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Improvement of planning and time control in the project management of a metalworking industry - case study

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Abstract

Due to the competitiveness in the job shop nature of the metalworking industry, project management plays an important role in improving performance, efficiently and effectively managing its performance. Many of the generic problems observed in project management in metalworking industries were in the domain of document management, communication, multiple projects simultaneously, organizational structure, and poorly time estimation of project activities. The aim of this study was to improve the planning and time control in the project management of a metalworking industry in order to reduce the delivery delays. Using the existing data, an analysis of the project management process was carried out with the view to optimize the production system. In order to meet the established objectives, some of the project management tools were used, such as the Ishikawa diagram, PERT (three points estimating times), Monte Carlo simulation, as well as the involvement of people in the estimation and sequencing of activities, and holding weekly meetings to ensure the alignment of professionals. After the implementation of the actions proposed for the production process, there were gains of 50% and 38% in the average of deviations of times for two different projects of the case study and the Monte Carlo gave the best approximation.

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1. Introduction

The project approach has long been a model for managing businesses in the various existing sectors and its importance has been growing. Perhaps the best indicator of this growth is the rapid expansion of the Project Management Institute (PMI) [1]. In the metalworking industry of job shop nature, the characteristics of each activity are unique and with unpredictable factors, such as activity durations, special project requirements, and sometimes its uncertainty regarding the manufacturing process. Given the above, together with the growing competitiveness in the job shop metalworking industry, project management plays an important role in the efficient and effective management of its performance.

Projects that are over-budget, delivered late, and fall short of user's expectations have been a common problem area related to the accuracy of estimation for years. Even in highly predictive, mature project environments like those recommended by PMI and Software Engineering Institute (SEI), estimating is a serious challenge and estimates are frequently wrong [2]. The estimation of time and its control is one of the most critical problems in project management and it has been the subject of several studies in order to reduce the delays and costs that may occur, such as the work [3, 4, 5].

This work focuses on the theme of improving planning and time control in project management in a metalworking industry with the aim of reducing deviations between planned durations and those actually verified, in order to reduce delays in delivery times, more specifically, not exceeding five days delay.

To achieve the objective of this work, the rest of this article is organized as follows. Section 2 presents a brief literature review of this work, especially focused on time planning techniques for project activities. Section 3 presents the productive system of this study and the associated problem that will be the target of the improvement process. Subsequently, in section 4, two improvement proposals are presented that were applied to two projects of the company and the results obtained against the initial results are analysed in the section 5. Finally, some conclusions are made in the section 6.

2. Literature Review

Over time, several methodologies and tools have been created for project management, due to the demands of existing and constantly evolving markets. Some of the most important methodologies that the majority of the industry has used are: Project Management Body of Knowledge (PMBOK) [6]; ISO 21502:2020 - Project, programme and portfolio management — Guidance on project management; and Scrum [7].

The PMBOK is a set of best practices in project management, brought together by experts in the field, and organized by PMI. It is considered the most complete document on project management and is organized into ten areas of knowledge (integration, scope, Schedule, cost, quality, resource, communication, risk, procurement, and stakeholder) which are handled within five macro processes (initiating, planning, executing, monitoring and controlling, and closing). The ISO 21502:2020 has its origins in the PMBOK and does not present significant differences, so we excuse ourselves from further details. Scrum is a lightweight framework that helps people, teams and organizations generate value through adaptive solutions for complex problems. Scrum is founded on empiricism and lean thinking. Empiricism asserts that knowledge comes from experience and making decisions based on what is observed. Scrum is built upon by the collective intelligence of the people using it, rather than provide people with detailed instructions [7]. The use of Scrum methodology as expanded for different areas of its initial purpose, software development, and now it is considered an agile methodology for project management. Each of the methodologies presents concerns in terms of planning and time control and even define some methods to do so.

In a survey conducted by [8], framed with the characterization of the practice of project management in 30 Portuguese metalworking companies, the time management process, among the process of the PMBOK Guide, assumed 60% of relevance for a desired project management.

In terms of time planning, two aspects can be considered: 1st - the aspect of planning a project's network of activities;

2nd - the aspect of the duration of the activities of a project and its total duration. For the first strand, the PERT (Program Evaluation and Review Techniques) and the CPM (Critical Path Method) they are the best-known methods, based on the construction of a graph, or network, and represent a set of activities necessary to complete the project. The main difference between the two is that PERT uses times of a probabilistic nature while CPM is deterministic in nature and the application of both is clearly known in different areas of engineering in non-repetitive and more complex productions. For the second approach can be considered the methods: expert judgment, analogous estimating, parametric estimating, three-point, bottom-up estimating, and simulation where it is included the Monte Carlo (MC) technique.

In recent literature, several studies focused on improving the project duration forecasting accuracy using historical data or Monte Carlo simulation. The potential of using MC simulation to predict project execution is well known [5], [9]. The MC simulation has good capabilities for project management solutions, and enough margins to be extended in terms of simulation model evolution and offers good results in data generation, in order to assist the project manager [10, 11]. One of the main features of MC simulation is its ability to consider the entire spectrum of possible outcomes, which can become one of its main weaknesses, as it can hide important and specific results due to the overlap of information in metrics or result graphs global. All project information, such as schedule, task durations and costs, conditional and probabilistic events, time, cost risks and constraints, can be simulated with the MC simulation method [12].

PERT get the advantage of be simple and practical while the MC provide the more accurate results. However, the limitation of the first one is the production of unrealistic results and for the second one, the requirement of large computation load. In the case study of this work, booth techniques will be explored, and its results analysed [13].

3. Presentation of the system and its problem

A schematic description of the production process and quality control it is illustrated in figure 1, for the metalworking company addressed in this work. The global production process is similar for many metalworking industries, starting with the cut of materials, then are produced the components using mainly mechanic processes, and finally the product is assembled, normally trough welding and bolting processes. In terms of layout, we are in the presence of a job shop production system until components fabrication and after, for the assembly activities, in the project layout. Considering that each product is tailored according to the client specifications, the production system type is the project system, and its management follows the principles of the project management.

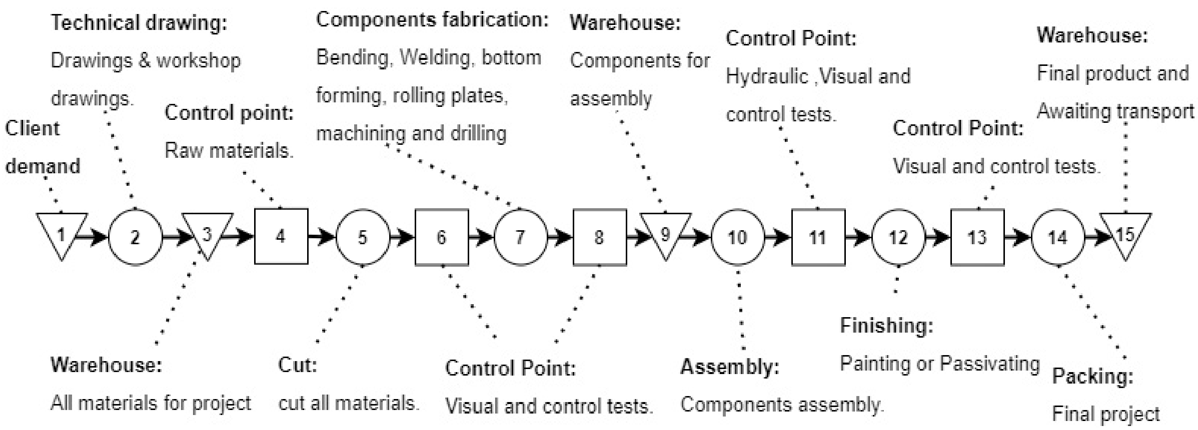

Figure 1- A schematic description of the production process.

In order to quantify the problem addressed in this work for the metalworking company, a study was carried out, over a period of one year, to quantify the delay in the delivery of projects. It was observed that there was an average delay in the delivery of projects greater than five days, that is, greater than the company's objective (less than or equal to 5 days). It was found that 20% of projects were completed on the contractual delivery date, 15% below 5 days, 65% above 5 days as it shows in table 1. Cumulatively, according to an analysis of the historic durations for the process activities, for similar projects under study, it was confirmed that there are also significant deviations between the planed duration and the real duration verified for each activity of the production process. It was confirmed that there was an average of 64% for its durations' deviations.

Table 1- projects completed between study dates.

Total of projects (one year duration)	Projects finished on time	Projects finished up to 5 days late	Projects finished with more than 5 days late
60	20%	15%	65%

4. Case Study

4.1. Problem Analyse

To help better understand the problem that puts at risk the completion of projects within the deadlines, the Ishikawa diagram was used and, later, the contributions of each root cause to the problem were identified. The results of interpreting the cause-and-effect diagram in identifying the problem's causes are summarized in the Table 2.

Table 2 - Root causes of the problem.

Root cause	Contribution for the case study problem (%)
Time planning - Badly estimated times of activities	40%
Time control - poor control of the dates and times of activities	23%
Activity sequencing	17%
Lack of communication	8%
Planning was not consulted	6%
Poorly prepared project\ Inappropriate process methodologies	3%
Unplanned resources and insufficient resources	2%
Materials did not arrive on schedule	1%

4.2. Improvements Plan

Based on table 2, it was decided to attack the first two root causes and define their respective improvement proposals, as it is shown in table 3.

Table 3 – Improvement proposals.

1- Time planning - Badly estimated times of activities	- Option a) Forecasting task times using the three-point PERT method - with the participation of those responsible for each work centre and thus achieving more realistic durations for the duration of each activity and for the total duration of the project (critical path length). - Option b) Forecasting task times using Monte Carlo simulation.
2- Time control - poor control of the dates and times of activities	- Weekly meetings in production lasting fifteen minutes or less to verify that human resources are aligned with the goals to be achieved, help with problems that may arise during the work week and ensure the quality of the project. - Respect the precedence, as well as the dates for the start of activities in order to avoid waiting periods for the components between activities. It is intended that the components are manufactured where their completion is essential for the start of the next assembly. - Weekly reviews of the schedule and preparation of work progress reports so that the sequencing of activities is adjusted according to the work performed, being able to resolve possible obstacles in a more fluid way and ensuring the delivery of the project on the agreed delivery date.

The two options that are presented in table 3 for estimating time will be applied to two production projects, which we will discuss in 4.3, so that it is possible to evaluate which of the methods presented will bring the best results.

4.3. Improvement implementation

In this case study, two projects were considered for the implementation of the improvement plan: Project 1 - tubular construction heat exchanger with 4000 mm of length and 356 mm of external diameter; Project 2 - Condenser of tubular construction 4270 mm of length and 356 mm of external diameter. The expected durations found, applying the usual method by the company (analogy), for the two projects were 61 days for Project 1 and 45 days for Project 2, distributed by the work centres associated with their manufacturing processes.

For the first improvement proposal. The estimation of the activities duration using the 3-point method were determined together with the professionals in a meeting, thus obtaining the optimistic duration (to), normal duration (tm) and pessimistic duration (tp) for each activity. At the same time, the expected durations (te) of the tasks were compared with the historical data to help the estimates, trying to avoid their inflation. Monte Carlo was also used estimate according to the PERT methodology [14], but while estimating the activities it was realized that it would be important to consider this method. However, we made official the initially planned methodology (PERT), but the monitoring of projects for clients was the PERT methodology and internally, for future comparison, the planning by the Monte Carlo method was used [15].

For the second improvement proposal. Two multidisciplinary teams of professionals were formed to control the projects, with elements from the various work centers, such as technical drawing, cutting, component manufacturing, assembly, finishing and quality. During the weekly meetings, two questions were asked to the work teams “What can we change in the way we work to improve practices and processes?” and "What is our biggest problem in getting the job done?" [7]. These two questions had to be answered in an open and direct way. The objective was to eliminate everything that is “hindering” the good practices of the processes and to facilitate the teams' work.

It was considered in our case study three methodologies for project duration, analogy, PERT (3 points) and Monte Carlo. The Tables 4 and 5 presents the 3 values for the project 1 and 2, respectively. The probability that the project will finish within the duration of the critical activities (project duration) is 50%.

Table 4 - Time duration of project 1.

	Analogy method	PERT (3 points)	Monte Carlo
[a]Project duration [days]	61	49	53
Project duration more than 5 days late	66	54	58
Probability of project ending up to 5 days late	It is not a probabilistic method	99.0%	92.7%

a - Sum of the duration of critical project activities.

Table 5 - Time duration of project 2.

	Analogy method	PERT (3 points)	Monte Carlo
[a]Project duration [days]	49	38	41
Project duration more than 5 days late	54	43	46
Probability of project ending up to 5 days late	It is not a probabilistic method	99.6%	94.1%

a - Sum of the duration of critical project activities.

As shown in the Table 4, the probability of the project 1 ending with a maximum duration of 5 days is 99.0 % with the PERT methodology and 92.7% with Monte Carlo. For the project 2, the Table 5 gives 99.6% and 94.1%. With these high values of probability, can be sad that the methods used (PERT and Monte Carlo) provide confidence to complete the project within the expected delay (5 days).

5. Results Analysis

After the conclusion of the projects 1 and 2, the necessary data were obtained to analyse the difference between the activities' duration in the work centres in relation to the planed times. Two deviations were calculated for booth projects and are presented in the Table 6 and Table 7 in percentage. The deviations calculated in the column Historic was obtained through the difference between the real duration and the planned duration using the analogy method; and the deviations calculated in the column Real was obtained through the difference between the real duration and the planned duration using the PERT (3 points).

Table 6 - Difference between the activities' duration in the work centres in relation to the planed times (project 1).

Work center	Historic (% Deviation in hours)	Real (% Deviation in hours)
Design / Technique	+74%	+7%
Cutting and mechanical polishing	+71%	+34%
Machining	+77%	+37%
Radials and Mills	+84%	+11%
Bending, welding, and calendaring	+85%	+17%
Pumps / Light Fitting	+87%	+35%
Cupped bottoms, profiles, heat treatments	+82%	+25%
Heavy boiler	+71%	+34%
X-ray	+50%	+4%
Pickling and painting	+43%	+19%

In short, in project 1, the averages of the deviations of work centres durations for historical and for real were 72% and 22% respectively, as can be seen in figure 2.

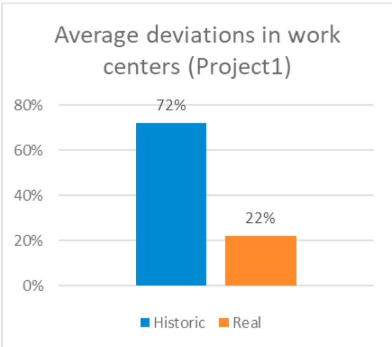

Figure 2 - Average deviations in work centres for Project 1.

Table 7 - Difference between the activities' duration in the work centres in relation to the planed times (project 2).

Work center	Historic (% Deviation in hours)	Real (% Deviation in hours)
Design / Technique	+71%	+4%
Cutting and mechanical polishing	+76%	+27%
Machining	+82%	+26%
Radials and Mills	+85%	+16%
Bending, welding, and calendaring	+81%	+33%
Pumps / Light Fitting	+85%	+23%
Cupped bottoms, profiles and heat treatments	0%	------
Heavy boiler	+50%	+37%
X-ray	+50%	+35%
Pickling and painting	+50%	+25%

In short, in project 1, the averages of the deviations of work centres durations for historical and for real were 63% and 25% respectively, as can be seen in figure 3.

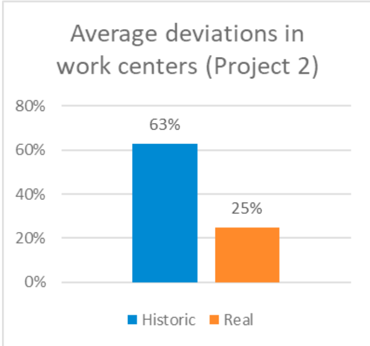

Figure 3 - Average deviations in work centres for Project 2.

Based on the averages obtained in project 1 (72% and 22%) and in project 2 (63% and 25%), it can be concluded that, there was an improvement (difference between historical and accomplished) of 50% and 38% in project 1 and 2 respectively. Can be sad also that booth projects were completed within the planned margin not exceeding the five margin days.

In the table 7 are presented the times duration for booth projects attending the historical times, the real duration, and the estimations by PERT – 3 points estimation, and the Monte Carlo simulation. Analysing the data of the table 7 two main conclusions can be collected: 1st – Projects 1 and 2 were concluded within the expected margins (five days of delay) for the booth estimation times techniques; 2nd Monte Carlo presented better estimation than PERT – 3 points.

Table 7 - comparison between the historical work and the performed one.

	Project 1	Project 2
Historical (days)	61	49
Real (days)	52	41
PERT – 3 points estimation (days)	49	38
Monte Carlo estimation (days)	53	41

6. Conclusions

The aim of this study was to improve the planning and time control in the project management of a metalworking industry in order to reduce the delivery delays. Using the existing data, an analysis of the project management process was carried out with the view to optimize the production system. Using the Ishikawa diagram, it were identified and prioritized the major root causes for the delivery delays and it was decided to concentrate the improvement efforts in the first two: 1) - Badly estimated times of activities; and 2) the poor control of the dates and times of activities.

In order to meet the established objectives, a case study was defined for 2 different metalworking projects. For mitigate the cause 1) it was applied PERT (three points estimating times) and the Monte Carlo simulation to plan the times duration for the projects activities. For mitigate the cause 2) essentially, it was implemented weekly meetings to perform the project control. After the implementation of the actions proposed, the results showed that were gains of 50% and 38% in the average of deviations of times for the two different projects of the case study and also were concluded within the expected margins. Comparing the results between PERT (three points estimating times) and the Monte Carlo, this last one gave the best approximation for the competition times. It can be concluded that, compared to the previous method of estimating the durations of activities throughout the project, they were more assertive and the performance of activities in the work centres more fluid, because it was possible to give a faster response to their needs and thus the projects were delivered on the scheduled date (contractual).

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