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# 8

# Scheduling and planning the project of rehabilitation and upgrading the installations in the oil port of Bejaia, Algeria.

Makhloufi S., Boudjadja C. et Aïssani D.

lamos_bejaia@hotmail.com, sylia_makhloufi@yahoo.com

**Abstract :**

This article treats problem met in company, it acts to find a scheduling of the spots for the project of rehabilitation of the oil port of Bejaia, by minimizing its total duration. We used the technique of the Gantt chart, method PERT, and method PDM. These methods are based on the graphs for modeling and the resolution, for the latter we calculated more the long way which represents more the long series of spots, of which the total duration represents the minimum duration of the project. We also modelled the problem in the form of linear program with limited variables, which we solved by the method of interior point by using the Matlab software, considering the big size of our data. We could minimized the total duration of the project by solving the problem of scheduling under constraints of temporal anteriorities and localization. However the problems of scheduling in practice imply the taking into account of the limited number of resources. For that we used software ms project for the assignment of resources to the spots, and for the resolution of the overuse of these last.

**Keywords :** Scheduling tasks, project planning, project management, graph theory, linear programming.

## 8.1 Introduction

Sonatrach is an Algerian state-owned company and a major international player in the hydrocarbon industry, which is involved in the exploration, production, pipeline transport, processing and marketing of hydrocarbons. The Central transport region of Bejaia is one of the five regions composing the activity of transport of hydrocarbons by pipeline of the company Sonatrach.

In order to improve the operating and safety conditions of the oil port installations renovation work was started in 2006. However, the work was not completed by the previous contractor. Therefore, the main task of the new contract is the rehabilitation and commissioning of the surface facilities of the oil port of Bejaia. The remaining works to be carried out are essentially : the works of removal, demolition and evacuation. And the works of the new works to be realized.

Growing a business requires good planning strategies to increase profits, reduce expenses, and bring more clarity. The planning department of the new works department at Sonatrach is in charge of the study and follow-up of the company's projects, including the rehabilitation of the oil port of Bejaia.

Scheduling techniques within the framework of project management aim to meet needs expressed by a customer, at the best cost and in the best time, taking into account the various constraints. Scheduling takes place in three stages :

- Planning : which aims at determining the various operations to be carried out, the corresponding dates, Scheduling techniques within the framework of project management aim to meet the needs expressed by a client in the best possible way. The needs expressed by a customer, at the best cost and in the best time, the taking into account the different constraints.

- Execution : which consists in the implementation of the various operations defined in the planning phase.

- The control : which consists in making a comparison between planning and execution, either at the level of costs, or at the level of realization dates.

In order to optimize the time of realization of the project of rehabilitation, it is essential to use the techniques of scheduling and project planning. The objective of this work is thus, to find a scheduling of tasks of minimal duration, in order to reduce the time of realization of the project of the rehabilitation of the oil port.

The specificity of the work consists in presenting two different concepts of modeling and resolution for the project scheduling problem in order to bring a solution to the problem of optimization of the time of realization of the project.

Moreover we use a project management software, and we introduce the constraint of limited resources. For that we used the computer tool for the smoothing of the resources.

## 8.2 Solving tools and methods

The purpose of planning is to organize the progress of the project stages over time. A fundamental task for the control of the deadlines. Generally, to plan a project, the first phase consists of dividing it into several stages, estimating the duration, identifying the sequence of the stages (including those that can be carried out in parallel), allocate resources (financial and manpower). Finally, modeling this organization on an operational document shared by all the actors involved.

Scheduling is exactly in the planning phase, it consists in organizing in time the realization of a set of the realization of a set of tasks, taking into account temporal constraints (deadlines, constraints of constraints, ...) and constraints on the use and availability of required resources, by choosing an optimization criterion (e.g. minimizing the total duration of the project, minimizing the total cost, ...etc).

Methodical modeling is a translation of an observation in order to apply mathematical tools, techniques and theories. It is a crucial step for the study of any problem in operations research. Modeling project scheduling problems requires the knowledge of some basic concepts of graph theory and linear programming.

### 8.2.1 Gantt chart

The Henry Gantt chart is a horizontal bar graph that was an innovative way for managing overlapping tasks. This chart was revolutionary at the time because it was based on time rather than quantity, volume or weight. The Gantt chart represents :

- On the x-axis the time (expressed in months, weeks or days).

- On the ordinate axis the list of tasks.

- Horizontal bars aligned with the extension of each task represent the duration of the task (these bars allow to represent overlapping tasks in time).

- Arrows represent the dependency links between tasks because some tasks cannot be started until others are completed while others can be carried out in parallel, the dependency links are therefore not automatic.

### 8.2.2 Graph theory

A graph is a geometrical design defined by a set of points (called vertices or nodes), connected by a set of lines or arrows (called edges or arcs). Each edge has for extremities two points, possibly confused.

Graphs can be used to represent many common situations such as : Road links, communication networks, electrical circuits, links between various people or administrative entities. The theory of graphs allows to concretely transcribe facts by modeling them with mathematical objects, in order to solve different problems.

There are two main graphical representations of a project :

- The AoN (Activity-on-Node) representation.

- The AoA (Activity-on-Arrow) representation.

The abbreviations AON and AOA stand successively for : Activity On Network and Activity On Arc. These two notions are used in the representation of a project management network, which in turn is part of a broader and more general branch : graph Theory. The latter is used in several domains such as transportation, neural networks, optimization, etc. These two concepts were developed in the 1950s, AON to establish what is called the critical path of a project schedule and AOA in the PERT method (graph). CPM (Critical Path Method) to determine the critical path.

In the AoN representation, each activity is represented by a node and each directed arc represents a required a required precedence relation between two activities. Otherwise, the arcs represent the dependency links dependencies, nodes represent tasks.

The method of potentials or MPM Created in 1958 by M.B. Roy, under the name of MPM (Method of Metra Potentials), it systematically uses initial order relations (Start-Start). It is part of the so-called "potential-task" methods where the Activities (tasks) are represented by the vertices and the order relations between successive activities by links. We add a node 0 which corresponds to the date of the beginning of the project and a node $f = n + 1$ which corresponds to the end of the project. The major inconvenient of this method is that it only provides links between tasks of the type Start-Start. This means that a task j following a task i in the network can only start after the start of task i. This is why the minimum time that must elapse between the start of the previous activity and the start of the next activity must be systematically mentioned. The notion of precedence is completely absent in this method.

The Precedence Diagramming Method (PDM) Precedence Diagram Method (PDM) is a project planning tool. It consists in representing the possible overlaps of each task by using four types of links :

-Start-Start : The dependent task (B) cannot start until the task on which it depends (A) has started.

- End-Start : The dependent task (B) cannot start until the task it depends on (A) has finished.

- Start-End : The dependent task (B) cannot end until the task on which it depends (A) has started.

- End-End : The dependent task (B) cannot end until the task on which it depends (A) has ended. The dependent task can end at any time once the task it depends on is itself finished. The Finish to Finish link does not require that both tasks to finish at the same time.

The expression of the graph uses, as for the method of metra potentials (MPM), rectangles representing activities and arrows representing links. The antecedent method was developed following the PERT and critical path techniques ; its function is to allow a more accurate re-

presentation of the relationships between the different activities. the relationships between the different activities.

In the AoA representation each activity is represented by an arc and each event by a node. Otherwise the arcs represent tasks, the nodes represent "steps" of zero duration. The start node of the arc corresponds to the beginning of the activity, the finish node corresponds to the end of the activity or task. The classical end-start precedence relation with zero margin between two activities a and b (also noted $a \leq b$) means that the activity b can start as soon as the activity a is finished.

The PERT method During the years 1957-1958, the American navy sought to quickly complete the POLARIS project, a simultaneous production of a missile-launching submarine and the adapted rocket, made operational at the same date. This project, involving some 250 suppliers and more than 9000 subcontractors, posed a complex coordination problem, to say the least, as the scheduling of tasks exceeded the usual limits. The engineers of the navy's planning office then developed a scheduling method based on modern mathematics. The PERT method was born and, according to some authors, would allow a gain of two years on the duration of the POLARIS project. It made it possible to carry out the project in two and a half years whereas it had been planned for seven years. Program Evaluation and Research Tasks.

The PERT method makes it possible to evaluate the duration of a complex project and to detect the parts of the project that cannot be delayed. parts of the project that cannot be delayed. The project will be subdivided into tasks. In general, they will not all be the project will be subdivided into tasks. In general, they cannot all be carried out simultaneously, some tasks must be completed before others can be started. The project information will be summarized in a table, called a schedule, where the tasks, their duration, and any prioritization constraints are listed.

The method starts with the construction of a graph, called PERT graph, from the schedule. This graph will be a valuated graph whose arcs will be the tasks, the values of the arcs being their duration and the vertices will represent vertices will represent the project's progress states, numbered from 1 to n.

The CPM (critical path method) The first use of the critical path method, borrowed from the theory of graphs dates back to 1956. It is due to the Americans J.E. Kelley (Du Pont de Nemours) and M.R. Walker (Remington Rand) and is sometimes also called C.P.S. (Critical Path Scheduling), the notion of "Critical Path method" having been extended in the meantime to indicate all the standard procedures, used in the various systems to determine the minimum total duration of execution of a program, compatible with the constraints.

The project for the rehabilitation and implementation of the oil port facilities, consists of 40 main tasks. In addition, we note that most of the tasks can be started as soon as a percentage of the percentage of the previous tasks is completed. For example, task 3 can start after 5 days from the For example, task 3 can start after 5 days from the beginning of task 2, task 11 can start after 10 days from the beginning of task 10.

In order to facilitate the construction of the PERT network and the MPM network, and to express the conditions of partial conditions, we have split the tasks((see tables in appendix)). After splitting the tasks, determining the associated dates and margins, determining the levels of the tasks we obtain two types of graphs :

In a potential-step graph, we associate a graph $G = (X, U)$ with the scheduling problem : The tasks are represented by arcs in a network. The ends of these arcs are events which materialize either the beginning or the end of a given operation. The arcs, either real tasks, or fictitious

tasks allowing to represent some potential constraints. In a potential-task graph, we associate a graph $G' = (X', U')$. The tasks are represented by vertices and the arcs represent the precedence constraints. Thus the constraint $i$ precedes $j$ is symbolized by an arc between vertices $i$ and $j$.

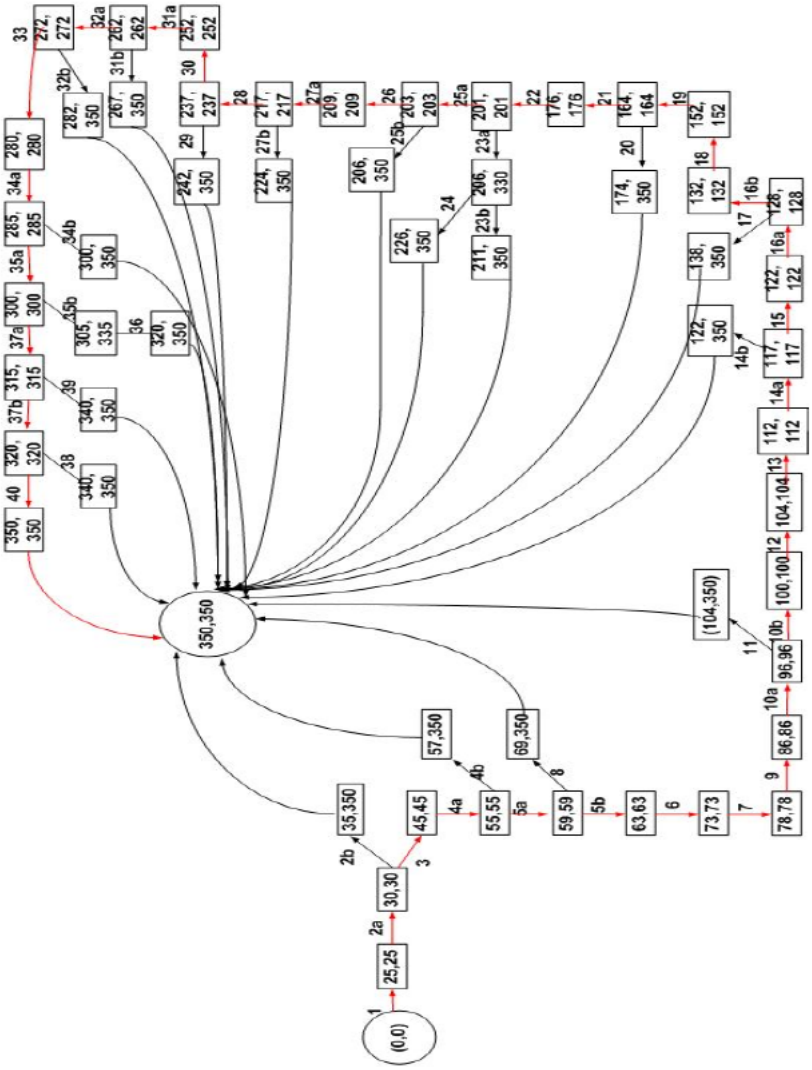


**FIGURE 8.1.** PERT network.

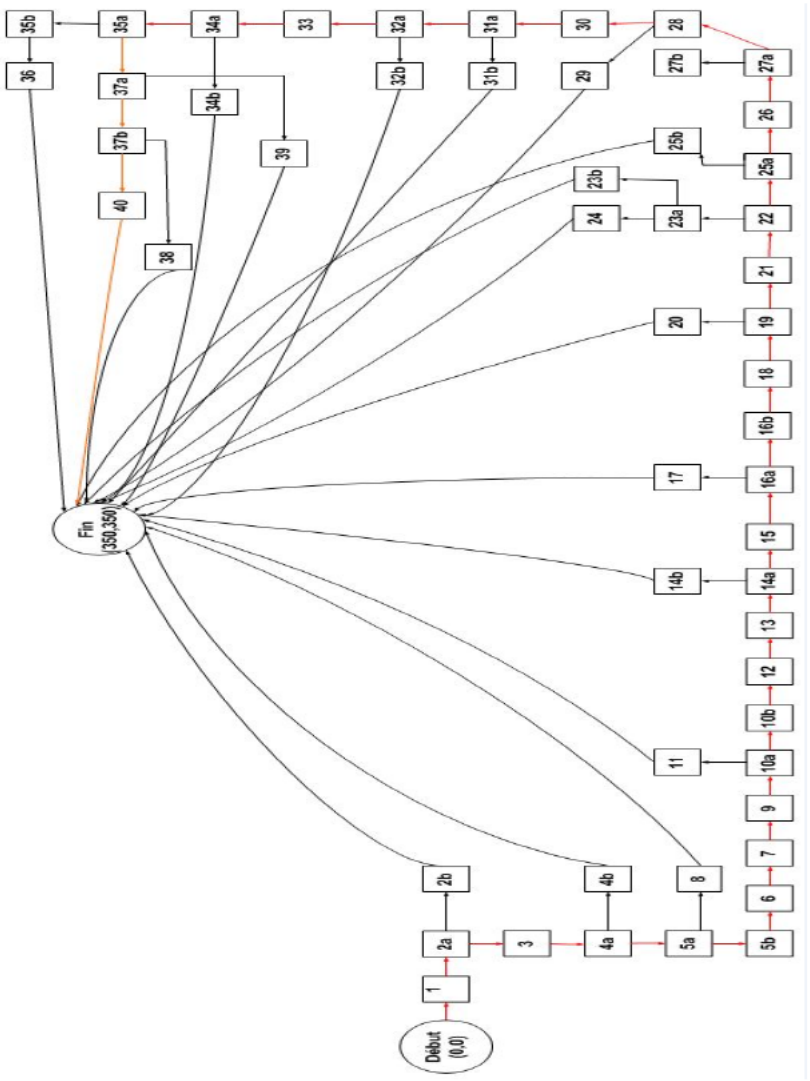


**FIGURE 8.2.** PDM network.

The critical path in both networks is the longest path from the beginning to the end, its value is the minimum duration of the project. In our situation we have obtained the following critical path :

$1 \to 2a \to 3 \to 4a \to 5a \to 5b \to 6 \to 7 \to 9 \to 10a \to 10b \to 12 \to 13 \to 14a \to 15 \to 16a \to 16b \to 18 \to 19 \to 21 \to 22 \to 25a \to 26 \to 27a \to 28 \to 30 \to 31a \to 32a \to 33 \to 34a \to 35a \to 37a \to 37b \to 40.$

After applying the PERT and PDM methods, we were able to optimize the total duration of the project by 190 days in working days. The minimum duration of the project is about 350 days in working days.

The Gantt chart, commonly used in project management, is one of the most effective tools to visually represent the progress of the different (tasks) that make up a given project.

Each task is represented in the left-hand column of the diagram, while the top line represents the The left-hand column of the diagram lists all the tasks to be carried out, while the top line

represents the time units most appropriate for the project (days, weeks, months, etc.). Each task is materialized by a horizontal bar, whose position and length represent the start date, duration and end date. In order to represent the Gantt chart representing our project we used Ms project 2003.

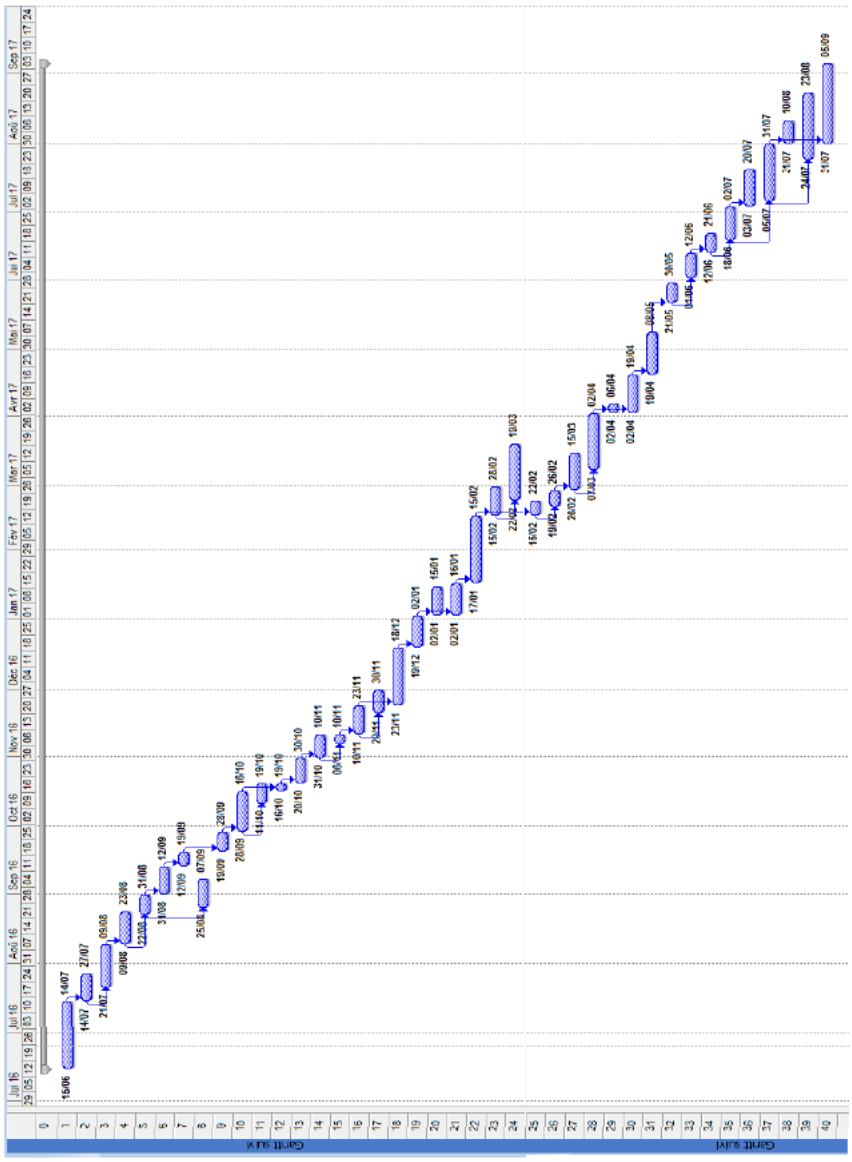

**FIGURE 8.3.** Gantt diagram representing the project.

### 8.2.3 Linear programming

All linear programs have three crucial elements :

-Decision variables : what the decision is about, what allows the constraints to be expressed, and the objective function.

-Objective function : it is used as a criterion to determine the best solution to an optimization problem. To each decision variable, there is an economic coefficient indicating the unit contribution of the corresponding variable to the objective.

-Constraints : In the decision problem, it is necessary to be able to identify any kind of restriction (manpower, space, budget,...) that can limit the values that the decision variables can take.

Each restriction, limitation or requirement usually corresponds to a constraint that will take the form of an equation. The set of constraints formulated in this way constitutes the domain of possible solutions to the model.

The general form of a linear program (LP) is as follows :

$$min \text{ ou } max\ z = \sum_{j=1}^{n} c_i x_j$$

$$\sum_{j=1}^{n} a_{ij} x_j\ \leq ,\ \ =,\ \ \geq\ b_i \,\forall\, i = 1, ...m$$

$$x_j \geq 0 \,\forall\, j = 1, ...n$$

This program has an objective function to be optimized, $n$ non-negative variables, and $m$ equality or inequality constraints. $c_j$ is the profit coefficient of the variable $x_j$ ; that of the variable $x_j$ in the constraint $i$ is denoted $a_{ij}$ . The constraint $i$ has a constant second member $b_i$.

The problem's data :

-Let $T$ be a set of tasks (phases of the project) ;

- $d_i$ a duration for each one ;

- we have for each task a predecessor.

- The decision variables : let $t_i$ be a decision variable, such that $i \in T$, with $T = 1, 2, ...40$.

Two fictitious tasks are introduced : $\alpha$ represents the beginning of the work and $\omega$ represents the end of the work. These two tasks have a zero duration. We take $t = 0$, i.e. the origin of time is set at the date of the beginning of the work. The end date of the work will be measured by The end date of the work will be measured by $t_\omega$, the execution date of the fictitious task $\omega$. $t_\alpha = t_0 = 0, t_\omega = t_{41}$ represents the duration of the work.

Decision constraints :

a) Constraints of successions : $t_j = t_i + d_i \Rightarrow t_j - t_i \geq d_i$.

b) Constraints of partial successions : $t_j \geq t_i + p_i d_i \Rightarrow t_j - t_i \geq p_i d_i$.

The objective function :

$\omega$ represents the task "end" of the project, the criterion can be translated by :

$Min(t_\omega) = t_{41} - t_0$

In order to solve the linear program associated with the scheduling problem of the oil port rehabilitation project, we used a Matlab function program which uses a primal-dual interior point method, it solves both primal and dual problems by an interior point method based on Newton's method. The program looks for the minimum of the problems.

We obtained the same result as before, we found that the minimum duration of the project is 350 days in working days. This result is obtained after 5 iterations of the interior point algorithm.

## 8.3 conclusion

Project scheduling problems are among the most studied scheduling problems since the origins of scheduling theory. In spite of the numerous signs of progress made despite their apparent simplicity, these problems constitute a challenge for current operations research. Since they were first used in the late 1950s, PERT, CPM, and MPM have been used extensively to assist project managers in planning, scheduling, and control of their projects. Over time, these two techniques gradually benefited from the advantages of each other.

In this work, we have presented different phases of project development. We have studied in detail the central problem of scheduling under its various aspects : models, methods and tools of calculations. We have modelled and solved the scheduling problem of the project of the rehabilitation of the oil port with the help of the graph theory, using the Gantt technique, the PERT method, and the PDM method. We have also modelled our scheduling problem as a linear program that we solved using Matlab software.

In the presence of resource constraints, scheduling becomes essentially difficult and the critical path resolution methods are therefore inadequate. In this situation, we have used the functionalities of the Ms project software for resource levelling.

Unlike the work done on scheduling at Sonatrach, which attempts to solve the resource-constrained project scheduling problems (RCPSP) using metaheuristics such as the genetic algorithm and the ant colony algorithm, our first study focuses on the central scheduling problem (unlimited resources) for which we apply two modelling and resolving approaches.

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