Cossio, N.A. and Salazar, L.A. (2021). "Implementing elements of Last Planner® System in the Orchestra Wheel method" *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC29)*, Alarcon, L.F. and González, V.A. (eds.), Lima, Peru, pp. 657–666, doi.org/10.24928/2021/0108, online at iglc.net.

IMPLEMENTING ELEMENTS OF LAST PLANNER® SYSTEM IN THE ORCHESTRA WHEEL METHOD

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ABSTRACT

Due to the high costs and low level of productivity of high-rise building constructions, it is necessary to plan the Tower Crane's stay on site. In a first instance and to establish a baseline, a survey was conducted along with a Panel of Professional Experts to validate how the Tower Crane works and the performance indicators mostly used in Chile. The authors then developed a planning methodology, which has its origin in the "Orchestra Wheel" method but incorporates elements from the Last Planner® System. The primary aims were to achieve strategic planning and greater logistical detail to program the crane, generating greater control of the fulfillment of tasks, adding stages for better planning, and improving productivity. This new method was validated with an expert in the "Orchestra Wheel" methodology and with a Panel of academic experts and researchers who specialize in LPS—posing as future research, implementing this methodology in different high-rise building construction projects.

KEYWORDS

Planning system, orchestra wheel, Last Planner® System, high-rise building.

INTRODUCTION

CONTEXT

The construction industry is among the most relevant economic sectors worldwide, providing employment to 7% of the world´s working age population, generating expenditures in goods and services that reach 13% of the world's GDP (McKinsey 2017). However, this sector lags far behind other industries, as labor productivity growth in construction has only been 1% in the last 20 years (McKinsey 2017; The World Bank 2020). The above has led to rise in construction costs due to the low level of productivity because of the large number of activities that do not add value to the final product (Salazar et al. 2020).

Therefore, the construction industry, particularly regarding high-rise constructions, finds itself in the need and obligation to create new forms of planning, including performance measurement. Productivity must be measured to control and maximize the value of production by minimizing losses (Ballard and Tommelein 2016).

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NEED AND RELEVANCE OF THE RESEARCH

In the '80s, in France, a construction company noticed the problem of productivity in construction and created a planning methodology for high-rise buildings by optimizing the use of the Tower Crane. Hence, the main problem in the stage of thick and finished works is the low productivity of the lifting of materials due to the large number of stops and waits. This methodology, known as "Orchestra Wheel" (OW), consists of saturating the Tower Crane(s), scheduling their use and the rotation of materials, and thus guaranteeing compliance with simple and repetitive series of operations (daily production unit) under the same construction rhythm. Its name comes from the fact that the Tower Crane directs the work, giving it a continuous constructive rhythm throughout the team's stay, just like a conductor conducts a concert. In addition, it has a circular movement and it is based in its axis of rotation, just like a wheel. In this case, the idea is that the work revolves around the crane as the main axis (Muttoni 2015). Subsequently, another construction company in Colombia adopted this methodology, managing to improve its productivity by strengthening the planning and integration of the processes of all the areas that participate in the planning and construction of the work (Muttoni 2015).

On the other hand, in the '90s, Ballard and Greg Howell developed The Last Planner® System (LPS) to better integrate Lean principles in construction (Salazar et al. 2020). LPS is based on reducing workflow uncertainty and maximizing performance due to reliable planning (Ballard 2000), improving management of commitments in stabilizing the work flow, reducing variability and improving the operation of the processes (Álvarez Pérez et al. 2019). Therefore, the authors propose to integrate both planning systems since both are based on people, the trust of teamwork, and the efficiency of its elements, understanding that the fulfillment of processes in a timely and optimal way benefits both the work in which it is working as well as each collaborator who works in it (Álvarez Pérez et al. 2019; Muttoni 2015).

STATE OF THE ART AND PRACTICE

According to the IGLC state of the art, we found seven studies addressing high-rise building constructions, focusing mainly on productivity, planning, reduction of project duration and associated costs, how to deal with changes in client-initiated floor designs, environmental impacts, workflow monitoring, and advanced formwork systems (Bae and Kim 2008; Esquenazi and Sacks 2006; Ibrahim and Hamzeh 2015; Kemmer et al. 2008; Linnik and Berghede 2013; Maia et al. 2016; Priven et al. 2014). In addition, from these studies published in the IGLC, we found two studies that propose different planning methods and tools for high-rise construction, in both studies it is confirmed that the Critical Path Method (CPM) is the most currently used method (Aburto 2016; Toro 2017).

Moreover, we found studies in other countries where the planning, productivity, location, interference between towers, and operating costs of the Tower Crane are discussed (Al Hattab et al. 2014; Mena 2007). Still, none in conjunction with the OW or LPS method; Nevertheless, the research found helped us understand how it has worked in other countries and how to improve the Tower Crane's productivity in high-rise building constructions.

METHODOLOGY "ORCHESTRA WHEEL" (OW)

There is practically no literature apart from the publication of Muttoni (2015), so we decided to contact a collaborator of the Colombian construction company who had already implemented this methodology, and according to the above we could determine that the OW methodology is a strategic planning, with a scope of greater logistical detail, which rigorously schedules the use of the Tower Crane and the internal rotation of materials to guarantee compliance with the daily production unit. It is a method that requires measuring and collecting performance data, which allow obtaining the production capacity with a synchronization of all the variables. Additionally, OW is concerned with having an incentive plan for workers so that they have a better income and therefore, generate a better work environment and thus improve productivity.

PURPOSE OF THE INVESTIGATION AND WHY IT IS NEW KNOWLEDGE

Tower Cranes' implementation has transformed the perception of high-rise building constructions; the Tower Crane is no longer just load-lifting equipment but it is an essential instrument to give flow to construction processes, maximizing the use of time in productive tasks.

The main objective of this research is to develop a methodology for implementing elements of LPS in the OW method, to improve the planning of construction projects of high-rise buildings and thus increase productivity, since, as previously mentioned, the OW methodology is based on enhancing project productivity by saturating the Tower Crane (Muttoni 2015).

Although the OW methodology has worked well in France and Colombia (Muttoni 2015), it has deficiencies in achieving commitments in planning, given that it does not keep a record of planning and productivity indicators, identification record nor a release of restrictions record (as discussed with the Colombian collaborator), and therefore LPS provides those maneuvering tools that lead to an even more adequate level of control and detail (Ballard 2000; Álvarez Pérez et al. 2019).

As there is currently no research that relates LPS with OW Methodology, this study is a contribution to the planning and improvement of productivity of the Tower Crane.

RESEARCH METHOD

DESIGN SCIENCE RESEARCH

For the development of this research, the authors used Design Science Research (DSR), which is a methodological approach that tries to solve a problem in the real world, from the innovative creation of an "artifact" that has outstanding theoretical and practical contributions (Lukka 2003), given that the final purpose is to perform an Applied Science/Engineering (AS/E) to produce a methodology (artifact) (Briggs and Schwabe 2011).

Therefore, this research consists of five primary activities proposed by Salazar et al. (2020), based on: 1) Discovery of problems and opportunities through an exhaustive analysis of the context; 2) In-depth knowledge of the subject, state of the art and practice; 3) Design and construction of artifact; 4) Evaluation of the artifact to find a satisfactory solution; and 5) Validation of the artifact, through a survey, expert panels and analysis of results.

This artifact was developed through four cycles, based on the five activities described. The first cycle was set from the problem encountered, the low productivity in the construction area, where we looked for opportunities to solve the problem through strategic planning of the Tower Crane to improve construction projects' productivity in high-rise buildings. To find out which planning methods and productivity indicators are used and controlled in high-rise constructions in Chile, the authors created a survey for professionals with experience in the high-rise building sector; the survey was evaluated and validated by a panel of academic experts (Delphi Method), to be later applied and subsequently analyzed. This leads to cycle number two, where it is necessary to know if the Tower Crane is planned in the time of permanence at work, which was reflected in a process diagram and was later evaluated and validated by a panel of professional experts with extensive practical experience in high-rise building constructions and the use of the Crane-Tower (Delphi Method). After that comes the third cycle, where the authors realized that the current form of planning is not the optimal one to solve productivity problems, so we evaluated the state of practice, finding that there is a methodology that by saturating the Tower Crane it improved productivity, which is called "Orchestra Wheel" (Muttoni 2015). Therefore, we designed a process diagram with this methodology, validating it with the Colombian construction company's collaborator. To improve the OW methodology, the fourth cycle is complemented with LPS elements, which provide implementations and strategic planning controls (Ballard and Howell 2003). The LPS elements are entered into the Orchestra method's process diagram where a panel of academic experts and researchers (Delphi Method), who have worked and studied LPS in different investigations and practical implementations, evaluated and validated it.

DELPHI METHOD

The Delphi Method consists mainly of collecting expert judgments on a topic to evaluate and validate the process diagrams used during the investigation to determine each of the summoned experts' opinions in a collective and superior review (Caldera 2018). In the panel of professional experts, relevant information emerged to consider the solution to the productivity problem, thus adding essential aspects when planning the Tower Crane's use. To mention important considerations: assembly and disassembly, bracing, maintenance, security, among others.

SURVEY: CURRENT PRODUCTIVITY PLANNING AND CONTROL

To understand the real planning and productivity control problems of the Tower Crane, a survey containing closed questions (yes or no) was carried out, in Likert scale, and open-ended (justified). This survey took place online due to the pandemic.

The survey was conducted with various professionals in the area of high-rise construction: 6 Project Managers (PM), 7 Site Administrators (SA), 3 Field Managers (FM), 3 Technical Offices (TO), 3 Planners (P), and 3 others. Where more than 50% of the respondents have more than 10 years of experience in the sector. The main idea of the survey was to know how they currently work with the Tower Crane. Based on the answers obtained, 90% of the respondents agreed that it is essential to measure productivity and plan exclusively with the Tower Crane. However, only 36% currently measure productivity and plan for the Tower Crane.

CURRENT WORK PROCESS DIAGRAMS AND METHODOLOGY "ORCHESTRA WHEEL"

As previously described, during the investigation, the authors developed a process diagram which represents, in a preliminary way, how Chile is currently working in terms of planning and production control, specially the operation of the Tower Crane. The diagram was presented to a panel of professional experts to generate contributions, evaluate and later validate the proposed artefact.

After that, the authors created an activity diagram from Muttoni (2015) presentation, which they later validated thanks to the conversation with the Colombian construction company's collaborator. According to Muttoni (2015) and the expert in OW, the method is divided into 3 phases, which are explained below:

1. **Starting point:**

It begins at least three months before the start of the construction, with a transfer meeting, in which the most important background of the project must be obtained. Orchestra team members should provide planning and strategies for selecting the most productive methods.

Later, meetings are held (two weeks maximum), where the team studies all the antecedents before presenting themselves in the sessions, so that the meetings can hold question and answer sessions.Then the tasks and managers are defined, the suppliers are integrated in order to plan the supply and make strategic decisions, people who meet the profiles for the operational functions of the project are sought, and the 4M are defined: 1) Machinery: Crane -Tower, formwork and others; 2) Method: daily productive unit, sequence and rotation, Tower Crane saturation, logistics; 3) Labor: formation of crews, training; and 4) Materials: histograms, supply frequency, packaging units, negotiation with suppliers.

Finally, this phase is concluded by establishing the schedule, where the schedule and Gantt diagram are made with all the detailed activities. The Starting Point is defined with their respective time limits and budget, prioritizing the activities (20% of the actions represent 80% of the result).

2. **Programming studies:**

This second phase begins with the Work Quantities, where the following are defined: 1) the daily production unit; 2) the necessary resources for the execution of the project; and 3) quantity of material and packaging unit. Then, we proceed with the Definition of construction systems, where the best formwork systems, prefabricated, stairs, collective protections and packaging units are selected, in this way the most productive combination is chosen.

Afterwards, we continue with the Cadence Calculation, which is a tool that allows determining the daily workload of the Tower Crane with which the productive unit defined in this process is achieved. This begins two months after the “Transfer Meeting”. The capacity and dimensions of the Tower Crane are defined according to the selected construction systems. The number of cycles is calculated with the amount of material and weight to be transported, and depending on the results obtained, the number of Tower Cranes and their respective specifications are defined.

It continues with the Installation Plan (layout), which defines the location of the Crane (s), with the provisional facilities, loading and unloading areas, vehicle circulation routes within the project, materials storage areas, collection of waste, and finally, safety zones and routes. Then, we continue with the Planning of the schedule, where a detailed planning of each of the activities that will be carried out day by day is created. The respective schedules and execution times are designed in order to know how many hours a day are required to move each material, and thus continue with the next stage, having the necessary information.

Finally, this second phase is finished with the definition of daily material rotation. In this process, a list of materials is drawn up, which will be included in each daily production unit. These materials must be transported just in time to the work fronts, before the execution of each activity, by being unloaded directly from the truck to the site where they will be used.

3. **Application and safety history:**

At the same time, four very important concepts are being worked on, constantly on site: 1) Detailed rotation; 2) Safety; 3) Time Budget; and 4) Work sequence diagrams. Each team progresses in its activities at a work rate that allows the Tower Crane to be used in the assigned time and place. In order to comply with the hours of use of the Tower Crane, the exact hours in which the planned activities will be carried out are assigned and established to achieve the synchronization and the programmed work rhythm.

Similarly, regarding the management and productivity monitoring, the next follow-ups are carried out in parallel: 1) Planning and execution of material rotations; 2) Continuous improvement strategies; 3) Execution of the planning of the saturation of the Crane; 4) Performance of the workforce; and 5) Decisions on safety and quality.

At the end of the three phases, we have the "Return of the experience", where the lessons learned are documented and consolidated. This is the most important step, it serves for all the company's processes, since it allows learning from experience and guarantees continuous improvement.

ORCHESTRA WHEEL METHODOLOGY PROPOSAL WITH LAST PLANNER® SYSTEM ELEMENTS

Starting from the original OW methodology, for each phase, we propose the integration of the following LPS elements: 1) Starting point, integrating the master planning and the main activities through Pull Planning; 2) Programming study, merge Lookahead, managing and controlling restrictions; and 3) Application and security history, combine Weekly Planning and Daily Planning, managing commitments and detecting deviations.

Therefore, we included the LPS elements mentioned within the process diagram of the Orchestra method, and we presented them to a panel of experts, academics and researchers, with a vast knowledge of LPS, in theory, and application, to contribute, evaluate and validate the proposed diagram (Figure 1).

Each phase of the OW + LPS diagram is detailed below:

1. **Master plan through Pull Planning:**

Like the original methodology, it must be started at least three months before the start of the construction. It begins with a transfer meeting to empower the Orchestra team with all the information of the under study project. The Orchestra team will arrive at the transfer meetings with all the background studies since, in 2 weeks, they must clear up doubts and propose solutions to possible problems.

Besides, according to the original methodology, the 4M must also be defined: 1) Machinery; 2) Method; 3) Labor; and 4) Materials.

Preliminarily, the team must create the Master Plan or Schedule through Pull Planning by dividing the plan into different proposed stages to develop more detailed work plans, clearly defining the objectives (Koskela et al. 2010). Two tools that contribute directly to the exhaustive list of tasks are the definition of duration and the crane's movement times through the determination of: 1) The quantities of work; and 2) The construction systems.

When the Master Plan of the work is approved, the Tower Crane cadence must be calculated, defining its capacity and dimensions. This is how the Tower Crane's daily workload is determined to achieve the desired productive unit.

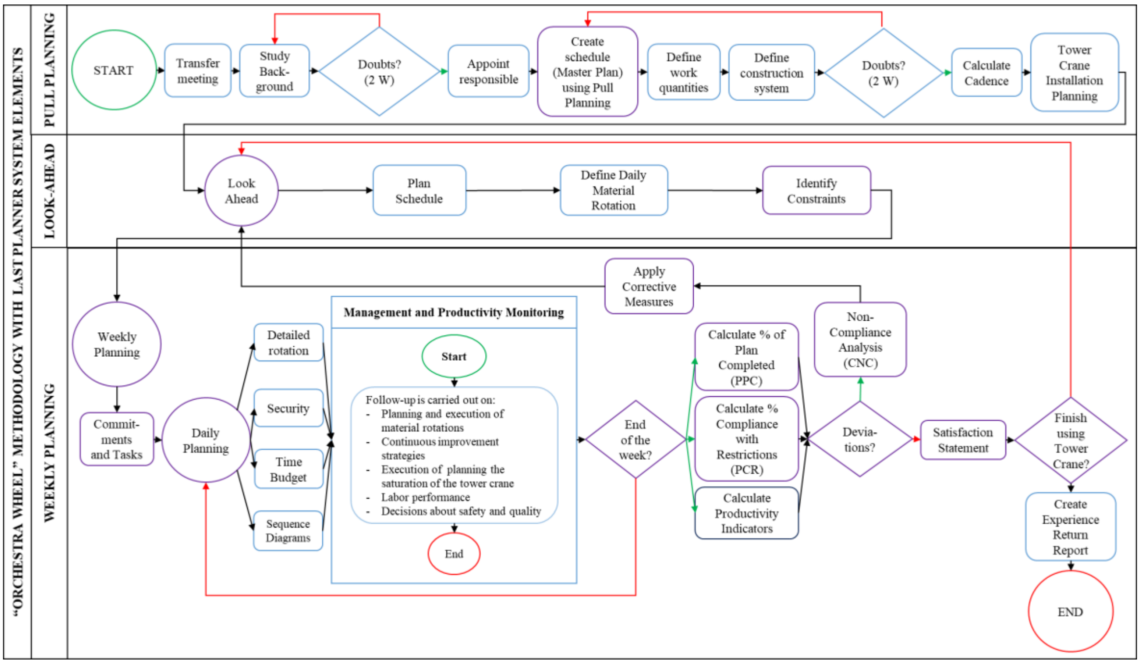

Figure 1: Diagram of the "Orchestra Wheel" methodology processes with LPS elements, validated by a panel of academic experts (Own elaboration).

Finally, the Installation Plan is carried out, defining the Tower Crane (s) location for its subsequent disposal on the ground.

2. **Identification of restrictions through Look-ahead:**

At this stage, the orchestra team must anticipate what will happen in the future, that is, generate an anticipated planning, and the activities to be studied in this way are: 1) Planning the schedule, defending it and also calculating execution times of each one of the tasks to be performed daily; and 2) The rotation of the material, detailing how, when and where the materials should be transferred before their use in each activity, always taking into account the daily production unit. Subsequently, the restrictions are identified, which will be modified according to the work's needs, calculating the percentage released (or compliance, PCR) in each one.

3. **Control of commitments and planning and productivity indicators through Weekly and Daily Planning:**

This phase begins with Weekly Planning and Daily Planning. The first thing is to commit to periodic weekly and daily meetings, so that through iterative control, all programmed processes are fulfilled (Koskela et al. 2010). In these meetings, commitments are established regarding safety, quality, resources, construction methods, and any problem in the project. The original methodology works in parallel: 1) Detailed rotation; 2) Security; 3) Time Budget; and 4) Work sequence diagrams.

In Management and Productivity Monitoring, deviations from scheduled tasks are also periodically measured and recorded to later review the Non-Compliance Analysis (NCA) (Sabbatino 2011). With this information, it is possible to analyze the improvement strategies to apply the corrective measures in the next iteration (weekly or daily according to the corresponding process). Also, the planning and correct execution of the tasks must be continuously monitored, mainly the Tower Crane, labor performance, and decisions on safety and quality, which are also included in the analysis of possible restrictions of the construction site (Ballard and Howell 2003; Koskela et al. 2010).

At the end of a work day on the site, it is consulted if it is the end of the week. If the week does not end, the cycle is returned to the Daily Planning; If the week ends, the planning and productivity indicators are calculated.

The planning indicators used will be the PPC and the PCR since they generate a release of restrictions in an appropriate time to have a good performance in the short term (Sabbatino 2011). For productivity indicators, according to Caldera (2018), The factors that cause productivity decreases must be taken into account: 1) Use of overtime; 2) Program compression; 3) Type of project; 4) Security; 5) Quality; 6) Management factors; 7) Manpower equipment; 8) Motivation; 9) Supervision; 10) Materials and tools; 11) Project management factors; 12) Natural factors; 13) Political factors. Therefore, the authors suggest that at least one performance indicator, which directly affects the construction site, must be measured in each area. On the other hand, it is also suggested, according to the results of the survey, that the work be controlled with Curve “S” or Curve of Progress, since a follow-up can be carried out that allows establishing if the project is ahead or behind according to what is expected. In addition, it is also possible to analyze project trends and help make preventive and/or corrective decisions.

According to the result of the indicators mentioned, it is later verified if there are deviations in these; if there are deviations, the non-compliance analysis is made, the respective corrective measures are developed and applied, and a return to the Lookahead planning is carried out so as to re-identify restrictions and go through the Weekly Planning and the Daily Planning again; If there are no deviations, the Declaration of Satisfaction of compliance with the schedule is made. It is then verified if the Tower Crane is still necessary; if required on-site, the cycle is returned to the Lookahead schedule, restarting the weekly and daily control cycle. When the Tower Crane is no longer required on-site, it is uninstalled. A report is created with all the information on the Tower Crane's operation, compiling all the documents and experiences learned, which helps future construction sites to understand and learn from the previous occasion. With this, continuous planning and productivity improvements of the project are guaranteed, thus, terminating the participation of the Tower Crane in the project.

DISCUSSION OF THE ARTIFACT

According to the results obtained from the surveys and the Panel of Professional Experts, we were able to determine the Tower Crane's planning system in high-rise building projects in Chile. Also, we managed to implement elements of the Last Planner® System in the “Orchestra Wheel” methodology, validating this proposal through a Panel of Academic Experts. Thus, creating an Orchestra Wheel Method 2.0, which achieves greater control and management of commitments in the construction process.

With the above mentioned, this method has great potential to be generalizable worldwide. It must still be applied in real projects since it was only validated by a panel of experts (Delphi Method) and could not be implemented in an actual project. Furthermore, the pandemic being experienced worldwide has caused quarantines and, therefore, it prevented the researchers from carrying out the practical implementation.

CONCLUSIONS

Due to the low productivity of construction, the authors proposed the integration of the unknown “Orchestra Wheel” method and the famous “The Last Planner® System, since both are concerned with improving project productivity and are based on people, the trust of the work team and the efficiency of its elements, understanding that the fulfillment of processes in a timely and optimal manner benefits both the work on which we are working and each collaborator who works on it. The authors, for this research, used two research methods: 1) DSR: a methodological approach that tries to solve a problem in the real world, based on the innovative creation of an "artifact" that has great theoretical and practical contributions, which is just what the authors had as their objective; and 2) The Delphi Method: consists mainly of collecting expert judgments on a topic, which contributed to the evaluation and validation of the process diagrams and the methodology proposed in this research. The main contribution was creating the methodological proposal for the implementation of the elements of LPS in the OW method to improve the planning of projects in high-rise buildings that use Tower Cranes. The main limitation of this research was that the system could not be implemented in a case study. Furthermore, this methodological proposal is limited to a single Tower Crane. However, although the proposed diagram could be adapted to two or more Cranes- Tower, it is not shown in the present investigation. Finally, as future research, we offer to implement this new methodology in different construction projects in high-rise buildings in other countries around the world.

ACKNOWLEDGMENTS

The authors are grateful for the support provided by the Professional Expert Panels, the collaborator of the Colombian Construction Company and the Panel of Academic Experts and Researchers of YR4-AECI, for Natalia Cossio's undergraduate degree study.

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