Proposal for the application of ICE and BIM sessions to increase productivity in construction

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Abstract. Several studies have shown that the main problem in the construction industry is low productivity. Therefore, this study focuses on developing a proposal through a methodology that can increase productivity in the construction of buildings. The proposed methodology is Virtual Design and Construction (VDC), which has 4 pillars: Building Information Modeling (BIM), Integrated Concurrent Engineering (ICE), metrics and Project Production Management (PPM). However, the article mainly develops BIM and ICE sessions. In addition, in the ICE sessions, "work executors" will be added, so that the information is fed back by both parties, specialist engineers and work executors. Finally, the proposal will be applied in a multi-family building project in the city of Lima - Peru, in order to obtain improvement results.

1. Introduction

The industry, in general, is marked by constant significant changes in its processes, known as "industrial revolutions", these are transforming the way of working in companies of different economic sectors. In fact, the fourth industrial revolution or also known as digital transformation is currently taking place. This revolution brings with it a reformulation of business models, making use of artificial intelligence, virtual reality, among others. In this sense, the changes generated by this revolution are increasingly noticeable in our lives due to the accessibility of new technologies [1]. However, not all sectors are able to adapt quickly to current trends and this can be seen on a larger scale in the construction sector. In this sector, traditional methods are still used for projects execution, according to Mckinsey Global Institute, in the last 20 years annual productivity grew only 1%, presenting a product with lower quality and inefficiency in meeting deadlines, generating thus higher production costs [2]. Productivity is a worrying issue for the construction sector that has generated multiple debates about what should be the methodology that should be applied to obtain adequate production in the execution of projects [3]. It is for this reason that investing in key factors such as technology and innovation, that is, in new methodologies, is extremely important to obtain high productivity due to obtaining information and reliable workflows for a new way of writing, developing and presentation of construction projects [4]. In Latin America, one of the countries that is achieving rapid adoption of new methodologies such as BIM, is Chile, since, for example, in 2016 they developed PlanBIM, an initiative that seeks to increase the productivity and sustainability of the construction sector from methodologies that make recurrent use of technology [5]. In Peru, there is still the problem of adapting to this new paradigm, since construction companies invest in unsophisticated resources with few innovations due to the lack of technological development [4].

BIM and VDC are methodologies that have been adopted in Peru since 2005 and 2014 respectively, however, adoption is slow and is only of interest to larger companies. On the part of the private sector,

studies in 2017 in the city of Lima affirm that only 24.5% of private projects have adopted this methodology. On the part of the public sector, the Peruvian state at the beginning of 2012 created a BIM committee belonging to the Peruvian chamber of construction (CAPECO), in 2017 the National Quality Institute (Inacal) approved the conformation of the Technical Committee for Building Standardization and Civil Engineering Works to generate the first Peruvian technical standards (NTP-ISO/TS 12911: 2018 and NTP-ISO 29481-2:2018) on said methodology. Finally, at the end of 2019, the Peruvian government issued a supreme decree No. 289-2019-EF for the progressive incorporation of BIM in public investment [6].

For this reason, this document focuses on a proposal for the application of the VDC methodology based on the ICE and BIM sessions to increase productivity in the execution of a building project.

2. Materials and methods

The study begins with the search for the main causes of low productivity in the construction of buildings in the city of Lima through surveys of multi-family projects. To obtain the sample, one of the districts with the highest index of building construction was selected, which is Miraflores with 48 multi-family projects under construction [7]. With this population, the sample can be determined with a confidence level of 85%, probability of success of 0.7, probability of failure of 0.3 and a precision of 20%, from which a sample of 10 multi-family projects was obtained. From the survey it was possible to identify that the main cause of low productivity is poor communication between the project team, as shown in table 1. This cause is mainly the result of the use of: remote technological methods, processes and tools, which only provide inconsistent information. Increase in the complexity of the projects, which frequently generate irregularities in the architectural and structural plans, requiring a more complete and sophisticated communication for the construction of the project. Lack of training for the team, thus leading to erroneous constructions that finally become reworks. As well as, ineffectiveness of work meetings, since the meeting rooms are not adequate, that is, they do not have enough technology for the meeting to be dynamic.

Table 1. List of causes detected in 10 multi-family projects.

	Causes of low productivity	Nº of projects
Cause 1	Complexity of projects	6
Cause 2	Poor management of workman	5
Cause 3	Poor communication between the project team	9
Cause 4	Use of old systems and tools	3
Cause 5	Lack of investment in digitization and innovation	7
Cause 6	Mechanical equipment failures	5
Cause 7	Unskilled manpower	5

After identifying the main cause of low productivity, the VDC methodology was applied in such a way as to reduce the impact of the problem and increase productivity in the execution of the project. For this, ICE sessions were developed, which were in charge by the main agents involved in the problem identified in the project. Likewise, the work executors (foreman, construction master) were involved in order to reinforce the concepts of the necessary tasks to efficiently execute the deliverables, with the help of BIM models and opinions of different specialists.

However, for the effective development of the ICE sessions, the use of technological tools that enhance the communication capacity in construction is essential, therefore the use of Navisworks Software is essential for this process, since it has an added value with the information that supplies by

being a BIM 4D tool (BIM 4D=3D modeling + Integration of programming and modeling times). The BIM 4D allows to control the efficiency and time necessary to execute the different tasks of the projects, simulating the deadlines of all the phases and works; as well as a better understanding of the construction by the project team through the visualization of the progress of all activities. [8].

Below is the flowchart of activities for the proper application of the VDC methodology (ICE and BIM sessions) in which it shows the steps to follow in order to eliminate the aforementioned problem. This application was developed in the Alameda Rimac - Lima real estate megaproject, which consists of the construction of 5,984 properties, executed by the company BESCO SAC.

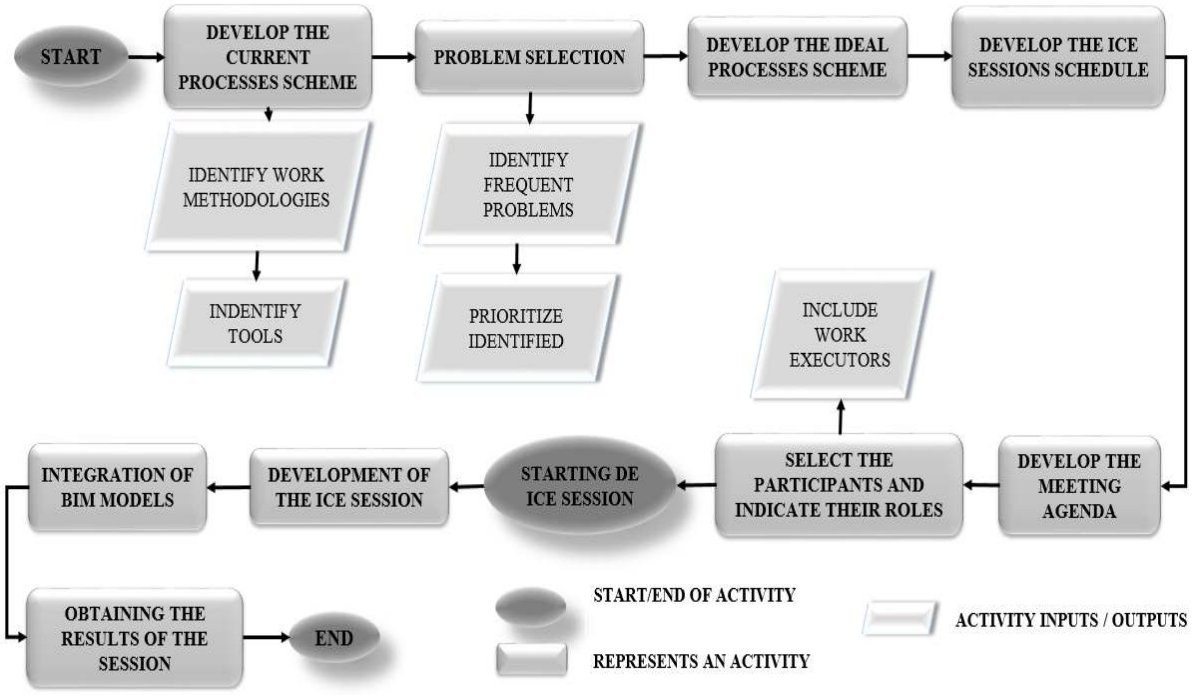

Figure 1. Flowchart of application of ICE and BIM sessions.

As shown in Figure 1, the methodology begins with the development of a current processes scheme, in order to detect the current situation of the set of procedures carried out in the Alameda Rimac project to solve the problems that constantly arise.

The processes scheme that was developed consists of 3 parts: Inputs, Process and Outpus.
- Inputs: problems that have been found in the project under study.
- Process: tools and methodology used to solve the problems detected.
- Outputs: results obtained after the respective solution processes.

Next, the processes scheme of the initial situation found in the Alameda Rimac real estate project is presented, see table 2.

Table 2. Processes scheme of the current situation of the real estate project.

INPUT	PROCESS	OUTPUT
Incompatibility of plans	Use of remote softwares Auto CAD	Constant RFIS
Delays	Greater control by the field engineer	Lack of time for key activities to be performed by the field engineer
Reworks	Greater control by the field engineer and the quality engineer	Excessive control of quality and field engineers, poor distribution of their activities in the project
Lack of quality of deliverables	Greater control by the quality engineer	Lack of time for key activities to be performed by the quality engineer
Non-compliance with security protocols	Call of attention to the preventionist and greater control of it	Compliance with most security protocols

After developing the processes scheme and knowing the behavior of the company in the face of the most common problems in the construction of the project, a survey was carried out with 15 project managers. This survey was carried out in order to determine the frequency of occurrence of the problems detected in the previous processes scheme, being P1 Incompatibility of plans, P2 delays, P3 Reworks, P4 Lack of quality of deliverables and P5 Non-compliance with security protocols. Next, in figure 2, the diagram prepared after collecting information from the surveys is shown with which it is sought to prioritize the problems to be addressed in the ICE sessions.

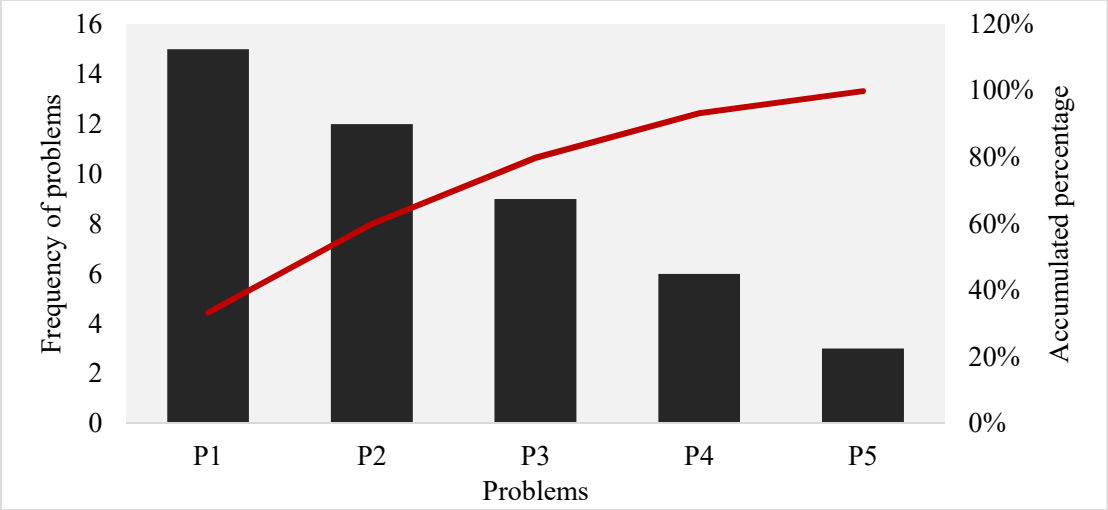

Figure 2. Pareto diagram of the problems of the case under study.

After this, the processes scheme to be achieved within the project was carried out, in order to obtain a clear and visible objective. In other words, the process to achieve the desired goals will be the implementation of ICE and BIM sessions to solve the identified problems (inputs) and have desired outputs that generate increased productivity on work. Next, the desired processes scheme that must be achieved with the application of the methodology in the project studied is shown, see table 3.

Table 3. Ideal processes scheme of the real estate project.

INPUT	PROCESS	OUTPUT
Incompatibility of plans	**Process of obtaining information through the VDC methodology * use of the ice sessions and the BIM 4D methodology in the construction of multi-family buildings in Miraflores-Lima * Techniques and Tools: 3d visualization and 4d-data analysis-comparison of models-techniques of metered-cost valuation-compatibility-interaction with the main stakeholders**	Reduction of RFIS, minimal amount of incompatibilities
Delays		Compliance with work schedules
Reworks		Increase in the production curve in work, reduction in tasks execution time
Inadequate quality of deliverables		Deliverables according to the client's quality specifications
Non-compliance with security protocols		Security protocols properly complied with, corroborated by the preventionist

After detecting and obtaining the problems to be treated, the dates of the ICE sessions were established, this must be in accordance with the incidence and importance that these problems represent. In addition, it is advisable to carry out the ICE session at the beginning of the week or at the end of the week, to carry out the solutions provided from the beginning of the train of activities. Next, in figure 3, the plan of ICE meetings that was carried out is shown.

Date	ICE sessions	s1 13/06/20	s2 20/06/20	s3 27/06/20	s4 04/07/20	s5 11/07/20	s6 18/07/20
It is recommended to carry out the meeting on Monday of each week	1st session						
	2nd session						
	3rd session						
	4th session						
	5th session						
	6th session						

Figure 3. Schedule of ICE sessions for the case under study.

Based on the list of problems to be addressed within the project and the indicated dates of the ICE sessions, the agenda for the next session was developed; likewise, the topics were developed in a specific order, from the Inputs presented in table 3. With the session carried out it was sought mainly, improving the transmission of information between engineers - construction master - foreman through the ICE and BIM sessions. In such a way that allows us to reduce incompatibilities in the plans, reduce delays, reworks, improve the quality of deliverables, reduce response time to a query or problem, and the fulfilment with security protocols in order to obtain the increase in the productivity curve in work.

After preparing the meeting agenda, the main stakeholders with the problems specified in the agenda for the next ICE session were selected. For this, each participant in the session was informed of the list of issues to be resolved at the meeting; in order that they are updated, prepared and developed to obtain the desired results. In the following table 4, shows the roles of each participant in the ICE session, where

the Team leader is a person who manages the information and knowledge of the project in its entirety, since he will direct and put the guidelines within of the session. The Facilitator has general and superficial knowledge of the project, and is in charge of indicating the order of the topics to be discussed, he is also in charge of helping and reinforcing certain points (opinions of the members of the ICE session) with his expert judgment. The Recorder, is a person who will take note of all the important points and substantial contributions that are generated within the session; it should be noted that the Team members are the key professionals who will be called to contribute their knowledge within the problems that have been generated and are directly linked to them.

Table 4. Roles of participants in the ICE session.

Team leader	Facilitator	Recorder	Team members
Projects manager	Person in charge of some management in the contractor company	Construction manager	Specialist of the companies involved

3. Results

Based on the flowchart presented in the methodology, this section analyzes the development of the ICE sessions and the integration of BIM models in all scheduled sessions. Obtaining the results after the implementation process of the ICE and BIM sessions, basically consists of improving in four parts: the productivity curve, the percentage of the completed plan, the balance card and a survey of compliance with the main work executors.

3.1. Productivity curve

The production curve is a control tool that indicates the quantity of deliverables produced as a function of the time of the different items of the work [9]. Therefore, by exceeding the amount of production planned in a given time, it translates into an increase in productivity in work. Next, the concrete productivity graph of the Alameda Rímac project in which the methodology was applied will be shown, it can be seen that the Real Value reached and even exceeded the Planned Value in one month; in other words, in this project, productivity was increased thanks to the implementation of the ICE and BIM sessions.

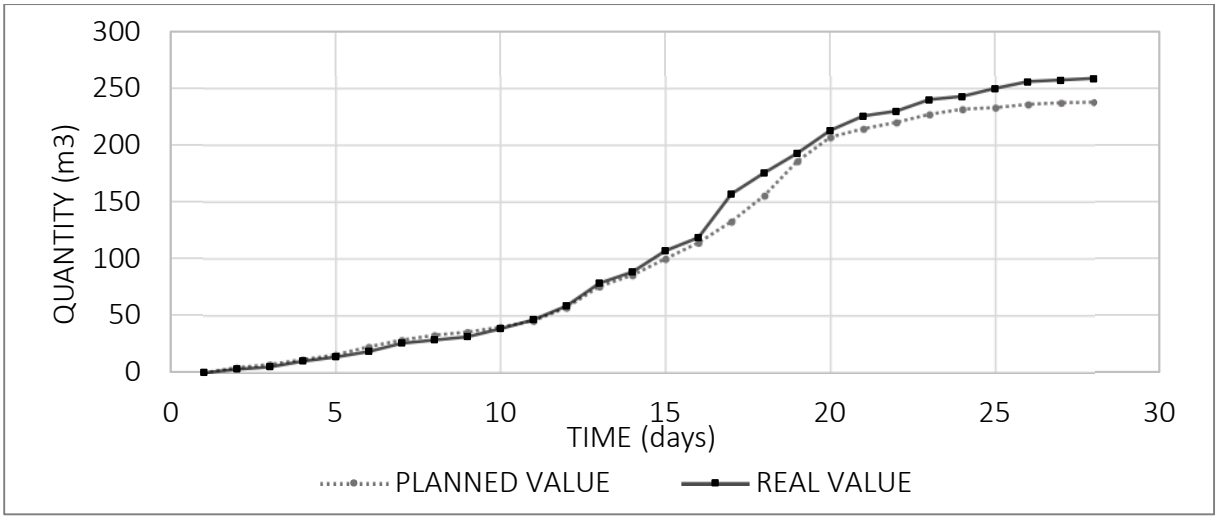

Figure 4. Productivity curve: Planned value vs. Real value.

3.2. Percentage of Completed Plan

The PPC is an indicator of the compliance of weekly activities. The lookahead (3-week schedule) indicates the restrictions that each item has and the worker responsible for releasing it. Initially, in the Alameda Rimac project, the accumulated PPC did not exceed the target PPC curve, this was due to the lack of an adequate production rhythm, communication was not optimal to execute tasks on time and with the required quality, and restrictions were not released due to lack of coordination between the team. When applying the ICE and BIM sessions within the project, it was observed that the target PPC is slightly exceeded by the accumulated PPC of the project, because productivity increased in the project thanks to the application of the methodology; this translates into time and cost reduction, see figure 5.

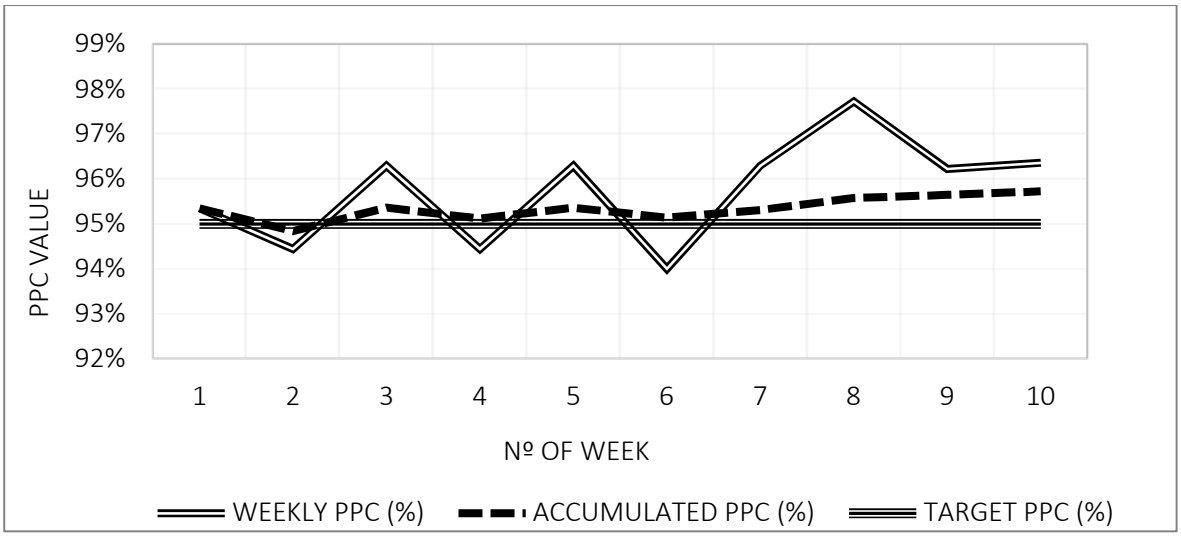

Figure 5. Comparative of the Completed Plan Percentage, Target Completed Plan Percentage, accumulated Completed Plan Percentage.

3.3. Balance card

This tool allows generating a diagnosis of the distribution of the time of the personnel that make up a work crew, within a specific activity. The types of work are classified into Productive Work (PW), Contributory Work (CW) and Non-Contributory Work (NCW) [10]. Therefore, with the implementation of the methodology, it was possible to increase the PW in the workmen, in this way the NCW was also reduced. The results obtained in the Alameda Rímac project will be indicated below, generating a time saving equivalent to 27%. Table 5, shows the relationship of the times that have been used in each item investigated.

Table 5. Optimized time vs. Used time.

Concept	Used time	Optimized time
Walls	34 minutes	27 minutes
Formworks	115 minutes	91 minutes
Slab enabled	126 minutes	100 minutes
concrete	125 minutes	99 minutes

3.4. Workmen Compliance Surveys

In this questionnaire addressed to the work executors, we want to know the level of satisfaction with the new communication dynamics in the project team. When the methodology was applied, an optimal level

of communication was desired in the project team, in this way the productivity results will be reflected in the field. Next, in table 6, the summary of the surveyed work executors and the respective responses will be shown.

Table 6. Results of the compliance surveys to the main work executors.

	The ICE sessions and the use of BIM within the meetings have achieved a great improvement in the understanding of the tasks to be carried out within the workman staff?	**What BIM tools have improved understanding of the project, according to your perspective?**
Construction master	Affirmative	Revit, Naviswork (BIM 4D)
Foreman - Concrete crew	Affirmative	Revit, Naviswork (BIM 4D)
Foreman - Formwork crew	Affirmative	Revit, Naviswork (BIM 4D)

4. Conclusions

The problems that have been generated around the world for more than 20 years are closely related to productivity. Therefore, working with the BIM methodology and ICE sessions will not only help to increase the productivity of projects in Peru but also to different projects around the world.

The results that have been achieved by applying this methodology, basically helped to improve the productivity curve and the completed plan percentage, this due to the improvement of the understanding of the deliverables to be carried out, both for the engineers and for the main work executors.

The cost necessary to apply the methodology is directly related to the magnitude of the effect it generates on the project or the company. In other words, if the methodology is to be applied to the entire company, it will be necessary to invest in more software and hardware equipment, more specialized personnel, etc.

Communication in the project team is key to avoid delays and reworks in any part of the project. Therefore, any methodology that improves communication between work personnel will have positive effects on the project reflected in its productivity.

The application of the methodology will have better results if it is applied from conception to completion. By way of example, in the short study period of the Alameda Rimac project, very encouraging results were obtained, in which the importance of its application is determined.

Finally, it is important to point out the importance of adding the work executors in the ICE sessions, since it has been shown that they generate added value to this type of meetings in the project execution stage. However, these results obtained were not achieved taking this recommendation into account, and even so the results were satisfactory.

5. References

[1] Del Savio A 2019 *Impact of the fourth industrial revolution on the construction industry* RPP News (January 10)

[2] Filipe B Jonathan W Jan M Maria J Mukund S Matthew P Nick B and Stephanie B 2017 Reinventing construction: a route to higher productivity Report in collaboration with MCKINSEY'S Capital Projects & Infrastructure Practice (Lucknow: McKinsey Global Institute) pp 2-12

[3] Latorre A Sanz C and Sánchez B 2019 *Application of a Lean-BIM model to improve productivity in drafting building projects* Construction Reports (España) 71(556): e313 (España: Superior Council of Scientific Investigations)
[4] Maceli A 2017 *Innovation in the Construction Sector of Peru: current status and diagnosis Master's thesis* (Valencia: Polytechnic University of Valencia) pp 54-61
[5] Planbim 2016 Standard *BIM for public projects Exchange of information between applicant and suppliers* (Chile: Digital transformation committee) pp 15-16
[6] Del Savio A 2019 *BIM in Peru* RPP News (January 10)
[7] Analistics Real estate 2019 *Real Estate Statistical Report* (Perú: Association of real estate companies of Peru) p 23
[8] Sulankivi K and Kiviniemi M 2010 *4D-BIM for Construction Safety Planning*. W099-Special Track 18th CIB World Building Congress
[9] Mejía G and Hernández T 2007 *Monitoring in work productivity: techniques for measuring labor performance* UIS Engineering (Bucaramanga) pp 45-59
[10] Pérez M, Gonzalo J, Del Toro H and López A 2019 *Construction improvement through lean construction and building information modeling: case study* Journal of Information Technology Research 7(14):110-21