PERT-CPM management to the optimization of production times in an SME in the south of Guanajuato

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Abstract— As a result of increased competition environment, it has been obligatory to complete the projects in the foresighted time and with the specified sources. An effective project management is necessary to finish the projects without delay and with the available qualifications identified beforehand. The project planning techniques are utilized to satisfy these necessities.

The objetive of the present paper is manage the PERT-CPM techniques using the POM-QM for Windows informatic program to optimize the production times of a company in the textile sector, whose commerce activity is the production and sale of sports uniforms locally and nationally. The methodology of the present paper consist of 9 steps: 1) Problem delimitation. 2) Sequential establishment of production activities. 3) Establishment of the duration for each activity. 4) Definition of precedence relationships betwen activities. 5) Early-time calculation. 6) Last-Time calculation. 7) Calculation of the total duration of the project 8) Define the critical phat. 9) Clearances calculation. The implementation of PERT-CPM shows the total duration of the production times based in the critical phat obtained and also shows the non-critical activities that allow the management to optimize their production times efficiently.

Keywords—PERT; CPM; Critical Path, Optimization, Clearances.

I. INTRODUCTION

The most commonly used methods when analyzing a project include the Critical Path Method (CPM) and the Project Evaluation and Review Technique (PERT). [1].

This article presents the application of PERT and CPM techniques with the objective of managing and optimizing production times of an SME located in the state of Guanajuato, Mexico.

In the state of Guanajuato there are 108,616 commercial economic units, of which 99.8% are MSMEs and represent 88.02% of the personnel employed in this sector [2].

The case study applies to an SME dedicated to textile production and marketing. Which does not have the theoretical or practical knowledge of any technological tool that helps them improve their productivity and thus be more competitive in the market.

Nowadays the competitiveness of a company depends mainly on its productivity [3]. Therefore, this study focuses on the production area of the SME with the objective of managing and optimizing their times in the most precise way possible since their main problem is the mismatch in their production and delivery times.

Planning and scheduling are among the most critical tasks in a project, demanding the attention of competent personnel [4].

The POM-QM for Windows software is used to develop the time recording tables necessary for the creation of the PERT-CPM graphs. These tables are manually fed with real information previously obtained by the SME's management, which provides a written report where it promptly establishes the number of activities necessary to carry out production, the time needed to complete each activity and the relationships. of precedence between activities.

The number of activities, the precedence relationship and duration times are used to create the PERT-CPM graphs through the software, which generates them quickly and effectively.

Critical activities are obtained through the graphs. These activities are those that must be carried out within the established time so as not to affect the total duration of the project, that is, they are those that do not have room for delay.

On the other hand, the graphs obtained also show non-critical activities, which are those that are allowed a small delay without affecting the total duration of the production process; this delay is known as temporal slack.

II. LITERATURE REVIEW

CPM scheduling was initially introduced in 1957; since then, the method has been classified as a traditional tool providing a theoretical master schedule-based network for small- and medium-sized projects [5], [8]. More recently, it has been adopted as a tool for controlling and trading-off the time and cost of project schedule activities, particularly those on the critical path [7]. The mathematical aspects of the CPM theory have been combined with PERT probabilistic concepts to provide a clearer estimation about uncertainty, as both methods adopt similar planning theory [8], [9], [10]. Nevertheless, the main distinction between the two techniques is that PERT has converted CPM's computational approach of a single time estimate into three-point estimates based on a probabilistic distribution of the observed mean of completion time [11], [12]. In this respect, CPM schedule-based PERT can be used as an integrated approach for optimizing time [13]. Furthermore, CPM adopts the management by an exception approach that allows project managers to focus mainly on deviations and variances of the activity from the original schedule [11], [14], [15]. This provides the opportunity to respond to the negative risks of in-progress critical activities [16]. Consequently, this might limit the focus of the project team on tracking activities on the critical path only such that non-critical activities are overlooked and then become critical [17].

Practitioners have reported some important benefits of CPM. First, it shows the logic of inter-related activities and their dependencies, which have to be resolved first in the schedule [7], [14]. Second, on small projects that are resource-constrained, CPM allows priorities to be set for activities, including mínimum free float [12], [18]. On the other hand, CPM has revealed some limitations: it is not concerned with resource allocation and the consumption of resources in non-critical activities, and, as a result, any changes during execution might be difficult to plan and control [7], [14]. In partial response, heuristic tools or algorithms have been developed for resource-constrained CPM schedules [19]. Another limitation is that CPM does not pay any attention to the uncertainties inherent in activities and their durations; hence, it is seen as unsuitable for multi-tasking projects with hundreds of dependencias [12], [20]. Many of the above limitations have, in fact, been overcome by commercial software tools that include, among other features, resource optimization.

PERT was devised in parallel with CPM. As noted earlier, PERT was produced as a computational method to estimate the possible completion time of the CPM schedule based on three-point estimates using probability distributions [21], [22]. PERT has been integrated with simulation models such as Monte Carlo to control and quantify the uncertainty inherent in a CPM time estimate [17]. PERT does not take adequate account of the schedule estimate in relation to quality and cost control [23], [24], [9]. Nevertheless, PERT is regarded as a suitable tool to estimate and quantify schedule uncertainty in Operations management and manufacturing processes [22], [25].

PERT applications have been developed to control the trade-off between time and cost. Moreover, the development of classical statistical aspects of PERT (e.g. variances and means) has attracted attention from other academic disciplines, for example, scientific fields driven by operations research [26]. In a sense, it is hardly surprising as operations researchers would lay claim to PERT and, to a certain extent, CPM because both methods were devised to bring about operational improvement in complex undertakings.

PERT has the further attraction of what-if-analysis, which can be helpful in identifying time uncertainties during execution of the schedule and, thus, improves risk control [27], [28]. Conversely, these authors have also argued that PERT estimates are based on a subjective approach to data collected from project parties that can lead to biased assumptions rather tan actual estimates. Furthermore, it is claimed that PERT practitioners can make incorrect assumptions, which include ignoring the interdependencies between scheduled activities. As a result, such assumptions might lead to oversights in regard to resource feeding and sharing between non-critical activities and critical activities [17].

In the review of the literature we can find authors who have applied PERT-CPM tools in various scientific fields and have obtained good results, for example Assis [29] use PERT-CPM graphics to visualize and create plans for the restoration of the electrical energy after a blackout, for their part Abramov [30] adapted the PERT-CPM methodology in Soviet algorithms and computers to develop their economic and industrial planning. Kholil [31] use the PERT-CPM techniques for programming housing development projects for time efficiency, on the other hand Pasca [32] combine the PERT and CPM methods with Monte Carlo simulation to program the risk analysis. of the projects, in the same way Bergantiños [33] combine approximation networks with PERT-CPM methods to improve cost allocation by studying the proportion of the cost between activities.

The cited references serve as scientific support for this research as they describe the usefulness and application of the CPM and PERT tools in managing the schedule of projects or processes with the objective of controlling and optimizing the established times.

In the same way, it is intended that the methodology of this study serves as a basis for future work and can be replicated in any type of company.

III. METHODOLOGY

The methodology corresponding to this work was developed where the stages into which the work is divided and the corresponding steps are established in a clear and orderly manner. See Fig. 1.

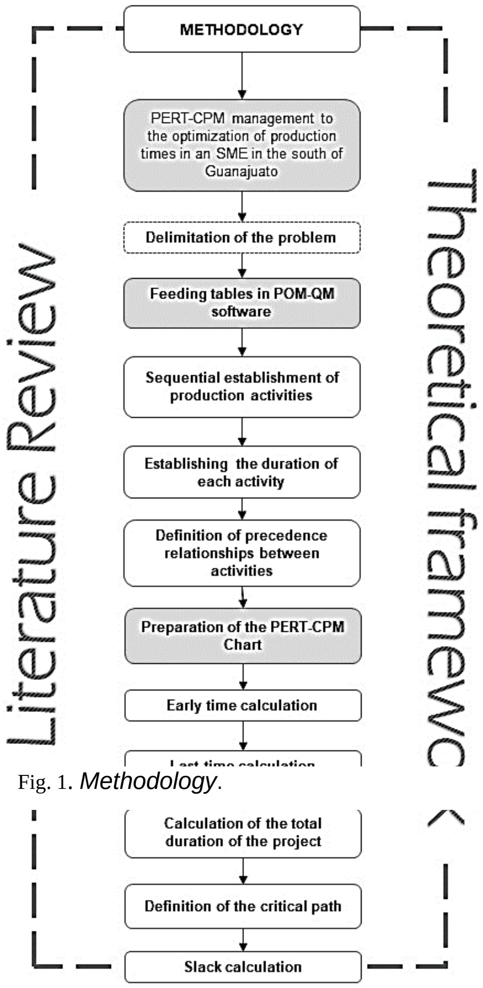

Fig. 1. *Methodology.*

IV. RESULTS AND DISCUSSION

Based on the methodology established for this study, 16 activities necessary in the production process were defined and listed sequentially in a table. See Tab. 1.

TABLE 1. ACTIVITIES FOR THE PRODUCTION PROCESS.

No. of Activity	Activity	Identifier
1	Order Quote	A
2	Order customization	B
3	Formalization of the order	C
4	Purchase of goods	D
5	Logo design	E
6	Establishing designs	F
7	Pattern making	G
8	Cutting	H
9	Plotter Programming	I
10	Impression	J
11	Assembly of the garment	K
12	Garment detail	L
13	Finishing of the garment	M
14	Bent	N
15	Bagged	O
16	Packaging	P

All the data provided by the SME was organized and recorded in a general table to improve its visualization and identification. See Tab. 2.

The table shows the number of activities required in the production process, their identifier, the duration expressed in days and the precedence relationships between the activities.

TABLE 2. DATA SET TO FEED THE POM QM SOFTWARE.

No. of Activity	Identifier	Duration (Days)	Precedence Relationship
1	A	1	-
2	B	1	-
3	C	1	B
4	D	1	B
5	E	2	C
6	F	1	E
7	G	2	F
8	H	2	G
9	I	1	F
10	J	2	H
11	K	3	J
12	L	3	K
13	M	2	L
14	N	1	M
15	O	1	N
16	P	1	O

The POM QM for Windows program was used to develop the PERT-CPM tool and manage the production times of the SME under study.

Using the program functions, a “Project Manager” of the type “Single Time Estimate” with “Immediate Predecessor List” was created with the data in Table 2.

The POM QM generated a data table that states the activities, their duration, the earliest start time of each activity, the latest start time of each activity, the earliest finish time of each activity, the finish time latest of each activity and the corresponding clearances. See Tab. 3.

TABLE 3. INITIAL SOLUTION OF THE POM QM.

Activity	Activity Time	Early Start	Last Start	Early Finish	Last Finish	Slack
A	1	1	0	1	21	22
B	1	1	0	1	0	1
C	1	1	1	2	1	2
D	1	1	1	2	21	22
E	2	2	2	4	2	4
F	1	1	4	5	4	5
G	2	2	5	7	5	7

Fig. 3. *Early start and finish times of the critical path and non-critical activities.*

H	2	2	7	9	7	9
I	1	1	5	6	21	22
J	2	2	9	11	9	11
K	3	3	11	14	11	14
L	3	3	14	17	14	17
M	2	2	17	19	17	19
N	1	1	19	20	19	20
O	1	1	20	21	20	21
P	1	1	21	22	21	22

The PERT-CPM chart was generated, which is displayed as a Gantt chart that interconnects circles and arrows, where the circles represent the start and end of the activities and the arrows identify these activities. See Fig. 2.

Each activity is observed with its respective identifier (A, B, C, etc.) inside the circle and with its respective duration (1, 2, and 3) outside the circle. See Fig. 2.

The Gantt chart shows the critical path in red. This represents the set of most important activities within the production area, which must be carried out in the established time without the possibility of delay, otherwise, the production time will suffer a considerable delay. See Fig. 2.

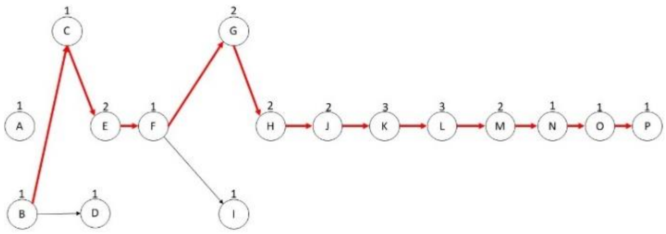

Fig. 2. *Gantt chart. Critical route.*

In addition to the Gantt chart, the POM QM software generates three graphs that show the behavior of activities with respect to production time.

Fig. 3 shows the relationship between the critical path and non-critical activities and highlights the earliest times at which non-critical activities can be started and finished. See Fig. 3.

Fig. 4 shows the latest times in which the activities that make up the critical path can be started and finished. The sum of the duration of all activities on the critical path represents the total duration of the production process. See Fig. 4

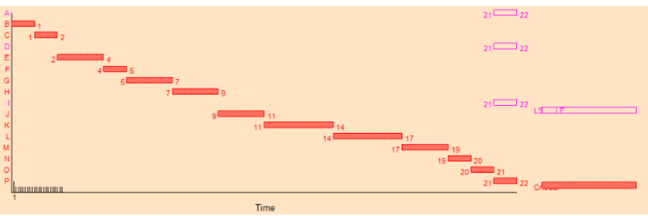

Fig. 5 shows the relationship between the critical path, non-critical activities, the total duration of the project and the existing slack. See Fig. 5.

Adding the duration of the critical activities results in 22 days, which represents the total duration of the project. See Fig. 5.

It is observed that three activities have time slack of one day each, which means that the project can be finished 3 days before the estimated date. See Fig. 5.

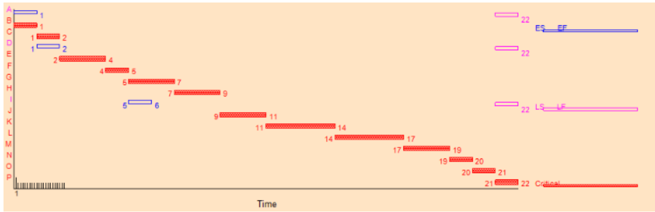

Fig. 5. *Correlation between early times, late times and critical path, non-critical activities and slack.*

V. CONCLUSIONS

It is not very common for SMEs dedicated to the textile sector to use tools such as PERT-CPM to manage their projects or processes. They regularly rely on trial and error or imprecise estimates when managing their production areas.

This is because referentially and based on the literature review, the PERT-CPM is mostly used in the construction sector.

For this reason, this article was prepared by applying the PERT-CPM tool in the project and process management of an SME in the textile sector with the aim of optimizing its production times.

The application of PERT-CPM as process management allows the SME to optimize production times, in such a way that it makes it easier for management or direction to visualize the critical productive activities, on which they must focus their efforts to be able to meet established times.

The use of the tool also allows you to detect and manage non-critical activities, which are those that have time slack, that is, a possibility of delay within the process that does not affect the total duration.

As a result of the application of the PERT-CPM in the case study, 13 critical activities were identified in the production process of the company under study and 3 non-critical activities.

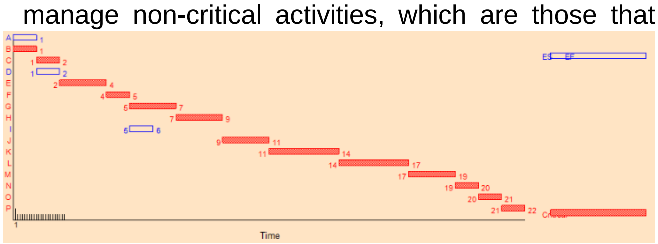

Fig. 4. *Late times to start and finish critical path activities. Total, project duration.*

A total duration of the production process of 22 days was obtained and a clearance of 3 days was identified, this means that thanks to the results of the application of the tool the company knows that its production times can be reduced from 22 to 19 days.

In conclusion, it is established that by using the PERT-CPM the SME can optimize its production times by 13.63%, since it successfully reduced its production time from 22 days to 19 days, keeping productive activities, work hours, constant. personnel and machinery.

In addition to optimizing its production times, the SME also achieves greater efficiency in its processes and a notable improvement in its deliveries. Which in turn better satisfies the needs of its customers by delivering their products sooner and thus leaving a greater margin of free time to receive and produce a greater number of orders.

According to the results obtained, it was demonstrated that the tool can also work to improve the management of the processes of companies belonging to other productive sectors outside of construction.

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