

In Spain, however, and in spite of the fact that a few studies have been found which analyzed collaborative work with LPS in the construction sector and the benefits that the tool could generate (24, 25), there is still a lot to do in order to be able to incorporate this new paradigm in the construction sector. It is probably because the construction sector, in Spain, is different from other industrial sectors. This sector has unique characteristics such as, among others: it is a very traditional sector, a sector that believes that things should continue to be done as usual, also it is a sector where most of the workers are temporary, and have a low level of training and another important thing is that almost all the projects are different, so it is very difficoult to organize production methods systematically.

On the other hand, and regarding the studies analyzed in the article, only few of them are written by Spanish authors (20, 24, 26) but none of them identify the obstacles or Best Practices (BP) to be implemented in relation to the LPS in Spain. As such, the present article has the following objectives:

1. To find out the level of knowledge that stakeholders, in the Spanish building sector, have of the Lean Construction tool, LPS, as well as its degree of implementation.
2. To find out the interest that supplementing the BIM environment with the LPS tool could hold for the stakeholders involved with regard to planning the execution of works.
3. To determine possible Best Practices (BP) in order to facilitate the implementation of LPS in Spain and to verify its feasibility in a case study.

2. METHODOLOGY

In order to achieve the established objectives, the work is carried out in three stages:

The first stage involves a quantitative analysis based on a survey. The design of the survey is descriptive, observational, prospective and cross-sectional, with the aim of responding to objectives 1 and 2.

The target population for the survey is the stakeholders which participate in the Spanish construction sector. A non-probability sample of convenience was used, also known as an accidental sample, because the sample selected consists of individuals who freely answered the survey. The way in which we have proceeded is the same that we had used in other studies developed (8).

The questionnaire used for the survey was created using the open-source software SurveyMonkey, which enables users to create customized surveys online.

In order to distribute the survey, basically the contact network of the researchers was used, so 300 people were asked. All of the participants were informed of the objective of the study and their responses were treated confidentially. Participation was on a totally voluntary basis, with no financial incentives. The period for receiving responses spanned from 30 November 2018 until 15 January 2019 (45 days).

The questions were:

1. Are you familiar with the LPS (Last Planner System) planning methodology?
2. What do you think LPS is used for?
3. Do you use LPS in your construction projects?
4. Do you think that the implementation of LPS is important for optimizing the duration of construction projects?
5. How long do you think it will take to implement LPS in construction projects?
6. Do you think that using BIM as a virtual construction tool helps to reduce project costs and duration?
7. Do you think that LPS and BIM are complementary tools?
8. With which of the following statements do you agree?
    - I am very familiar with the Last Planner System methodology and I am capable of using it
    - I am very familiar with the BIM methodology and its application to the construction phase
    - Applying BIM to the construction phase improves the quality of the final project
    - Applying LPS reduces the construction time
    - If we apply BIM to the construction phase + LPS we will improve quality and reduce the construction time
    - I do not think that implementing BIM in the construction phase + LPS improves anything
    - It is very difficult to apply LPS to construction projects, the people who should be involved lack interest and training in the methodology
    - Applying BIM to the construction phase + LPS implies an increase in construction staff numbers which constructors are not prepared to assume
    - It does not matter which tools a project team uses, the result (quality, time and cost) will be the same if they are good professionals
    - The weekly meetings for implementing LPS are just a waste of time, the project will progress at the same pace with or without LPS
    - BIM is only for designing the building, it adds nothing to the construction phase
9. I am not familiar with these tools

In a second stage, an in-depth bibliographical and documentary search was carried out in relation to the obstacles which have made the application of LPS difficult in other countries. After, a list with the obstacles and barriers, which make implementing LPS difficult according to the aforementioned studies, has done (a).

Then, a group of five professionals, building engineers and architects, each with more than twenty years' experience in the building sector, were selected. These professionals are project managers and also, experts in the use of LPS, as a planning methodology (they have used LPS in their projects during the last years). The methodology followed by the experts was: first of all, the experts proposed a series of Best Practices (BP) to avoid the obstacles considered in

the list done, taking in to account the characteristics of the Spanish construction sector (b), and after, the research team bearing in mind the case study, concluded the BP to be applied (c).

Finally, in **a third stage**, the BP were applied in a building of a Spanish construction company (Arpada) in order to confirm their feasibility on a typical residential building project in the Madrid region of Spain. The project involved building 54 terraced houses with a garage, attached outbuildings and communal area.

3. RESULTS

3.1. Stage 1: Result and discussion of the surveys

112 valid responses were recorded so, more than a third of the surveys sent. The profile of the sample were: Technical Architects or Building Engineers (52.7%); Architects (32.1%); Civil Engineers (7.1%); Industrial Engineers (3.6%); Public Works Engineers (2.7%) and others (1.8%).

The most important results obtained were: only 37.5% of the people declared that they are familiar with the LPS planning methodology. Analyzing the responses in relation to the profession of those surveyed, we observe that a high percentage of the Technical Architects and Building Engineers are familiar with this methodology, however, this proportion reduces significantly in the Architects group (Figure 2).

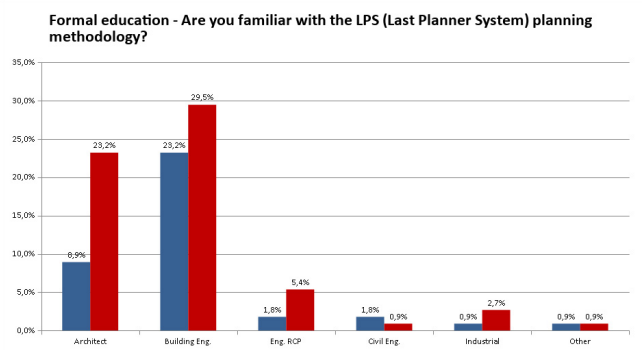

Figure 2. Knowledge of LPS methodology according to the sample analyzed (negative responses for each profile are indicated in red and positive responses in blue).

Although it may seem strange, there is really a simple explanation, it is usually the Technical Architects and Building Engineers who perform the monitoring and control tasks related to building project planning, and as such, they are more up-to-date with the new planning procedures and tools.

Meanwhile, considerable agreement is observed in the opinions concerning the results achieved when using LPS (Fig. 3).

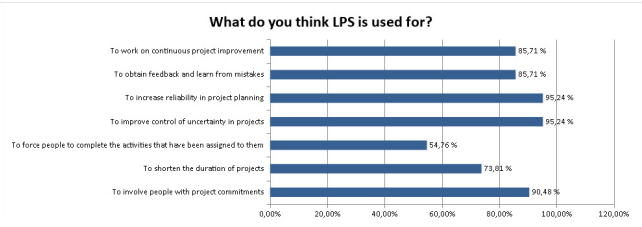

Figure 3. Answers to the question "What do you think LPS is used for?"

Over 90% of those surveyed who stated that they are familiar with the LPS methodology believe that LPS is mainly used to increase reliability in project planning, to improve control of uncertainty in projects and to involve people with project commitments. There is also considerable agreement (85%) concerning the fact that LPS is used to work on continuous project improvement and to obtain feedback and learn from mistakes.

However, there is less agreement concerning the fact that LPS is used to shorten the duration of projects, which is significant, since generally one of the objectives of time management and of using specific tools is to optimize project duration and, where possible, to shorten the duration. There is, however, greater deviation in opinions concerning whether LPS is used to force people to complete the activities that have been assigned to them.

In relation to the use of the LPS methodology the responses are in the Figure 4: only 9.52% states that they always use this tool and 16.67% use it occasionally, more than half of the professionals familiar with this methodology never having implemented it, either because they have not had the opportunity, because they do not know how to or because they have not been able to use it (47.62% and 16.67%).

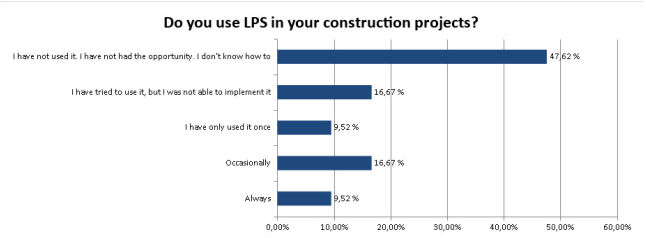

Figure 4. Answers to the question "Do you use LPS in your constructions projects?"

However, despite the fact that more than half (64.29%) of those surveyed who are familiar with the methodology have never implemented it, 26.19% believes that it is very important, and 69.05% believes that it is important to implement LPS in order to optimize the duration of construction projects (Fig. 5).

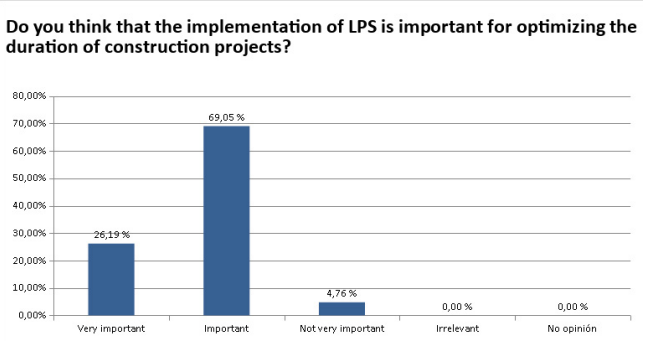

Figure 5. Answers to the question "Do you think that the implementation of LPS is important for optimizing the duration of construction projects?"

Almost half of those surveyed (40.48%) believe that it will take between another three and five years before LPS is implemented in construction projects (Fig. 6).

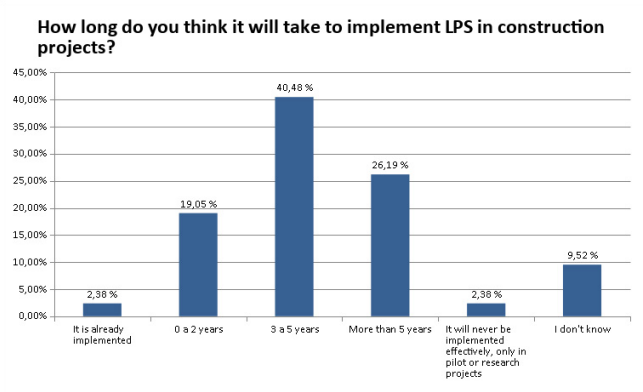

Figure 6. Answers to the question "How long do you think it will take to implement LPS in construction projects?"

Moreover, and as stated above, this survey was formulated as a continuation of the survey carried out by the QBIM research team in 2016 concerning the use of BIM in the construction sector in Spain, which revealed a very immature sector in terms of collaborative work in the BIM environment, but also a broad consensus (94%) with regard to the opinion that BIM is the path to take in order to improve professionalism and productivity in the sector.

In this scenario, the following question is posed: "Do you think that using BIM as a virtual construction tool helps to reduce project costs and duration?" (Fig. 7).

Those surveyed who stated that they were familiar with the LPS methodology mainly agree (30.95%) or totally agree (47.62%) that using BIM as a virtual construction tool helps to reduce project costs and duration. It is worth highlighting that all of those surveyed, both those who said that they were not familiar with the LPS methodology (74.28%) and those that said that they were (78.57%), share this opinion.

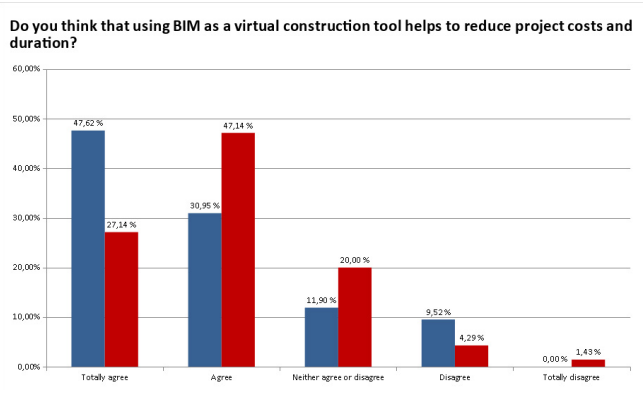

Figure 7. Answers to the question "Do you think that using BIM as a virtual construction tool helps to reduce project costs and duration?" (responses from people no familiar with LPS are indicated in red and responses from people familiar with LPS in blue).

When asked whether they consider LPS and BIM to be complementary tools, 38.10% totally agreed and 42.86% agreed with this statement in the group of those surveyed who said that they were familiar with the LPS methodology. However, in Figure 8 we can see that although a high percentage of those stating that they were not familiar with LPS have the feeling that they are complementary tools, 41.43% does not have a specific opinion.

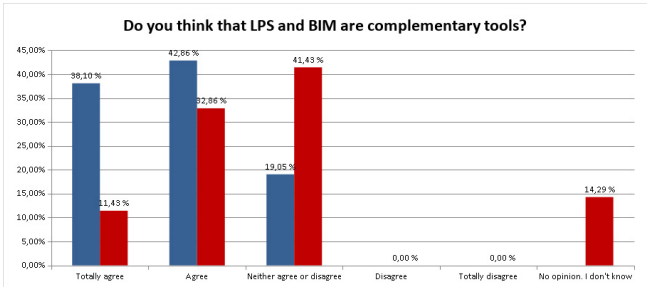

Figure 8. Answers to the question "Do you think that LPS and BIM are complementary tools?" (responses from people no familiar with LPS are indicated in red and responses from people familiar with LPS in blue).

To end the survey, an opinion question is asked (Fig. 9). It is observed that there is a high level of consensus, over 90%, (92.86%) among the group of those surveyed who are familiar with the LPS methodology, who state that applying BIM in the construction phase together with LPS can improve quality and reduce construction time.

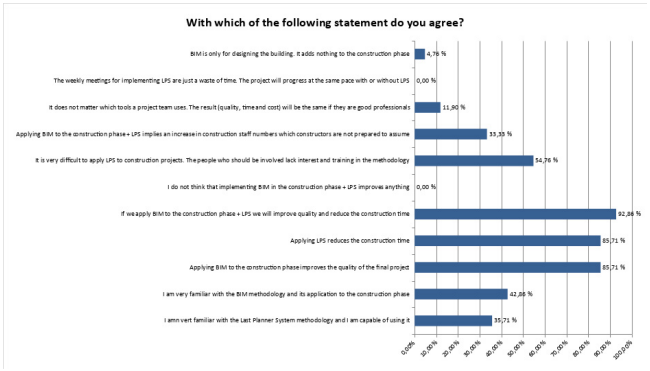

Figure 9. Answers to the question "With which of the following statements do you agree?"

A high level of agreement (85.71%) is also noted with the statements "Applying LPS reduces the construction time", confirming the result given to other survey questions, and "Applying BIM to the construction phase improves the quality of the final project", which highlights that the group of professionals that is familiar with these collaborative work tools is confident about the improvements that it would be possible to deliver in the sector when widespread use is achieved.

It is important to highlight that more than half of the survey participants (54.76%) view applying LPS to construction projects as difficult, since it requires the people involved to be committed and receive training in the methodology, and as can be seen in the final two options, only 42.86% of those familiar with LPS believes that they have sufficient knowledge of BIM to apply it in the construction phase and only 35.71% believes that they understand the LPS methodology sufficiently well to be capable of applying it. This highlights that there is still a long way to go, even for the most experienced professionals in the field.

3.2. Stage 2: Identification of the obstacles and selection of BP to be applied in Spain

Although, as mentioned in the introduction, some articles were found concerning the use of LPS in the construction

sector, the study by Hoyos et al (2018) (27) stands out since it is a bibliographical review of the theoretical aspects, case studies, support tools, integration with other methodologies and the implementation of the LPS and, particularly, of the obstacles associated with its implementation. The search was carried out using international databases and publications dated between 1996 and 2016 by the International Group for Lean Construction (IGLC), and the Lean Construction Institute (LCI). It is also worth highlighting that, of all of the studies analyzed in the said article, only one of them is written by Spanish authors (25) but it neither identifies the obstacles nor proposes BP to be implemented in relation to the LPS in Spain.

a. The most common obstacles, according to the aforementioned studies and grouped according to: human and social obstacles; organizational obstacles and procedural obstacles, are:

   Human (skills gap) and social obstacles:
   - Resistance to change: due to a fear of taking on commitments; due to working with subcontractors, etc.
   - Unfamiliarity with the system and skepticism about the benefits of its implementation
   - Competitive rather than collaborative relationships between project managers and subcontractors and as such a lack of trust and commitment between team members
   - Language and cultural difficulties in cases where the workers come from different countries
   - Difficulty in saying "no" for fear of violating the traditional protocol based on the management model. Lack of positive and committed leadership for: giving orders to contractors and motivating them to take on their own commitments; guaranteeing that those involved review the work carried out together and ensuring the existence of mutual under
   - standing and effective coordination within the organization's network of commitments.
   - Lack of effective communication, as well as negotiation skills

   Organizational obstacles:
   - Lack of relationship between the system planning levels
   - Lack of communication and visual management for generating appropriate information
   - Extreme difficulty associated with building executable activity bookings
   - Insufficient preparation of planning meetings
   - Low level of understanding of the LPS elements, of why it should be used and the benefits it offers
   - Lack of incentives for subcontractors
   - Contract model, since it is common for the design work to be done by a different company to the construction

   Procedural obstacles:
   - Lack of clear definition in assignments
   - Lack of logic when assigning a job without considering the production capacity of the work group or the available resources
   - Lack of knowledge concerning the what and the why of the system and of the instructions for the application of a standardized process
   - Lack of analysis of the restrictions and their frequency in order to identify the aspects which limit the execution of the activities

b. Considering the list, the group of experts proposed a group of Best Practices (BP) to avoid the obstacles, considering the characteristics of the Spanish construction sector. These BP are:

   To prevent human (skills gap) and social obstacles:
   - Inform about the system of work in order to avoid reluctance and about the benefits with examples of applications.
   - Provide LPS training to the people involved through courses.
   - Motivate the different stakeholders, identifying benefits for all. In this sense, it would be interesting, to generate the commitment of the subcontractors, adding clauses in their contracts requiring their active participation in the LPS implementation process.
   - Improve participants' transversal competences, particularly teamwork and communication, in order to:
   - Build teams and generate trust with the aim of bridging gaps.
   - Facilitate communication and the Exchange of ideas, without exerting pressure.

   To prevent organizational obstacles:
   - Obtain management commitment and leadership from the companies involved.
   - Identify benefits for the subcontractors.
   - Make people understand that the work done by one person affects others. Seeking complicity.
   - Work in a collaborative way from the start of the project.

   To prevent procedural obstacles:
   - Draft work procedures and instructions for each participant.
   - Inform participants in a clear way about the system, the tasks to be done and their benefits.
   - Be rigorous in planning and realistic about the resources available.
   - Facilitate understanding of the planning by using graphics and other more visual elements (BIM).
   - Assign an expert moderator in the sessions, as a guide and facilitator.

c. From the results obtained by the group of experts, the research team concluded that the BP to apply in the case studies must be:

   - Information and training, concerning the system, and particularly making all of the participants understand the medium-term benefits LPS can achieve.
   - To improve the soft skills of the participants in order to facilitate teamwork and make fluid, pressure-free communication and to generate commitment and complicity between them.
   - To prepare the plan which is to be used for the project in the clearest, most rigorous and realistic way possible, reinforcing meetings with tools which facilitate comprehension for the entire team, for example BIM models.
   - The moderator of the sessions must be a building professional with knowledge of the system and with technical, communication and leadership skills, as well as being firmly supported by the management teams of all of the stakeholders involved.

- Participants must be people and companies whose decisions can have an impact on the critical path, as well as those who always seek transparency, teamwork, strong leadership and the maintenance of discipline to ensure that the system is successfully applied to the end.

3.3. Stage 3: Application of the BP selected in the case study

In this third stage, the BP selected were applied in the case study, proceeding in the following way:

a. An initial meeting was planned with the project team and the subcontractors which were going to carry out the case study.

   At the aforementioned meeting, the general management of the construction company informed the project team of the new procedure that was going to be implemented in order to plan the project and made his commitment very clear, it being a strategic corporate matter. Furthermore, the general manager introduced the work group that was going to moderate the sessions and broadly informed the team of what the LPS methodology consisted and what its dynamic was going to be.

   As such, at this meeting, the following BP were applied:
   - Achieving the commitment and leadership of the management teams of the companies involved.
   - Designating an expert moderator for the sessions, as a guide and facilitator.
   - Informing participants about LPS.

b. Subsequently training courses were organized concerning both the LPS methodology and communication and negotiation skills, thereby managing to implement the following BP:

   - Building teams and generating trust with the aim of bridging gaps.
   - Facilitating communication and the exchange of ideas, without exerting pressure.
   - Making people understand that the work done by one person affects others and seeking the complicity of all participants.

c. After training the participants, work procedures were drafted with instructions for each participant and the Master Plan and intermediate plans were written, all in a realistic way and considering the available resources. Furthermore, at each of the weekly meetings held, graphic documentation was prepared, supported by digital models produced using BIM tools.

   With the application of these BP, it was possible to resolve the following problems detected in the construction company:
   - In the **planning and scheduling of the activities to be carried out as part of the project** a series of milestones was identified in the execution of the work. These milestones are established by the project manager and consist of dates on which a certain part of the work must be finished, such that if the said date is reached and that part of the work is not complete, a delay will be flagged up for it. The resources required to execute this part of the work are hired based on these milestones and penalty dates are set for missing them. This form of controlling project progress was considered to be insufficient to be able to carry out a proper control of the work being done and it represented one of the main issues when it came to applying LPS, since on certain occasions it proved difficult to identify the work that had to be completed during each of the reviews carried out.
     The lack of planning and scheduling is considered to be the main cause of the deviations that regularly occur during building projects (28), as such, on applying LPS, scheduling is compulsory and this problem is resolved.
   - **Maintaining records of delays in receiving supplies**: on starting the project there was no record of the delays to receiving supplies, since this was considered to be something that happens which has no solution. On applying LPS, the required materials are ordered sufficiently ahead of time so as to be able to absorb any delay that may occur in the delivery of the supplies, and by drafting an Intermediate Plan, the activities which are to be carried out in a specific time period are identified, making it possible to anticipate and resolve any possible delay. Furthermore, in the event of there being a delay, there is sufficient room for maneuver in order to minimize its impact as much as possible. If LPS is not applied, delays to the delivery of materials occur and when they are detected it is too late to act sufficiently in advance in order to be able to mitigate the damage that such a delay can cause.
   - **Adjusting warehouse orders in line with production capacity**: before applying LPS, the construction company did not keep track of orders based on production, since as previously mentioned, it was the project manager who was responsible for placing the necessary orders and the project manager did not know the production capacity of the resources at any given moment. The person responsible for tracking the production of the resources is the project manager and this person is not always able to establish their production level. By applying LPS, weekly monitoring of completed work took place and it was possible to ascertain the production capacity of the resources.
   - **Determining the staff responsible for placing orders in each phase**: in the collaborating company, there was only one person responsible for placing orders and this could not be changed, but applying LPS meant that this person had access to more information than usual before placing the necessary orders.

Since it was the collaborating construction company's first experience with the LPS methodology, it was noted that in the execution of building works the main problem is the lack of reliable scheduling available to follow the project progress. The tool used to monitor the project is compliance with certain dates on which the different project phases have to be completed and there is no detailed monitoring of the performance of the tasks required in order to finish the part of the project that is being worked upon. The main belief of the project team is that once the resources have been told the date by which their part of the work must be completed it is these resources that are responsible for allocating the work according to their execution criteria and the project team does not

indicate how they must do it. By applying LPS it has been seen that this is a significant error that should not be committed, since if the resources are left to distribute the work based on an established date, they will not manage to do the tasks that they have to do at the earliest opportunity as they tend to use up all of the available time, always complaining that the allotted time is very tight.

By drafting a Master Plan it was possible to demonstrate that the dates set as milestones were not as tight as first thought, the drafting of the Intermediate Plan also facilitated the resolution of several problems due to them being studied sufficiently in advance for them not to represent a serious issue for project progress.

Finally, weekly monitoring of project progress showed that LPS does not prevent all problems and at every weekly meeting it was seen how the planned work was not always completed in the week in question. The causes were not due to particular issues of the case study, most of the times were due to the idiosyncrasy of the sector noted previously: traditional sector not open to changes; lack of commitment from subcontractors; adverse weather; project modifications; unforeseen events, etc.

This led to the participants noting down the causes of non-compliance and these are:

- Contract and change requests: during the execution of certain tasks, changes were requested by Project Management which affected the normal progress of the task, in some cases implying that part of the work that had already been done had to be redone.
- Another resource's completion of a prior task: another resource's failure to complete a task on time prevented the next resource from starting their work at the allotted time.
- Completion of your own prior task: on other occasions, not having completed a previous task prevents the same resource from starting the second part.
- Availability of information or dates: it has been known to happen with the odd task that when the time came to start the task scheduled in the Master Plan it was not possible to precisely determine the real start time of the task to be performed.
- Design and Requests for information: since it was the first application of the methodology for all of the participants, there were issues with the way in which certain information, necessary for carrying out certain tasks, was requested.
- Staff availability: by performing weekly production monitoring, it was discovered that on several occasions the main issue preventing the scheduled task from being carried out during the week in question was a lack of staff. There is currently a significant problem in the construction sector concerning a lack of specialized staff and this implies that there are insufficient workers to perform the tasks at the time required in order to comply with the scheduling that was initially established.
- Availability of materials and equipment: another of the causes of non-compliance was that, although the resources were assigned to do certain tasks the previous week, when the meeting took place the following week they argued that they had not had the necessary material or equipment.
- Customer protocol: on certain occasions the cause of non-compliance was the customer arbitrarily changing part of the project which meant having to change the way in which the part of the project affected by the change would be implemented.
- Acceptance conditions: as it is the first time, it was noted that certain scheduled tasks which had been approved for execution had been granted a false release from restrictions and this was due to not having an established protocol for determining when tasks have been correctly released from the restrictions preventing their correct execution.
- Schedule and Sequence: the lack of experience in drafting the Master Plan has, on various occasions, involved wanting to update it since it was thought that not all of the required tasks were included and that they needed to be added.
- Incorrect time estimation: on many occasions, a lack of experience in establishing the duration of each of the tasks to be performed, since it is not usually a piece of information that is requested, has meant that the duration of the task was not properly estimated
- Requirements outside the project: it has also sometimes been the case that Project Management has requested changes to the project that were not initially reflected. These requirements required a certain period of negotiation which resulted in delays to the commencement of certain tasks which could not begin due to a lack of definition.
- Climate: the construction sector is, on certain occasions, highly exposed to different climatic situations, which means that certain scheduled tasks cannot sometimes be performed. It is also true that this is one of the main excuses that is usually offered to justify delays. Since with the application of LPS, production is recorded on a weekly basis, it is possible to demonstrate that certain delays have occurred due to the weather and people will cease to think that this is an excuse that is difficult to demonstrate.
- Unsafe Working Conditions: for some tasks it was initially thought that they would be carried out in a certain way and when it came to executing them it was decided that this method would not comply with the safety regulations and as such it had to be changed, with the result that the scheduling of the task also had to be modified.
- Customer decision: once certain tasks have been executed, the client has decided that the way in which the work has been done is not good enough and it has had to be redone, this implying an increase in the time spent performing such tasks.
- Availability of crane equipment: the availability of crane equipment is one of the main issues when carrying out certain tasks, especially those where this resource is necessary in order to be able to move certain materials which are necessary to perform the task. On certain occasions it has been necessary to establish time slots for each of the resources who need this equipment and even having established times for using it, there have still been issues.

Regarding the execution time for the case study project, it must be said that it was completed a month sooner than initially planned by the project team. This was not a large time reduction, but it may be said that since it was the first time that LPS had been applied in the construction company and bearing in mind that the participants had no experience with the LPS methodology, the reduction achieved may be considered a success. The opinion of all of the participants was that they consider LPS a good tool for tracking the progress of building projects and it is also believed that with more cases of applying the methodology, the execution times would improve.

Finally, it must be stressed that LPS is not capable of resolving the problem concerning the lack of resources which currently exists in the construction sector, but it can be an important tool to bear in mind when carrying out building projects because this tools allows us to schedule the work associated to the resources that are going to perform the tasks, and establish the time that will be required to complete it more accurately, instead of falling into the trap of thinking that because there is a completion date in the contract this will be met.

4. CONCLUSIONS

Thanks to the different methodologies used in each stage, it has been possible to respond the objectives of the Project.

The conclusions about the survey are:

- In Spain, the LPS level of implementation is still very low, only 37.5% of the professionals surveyed said that they are familiar with the aforementioned methodology, but only 9.52% of them use this tool regularly. These agents are mostly, Technical Architects and Building Engineers, probably because they are the professionals who perform the monitoring and control tasks related to building project planning.
- It has been confirmed that the agents involved in the building sector consider that LPS and BIM are complementary tools. Furthermore, professionals who are familiar with the LPS methodology, consider that applying BIM in the construction phase, together with LPS, can improve quality and reduce construction time.
- It has also been confirmed that professionals think that it will take, between three and five years, before LPS is implemented in most of the construction projects.

On the other hand, studies found in the bibliography confirm the survey conclusions, and consider that there are some obstacles, grouped according to: human and social obstacles; organizational obstacles and procedural obstacles, that are barriers to the implementation of the LPS methodology.

However, these obstacles could be overcome by applying Best Practices. Furthermore, these BP should consider the particular nature of the construction sector in the specific country where they are going to be applied.

As a final conclusion it can be said that the application of practices, such as: to inform the participants about the benefits that can be achieved from applying LPS; to improve the communication and negotiation skills of the agents involved in the methodology; to train them in the methodology; to carry out rigorous and realistic planning; to assign an expert moderator in the sessions, as a guide and facilitator, and, if possible, supports his communication using tools from the BIM environment, improved the application of the LPS methodology in the case study, because and despite the lack of experience about the methodology, the work was completed a month earlier than the initial planning, and with significant financial savings.

But it is also true that LPS does not fully resolved all the issues arose during the execution of the construction project, mainly because the special characteristics of the building sector, so there is still a lot of work to be done, in order to correctly apply the methodology.

In any case, and after the experience, it can be said that the most important thing is to achieve the complicity and the commitment of all the stakeholders involved in the project. They have to be convinced that LPS is a methodology which helps to resolve many of the issues which arise during the execution of the project.

5. DATA AVAILABILITY

All data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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