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Productivity improvement of tower crane in tall buildings

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Abstract. The tower crane is an electromechanical equipment that is used for the vertical transport of materials in a construction project and together with the two riggers form the work team to carry out this task. One of the main problems in the construction of multifamily buildings corresponds to the use of the tower crane because vertical transport causes non-contributory times, which is, dead times and waits above expectations. This research analyzes the current vertical transport process and proposes its optimization through some management tools with the aim of improving the productivity of the use of the tower crane by reducing non-contributory times. To this end, the productivity of the work team is recorded in several projects with similar characteristics, then the main problems are selected to analyze them and finally the process is optimized. The results determined that non-contributory times can be reduced by 10% if there is an orderly and continuous process.

1. Introduction

The tower crane, being a heavy equipment in construction, must justify its cost by optimizing its use; Therefore, it should be used optimally in construction works in order to make construction processes fast and safe, to obtain an improvement in productivity.

The literature on the productivity and operation of the tower crane is extensive. Ratios are used to measure the productivity of the tower crane, such as: the necessary space of the tower crane in action, the emptying time using the tower crane and the vertical transport time of construction materials. [1] Construction information modeling (BIM) is used to position the tower crane at construction sites with repetitive operations. BIM modeling optimizes the process through the user, which selects an appropriate optimization approach and formulates the positioning problem to minimize the total cycle duration. [2] Advance planning is used to plan daily operations and to provide a reliable daily schedule of the tower crane. The results show that overlapping activities and coupling advance planning balances the demand for work and reduces the duration of the tower crane process. [3] An agent-based simulation model is proposed to quantitatively assess the effect of the conflict over time and the overall costs of tower crane operations. The proposed model compares several tower crane design combinations to achieve an optimal solution. [4] Tower cranes operate in environments that are sensitive to unavoidable external disturbances, such as having buildings in much of the perimeter. An adaptive monitoring controller is proposed to deal with the uncertainties of external disturbances, which is implemented through experimental tests. [5]

This research focuses on analyzing the productivity of the tower crane in the vertical transport of materials during the construction of multi-family buildings, and then redesign the process through management tools.

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2. Method

To initiate the investigation it is necessary to define the characteristics of the projects to be evaluated, so that buildings with residential use between 15 and 20 floors are included, building height between 30 and 60 m, land area between 800 and 1200 m2, evaluation at the stage of structures and use of a tower crane. Three projects with the characteristics defined for this research are evaluated:

Table 1. Characteristics of the project evaluated

	Project 1	Project 2	Project 3
Number of floors	15	20	20
Project height (m)	50	58	58
Land area (m2)	840	920	1200
Project stage	Structures	Structures	Structures
Number of tower cranes by project	1	1	1

For the analysis of the vertical transport process it is necessary to use some management tools, such as: balance sheet that is used for the measurement of each activity in a period of time whose objective is to analyze the efficiency of the construction method used, rather than the staff efficiency; Pareto diagram used to detect failures caused during the process whose objective is to graphically select the process problems; Ishikawa diagram that is used to analyze the causes of the main problems previously identified; and the flow chart that is used to present the new process, including those responsible at each control point.

In order to meet the objective of this study and present the information and results in an orderly manner, the following research process is developed:

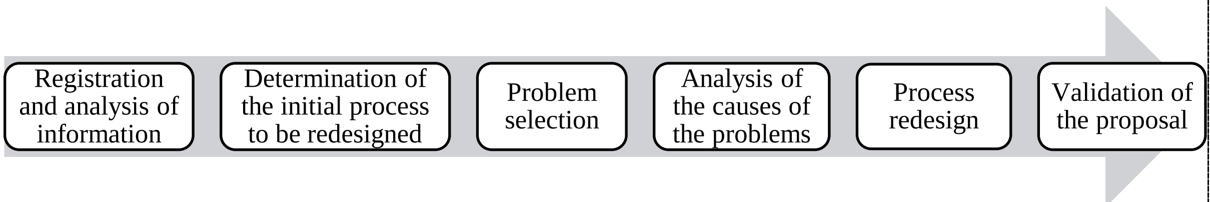

Figure 1. Research methodology

As a first step, the information of the measurements made in the selected projects must be recorded and analyzed. It is important to take into account that the work team for the general process of vertical transport of materials with tower crane is composed of rigger 1 in the free areas of the project, rigger 2 in the production area of the work and the tower crane.

Subsequently, the initial process must be determined, which presents the similar activities carried out within the data collection of each project. The general process presents four activities: movement, mooring, transport and unmooring. Movement and transportation are activities executed by the tower crane; while mooring and unmooring are activities executed by rigger 1 and rigger 2, respectively. The movement is defined as the maneuver of the tower crane without material; while transport is defined as the maneuver of the tower crane with material.

Once the activities are defined, each one must be classified by type of work PW - Productive work, CW - Contributory work and NCW - Non-contributory work.

Table 2. Activities for type of work

	Movement	Tie up	Transport	Untie
Resource	tower crane	rigger 1	tower crane	rigger 2
Type of work	CW	PW	PW	PW

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Then the main problems must be selected through Pareto statistics, with the aim of subsequently analyzing the causes of these problems until the root cause is identified. Finally, taking into account the previous information, the redesign of the process is proposed and applied in a study case to validate the research proposal.

3. Results

3.1. Registration and analysis of information

The recording of the information of the work team measurements is made for a period of five days for each project. The measurements are made at the structures stage, specifically at construction levels that exceed the zero level. Once the information is registered, the quantity of the main materials transported in the three projects must be classified to compare them.

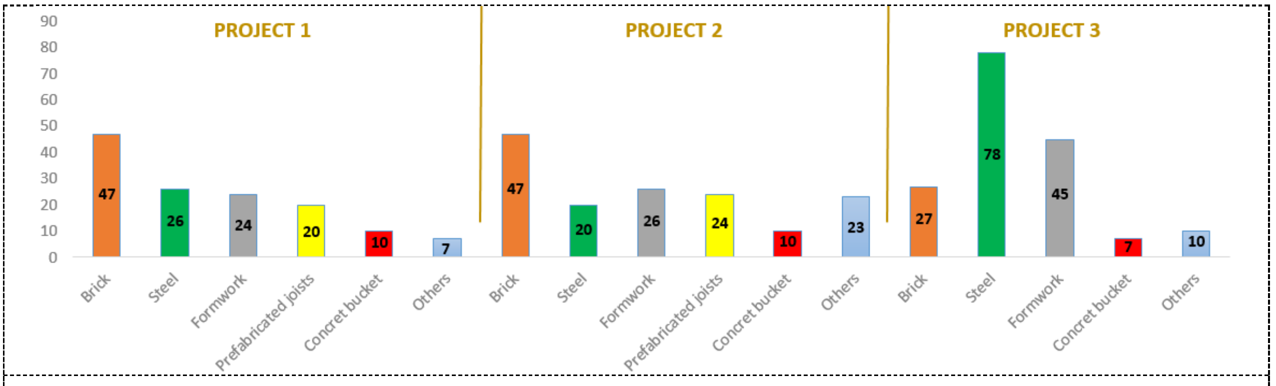

Figure 2. Quantity of transported materials by project

In project 3, prefabricated joists were not used because the construction system was made of solid slabs, so that steel is the most transported material. In the rest of the projects lightened slabs with prefabricated joists were used to optimize the construction processes.

All recorded information is analyzed and the overall results of the productivity of the three projects are classified according to the type of work.

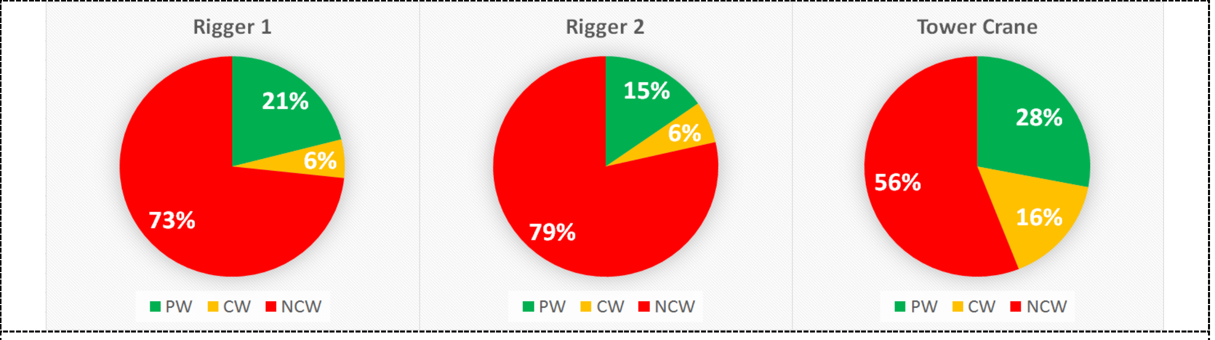

Figure 3. Overall productivity results

For the riggers, 21% and 15% of TP is the mooring and unmooring of the materials. 6% of CT are the use of the radio to guide the tower crane in the transport and unloading of the material and the use of the beep. 73% and 79% of TNC are the waiting times caused by the work done by the other rigger and the crane.

For the tower crane, 28% of TP is the transport of all types of materials to any point of the work. 16% of TC is the movement that the tower crane executes without material, it includes the movement of the empty brick cell. The 56% of TNC are the waiting times caused by the coordination of material with the foremen and by the work of mooring and unmooring of each rigger.

Within the TNC of each team member, the dead times (19%) are empty in which none of the members performs any activity; Research is not focused on these times.

3.2. Determination of the initial process to be redesigned

The common activities that together represent the initial process of vertical transport of materials with tower crane, observed in the measurements of the three projects, are identified.

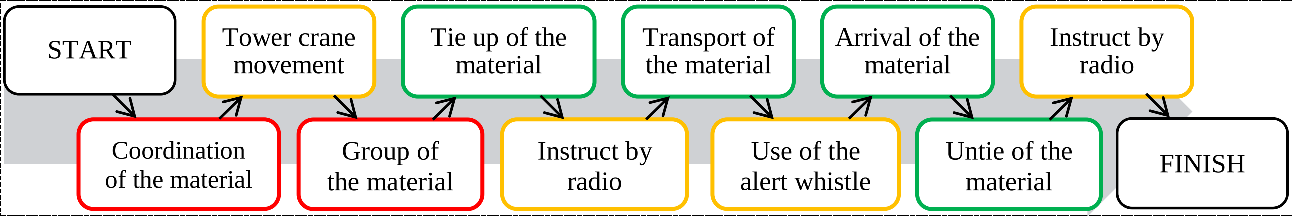

Figure 4. Initial vertical transport process

3.3. Problem Selection

Pareto statistics are applied to the activities corresponding to the TC and TNC, with the objective of identifying the activities that are within 80%. The following nomenclature is presented:

- Waiting for the rigger 1 : E1 - Waiting for the crane : EG - Movement : M
- Waiting for the rigger 2 : E2 - Dead times : U - Radio use : R

	Quantities (min)	%	Quantities accum (min)	% accum
W2	5,375	32.0%	5,375	32.0%
W1	4,666	27.7%	10,041	59.7%
WT	3,439	20.5%	13,480	80.1%
D	2,024	12.1%	15,504	92.2%
M	793	4.7%	16,297	96.9%
R	523	3.1%	16,820	100.0%
TOTAL	16,820	100.0%		

Table 3. Calculations and percentages of the activities

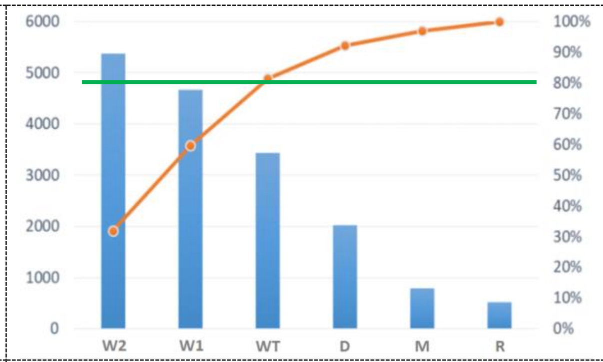

Figure 5. Pareto's diagram

3.4. Analysis of the causes of the problems

The main problems identified are analyzed. An analysis is carried out with the six categories to identify the causes, the sub causes and the root cause of the problem.

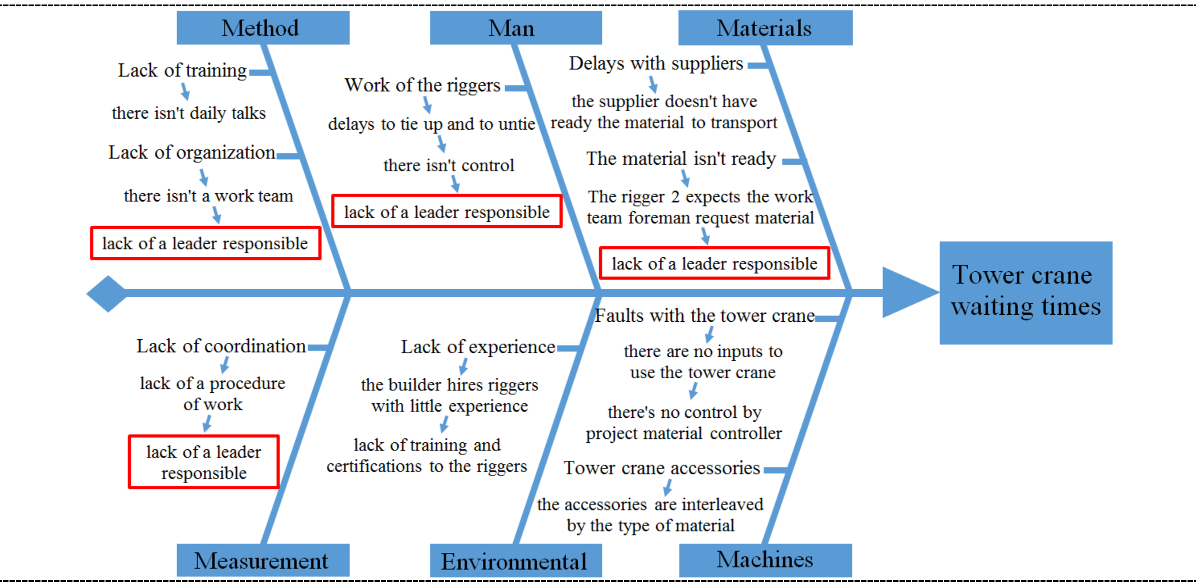

Figure 6. Ishikawa's diagram of the tower crane waiting times

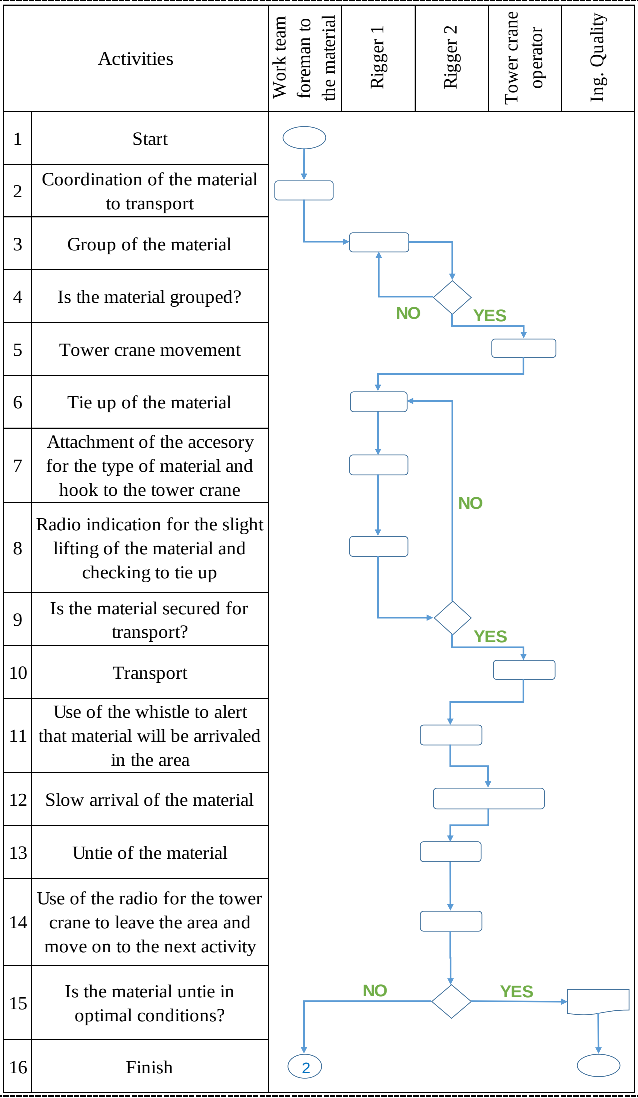

Figure 7. Redesigned vertical transport process

3.5. Process redesign

The objective of the redesign is to ensure that the general process is carried out consistently with an established sequence, complying with safety standards.

With respect to the initial process, control points have been added before the operator performs the respective maneuver and at the end of the process, in which the Quality Engineer is added for documentation through an inspection protocol.

3.6. Validation of the proposal

The proposal, applied to a project with similar characteristics, obtains a 10% productivity improvement in the TP of the tower crane product of an orderly process in which the rigger 1 has the grouped materials and makes the respective moorings in the times in which the rest of the work team performs its functions; also generating an 11% increase in CT.

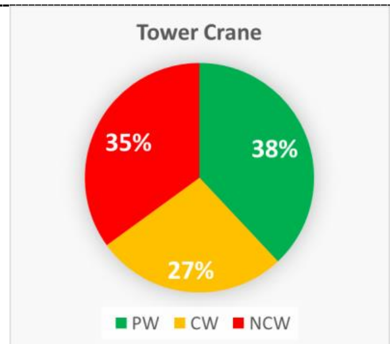

Figure 8. Productivity results

4. Conclusions

The proposal focuses on the team members working in a more integrated and intelligent way. For this, if you have an organization and programming you get to increase the productivity of the overall process. The organization is relevant because each member knows their roles and responsibilities within the process. The programming helps to have well defined schedules on the materials to be transported during the day. On the other hand, the reduction of the tower crane's TNC from 56% to 35% means that the tower crane is in operation for 1.2 more hours per day, taking into account that 8 hours per day are worked. Considering that the monthly rent of a tower crane is $ 10,000 on average, producing the 1.2 hours is equivalent to a saving of $ 60 per day, which is equivalent to $ 1,500 per month, which for a one-year project of the tower crane's operation equals $ 18,000 savings.

5. References

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