

PROCESS DEVELOPMENT FOR DCMA 14-POINT SCHEDULE HEALTH-CHECK AND PROGRESS MONITORING

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To my family
To my friends

Do the best you can until you know better. Then when you know better, do better.

Maya Angelou

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ABSTRACT

Over the past few decades, the construction industry has undergone a substantial transformation, becoming more sophisticated and reliant on cutting-edge technologies and processes to handle a wide range of projects effectively. Planning, scheduling, and delay analysis have become critical components due to the need for more accurate project management. Specialized software, such as Candy Software, Oracle Primavera P6, MS Project and others, revolutionized project planning and execution by providing powerful tools for managing timelines, resource allocation, and progress monitoring.

Several organizations developed internal processes to ensure adherence to best practices and standards regarding developing schedules, one of these is the USA Defense Contract Management Agency (DCMA) who developed strict criteria and protocols, such as the 14-Point Schedule Health Check. These advancements in software and regulatory frameworks enhance the precision and reliability of project management, offering essential training and insights to help professionals navigate the complexities of modern construction projects.

The objective of this dissertation is to comprehensively demonstrate the critical importance of these concepts in the effective management of construction projects. This was achieved through an in-depth analysis of real case studies, serving as practical examples to validate and underscore the relevance and impact of these methodologies and tools in real-world scenarios.

Furthermore, by emphasizing the crucial role of advanced planning methodologies in construction, this work aims to highlight the importance of increased investment in planning due to its significant impact on the industry's overall efficiency and success.

In support of these goals, this dissertation employs software tools and guidelines pertinent to planning and scheduling to optimize these processes. By integrating these tools and adhering to established guidelines, the research aims to demonstrate their advantages in improving construction project outcomes.

This approach provides concrete evidence of the benefits that such technologies and methodologies bring to the construction industry, reinforcing the need for their broader adoption.

KEYWORDS: Planning, Schedule, DCMA, Software, Delay Analysis, Construction.

RESUMO

Ao longo das últimas décadas, a indústria da construção sofreu uma transformação substancial, tornando-se mais sofisticada e dependente de tecnologias e processos avançados para gerir eficazmente uma vasta gama de projetos. O planeamento, a planificação e a análise de atrasos tornaram-se componentes críticos devido à necessidade de uma gestão de projetos mais precisa. Softwares especializados, como o Candy Software, o Oracle Primavera P6, o MS Project e outros, revolucionaram o planeamento e a execução de projetos, fornecendo ferramentas poderosas para a gestão de prazos, atribuição de recursos e monitorização de progressos.

Várias organizações desenvolveram critérios e protocolos rigorosos para garantir a aplicação às melhores práticas e normas relativamente a planeamentos, uma dessas organizações é a norte-americana Defense Contract Management Agency (DCMA), com o seu 14-Point Schedule Health Check. Estes avanços no software e nos quadros regulamentares aumentam a precisão e a fiabilidade da gestão de projetos, oferecendo formação e conhecimentos essenciais para ajudar os profissionais a navegar nas complexidades dos projetos de construção modernos.

O objetivo desta dissertação consiste sobretudo em demonstrar de forma abrangente a importância crítica destes conceitos na gestão eficaz de projetos de construção. Este objetivo é alcançado através de uma análise aprofundada de casos de estudo reais, servindo como exemplos práticos para validar e sublinhar a relevância e o impacto destas metodologias e ferramentas em cenários reais.

Para além disso, ao enfatizar o papel crucial das metodologias avançadas de planeamento na construção, este trabalho pretende realçar a importância de um maior investimento no planeamento devido ao seu impacto significativo na eficiência e sucesso global da indústria.

Em apoio a estes objetivos, a presente dissertação utiliza ferramentas de software e orientações pertinentes usadas no planeamento e planificação de trabalhos, para otimizar estes processos. Ao integrar estas ferramentas e aderindo às diretrizes estabelecidas, esta investigação pretende demonstrar as vantagens do uso dessas ferramentas com vista à melhoria dos resultados dos projetos de construção.

A abordagem seguida fornece provas concretas dos benefícios que estas tecnologias e metodologias trazem para a indústria da construção, reforçando a necessidade da sua adoção generalizada.

PALAVRAS-CHAVE: Planeamento, Planificação, DCMA, Software, Análise de Atrasos, Construção.

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SYMBOLS, ACRONYMS, ABBREVIATIONS

AACE - Association for the Advancement of Cost Engineering

ALAP - As Late As Possible

ASAP - As Soon As Possible

BEI - Baseline Execution Index

BIM - Building Information Modelling

C/SCSC - Cost/Schedule Control Systems Criteria

CAD - Computer Aided Design

CAS - Cost Accounting System

CCS - Construction Computer Software

COA - Course of Action

CPLI - Critical Path Length Index

CPM - Construction Project Management

CPM - Critical Path Method

DAT - Delay Analysis Techniques

DCMA - Defense Contract Management Agency

DoD - Department of Defense

DOE - Department of Energy

DOS - Disk Operating System

EDM - Electronic Document Management

EOT - Extension of Time

EPPM - Enterprise Project Portfolio Management

ERP - Enterprise Resource Planning

EVA - Earned Value Analysis

EVMS - Earned Value Management System

EVMSIG - Earned Value Management System Interpretation Guide

FF - Finish to Finish

FNET - Finish No Earlier Than

FNLT - Finish No Later Than

FS - Finish to Start

GAO - Government Accountability Office

ICPM - Industrial Committee for Program Management

IEC - International Electro-Technical Commission
IMS - Integrated Master Schedules
IS - Information Systems
ISO - International Organization for Standardization
IT - Information Technology
MFO - Must Finish On
MMAS - Management and Accounting System
MS Project - Microsoft Project
MSO - Must Start On
NAVAIR - Naval Air Systems Command
NDIA - National Defense Industrial
nth - n dimension
PAP - Program Analysis Pamphlet
PASEG - Planning and Scheduling Excellence Guide
PERT - Program Evaluation Review Technique
PM - Project Management
PMBOK - Project Management Body of Knowledge
PMI - Project Management Institute
QA - Quality Assurance
QTO - Quantity Take Off
RP - Recommended Practice
SCL - Society of Construction Law
SF - Start to Finish
SNET - Start No Earlier Than
SNLT - Start No Later Than
SS - Start to Start
TCPI - To-Completion Performance Index
TIA - Time Impact Analysis
USD A&L - Under Secretary of Defense for Acquisition Technology and Logistics
WBS - Work Breakdown Structure

1

INTRODUCTION

1.1. BACKGROUND

The construction industry is a complex and multifaceted field that plays a crucial role in shaping our built environment. It includes an extensive variety of activities, from building projects for residential and commercial properties to the construction of large-scale infrastructure, including highways, bridges, and airports.

Every construction project has a number of interconnected components that need to be properly taken into account to be completed successfully. These elements include engineering, labor management, safety regulations, environmental impact, design and architecture, and compliance with legal and regulatory obligations. Coordinating these different components demands careful planning and scheduling, which are essential features that significantly affect any construction project's success and efficiency.

In today's fast-paced construction environment, the use of software tools has become increasingly essential for effective planning and scheduling. These innovative software programs have many benefits that completely change the way construction projects are managed.

The improvement of project planning efficiency and accuracy is one of the main advantages. Project managers can create more accurate and practical plans with the help of software solutions that can incorporate large data sets. This minimizes the possibility of mistakes and omissions, which can result in expensive delays and additional effort.

Additionally, these software programs help project stakeholders to collaborate and communicate more effectively. Access to up-to-date information is ensured for all project participants through features like shared dashboards, integrated communication channels, and real-time updates, which promote a more integrated and cooperative work environment.

Decision-making and problem-solving become faster as a result of the ability to quickly identify and address challenges. Various software tools such as MS Project, Candy Software, and Oracle Primavera P6 offer distinct advantages and differences in their functionalities and features.

In order to carry out schedule planning in these software tools, there are crucial guidelines for the schedule health check that is being developed. These guidelines are essential bases for developing schedules.

There are many advantages to utilizing guidelines for schedule health checks in the construction industry. Firstly, by providing a structured framework, such as the Defense Contract Management

Agency (DCMA) 14-Point Assessment for evaluating project schedule performance and health, these guidelines enable early identification of potential issues.

By taking a preventive approach, project managers can minimize the possibility of delays and cost overruns by promptly addressing any deviations from the established schedule. By following these rules, schedule assessment procedures for various construction projects may also be standardized and consistent, which will improve the overall efficacy and efficiency of project management.

Additionally, construction companies can increase their capacity to adhere to legal requirements and industry best practices by using established rules for schedule health checks. This will ultimately improve project outcomes and stakeholder satisfaction.

1.2. SCOPE AND GOALS

The primary motivation of this dissertation is to deepen the understanding and application of scheduling tools and methodologies within the construction industry and to critically evaluate whether these tools and methodologies provide tangible advantages in enhancing project efficiency, accuracy, and overall success in this field.

As sub-objectives of this dissertation, the author has aimed to:

- Explore the North American Defense Contract Management Agency (DCMA) methodology and its 14-Point Assessment checklist, which are instrumental in developing high-quality project schedules, involving the understanding of its key metrics and criteria that define schedule health and performance;
- Explore case studies, to understand their planning and organizational strategies, using the DCMA 14-Point Assessment, identify their shortcomings, and consider areas for optimization;
- Gain a deeper knowledge and expand the understanding and practical skills of software tools for schedule planning, such as MS Project and Candy Software, as well as an Excel tool;
- Delve into the principles and application of WBS, appreciating its utility in breaking down complex project tasks into manageable ones and ensuring comprehensive task listing and resource allocation.

With the help of these objectives and sub-objectives, this dissertation aims to provide readers with the information and abilities they need to take advantage of sophisticated scheduling techniques and tools, which will ultimately improve project management techniques in the construction industry.

1.3. DISSERTATION STRUCTURE

This dissertation is structured into seven chapters, each offering a comprehensive exploration of the topics under study, presented with a coherent and logical progression of ideas.

The first chapter provides a concise introduction to the fundamental ideas that underpin this dissertation. It aims to familiarize the reader with key concepts, with particular emphasis on planning and scheduling. These concepts are presented as the primary focus, laying the groundwork for the more detailed discussions and analyses that follow in subsequent chapters.

Chapter 2 offers a theoretical framework for the historical development of planning and scheduling. It outlines the guidelines and methods that have evolved over time to enhance these concepts. Additionally, the chapter discusses the history and development of planning software, focusing on three notable

programs: MS Project, Oracle Primavera P6, and Candy Software, with particular emphasis on the evolution of Candy Software.

Continuing with a theoretical approach, Chapter 3 addresses the significance of delay analysis in the construction industry. It explores various methods, techniques, practices, and protocols that are crucial in this field. The chapter introduces the Defense Contract Management Agency (DCMA) and its contributions to delay analysis, along with an overview of the guideline it adheres to and a concise explanation of its checking metrics.

Following the theoretical exposition, the author transitions to a practical application by examining case studies in Chapter 4. This chapter provides an in-depth analysis of two specific case studies, demonstrating how to integrate the 14-Point DCMA Assessment for Schedule Health-Check.

Through these detailed examples, the chapter aims to deepen the understanding of the principles discussed earlier. Additionally, it offers valuable training on the practical application of these guidelines, showcasing their relevance and utility in real-world scenarios.

Chapter 5 focuses on optimizing one of the previously analyzed case studies to enhance the aspects discussed in Chapter 4. This optimization process utilizes Candy software as an essential tool for developing an improved schedule. The author details the measures implemented to meet the requirements set by the DCMA guidelines, demonstrating how these adjustments lead to a more efficient and effective planning process.

Chapter 6 mirrors the approach taken in Chapter 4 by analyzing the newly optimized schedule. The primary goal of this analysis is to determine whether the improvements made and presented in Chapter 5 satisfy the DCMA requirements. This chapter evaluates the new proposed schedule plan, using the 14-point assessment metrics, providing a comprehensive review of the work against these standards.

Finally, Chapter 7 summarizes the key conclusions drawn from the research conducted throughout this dissertation and outlines potential directions for future work.

2

SOFTWARE FOR SCHEDULE ANALYSIS AND PROJECT MANAGEMENT – A REVIEW

2.1. PLANNING AND SCHEDULING

Construction planning involves a problem-solving approach aimed at determining the most efficient utilization of available resources by a construction enterprise to bring to life a product outlined in architectural drawings and specifications [1].

According to J. E. Kelley and M. R. Walker, planning is “the act of stating what activities must occur in a project and in what order these activities must take place”, whilst scheduling is “the act of producing project timetables in consideration of the plan and costs”[2].

In the dynamic and complex world of construction, effective planning and scheduling play important roles in ensuring projects are completed on time, within budget, and to the satisfaction of stakeholders. These processes involve meticulously organizing resources, tasks, and timelines to optimize efficiency, minimize risks, and maximize productivity throughout the project lifecycle. However, many construction projects globally seem to overlook the importance of properly managing and defining project planning, particularly during the pre-planning stages [3]. We can see in figure 2.1 a scheme that represents the three concepts needed to achieve the scope.

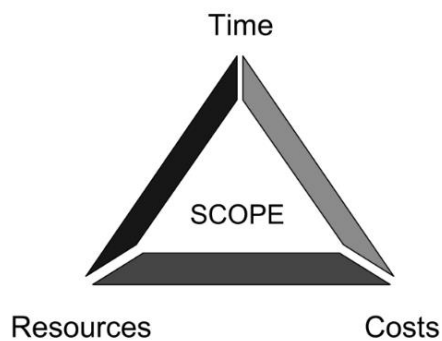


Fig. 2.1 – Representative scheme to achieve the scope [4].

Resources, tasks, and timelines play vital roles in managing construction projects, requiring skilled personnel to organize, schedule, and oversee the work effectively. The planning process encompasses tasks such as integrating the project scope, outlining inputs and deliverables, and establishing methods for executing and monitoring the project schedule.

It has been suggested that poor coordination and allocation of tasks and resources tend to lead to inadequate planning, and that can mask the managerial effort required to develop and to have good control of schedules. Despite being seen as a separate process with distinct inputs and characteristics, scheduling is a crucial step in the planning process [5].

Historically, efforts to establish control mechanisms have led to many approaches to scheduling [6]. This concept is not new: Since the Ancient Egypt pyramids (which are over 3000 years old), people have used scheduling and strategy to accomplish such masterpieces, and with it they could understand the included activities and sequences.

Although managers overseeing organizations responsible for completing tasks should ideally understand the concept of scheduling, there is little documented evidence of formal scheduling processes before the 18th century.

Between 1700 and 1800, there was an evolution in scheduling by perfecting the visualization of charts for activities. Joseph Priestley (England, 1733–1804) is credited with creating the "bar chart". In his "Chart of Biography", he mapped the lives of about 2000 famous individuals on a chart of time. Figure 2.2 represents Joseph Priestley's chart of biography.

Leading to 1900 where, by this time, the bar charts could visually represent activities and their corresponding timeframes, enabling the determination of when tasks would be performed. However, it couldn't illustrate the relationships or dependencies between activities [7].

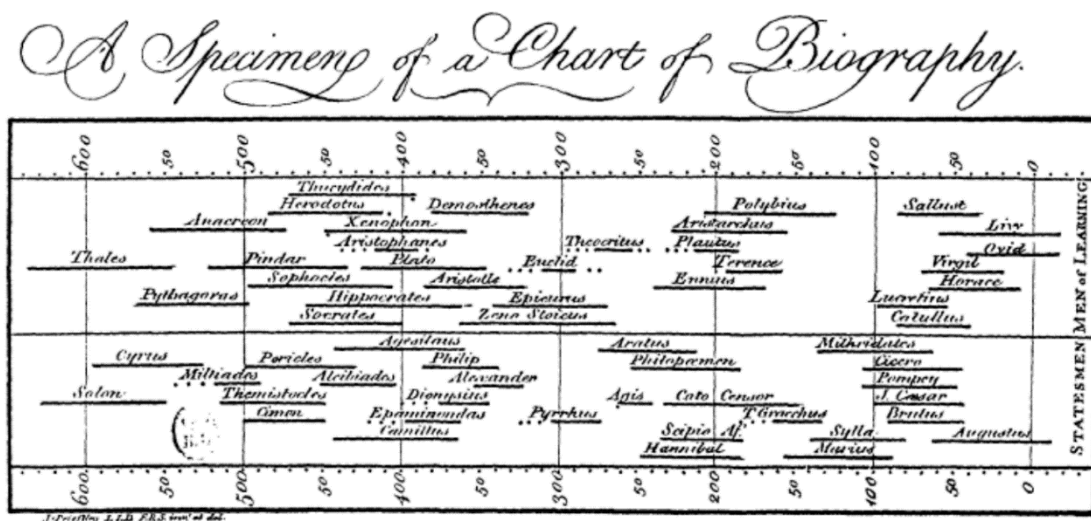


Fig. 2.2 - Joseph Priestley: Chart of Biography [7].

Advances in scheduling visualization and more sophisticated analytical techniques were made possible by the rapid expansion of computers from mainframes to personal computers throughout the second half of the 20th century [6].

Between 1900s and 1950s was the beginning of the current project management concept. Technology advancement at this time resulted in a shorter project schedule. Vehicles made it possible to move around and allocate resources efficiently. Communication speed was accelerated by the telecommunications infrastructure.

The Gantt chart was created by Henry Gantt, and the job definition was widely utilized. Afterward, the job specification served as the foundation for creating the Work Breakdown Structure (WBS) [8]. The

Work Breakdown Structure, or WBS, is a crucial component of the project's timeline and lifecycle. This is a crucial component of project planning, which starts with a hierarchy of tasks and levels that aids in determining how the project will go according to the project manager's planned schedule [9].

Figure 2.3 is an example of a very precise graphical building schedule that was set up for the task at hand. Considering every week is thought to consist of five full days of actual labor, any disruptions, such as bad weather, were considered.

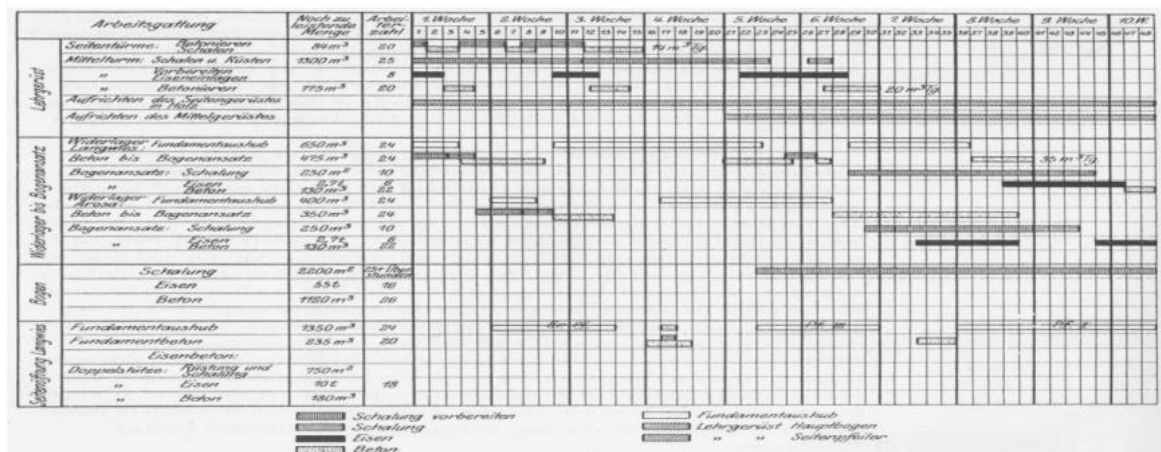


Fig. 2.3 - A Bar Chart developed for a bridge constructed in 1912 [10].

The modern bar chart appears to have reached a state of complete development and use by 1912, at least in Germany. An extensive account about an attempt to build a small mountain railway in Bavaria appeared in the October 1915, edition of *Armierter Beton*. Instead of the schedule, the railway piqued curiosity with its major bridge's inventive use of reinforced concrete. However, a brief discussion of the usage of a bar chart and histogram was included.

The total demand at Baustoffen was determined by adding up the needs for each individual service in the construction schedule into a second table (figure 2.4). With an eye toward the unpredictable and irregular supply, overall performance was accomplished by making timely provisions for all necessary supplies.

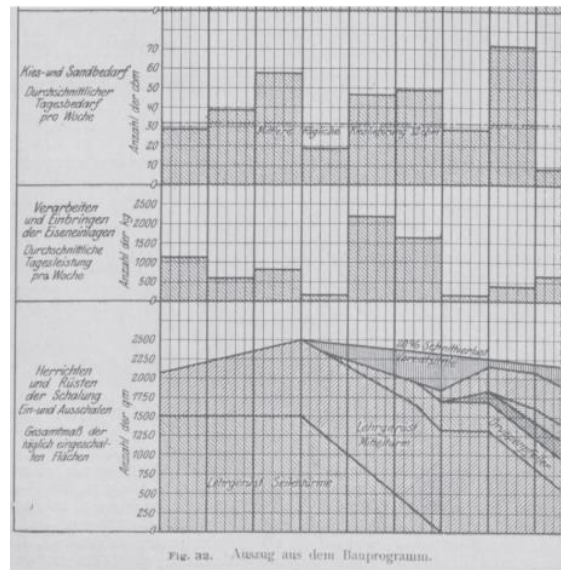


Fig. 2.4 - Part of the resource histograms from the same project [11].

The construction schedule was generally accepted, and despite relatively high investment costs, it has proven to be very economical. This is mainly thanks to the well-designed non-structural (performance) measures regarding the schedule, which were primarily created by Dipl.-Ing. J. Muller.

Team motivation, change management, and efficient use of control systems are only a few of the ideas that Gantt presented and which remain a major emphasis in modern management. Even though he focused on manufacturing, which benefits from repetition and uniformity, many of his concepts are still useful in projects today [11].

With that being said, for many years the military has utilized war gaming as a strategic tool for planning operations. Examples include Germany's successful invasion of France in 1940 and Japan's attack on Pearl Harbor in 1941, both planned through war games. However, the military planning process, outlined in manuals like the US Army Staff Organization and Operations manual, typically involves an ad hoc approach. This means that courses of action (COAs) are developed by staff members and the commander after discussing various options [12].

The planning concept gained ground quickly, with significant support from NASA and the U.S. Navy. For the Polaris project in the 1950s, the Navy used modern project management techniques. Large engineering and construction companies, NASA, the Department of Defense (DoD), and others used project management techniques and tools in the 1960s and 1970s to oversee ambitious, schedule-driven, and large-budget projects [8].

The Department of Defense also had an impact on the planning concept, since it decided to invest in preparing strategic plans and provide for the strategic direction of the armed forces to adjust DoD authorities and responsibilities. Since then it continued to invest in military planning [13].

With many project management tools available to help with work management, the idea that managing projects is only about managing work has been institutionalized. For optimal efficiency, work is planned and then handled according to that plan. This plan specifies the amount of labor needed as well as the budget and time needed to finish the project using a few calculations. The Project Management Body of Knowledge (PMBOK) published by the Project Management Institute (PMI) reflects this plan-centric approach to project management [14].

PMBOK appeared in 1981, when the PMI's direction agreed to start developing A Guide to the Project Management Body of Knowledge (PMBOK Guide). It contained practice management standards and guidelines, which are extensively used in this role. After its development, it was first published in 1987, becoming well-known among timeless business management securities [15].

A PMBOK Guide extension was developed by the U.S. Department of Defense to identify and define defense applications of the essential project management knowledge areas included in the Guide, along with those defense-intensive knowledge areas not covered in the Guide. The PMBOK Guide's adoption by DoD schedule managers as a useful resource served as the DoD's driving force. Consequently, it was possible to aggregate defense-intensive activities to the PMBOK by customizing PMBOK procedures to the military acquisition life cycle.

The DoD used the nine knowledge areas listed in the PMBOK Guide to develop, produce, and deploy defense systems. These areas are Procurement Management, Project Risk Management, Project Communication, Project Integration Management, Project Scope Management, Project Time Management, Project Cost Management, Project Quality Management, and Human Resource Management. The DoD has used project management best practices for many decades.

The acquisition of defense-related knowledge also depends on five additional defense-intensive knowledge areas [16].

Below, is shown a representative scheme of the nine knowledge areas listed in the PMBOK Guide (figure 2.5). These are:

- Project Systems Engineering Management;
- Project Software Acquisition Management (SAM);
- Project Logistics Management;
- Project Test and Evaluation Management;
- Project Manufacturing Management.

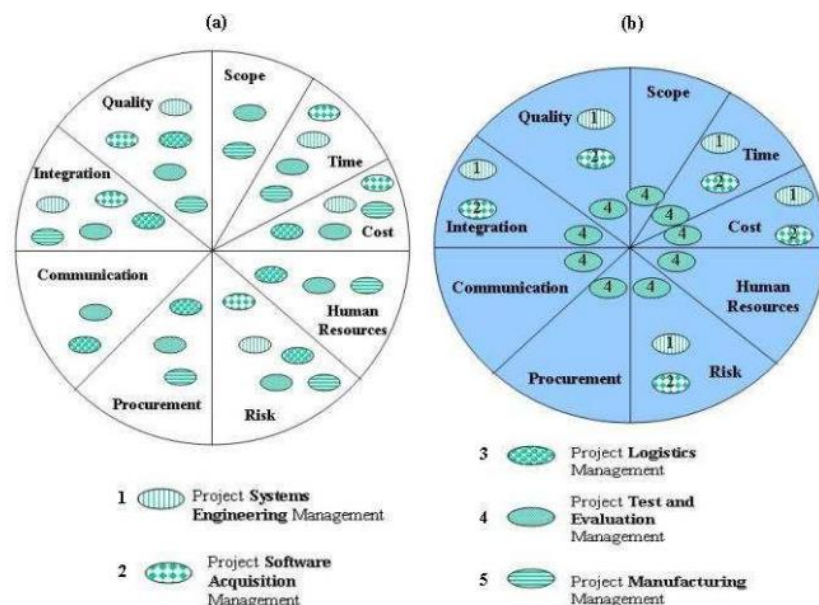


Fig. 2.5 – PMBOK core knowledge areas and defense-unique knowledge areas relationship [16].

2.2. A BRIEF HISTORY – PLANNING SOFTWARE AND COMPUTERIZATION

Following World War II (1939–1945), there was a rising interest in scientific management tools for the construction industry. Many countries had a lack of housing and other structures. Still, the rebuilding proved challenging due to a lack of fuel, machinery, and other necessities. Conversely, there existed a sufficient number of people who were ready to work for money. Several years were needed to plan and finance research and development. After that, finding sensible construction techniques at the lowest possible cost was the main objective.

By the late 1950s/early 1960s, most countries had access to computers, mostly through service centers. This led to planning schedules for management systems based on network concepts. Launched as a computerized arrow diagram, the Critical Path Method (CPM) allowed for the identification of critical operations and overall time [17].

As a computerized tool for project management, CPM has been around since the middle of 1956. E.I. du Pont de Nemours (Du Pont) was searching for practical applications for their "UNIVAC1" computer, which was just the third UNIVAC machine ever manufactured and one of the first computers ever deployed in a commercial setting [7]. Below is a diagram and a graphic that represented the CPM and its analysis made by a computer – Fisher Works (figure 2.6 and 2.7).

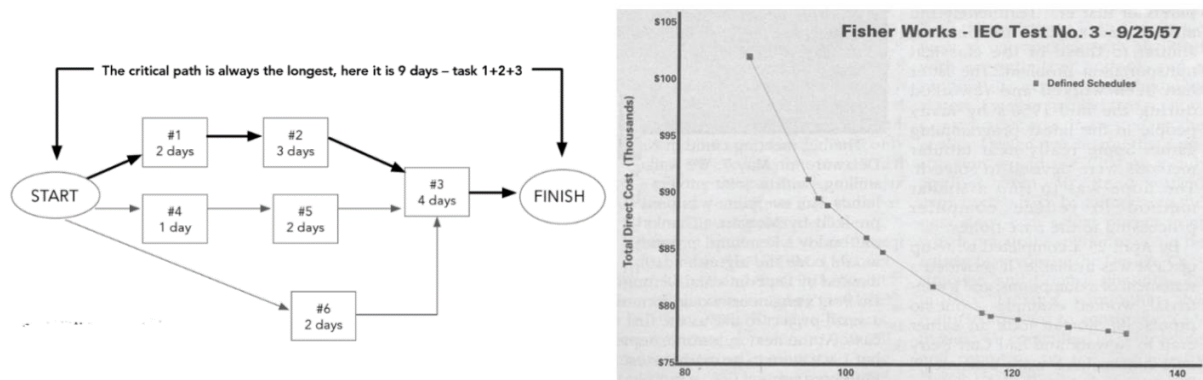


Fig. 2.6 and 2.7 – Critical Path [18]; Result of the first CPM analysis made by a computer [19].

In early 1967, there was a growing awareness of the increasing significance and influence of software systems across various societal activities. Simultaneously, the challenges encountered in software manufacturing underscored the need for a shift from ad hoc approaches to more structured methodologies rooted in established engineering principles. These circumstances served as the primary catalysts for the inception of the inaugural Software Engineering Conference in 1968, spearheaded by the NATO Science Committee.

The central objective of this conference was to advocate for the adoption of robust engineering principles to develop reliable, efficient, and economically feasible software solutions. Within the many activities of software engineering, maintenance was perceived as a post-production activity, occurring after the software product was delivered and deployed [20].

The Program Evaluation Review Technique, or PERT, was quickly implemented in the construction sector in the mid-1960s [17]. Instead of focusing on project tasks, the PERT network placed more emphasis on project events or milestones, such as designating important progress points that would be

used for overall management oversight. Using probabilistic duration predictions was one of PERT's other unique features [21].

PERT and CPM were very similar - they both employed the arrow diagramming method, where actions were represented by arrows [7]. Next is a representation of PERT and CPM, and the differences between them (figure 2.8 and table 2.1).

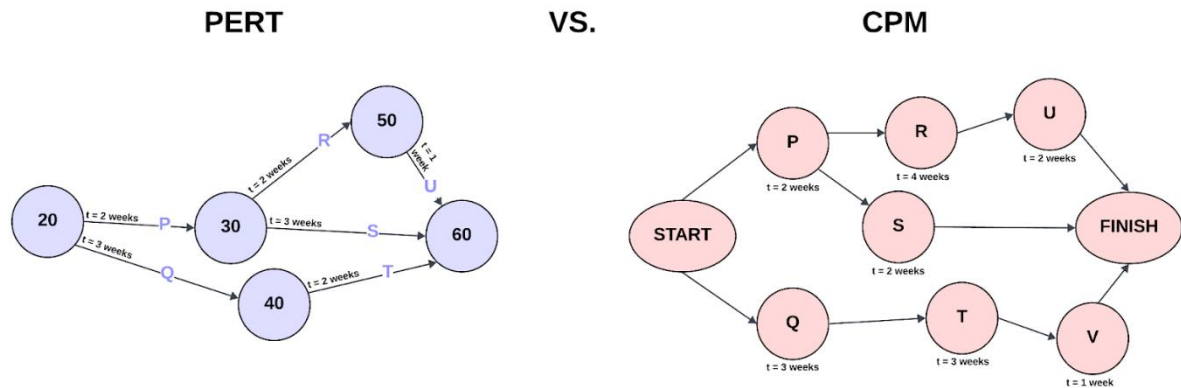


Fig. 2.8 – Difference between PERT and CPM - scheme [22].

The primary distinction was that Du Pont's industry, which was well-known for involving construction and maintaining chemical plants and activity durations, could be roughly estimated using known amounts and output rates. As a result, CPM concentrated on cost optimization through resource balance. Cost was just a minor concern in the Navy's work on Polaris, which was primarily research and development. Durations could only be evaluated, and PERT was used to calculate the probability of an event occurring by a specific future date. But, by the late 1960s, PERT and CPM had combined to form "network-based management systems", which took over as the industry standard for project scheduling [7]. Table 2.1 presents the main differences between PERT and CPM.

Table 2.1 – Difference between PERT and CPM - parameters [23].

Parameters	PERT	CPM
Model	Probabilistic	Deterministic
Type of Activities	Uncertain Activities	Certain well-defined activities are categorized into critical and non-critical
Importance	Optimizing time	Balancing time and cost
Nature of job	Non-representative	Repetitive
Ideal for	Research and development projects such as medical research	Non-research projects such as construction
Orientation	Event-Based	Activity-based
Time Estimation	Three types - pessimistic, optimistic, and most likely	One type of time estimate

The goal was to create master plans for every project and to be able to control it considerably more effectively than previously. Since the plans were connected to computer centers, planning consultants were engaged to create them. They relied on their planning on interviews because, generally speaking, they had little experience with the construction process. Getting the computation and outcome back took some time. The hardest part was that the early iterations, which primarily consisted of lists with tables and intricate networks, were hard to understand. Furthermore, it was challenging to convert a building project's nature into a network of this traditional first version.

The idea of a new generation of building process control employing databases for a general process flow and project modeling was another consequence of the presumed rapidly expanding computer facilities. In 1970, the UK was leading the way, having invested 20 man-years in a short time. Many flow charts outlining the construction process were shown, and next is an example of a flow chart in construction (figure 2.9). Although it improved comprehension of the process's components, it produced no workable answers [17].

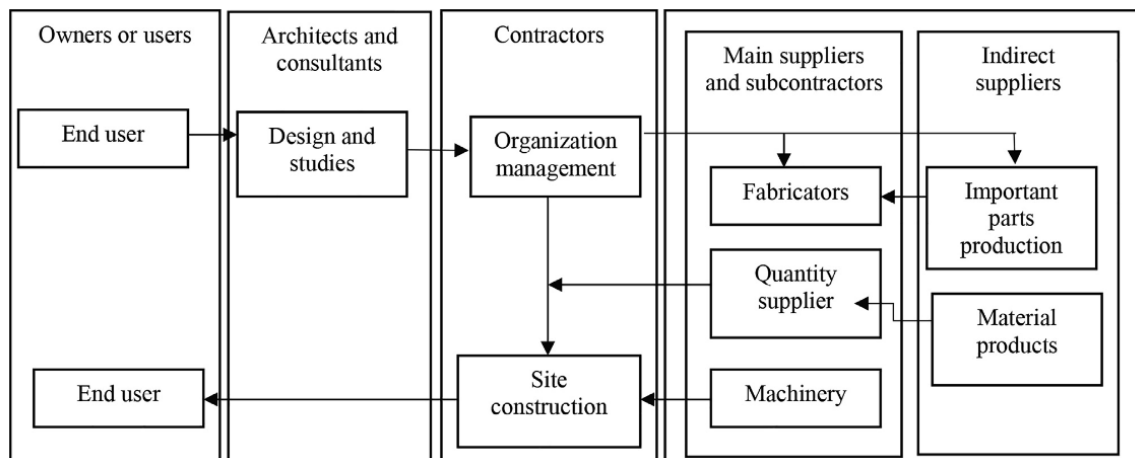


Fig. 2.9 – Flow chart of the general construction industry [24].

In 1978, CCS (Construction Computer Software) started working on the Candy integrated Estimating, Production Planning, and Control System, especially for the construction industry, in response to the growing need for businesses to keep up with the rapid advancements in technology and computer systems [25].

In the 1980s, it paved the way for the development of expert systems and data-based management information systems. Researchers started to focus on this topic, even though it was still a bit theoretical [17].

People switched from using mainframe computers to multitasking personal computers that were highly effective at organizing and coordinating complicated project schedules during the IT/IS revolution of the 1980s and early 1990s. Researchers and developers found use for the Internet in the middle of the 1980s, and Ethernet technology and local area networks were first introduced to rule the field of network technology [8].

A second generation of management programs and tools emerged in the 1990s as a result of the evolution of the market. Both CAD design schedules and planning tools have seen significant improvements. The primary ways of communication went from computers to wired networks to via the internet. However, because the market was small and dispersed, it took a while to make the necessary adjustments to the building procedures. The management of materials flow has been a major challenge in construction management.

In the mid-1990s the Supply Chain became a motto, even leading to partnering as a lasting cooperation between suppliers and buyers: Material need and delivery were integrated into the scheduling (MS Project) and automatically monitored. Materials ordering in 1980 from the catalogs with barcodes and optical readers moved over to the Internet in the late 1990s. Orders and payments became online between the supplier, the buyer, and the bank.

Benchmarking was first used in the construction industry (UK) in the 1990s. It means a methodical comparison of one's own and other processes and products, leading to concrete follow-up measures. Although consultants and researchers supported the idea, it was not caught on. However, it resulted in the sharing of important performance measures within some company groups [17].

For construction professionals pursuing further education, Construction Project Management (CPM) and Earned Value Management System (EVMS) were and are crucial subjects. EVMS is a useful method for calculating actual profits and losses on projects and offers a way to balance profits and losses and optimize profits. Below there's table 2.2 indicating the processes related between EVMS and PM.

EVMS is an effective method for controlling both cost and physical performance at the same time. It offers integrated schedules, progress, and cost management information regarding risks, quality, procurement, and scope.

According to Flemming (1996), the original Cost/Schedule Control Systems Criteria (C/SCSC) served as the basis for EVMS, which was developed by the US Department of Defense. To improve cost and schedule control, the EVMS technique is applied in multiple nations [26].

Table 2.2 – EVMS Processes related with Project Management processes [26].

PLANNING	EXECUTION	CONTROL
Model Definition	Register of results for financial control	EVA Progress Report elaboration
Planning activities, resources, and costs in an accounting plan	-	Monitoring and Control with actions

Standards like the International Organization for Standardization (ISO)/International Electro-Technical Commission (IEC) 12207 and ISO/IEC 15288 started to appear in the 1990s and early 2000s, placing software project procedures and systems inside an enterprise framework. Enterprise architectures were

developed at the same time as a series of commercial enterprise resource planning¹ [27] (ERP) packages [28].

Information Technology (IT) is important when applied to construction project management (CPM), in order to complete construction projects on schedule, within budget, and with acceptable quality. Production management information can be gathered at various phases of a project's life cycle through the use of Building Information Modelling (BIM) [29].

The availability of a method that distributes the load across the server nodes in an appropriate manner is a primary objective for the scalability of a distributed or parallel system. Several scheduling strategies were put out for multi-node architectures running distributed or parallel programs.

In addition to the fact that HTTP request response times can vary greatly, internet traffic typically happens in waves with strong peak intervals in between. Because of this, heavy tail distribution functions are commonly used to represent the Web burden for both inter-arrival and service times. The primary reasons for utilizing global scheduling strategies based on dynamic state information rather than informationless static algorithms, even in Web server farms, are these load characteristics and their resemblance to the classic problem of scheduling applications on multi-node architectures.

The system can be made adaptable even without complex scheduling algorithms if the dispatcher mechanism has complete control over client requests and the majority of clients only need HTML pages or simple database consults.

Simple static regulations work just as well in these situations as those with more complex dynamic variants. Only on websites where the bulk of client requests are three orders of magnitude more complex than offering a static HTML page with a few embedded objects does scheduling based on dynamic state information seem to be required [30].

Maintaining all the information required to plan and build an elaborate construction is a difficult undertaking, and many think that one of the main ways the construction industry can become more productive is through improved information management.

There are two streams in the construction IT research literature that offer different approaches to the issue of project information management:

- Enhancing the industry's current documentation practices;
- Increase the use of WEB-based processes.

Enhancing the industry's current documentation practices, through the widespread use of electronic document management (EDM) systems, both within companies and specifically among project participants, is one way to improve construction IT procedures gradually.

¹ - ERP (Enterprise Resource Planning) systems are enterprise-wide systems that integrate to automate all business activities within a corporation. They have quickly emerged as the real industry standard for replacing outdated systems.

These systems' main benefit is that they offer an integrated software platform that is common for corporate processes. These systems have two key characteristics: first, they make it easier to establish a causal relationship between a visual model of business processes and the software that implements those processes; second, they guarantee a level of integration, data integrity, and security that is difficult to achieve with multiple software platforms.

The primary goal of electronic document management systems is to make it easier for workgroups, projects, and specific enterprises to manage their documentation over computer networks. Apart from the fundamental file management functionalities present in operating systems, electronic document management systems offer improved features associated with the life cycle and versioning of certain document classes [31].

In what concerns the increase of wider use of internet-based processes, with the introduction and further developments of the internet, there was a lot of availability when it comes to web-based packages. A new idea in construction project management called 4D Construction Project Management appeared and had the intention to focus on project planning, management, construction, and model tracking [32].

By lowering misunderstanding differences and increasing schedule reliability, 4D models (figure 2.10) help minimize communication issues. Effective communication of progress updates and schedule modifications is seen as strategic for project management since it enables timely remedial action. Color changes are used in 4D modeling for control throughout construction to show how the activities progress over time [29].



Fig. 2.10 – 4D BIM Modeling [33].

There are currently several software programs that facilitate construction management, and some of them that stand out the most when it comes to planning and scheduling the project are the following:

- Candy System - CCS (1978) - Cost management, project control, planning, and budgeting;
- Microsoft Project (1984): Resource management and activity scheduling;
- Oracle Primavera (1983): Cost, resource, and planning management;
- Gantt Pro (2014): Cost control, resource management, activity management, and planning;
- Arentia (2011): Budgeting, planning, managing a team, and overseeing real-world events on site;
- Cobra (1986): Project management, inventory control, tracking, and administration of payments, goods, and equipment;
- Microsoft Excel (1985): Spreadsheet for planning and managing expenses;
- Ares Prism (1990): Budgeting, real-time field management, and cost control;
- Tilos (1999): Scheduling and planning, linear scheduling view.

It is worth mentioning that these tools can also be integrated into the Enterprise Resource Planning (ERP) concept since they integrate the framework for arranging, characterizing, and standardizing the

business processes required to efficiently plan and manage an organization so that it can leverage its internal expertise to pursue external advantage [34].

For better understanding, we will take a closer look at some of these tools.

2.3. MICROSOFT PROJECT

The original idea for the Microsoft Project came from Alan M. Boyd, Manager of Product Development at Microsoft, who wanted an internal tool to help manage the enormous number of software projects that the business had going on at any given time. Boyd wrote the specifications and hired a Seattle-based business to develop the prototype.

In 1984, the Project's first commercial version was made available for the DOS (Disk Operating System). 1990 saw the release of the first version of Windows, known as version 1 (figure 2.11) [35]. The newest versions are presented with the logo next shown in figure 2.12.



Fig. 2.11 and 2.12 – Microsoft Project first version; most recent MS project logo.

Microsoft Project became a well-known software program designed to assist project managers with planning, delegating resources to tasks, monitoring progress, controlling costs, and workload analysis. Because it offers a wide range of features like scheduling management, resource cost assignments, and monitoring and control over task execution, it is a helpful tool for project management in general [36].

A vast array of tasks can be planned and managed with the help of this tool. Projects can be more productive and realize better results by utilizing the set of highlights Microsoft Project offers, from meeting important deadlines and budgets to choosing the proper resources. Microsoft Project may be used to complete the following tasks [37]:

- Making plans with the appropriate amount of detail for the project;
- Starting to work with summary data and moving to a more detailed approach if needed;
- Choosing which tasks will be scheduled manually and which ones the Project can arrange automatically;
- Depending on the level of detail required for the requirements of the project, manage work, resources, tasks, and expenses;
- Utilize the data in the plan in several types of views and reports;
- Throughout the project's duration, monitor and oversee the plan;
- Work together and exchange information with other members of the team;
- To spread the project-management attention across several projects, make use of resource pools, consolidated projects, and cross-project links [38].

Understanding the fundamentals of working with the Outline, Project Summary Task, Summary Tasks, and Subtasks will be essential to achieving success while using project plans in the Gantt Chart view (figure 2.13), which is the default view of new project plans in Microsoft Project [39].

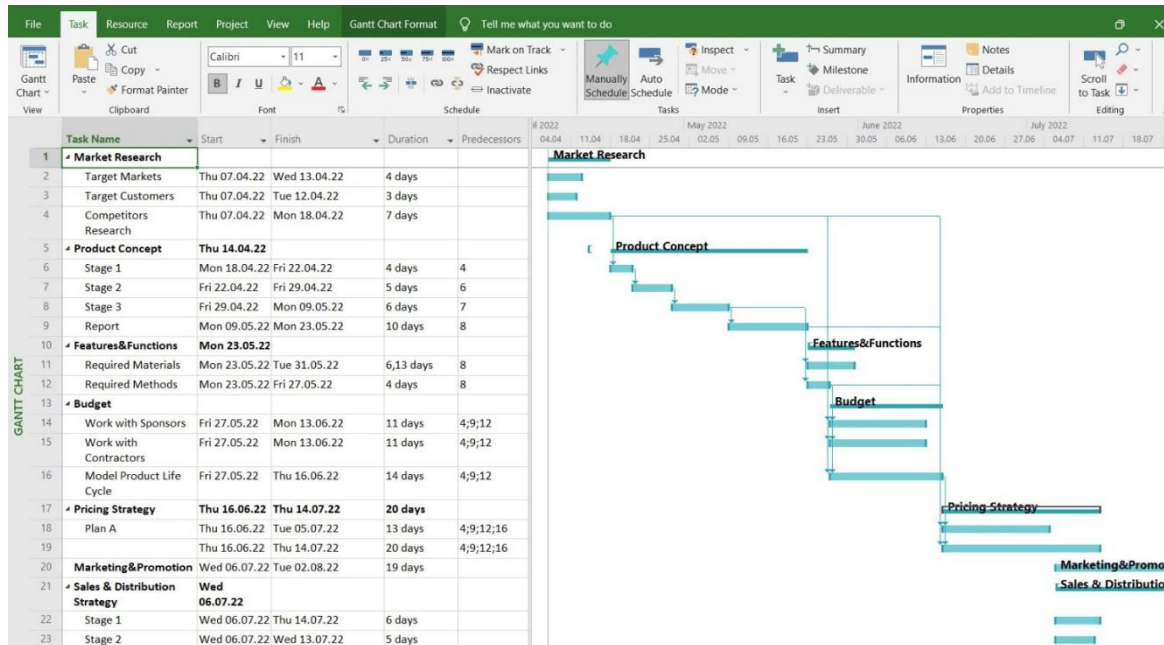


Fig. 2.13 – Example of Gantt Chart on MS Project [40].

The latest version of MS Project is included in Microsoft 365 and is version 2312 (January 9, 2024). This version represents a major improvement in project management skills - it strives to simplify project management procedures with an emphasis on intuitive interfaces, cutting-edge collaborative features, and smooth integration [41].

2.4. ORACLE PRIMAVERA P6

The versatile and user-friendly Oracle Primavera P6 Enterprise Project Portfolio Management (P6 EPPM) is a comprehensive system for planning, arranging, overseeing, and carrying out enterprises, projects, and portfolios. The following tasks can be completed with Primavera P6:

- Organize, schedule, and plan the appropriate project strategy;
- Oversee resource management and project cost decisions;
- Boost the effectiveness of the work process and group coordination;
- Make the most of each project participant's abilities and obligations;
- Progress monitoring and tracking [37].

Oracle's Primavera P6 EPPM is a software-as-a-service program that runs in the cloud and is supported by one of the biggest cloud suppliers in the world as well as a global network of Oracle Project Portfolio Management experts. It offers a fully web-based approach to project management for any size project, adjusts to different project complexity levels, and scales intelligently to accommodate all roles, functions, and skill levels inside a company and on the project team.

The project team can access project data with Primavera P6 EPPM thanks to adaptable web-based user interfaces. To access role-specific data, users have access to alternative interfaces such as web applications, interactive dashboards, and basic forms. Additionally, team members can choose whichever interface best suits their field of work to update their status.

While schedule and activity network views offer team members an easy way to see their assignments and the data they need to complete the task at hand, interactive Gantt charts enable planners, schedulers, and project managers to convey a more precise and comprehensive graphical depiction of a project's schedule, see figure 2.14 [42].

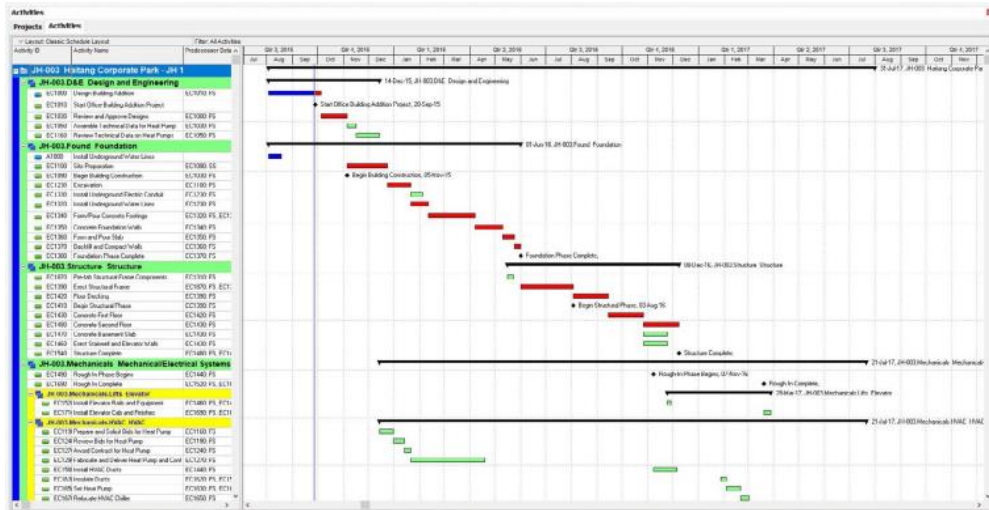


Fig. 2.14 – Example of a Gantt Chart in Oracle Primavera P6 [42].

2.5. CANDY SOFTWARE

The Candy System provides the tools required to meet user requests, respond to tight deadlines and severe construction market requirements, and enable the systemization of the whole budgeting process for all project types within the organization [43].

This software offers a wide range of tools to improve project planning, management, and estimating. Software for precise estimating, quantity takeoff, planning, forecasting, and cash flow is included in this. Candy was also developed using *First Principles Estimating*. Therefore, it may help in preserving profit margins, digitizing labor-intensive procedures, and removing expensive mistakes [44].

According to the Oxford Advanced Learner's Dictionary (2014), first principles are the essential ideas or presumptions that form the foundation of a theory, system, or methodology.

Harrington Emerson famously said, "As to methods there may be a million and then some, but principles are few. The man who grasps principles can successfully select his own methods. The man who tries methods, ignoring principles, is sure to have trouble." This statement dates back to 1911. A detailed review of the equipment and work crews needed to complete tasks at presumptive rates of productivity is necessary when estimating from fundamental principles [45].

Candy facilitates real-time editing and enhances teamwork, guaranteeing that data is updated at all times [44]. Below is the most recent Candy's logo (figure 2.15).



Fig. 2.15 – Candy's logo.

2.5.1. HISTORY OF CANDY SOFTWARE

In the mid-1970s, Murray&Roberts² (including Peter Reynolds) [46] embarked on a trip to Iran, exploring prospects for pre-cost housing operations. This initiative required frequent trips to Iran to assess the feasibility of the endeavor.

During these visits, Peter Reynolds observed Iranian companies utilizing computers for estimating, marking one of the earliest instances of computers being employed in construction beyond accounting functions. Witnessing this innovative approach sparked his interest in utilizing technology to make construction procedures more efficient.

At that time, handheld devices like Texas Instruments calculators were the extent of technological assistance available. Despite their limitations, they utilized these devices (figure 2.16) to calculate materials for construction projects. While he traveled for planning purposes, spending short periods in Iran, the building estimator would remain for 3 weeks, meticulously quantifying materials and performing related tasks. This striking contrast highlighted the potential efficiency gains through computerization and standardized processes.



Fig. 2.16 – HP 9845 (1977-1982) [47].

Given their lack of programming knowledge, they initially relied on a simple system called "Betsy" - Building Estimating SYstem (1977), and it worked on the principles of the future "Candy".

²- Douglas Murray e Douglas Roberts (M&R): Murray & Roberts was formed in 1967 following its merger with Murray & Stewart, but the two companies continued to operate as separate businesses until all operations were fully consolidated in 1979.

They had all the support from Murray & Roberts and Murray & Stewart, including Christiani & Nielsen [48], a Norwegian coastal and sea construction company.

Since Christiani & Nielsen helped them in getting more complex resources for the system, they honored them by giving the next generation the name “CAN” for Christiani Nielsen in CANDY (1978) [49]. The system revolutionized their approach to construction estimation and project management. Subsequently, they made a move into the industry of software development, creating CCS (1982), one of the first rental software solutions – the logo is represented in figure 2.17. Despite initial opposition, particularly from mainframe proponents, CCS gained traction within the Murray and Roberts group, spearheading a shift toward technology-driven construction management.

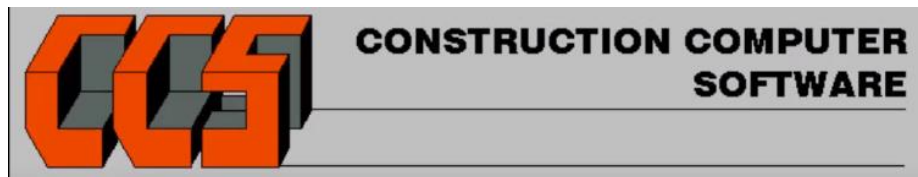


Fig. 2.17 – The beginning of the CCS logo [47].

Their journey with technology continued as it adapted to evolving platforms, transitioning from HP computers (1983-1987) to IBM PC 8086 (1986-1992) and eventually embracing Windows operating systems. Along the way, they encountered challenges and innovated solutions, such as custom-built boards bridging HP and PC technologies. Their commitment to innovation extended to software development, where it drew inspiration from pioneers like Rank Xerox to create intuitive user interfaces resembling a desktop environment. These innovations predated mainstream adoption, underscoring proactive approaches to technological advancement.

Behind these developments were visionary individuals like Willem, Roger Bull, Dale Kuys, and Paul Bruins, who navigated technological shifts and user needs with ingenuity and resilience. This culture fostered creativity and experimentation, enabling them to pioneer solutions that shaped the construction industry's technological landscape. Next is the evolution of CCS over time, accompanied by the evolution of Windows, see figure 2.18.

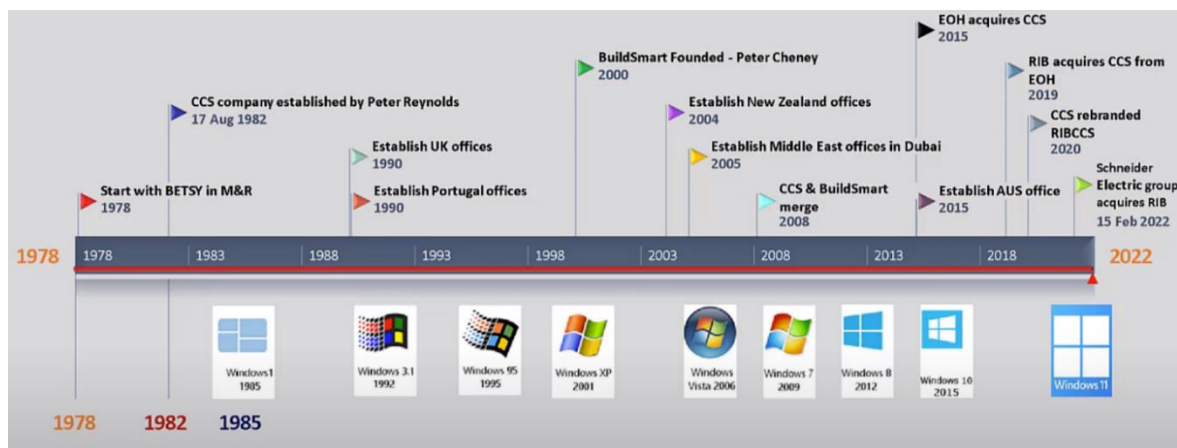


Fig. 2.18 – Construction Computer Software Timeline [47].

This journey from manual estimation methods to sophisticated software solutions reflects their commitment to innovation and adaptability. By embracing emerging technologies and nurturing a

culture of innovation, they laid the foundation for groundbreaking advancements in construction project management [47].

The process of bidding and winning tenders carries significant costs, consequently, contractors need to optimize their internal operations to achieve best practice efficiencies and increase their chances of winning projects [50].

The main features of the Candy System include:

- Estimating: One of the main Candy System modules that enables users to create estimates that are rigorous, consistent, and accurate in their calculations with fewer errors. Reports and analysis documentation are accessible, and users can further customize them. An estimator can discover the budget's key components and limits while preparing a tender more quickly with the Candy System.
- Planning: Schedules created in Candy are produced using the Critical Path Method. The user is assured accuracy and precision when preparing the construction schedules by using the tools that match the needs of the construction sector. Additionally, this module provides the option for Time-Place diagrams, which facilitate better task management by allowing a better knowledge of the sequencing of operations at each place. Both professional and non-professional planners can utilize this simple-to-use tool.
- Forecasting: This module makes it possible to forecast the quantities, values, and resources that will be used on-site by dynamically integrating the Estimate budget with the Planning timetable. Two predictions are given for ongoing projects with altered budgets: one based on the original budget and the other based on the revised budget.
- Cash flow: The best course of action for increasing the project's profitability can be found by examining any number of Cash Flow scenarios. It can be applied and adjusted financial considerations on the project.
- QTO (Quantity Take-Off): Bills of quantities are assembled for the estimate using Candy's QTO module, a tool for extracting and measuring quantities from 2D designs. It can also be used to record the amount of work completed [43].

The next figure 2.19 is an example of a barchart in the software Candy.

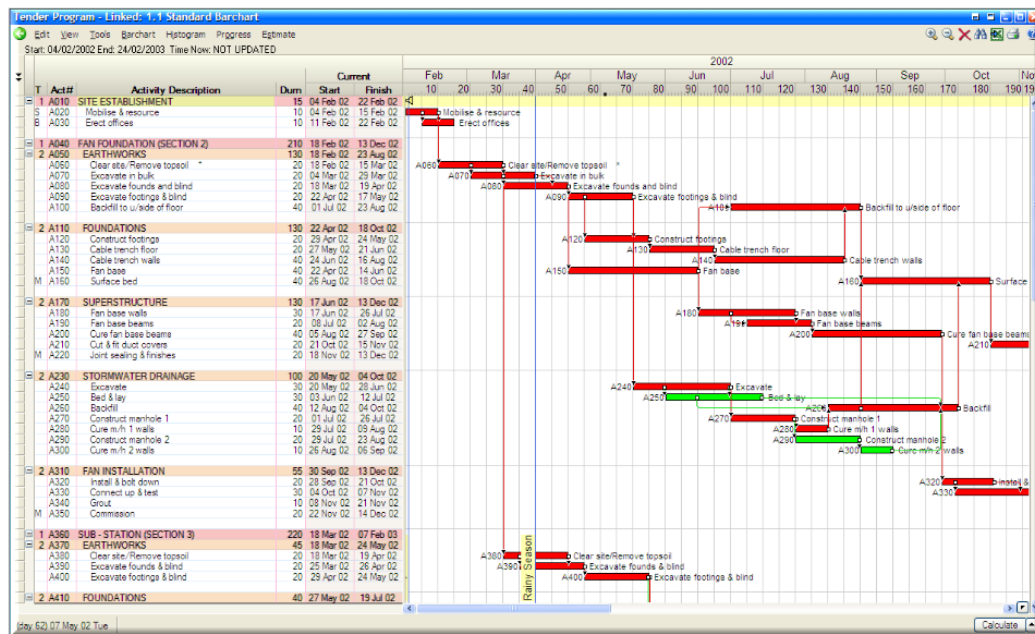


Fig. 2.19 – Example of Bar Chart on Candy [51].

The following is a flowchart comparing the three types of software mentioned before (Microsoft Project, Oracle Primavera, and Candy CCS), presenting them over time and their changes, figure 2.20.

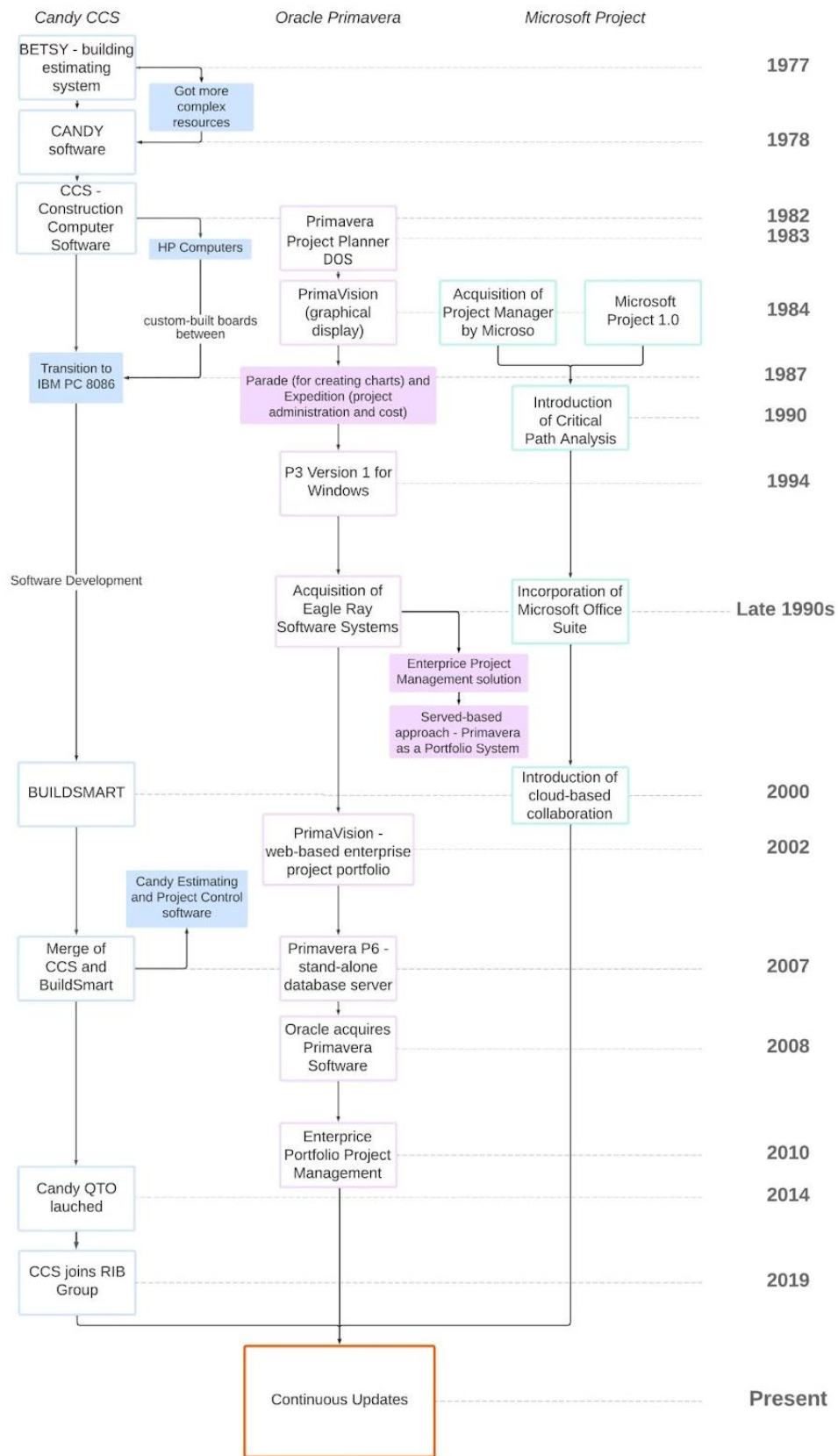


Fig. 2.20 – Timeline comparing MS Project, Oracle Primavera, and Candy software.

This timeline (figure 2.20) shows how three renowned project management software platforms have changed and grown over time. Each started out with simple functions before adding cloud-based solutions, enterprise-level connectors, and increasingly sophisticated project management features. They have produced reliable software that meets extensive project management requirements across a range of industries as a result of their ongoing adaptation to market demands and technical advancements. Regular updates demonstrate continuous growth and a dedication to enhancing capabilities in order to satisfy contemporary project management standards.

2.6. CONCLUSIONS

In conclusion, the importance of careful planning and scheduling in project management cannot be overstated. Utilizing planning software and computerization offers substantial advantages, streamlining processes, enhancing accuracy, and facilitating real-time adjustments. Of all the tools available, the bar chart is one of the most important for planning. Throughout history, the bar chart has developed from a straightforward scheduling tool to a complex tool for illustrating project milestones and timelines. The bar chart's usefulness has grown to be essential in today's fast-paced and complex project contexts, helping managers to effectively allocate resources, monitor progress, and guarantee project completion on schedule. Embracing these technological advancements not only optimizes project execution but also fosters a proactive approach to managing the intricacies of modern projects.

3

DCMA SCHEDULE HEALTH CHECK AND CONSTRUCTION PLANNING SOFTWARE

3.1. DELAY ANALYSIS

In the construction industry, a delay is a period of time that extends past a contract's (or a milestone's) set completion date or past the date that the parties agreed to deliver the project. A delay, in the author's opinion, results in revenue loss due to a deficiency of production facilities, available rental space, or dependence on current facilities. In certain circumstances, a delay results in increased overhead expenses for the contractor due to prolonged work periods, rising material costs as a result of inflation, and rising labor costs.

Therefore, finishing projects on schedule is an indication of efficiency. However, the construction process is subject to numerous unpredictable variables that come from a variety of sources, so it is imperative to conduct a thorough assessment that takes into consideration the loss caused by delays for both parties and determines how long the project will take to extend if it is delayed.

Project managers and schedule (timing) analysts frequently struggle with the issue of how to evaluate complex delays and address the resulting claims. Furthermore, the majority of construction contracts lack specificity regarding the methodology to be employed for the assessment and examination of delays. However, the contractor and the employer hold different views regarding the analysis and assignment of blame for the delay. Determining the length of delays and assigning responsibility to each party is therefore a crucial matter.

As a result, delays must be assessed using a methodical approach. There are various techniques for analyzing delays, including the following: the critical path method, the collapse technique or (but for), the global impact technique, the net impact technique, the impacted as-planned technique, the collapsed as-built technique, the sectional technique or snapshot technique, and the isolated delay type technique [52].

When it comes to these techniques, also known as "Delay analysis methods" for performing forensic investigations into delays, there are some respected organizations that use delay analysis techniques [53] - Numerous documents exist in the literature that offer guidance on how to handle allegations of delays, with the goal of resolving disputes in a way that doesn't negatively impact the project. Among these is the AACE International (Association for the Advancement of Cost Engineering Int.) Recommended Practice No. 29R-03, titled "Forensic Schedule Analysis", and the "Delay and Disruption Protocol," which was published by the UK's Society of Construction Law (SCL) in 2002 and then a later, second edition, was published in 2017 [54].

SCL has identified a number of factors, such as contract-related conditions, the nature of causal events, the value of claims, time in hand, recorded information, information from the current time plan, and the

planner's experience on the project, that should be taken into account when selecting the method of delay analysis [52].

3.2. SOCIETY OF CONSTRUCTION LAW – DELAY AND DISRUPTION PROTOCOL

In 1983, the Founder Members of the Society of Construction Law (SCL) in the United Kingdom signed the first constitution at the Whig and Pen Club located in the Strand, just across from the Law Courts. Later in 1983, the Rt Hon Sir Derek Walker-Smith PC QC officially launched it at the RIBA in London. Compared to expectations at the time of its founding, it has proven to be a far more effective and valuable organization, and many other nations have adopted its organizational structure and goals as a model [55].

The "Delay and Disruption Protocol" was created in 2002 by the Society of Civil Law with the goal of preventing future problems in the project and offering straightforward guidelines for handling time-related claims. Four methodologies/techniques are covered in the protocol: time impact analysis (TIA), impacted as-planned, collapsed as-built, and as-planned versus as-built [54].

The Protocol's goal is to facilitate communication between the parties who want to recover from each other an extension of time (EOT) and/or payment for the additional resources and time needed to finish a project by offering helpful guidance on some of the common delay and disruption issues that occur on construction projects. The Protocol's objective is to offer the parties a way to resolve these issues and stay clear of pointless arguments. One of the Protocol's focuses is to prevent disputes and, in the event that they cannot be avoided, to minimize their costs by offering reasonable and practical guidance on how to deal with issues of delay and disruption that can be applied to all projects, regardless of their size or complexity. The Protocol provides a range of solutions for some difficulties; the best option is determined by the specific project's nature, scale, and complexity as well as the context in which the issue is being examined. On other matters, there is a recommendation available that the Protocol suggests as the best course of action [56].

Based on whether the impact of the delay is determined before or after the delay event has occurred, SCL classifies each of the four techniques mentioned before as either prospective or retrospective techniques, as illustrated in figure 3.1. Regarding the TIA and window analysis techniques, they can be applied both in the past and in the future because their application depends on the availability of project updates just prior to the event. It further specifies that the following factors will primarily determine which DAT (Delay Analysis Techniques) is selected: the conditions of the contract, the nature of the delay event, the time and documents that are available, the extent of the disagreement, the accessibility of schedule information, and the expertise of the scheduler. Additionally, the protocol emphasizes when each of these techniques should be used depending on the availability and/or dependability of the project documentation, as well as the time and expense involved in using each methodology [54].

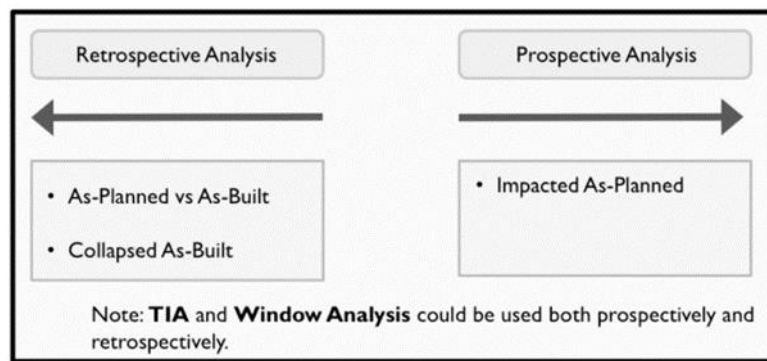


Fig. 3.1 - Delay Analysis Techniques [54].

3.3. ASSOCIATION FOR THE ADVANCEMENT OF COST ENGINEERING

Another document that is relevant mentioning when it comes to offering basic technical principles and guidelines for the application of critical path method (CPM) scheduling is the AACE International (Association for the Advancement of Cost Engineering Int.) Recommended Practice (RP) No. 29R-03, titled "Forensic Schedule Analysis".

AACE International, the Association for the Advancement of Cost Engineering, was founded in 1956. Cost engineering is a study field that employs a combination of integrated techniques and strategies to support business enterprises' asset management decision-making. Global industry professionals create, develop, and apply AACE's Body of Knowledge [57].

The RP is not meant to be a prescriptive guide that is followed strictly or to set a standard of practice. Therefore, as long as any deviation from the recommended protocols depends on a thoughtful and sensible use of schedule analysis principles, it shouldn't be instantly interpreted as an error or a flaw. The RP should be used in conjunction with professional judgment and subject-matter expertise, just like any other recommended practice. Although the recommended protocols are meant to assist the practitioner in producing a competent work product, there may be situations when more or fewer steps are needed.

AACE acknowledges that the methods of analysis to be performed in a given scenario and how a specific methodology might be applied depend on a number of variables, such as the contract, the facts, the applicable laws and regulations, the quality and availability of contemporaneous project documentation, and other particular to the situation aspects.

Now to comprehend the concept of "Forensic scheduling analysis" - it is the study and the examination of occurrences using CPM or other accepted schedule computation techniques. It is acknowledged that these assessments could be relevant to a legal case. In order to comprehend the relevance of a particular departure or set of deviations from some baseline model and their involvement in figuring out the order of tasks within the complex network, it is the study of how actual events interacted in the context of a complex model.

The forensic schedule analysis technique and methods are well-known in the business and go by common names. However, the industry uses these names in an undisciplined and loose manner - instead, the RP connected the common names with a taxonomic categorization. This taxonomy enables a more focused and objective analysis as well as the freedom of regional, cultural, and temporal variations in

the usage of common names for these techniques. The taxonomic classification to which different methods belong is described in detail in figure 3.2 below [58].

TAXONOMY		1	RETROSPECTIVE													
		2	OBSERVATIONAL							MODELED						
		3	STATIC LOGIC			DYNAMIC LOGIC				ADDITIVE				SUBTRACTIVE		
		4	Gross	Periodic		Contemporaneous Updates		Modified / Reconstructed Updates		Single Base		Multi Base		Single Simulation		Multi Simulation
		5		Fixed Periods	Variable Windows	All Periods	Grouped periods	Fixed Periods	Variable Windows	Global Insertion	Stepped Insertion	Fixed Periods	Variable Windows or Grouped	Global Extraction	Stepped Extraction	Fixed Periods
COMMON NAMES		As-Planned vs As-Built	Window Analysis		Contemporaneous Period Analysis, Time Impact Analysis	Contemporaneous Period Analysis, Time Impact Analysis, Window Analysis	Contemporaneous Period Analysis, Time Impact Analysis	Window Analysis, Time Impact Analysis	Impacted As Planned, What-if	Time Impact Analysis, Impacted As-Planned	Time Impact Analysis	Window Analysis, Impacted As-Planned	Collapsed As-Built	Time Impact Analysis, Collapsed As-Built	Time Impact Analysis, Collapsed As-Built	Time Impact Analysis, Window Analysis, Collapsed As-Built

Fig. 3.2 - Taxonomy Classification [58].

The Schedule Impact Analysis Taxonomy, developed by RP, is a hierarchical classification system that includes established procedures for analyzing the effects of delays and disruptions on complete CPM networks.

3.4. IMPORTANCE OF THE BASELINE FOR DELAY ANALYSIS

Despite the contractual provisions addressing delays, contracting parties frequently encounter challenges determining the true cause(s) of the delay and the proportion of each party's responsibility, in order to determine the appropriate time and/or cost compensations. First, there are issues related to contracts, such as unfair risk allocation in contracts and unclear or incomplete contract documents. Despite efforts to resolve these concerns, companies have not been able to do so, in part because their contract agreements do not appropriately and completely cover all potential ambiguities. The second concern is the insufficiency or absence of information required to support and quantify the claims made. Compared to the prior, the second problem is less difficult to resolve, for instance by starting to upgrade construction companies' information management systems. The development and maintenance of construction schedules is a significant source of the required information. Specifically, the critical path method program form is currently a crucial prerequisite for the examination of delay claims [59].

When it comes to these traditional CPM programs, they are based on the fundamental premise that resources are endless, but this is not always the case because most real-world scenarios include limited resources. Therefore, it is crucial that baseline schedules have a lot of resources in order to guarantee consistent timelines for task conclusion and network logic, particularly when multiple tasks use the same resources at once.

Without this loading, the delay analysis schedule would not display realistic float values in its non-critical tasks, which would have an impact on the analysis's results, particularly in situations where time extension claims are resolved. To ensure accurate and reliable results, resource loading or leveling considerations are therefore very important in delay analysis, with the exception of the collapse as-built technique, which does not rely on baseline schedules [60].

As mentioned before, project scheduling is one essential tool for project management. Schedules for all projects must be managed, even for smaller projects. The project's milestones and completion dates are projected in the schedule, and it is also used to track status and manage daily tasks and resources. That

is why, one of the most common and recognized tools regarding project management disciplines is scheduling [61].

A high-quality project schedule integrates technical and financial information to facilitate project management choices and actions. This is a crucial tool for stakeholders and project managers to comprehend project status and the probable trajectory of following activities, which is why choosing a suitable project organization form and construction method can be greatly influenced by a high-quality project schedule [62]. In the next figure 3.3 is a scheme representing a possible way to arrange and organize a project schedule.

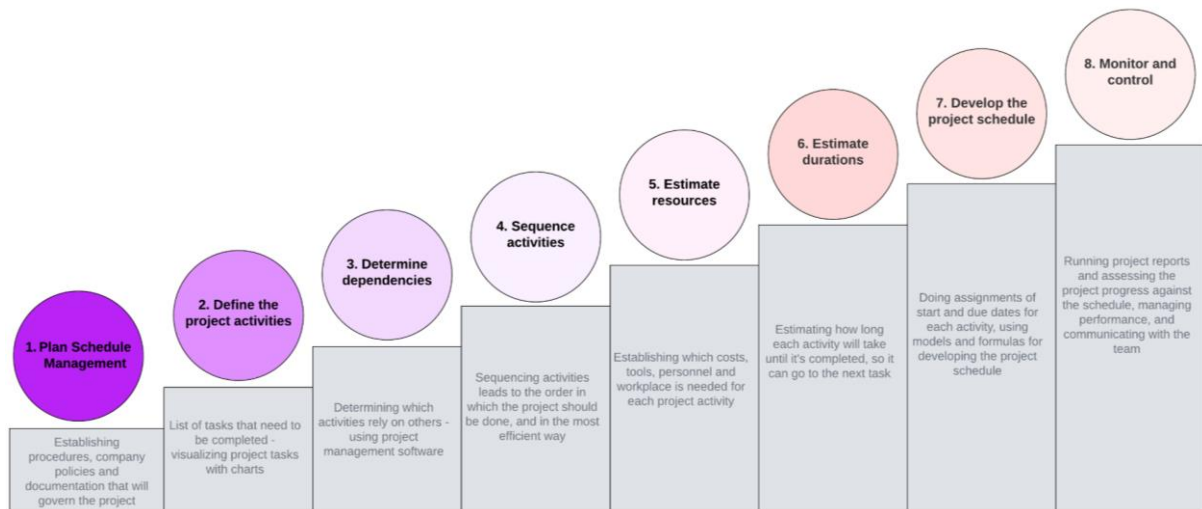


Fig. 3.3 - Project Scheduling Process [63].

In project planning and controls, project scheduling is probably the most often used discipline. In every sector, nation, and organizational setting, thousands of people with varying degrees of education and expertise engage in scheduling. Many organizations offer scheduling software, and they are more than willing to teach schedulers the most recent versions [61].

To guarantee that a schedule is developed correctly, schedule assessment models were established. Constructability reviews and scheduling-related reviews are two categories under which the checks fall. Despite the rise of building information modeling in the construction sector, the majority of automated models now in use are designed for two-dimensional schedules. Typical two-dimensional schedules are not the same as the type, method, and relationships between stored temporal information for activities in nth-dimensional models [64].

A few guides have been created by US government agencies. The Government Accountability Office (GAO) and the National Defense Industrial Association's (NDIA) Industrial Committee for Program Management (ICPM) produced the Planning and Scheduling Excellence Guide (PASEG) and the GAO Cost Estimating and Assessment Guide, where a few recommended practices for schedule development [65].

The US Defense Contract Management Agency's (DCMA) assessment approach is the most widely used when it comes to pre-construction and construction processes [64].

In the interest of generating project baselines, detailed schedules are necessary. They are also required for tracking, reporting progress, and managing construction conflicts. Additionally, they offer the fundamental legal framework for resolving construction-related disputes and claims and it is highly

important to confirm that these schedules are appropriate for the purposes for which they are designed [65].

A well-developed project schedule and model not only provides tools for various analyses, project control, and partner cooperation, but it can also aid in the explanation of the project dynamics. Generally speaking, scheduling serves as a guide that specifies how and when the project will deliver the items that the team and the project scope have agreed upon [62].

The term "dynamic nature of project management" refers to dynamic project scheduling, and baseline scheduling, schedule risk analysis, and project control are its three components (scheme represented in figure 3.4). It has been demonstrated in earlier research that schedule risk analysis and project control work best together as complementary instruments to assess a project's progress and enhance the process of project control and decision-making for corrective action when the project is at risk [66].

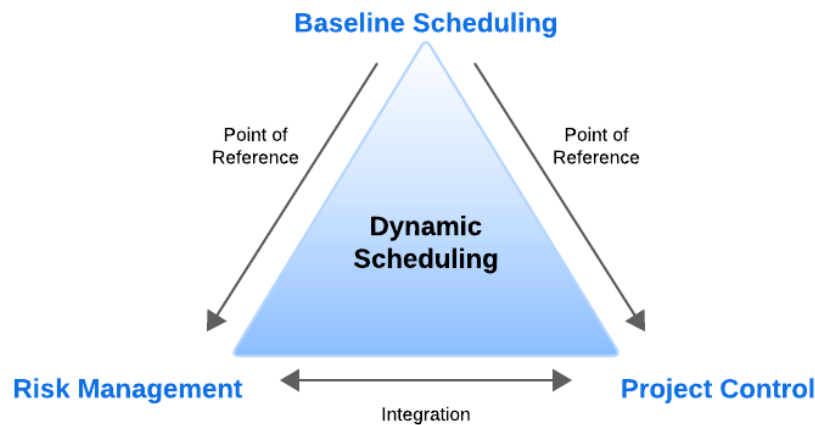


Fig. 3.4 - Dynamic Schedule [67].

3.5. BASELINE SCHEDULING

In order to optimize a specific project objective (such as lead-time minimization, cash-flow optimization, etc.), project scheduling started out as a research track within the mathematical field of operations research. This allowed researchers to determine the start and finish times of project activities subject to precedence and resource constraints. The early research, which was carried out in the late 1950s/early 1960s, primarily concentrated on network-based techniques, such as the previously mentioned PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method), which are now widely acknowledged as crucial tools and procedures for project management. Since then, a significant quantity of research has been conducted on a range of project scheduling topics (e.g., time scheduling, resource scheduling, cost scheduling).

It requires assigning start and end times to each task in order to maximize a scheduling objective. Consequently, the quality of the project's baseline schedule and the scheduling performance of the algorithm or software used to create the schedule are determined by this scheduling objective, which is a critical component in the creation of the baseline schedule. The majority of evaluations of project scheduling software products do not provide scheduling performance findings for other objectives, instead emphasizing time minimization as the main scheduling goal [66].

The contract master schedule, contract specifications, and contract documents serve as the foundation for the approval of baseline schedules. The contractor's timetable becomes the standard schedule if it is

accepted by the owner's project team. In this case, the contractor's baseline schedule needs to meet three main conditions:

- Firstly, there can be no extensions to the project's entire time. If an early completion is requested during the bidding process, it can be reviewed. Certain design-build bids assess early completion in determining contract award and may include an additional (success) fee to compensate for early completion. Late completion during project execution is discouraged with penalty (late) fees, as stated in all contracts;
- The needed production rate is the subject of the second requirement - In one-time contracts, the proposed schedule should generally state the set money worth of work to be completed for each full year from the start of on-site work. According to these criteria, the construction process has to deliver an average production rate on-site, which will be displayed in the baseline schedule. As a result, the schedule needs to estimate the desired production rate and contain the entire scope of work as specified in the Work Breakdown Structure;
- The third requirement focuses on the building process's health and safety as well as workflow. The baseline schedule's process logic must demonstrate an efficient, practical, and safe flow of work. Interferences are not allowed, so crew time-space conflicts are permitted.

Since the baseline approval process is contract-based, obtaining the owner's permission requires fulfilling each of these three primary contract requirements in its entirety [68].

3.6. DCMA

The government agency in charge of managing the supply of goods, equipment, and components used by the US military and associated warfighters is called DCMA (Defense Contract Management Agency). DCMA is responsible for the management and supervision of procurement-related activities that improve the lethality of warfighters as part of its contract administration services [69].

The Department of Defense (DoD) makes use of contract administration services from the Defense Contract Management Agency (DCMA). Their goal is to oversee and give "actionable acquisition insight" so that the government and contractors can fulfill their contractual duties. A 14-point schedule assessment was created by The DCMA as part of this initiative, and it is detailed in the Program Analysis Pamphlet (PAP), a Portfolio Management and Integration policy, and the Earned Value Management System (EVMS) [70] - As mentioned before, the EVMS is a useful method that creates a baseline plan that serves as the foundation for tracking progress by integrating the internal business systems, processes, procedures, and tools of a contractor. The Cost Accounting System (CAS), the Material Management and Accounting System (MMAS), the Cost Estimating System, the Purchasing System, the Program Management, and the Engineering Cost and Schedule Planning Processes are the business systems and procedures associated with EVMS [71].

Beyond the simple examination of cost and schedule reports, the project manager can determine the quantity of work that is really completed on a project by using the Earned Value Analysis (EVA) method. EVA offers a way to measure the project's success based on the amount of progress made. Based on trend analysis or the application of the project's "burn rate," the project manager can then estimate the project's total cost and completion date using the progress that has been monitored. The project's earned value serves as the foundation for this methodology [72]. The Defense Contract Management Agency's (DCMA) Earned Value Management Center uses the Earned Value

Management System Interpretation Guide (EVMSIG) [73], the Department of Defense policy for EVMS, to evaluate conformity [71].

The DCMA 14-Point assessment is a set of schedule evaluation recommendations that were initially provided by the Defense Contract Management Agency [74] - the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L) issued a memorandum in March 2005 requiring Integrated Master Schedules (IMS) for all contracts exceeding \$20 million, which served as the primary stimulus for the creation of the 14-point assessment. This memorandum also required DCMA to create and maintain guidelines for schedule conformity and evaluation. In response, DCMA created a 14-point evaluation as a scheduling quality control tool [70]. The DCMA 14-Point assessment is the most extensively used and well-known of the schedule-driven standards or evaluation criteria that have been produced by many other Agencies and organizations, including the DOE, NAVAIR, GAO, NASA, and NDIA.

The purpose of the DCMA 14-Point evaluation is to serve as a tool-agnostic and enable the least amount of work necessary to complete an evaluation for scheduled health. Based on quantifiable standards derived from industry-defined scheduling best practices, the 14-Point Assessment offers a quantitative evaluation of schedule quality [74].

The 14-point evaluation is based on mathematical computations and can be completed manually or automatically using macros or applications/programs. To achieve the necessary schedule quality, the DCMA metrics can be changed based on predetermined thresholds [75]. The list of the 14-point checks done with the DCMA guidelines is the following [74, 76] :

1. LOGIC

This metric check verifies that all unfinished tasks have clearly defined predecessors and successors. The progress of the project can be greatly affected by a single missing link, consequently, the team must carefully examine the network logic to make sure all dependencies are taken into account. For this metric, the DCMA requirement is that no more than 5% of incomplete actions should be missing a predecessor and successor. Organizations frequently enforce a stricter approach, however, stating that all incomplete tasks — aside from milestone, level-of-effort, and summary tasks—have predecessors and successors. It is recommended that activities without true predecessors or successors in scope be connected to the project start or project ending milestones, respectively, at the very least. This shows that it's not just to overlook the dependencies — it takes them into consideration.

2. LEADS

A lead is a negative lag between two tasks when one begins a few days ahead of the other's completion date. Utilizing leads may negatively impact the project's overall float, making it more difficult to identify the true critical path. Consequently, this makes it one of the rare measures with a zero DCMA threshold. It is preferable to break down tasks into segments allowing the application of conventional finish-to-start relationships rather than utilizing leads.

3. LAGS

Positive lags, in which a task begins a certain number of days after its predecessor work's completion date, can also have a negative impact on the critical path analysis of the project. Furthermore, lags can

be confusing if their cause is not clear right away. With regard to this statistic, DCMA is more tolerant, putting the threshold at 5% of all task relationships. Nonetheless, it is frequently preferable to indicate a lag with a task that is specifically mentioned. For example, using a separate task to represent delivery time rather than adding a 5-day lag to account for customer shipping.

4. RELATIONSHIP TYPES

The finish-to-start (FS) relationship is the ideal one when it comes to tasks. To provide the best possible understanding of the critical path, every task in the schedule should ideally be ordered in this manner. However, there are situations where other kinds of connections are appropriate. According to DCMA, finish-to-start relationships should account for at least 90% of all activity relationships. When the dependency actually is finish-to-finish (FF) or start-to-start (SS), those relationships may be applied. It makes reasonable sense, for instance, for a review to start after the action it is auditing has started. Furthermore, it's reasonable that a Quality Assurance (QA) examination would not be finished until the product or process under inspection is finished. It is not advisable to make use of start-to-start and finish-to-finish relationships only to arrange activities in parallel if they are not really dependent on one another. Giving the two simultaneous activities the same finish-to-start predecessor(s) is preferable in these situations. Start-to-finish (SF), the fourth relationship type, should only be utilized in exceptional circumstances because it can overly complicate the schedule's network logic.

5. HARD CONSTRAINTS

Generally speaking, constraints should be applied with caution, letting task dates emerge naturally from dependencies and activity duration. But when it comes to scheduling, soft constraints - Start No Earlier Than (SNET) and Finish No Earlier Than (FNET) - are better because they preserve the schedule's logic-driven nature. There are also two more soft constraints - As Soon As Possible (ASAP) and As Late As Possible (ALAP). Hard restrictions, on the other hand, artificially prevent the schedule from shifting to the right. These constraints are Start No Later Than (SNLT), Finish No Later Than (FNLT), Must Start On (MSO), and Must Finish On (MFO). This could have the impact of making it harder to detect late performance before it's too late to make corrections. The critical path of the schedule may also be obscured by hard constraints. Hard constraints should be used for no more than 5% of the incomplete activities in the schedule, according to the DCMA criteria. But this is another area where an organization may decide to set stricter limits. The schedule should ideally not have any rigid restrictions. It is better to represent hard dates with deadlines so that the schedule can foresee late deliveries early and make necessary corrections.

6. HIGH FLOAT

Corrective actions deal with quickly approaching or actual issues; high float is defined by DCMA as a total float of 44 days, or roughly two working months, or more. It seems to make sense intuitively to think of high float activities as a positive aspect of schedule margin. High float, on the other hand, is typically the consequence of missing dependencies. Occasionally an activity can take longer than two months to complete without affecting the project's deadline. This metric's cutoff is established at 5% of all incomplete tasks.

7. NEGATIVE FLOAT

Negative float appears when a hard constraint moves a task further to the left than it would normally be, or when the project schedule forecasts missing a deadline. In both cases, there's a good chance that a crucial date will be missed in the future, and the project team will probably have to accelerate or drastically alter the schedule to bring it back under control. DCMA would prefer to see absolutely no negative float. The project manager has the right to ask for an explanation and a corrective plan if the negative float is accurate with regard to a contractual or important date.

8. HIGH DURATION

Breaking down work assignments into manageable sections involves making sure that each activity is distinct enough to be monitored and controlled. Any incomplete activity that falls under the detailed planning period or rolling wave and has a baseline duration longer than 44 days, or roughly two working months, is considered to be in violation of this criteria by DCMA. This makes it easier to decide if it's best to divide a task into two or more smaller projects or leave it as one larger activity. Activities that go longer than the established make it challenging to evaluate performance and estimate resources in a way that is fair. In situations where additional decomposition of an activity is not possible, the project manager should have a well-defined approach for evaluating performance.

9. INVALID DATES

The invalid date check is when a task has projected start and finish dates in the past or actual start and finish dates in the future in relation to the project status date. This metric's threshold is zero. Tasks that have not yet begun or completed must be advanced past the status date and tasks that have begun or finished ahead of schedule must be updated with the correct start and end dates. One of the most important criteria is this one, since tasks that don't meet their call on the legitimacy of the rest of the schedule.

10. RESOURCES

Ideally, resources or costs should be allocated to every activity on the project schedule. Not every organization resource loads its project schedules in reality. Furthermore, there are times when tasks with durations longer than zero - like procurement lead-time or customer reviews of deliverables - represent time but involve no work. When resources are added to the schedule, this metric looks for missing resources. This is one of the 14-point assessment's flexible metrics.

11. MISSED TASKS

The missed tasks measure shows how well the schedule is doing in comparison to the original plan. It is the percentage of tasks with actual or estimated finish dates that are later than their baseline finish dates and whose baseline finish date is on or before the project status date. If a task's baseline finish date is after the status date, it excludes tasks that are currently forecasted late. It is entirely retrospective in that sense. The DCMA threshold for missing tasks is 5% of the anticipated total tasks of the project; however, once a project is delayed too much, recovery is no longer guaranteed.

12. CRITICAL PATH

The critical path test is a pass/fail metric used to assess how well the schedule's network logic is integrated. To conduct this test, it's necessary to locate the critical path in the schedule, and then intentionally add a small bit of schedule slip to the path's initial task. The test is considered successful if there is an equivalent amount of scheduled slides on the project completion milestone. A failing test indicates that there are dependencies missing, which calls for a more thorough examination of the network logic.

13. CRITICAL PATH INDEX (CPLI)

The amount of schedule efficiency needed to finish a project or an important milestone is measured by the Critical Path Length Index or CPLI. It functions as the To-Completion Performance Index's (TCPI) scheduling equivalent. Its definition is the number of working days on the critical path (the amount of time from now to the baseline finish of the task or milestone being measured) plus the total float, divided by the same amount of duration without float. In this case, the total float is the variation between the baseline finish date of the task/milestone anticipated finish date and the actual projection. A CPLI of 1.00 means that in order to complete the assignment or reach the milestone, the project must go precisely as planned. In order to fulfill the baseline finish date, the team must overachieve if the CPLI is less than 1.00, indicating that there is still a scheduling margin. A CPLI of below 0.95, in the opinion of DCMA, may indicate a possible problem that needs more research.

14. BASELINE EXECUTION INDEX (BEI)

The Baseline Execution Index (BEI), the last metric, is an additional indication used to compare performance to the baseline plan. Stated differently, it quantifies the rate at which the project team completes tasks. The cumulative and hit task computations are defined by DCMA. To compute the cumulative computation, divide the total number of tasks performed regardless of the baseline by the total number of tasks that have a baseline completion date on or before the current reporting period (status date) and tasks that do not have a baseline finish date. When the BEI is 1.00, it means the project team is working according to the plan; a BEI of less than 1.00 means the team is running behind schedule. A BEI of less than 0.95 is regarded by DCMA as suggestive of a possible problem requiring additional research.

Every year, the DCMA monitors the contractor's EVMS to make sure it continues to be compliant through compliance surveillance. Let's say that, during this annual process, the DCMA EVMS Center discovers any substantial vulnerabilities. They can then advise the contracting officer to review the system to determine its root cause or level of dissatisfaction. The contracting officer has the authority to demand a compliance check in any scenario [71].

During the schedule's delivery phase, the DCMA 14-point analysis is applied. This approach initiates at the beginning of the delivery phase and can be used at the beginning of each project update cycle throughout the schedule. The objective is to ensure the preservation of schedule quality across the entire delivery lifecycle. Maintaining the coherence of a project schedule within a schedule is essential for achieving the delivery of schedule outcomes. Improving the quality and stability of each individual schedule has been proven to boost project team productivity and enhance overall project execution.

Additionally, from a schedule perspective, the key information derived from the projects is crucial for upholding the overall integrity of the schedule [77].

After describing the DCMA 14-point assessment, it is possible to conclude that in order to make a complete assessment of a schedule baseline, only points 1 to 10 and point 12 would be applicable, since the remaining 3 relate the schedule defined initially to what is happening during the course of the project in question.

When also assessing delay and disruption claims, experts often encounter a lack of clarity and missing documentation regarding what was delayed or interrupted and how specific aspects of the project were affected. This uncertainty underscores the importance of maintaining accurate records and leveraging effective schedule management practices. Comprehensive documentation not only helps in managing progress effectively but also facilitates early claim evaluation, thereby reducing the possibility of disputes. The presence of adequate and accurate documentation streamlines progress management and enables timely assessments of delays or disruptions, consequently reducing the cost associated with these evaluations. Thus, the significance of maintaining top-quality records and doing schedule health checks for every project is very important, and cannot be underestimated [77].

3.7. CONCLUSIONS

In conclusion, regular schedule health checks, guided by frameworks such as the DCMA 14-Point Assessment, are outstanding for ensuring project controls, maintain appropriate records and a project's success. These assessments not only validate the integrity of project schedules but also serve as crucial tools for identifying potential risks and deviations from the baseline. By conducting thorough evaluations of schedule quality, project teams can proactively address issues, optimize resource allocation, and mitigate delays. Furthermore, the establishment of a robust baseline provides a solid foundation for delay analysis, enabling stakeholders to accurately assess the impact of disruptions and deviations from the original plan. In the next chapter, the author will delve into the methodology employed for the study cases, elucidating the steps taken to analyze and optimize project baseline schedules using the principles outlined herein.

4

ANALYSIS OF CASE STUDIES

4.1. INTRODUCTION TO CASES OF STUDY: ENHANCING PROJECT MANAGEMENT EFFICIENCY

In the previous chapters, the author presented the importance of delay analysis, and the need for a quality baseline so that the software can reliably project delays resulting from certain events. The author will then present two case studies where these concepts will be explored.

For these case studies, a meticulous examination and optimization of real-world projects was initiated. The focus lies in employing the notable Defense Contract Management Agency (DCMA) 14-Point Assessment guidelines to assess the projects' baselines comprehensively.

Initially, information from each project's schedule was transferred from Microsoft Project. The aim was to simplify the transfer of relevant project information into Microsoft Excel, facilitating a detailed analysis. Excel's robust analytical capabilities made it possible to examine the projects' schedules, resource allocations, and critical milestones.

Subsequently, attention will be turned to enhancing project scheduling and management through the implementation of Candy software. This tool facilitates the meticulous replanning tasks of the projects, ensuring alignment with the rigorous criteria outlined in the DCMA 14-Point Assessment guidelines. The aim is to optimize scheduling, resource utilization, and task sequencing while upholding the integrity of each project's baseline.

By meticulously analyzing and optimizing the projects using a combination of Microsoft Project, Excel, and Candy software, the aim is to validate adherence to the DCMA 14-Point Assessment guidelines. Through this rigorous process, the goal is to enhance project management efficiency, mitigate risks, and pave the path for successful project execution.

4.2. CASE OF STUDY NO. 1 - BASELINE ANALYSIS

4.2.1. PROJECT SUMMARY

The first case study consists of the examination of an infrastructure project—a communication route. It will serve as the first case study in the author's exploration of project management methodologies and their applications. The route, which is situated in Portugal's Viseu district, intends to provide a substitute between the area's Enterprise Zone and a national road in order to enhance mobility and safety conditions and reduce travel times, particularly for large vehicles, to the business park. Next is represented the project (figure 4.1).

This project consists of linking two existing routes and is divided into three major sections: the first is the rehabilitation of an existing main route and the construction of uneven crossings made of an

embankment and their accesses so that they can later connect with section 2 of the project. Section 2 will be the widening of a channel of a former municipal road, which will include the widening of the road and the rehabilitation of the existing lane.



Fig. 4.1 – Section 1 from project of Case Study 1.

As for the third and final section of the project, it will be completely new, connecting with section 2 to a national road.

The communication route project stands as a critical endeavor, pivotal for enhancing connectivity and facilitating efficient communication flow. To begin with the project analysis, the primary objective is to scrutinize the project's baseline meticulously. To achieve this, it will utilize the Defense Contract Management Agency 14-Point Assessment guidelines, as mentioned before.

Following this introduction, the author will initiate the analysis of the project's baseline, employing the DCMA 14-Point guideline as the framework for evaluation. Through rigorous examination and meticulous assessment, the aim is to unravel insights contributing to project optimization and success.

4.2.2. ANALYSIS

To begin the baseline analysis, it is necessary to use the first 10 points, as well as point 12, of the DCMA's 14-Point Assessment.

The information needed to proceed with the analysis of points 1-10 was transferred from MS Project to Excel, allowing the author to analyze the DCMA points with ease. For point 12 the author used the MS Project to analyze its changes when checking this requirement.

It's important to mention that for this case, the schedule that will be presented below in figure 4.2 as the baseline for using DCMA 14 - Point Assessment was based on a bill of quantities, so it won't have the desirable structure and arrangement that the result of the analysis is the best.



ID	Outline Level	Work fronts	Item	Activities	Quant	Un	Duration	Start	Finish	Predecessors	Successors	Prod.day	Total Stock	Resource Names	Duration (d:calend)	Constraint Type	Cost	
1	1			ASSINATURA CONTRATO			0 d	Tue 26/11/22	Tue 26/11/22				586 d			Start No Earlier Than	#####	
2	1			CONSIGNAÇÃO			0 d	Mon 15/01/24	Mon 15/01/24		546.549.551.552.553.548		0 d			Start No Earlier Than	#####	
3	1		R.01	Terraçaplagagem			181 d	Mon 29/01/24	Mon 07/02/24				0	0 d		As Soon As Possible	#####	
4	2		R.01.01	Trabalhos preparatórios			120 d	Mon 29/01/24	Fi 12/02/24				0	0 d		As Soon As Possible	#####	
5	3	Trapa 2	R.01.01.01	Desmatagem, incluindo derruba de árvores, desmatamento, limpeza do terreno	127650	m2	25 d	Mon 29/01/24	Fi 01/02/24	54655+10 d	1055.41.55555.55855.6.7.54755.12	5118	0 d	Servente / Ajudante(200%)	33 d	As Soon As Possible	#####	
6	3	Trapa 1.2+3	R.01.01.02	Demolição de construções (excluindo muros)	666	m2	5	955	Mon 29/01/24	Fi 12/02/24		22.2	227 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	
7	3	Trapa 1.2+3	R.01.01.03	Demolição de muros	1568	m2	5	955	Mon 29/01/24	Fi 12/02/24		52.27	227 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	
8	3		R.01.01.04	Desativação de poços, nascentes ou outras captações existentes			35 d	Mon 29/01/24	Fi 16/02/24				0	247 d	Servente / Ajudante(200%)	47 d	As Soon As Possible	#####
9	4	Trapa 1+2	R.01.01.04.01	Enchimento de poços com entrocamento	260	m3	10 d	Mon 04/02/24	Fi 15/02/24	755.655		26	247 d		12 d	As Soon As Possible	#####	
10	4	Trapa 1+2	R.01.01.04.02	Captação e condução de águas	197	m4	5	955	Mon 29/01/24	Fi 15/02/24	555	5.63	247 d		47 d	As Soon As Possible	#####	
11	3		R.01.01.05	Decapagem na linha de terra vegetal			60 d	Mon 04/02/24	Fi 24/02/24				0	0 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	#####
12	4	Trapa 1	R.01.01.05.01	Vazadouro	39937	m3	60 d	Mon 04/02/24	Fi 24/02/24	5 1355.1555.1755.1855.297.298.299.		648.95	0 d		#####	As Soon As Possible	#####	
13	4	Trapa 1	R.01.01.05.02	Depósito Provisório	3730	m3	4 d	Mon 04/02/24	Tha 07/02/24	1255		932.5	253 d		#####	As Soon As Possible	#####	
14	3		R.01.01.06	Preparação da fundação de aterros em condições especiais (Sanamentos)			95 d	Mon 04/02/24	Fi 12/02/24				0	0 d		As Soon As Possible	#####	
15	4	Trapa 1	R.01.01.06.01	Sanamento em fundação de aterros	59015	m3	10 d	Mon 04/02/24	Fi 14/02/24	1255 20FF.2355+30 d.527.490.16FF+30 d.		907.92	0 d	Servente / Ajudante(200%)	89 d	As Soon As Possible	#####	
16	4	Trapa 1	R.01.01.06.02	Preenchimento dos volumes saneados	86200	m3	10 d	Mon 11/02/24	Fi 12/02/24	16FF+30 d 20FF.527.490		960	7 d	Servente / Ajudante(200%)	124 d	As Soon As Possible	#####	
17	4	Trapa 1.2+3	R.01.01.06.04.01	Geossintéticos fundação Sobre bacias abissolares	95494	m2	10 d	Mon 04/02/24	Fi 24/02/24	1255		1591.57	197 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	#####	
18	4	Trapa 1.2+3	R.01.01.06.04.03	Geossintéticos em fundação função de reforço	82282	m2	60 d	Mon 04/02/24	Fi 24/02/24	1255		1371.37	197 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	#####	
19	3		R.01.01.07	Camada drenante subjacente ao geotêxtil			30 d	Mon 03/02/24	Fi 12/02/24				0	7 d		As Soon As Possible	#####	
20	4	Trapa 1	R.01.01.07.04	Em materiais britados	8874	m3	30 d	Mon 03/02/24	Fi 12/02/24	16FF.16FF 22355+14 d		295.8	7 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	
21	2		R.01.02	Escavação na linha e colocação em aterro ou vazadouro			116 d	Mon 15/04/24	Fi 25/05/24				0	0 d		As Soon As Possible	#####	
22	3	Trapa 1	R.01.02.01	Escavação	47707	m3	75 d	Mon 15/04/24	Fi 26/07/24	1555+30 d 6355.5055.2955		636.09	0 d	Servente / Ajudante(200%)	103 d	As Soon As Possible	#####	
23	3	Trapa 1	R.01.02.03.01	Aterro	47707	m3	75 d	Mon 15/04/24	Fi 26/07/24	1555+30 d 6355.24.5055		636.09	38 d	Servente / Ajudante(200%)	103 d	As Soon As Possible	#####	
24	3	Trapa 1.2+3	R.01.02.05	Escavação de solos a rejeitar	1463	m3	10 d	Mon 29/07/24	Fi 06/08/24	23 29FF		146.3	142 d	Servente / Ajudante(200%)	12 d	As Soon As Possible	#####	
25	3	Trapa 1.2+3	R.01.02.06.01	Regularização de taludes de Escavação	8335	m2	30 d	Mon 07/07/24	Fi 06/08/24	24FF		277.83	142 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	
26	3	Trapa 1.2+3	R.01.02.07	Regularização de taludes de aterro	30738	m2	10 d	Mon 13/08/24	Fi 30/09/24	39FF 42FF		1024.6	68 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	
27	3		R.01.03	Escavação em empreitadas			116 d	Mon 15/04/24	Fi 25/05/24				0	0 d		As Soon As Possible	#####	
28	3		R.01.03.01	Escavação em empreitadas em terreno de qualquer natureza e colocação em aterro			116 d	Mon 15/04/24	Fi 25/05/24				0	0 d		As Soon As Possible	#####	
29	4	Trapa 1	R.01.03.01.01	Carga, transporte, equipamento e compactação	147114	m3	115 d	Mon 15/04/24	Fi 25/05/24	2355 36FF.33FF+10 d.154FF		1279.25	0 d	Servente / Ajudante(200%)	159 d	As Soon As Possible	#####	
30	2		R.01.04	Leito do pavimento, incluindo tratamento ou fornecimento, e colocação dos materiais			30 d	Mon 19/08/24	Fi 27/09/24				0	101 d		As Soon As Possible	#####	
31	3		R.01.04.03	Em aterros de solos/ Em escavações ou perfis mistos em solo			30 d	Mon 19/08/24	Fi 27/09/24				0	101 d		As Soon As Possible	#####	
32	4			Em material granular			30 d	Mon 19/08/24	Fi 27/09/24				0	101 d	Camêlo Bascante VOLC	40 d	As Soon As Possible	#####
33	5	Trapa 1	R.01.04.01.03.04	Aterro com 0,20m	35306	m2	15 d	Mon 19/08/24	Fi 06/09/24	29FF.10 d 34.3555		2353.74	101 d		19 d	As Soon As Possible	#####	

Fig. 4.2 – Extract from the project's schedule of the Case Study 1.

As the first step of action, the author identified in a logical way what was a task and what wasn't, for example, in the figure above (4.2) there were some cells with different outline levels, meaning that some of these lines weren't representing tasks, but a group of them.

The method used to identify the tasks consisted of counting, for this case, the tasks that had units (e.g. ml, m², m³). The results were presented as the following (figure 4.3):



Activities	Quant	Predecessors	Successors	Prod.day	Total Stock	Resource Names	Duration (d:calend)	Constraint Type	Cost	tasks count
ASSINATURA CONTRATO					586 d			Start No Earlier Than	#####	
CONSIGNAÇÃO			546.549.551.552.553.548		0 d			Start No Earlier Than	#####	
Terraçaplagagem:				0	0 d		253 d	As Soon As Possible	#####	1
Trabalhos preparatórios				0	0 d		166 d	As Soon As Possible	#####	0
Desmatagem, incluindo derruba de árvores, desmatamento, limpeza do terreno	1E+05	54655+10 d	1055.41.55555.55855.6.7.54755.12	5118	0 d	Servente / Ajudante(200%)	33 d	As Soon As Possible	#####	1
Demolição de construções (excluindo muros)	666	5 955		22.2	227 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	1
Demolição de muros	1568	5 955		52.27	227 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	1
Desativação de poços, nascentes ou outras captações existentes				0	247 d	Servente / Ajudante(200%)	47 d	As Soon As Possible	#####	0
Enchimento de poços com entrocamento	260	755.655		26	247 d	As Soon As Possible	#####	As Soon As Possible	#####	1
Captação e condução de águas	197	555		5.63	247 d	As Soon As Possible	#####	As Soon As Possible	#####	1
Decapagem na linha de terra vegetal				0	0 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	#####	1
Vazadouro	39937	5 1355.1555.1755.1855.297.298.299.		648.95	0 d	As Soon As Possible	#####	As Soon As Possible	#####	1
Depósito Provisório	3730	1255		932.5	253 d	As Soon As Possible	#####	As Soon As Possible	#####	1
Preparação da fundação de aterros em condições especiais (Sanamentos)				0	0 d		131 d	As Soon As Possible	#####	0
Sanamento em fundação de aterros	59015	1255 20FF.2355+30 d.527.490.16FF+30 d.		907.92	0 d	Servente / Ajudante(200%)	89 d	As Soon As Possible	#####	1
Preenchimento dos volumes saneados	86200	15FF+30 d 20FF.527.490		960	7 d	Servente / Ajudante(200%)	124 d	As Soon As Possible	#####	1
Geossintéticos fundação Sobre bacias abissolares	95494	1255		1591.57	197 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	#####	1
Geossintéticos em fundação função de reforço	82282	1255		1371.37	197 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	#####	1
Camada drenante sobrejacente ao geotêxtil				0	7 d		40 d	As Soon As Possible	#####	0
Em materiais britados	8874	16FF.15FF 22355+14 d		295.8	7 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	1
Escavação na linha e colocação em aterro ou vazadouro				0	0 d		159 d	As Soon As Possible	#####	0
Escavação	47707	1555+30 d 6355.5055.2955		636.09	0 d	Servente / Ajudante(200%)	103 d	As Soon As Possible	#####	1
Aterro	47707	1555+30 d 6355.24.5055		636.09	38 d	Servente / Ajudante(200%)	103 d	As Soon As Possible	#####	1
Escavação de solos a rejeitar	1463	23 29FF		146.3	142 d	Servente / Ajudante(200%)	12 d	As Soon As Possible	#####	1
Regularização de taludes de Escavação	8335	24FF		277.83	142 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	1
Regularização de taludes de aterro	30738	29FF 42FF		1024.6	68 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	#####	1

Fig. 4.3 - Task Count of the Schedule from Case Study 1.

After this evaluation, the tasks were counted, and it was found that there were 312 tasks in this schedule.

4.2.2.1. Missing Logic

The first and major point to be evaluated was the logic point. In this case, the aim was to assess whether there were any incomplete tasks in the project's schedule with missing logical links, i.e. incomplete tasks

that did not have simultaneous links to predecessors and successors. The number of links with missing logic should not exceed 5% of all tasks of the project. Next is figure 4.4 with what was shown in the schedule.

ADAPT

Predecessors	Successors	Prod./day	Total Slack	Resource Names	Duration (d. calend.)	Constraint Type	Cost	tasks count	PRED & SUC
			586 d			Start No Earlier Than	####		
	548;549;551;552;553;548		0 d			Start No Earlier Than	####	1	0
		0	0 d		253 d	As Soon As Possible	####	0	0
		0	0 d		166 d	As Soon As Possible	####	0	0
546SS+10 d	10SS;41;555SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante(200%)	33 d	As Soon As Possible	####	1	1
5 9SS		22.2	227 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	####	1	1
5 9SS		52.27	227 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	####	1	1
		0	247 d	Servente / Ajudante(200%)	47 d	As Soon As Possible	####	0	0
7SS;6SS		26	247 d		12 d	As Soon As Possible	####	1	0
5SS		5.63	247 d		47 d	As Soon As Possible	####	1	0
		0	0 d	Servente / Ajudante(300%)	82 d	As Soon As Possible	####	0	0
5 13SS;15SS;17SS;18SS;297;298;299		648.95	0 d		82 d	As Soon As Possible	####	1	1
12SS		932.5	253 d		4 d	As Soon As Possible	####	1	0
		0	0 d		131 d	As Soon As Possible	####	0	0
12SS 20FF;23SS+30 d;527;490;16FF+30 d		907.92	0 d	Servente / Ajudante(200%)	89 d	As Soon As Possible	####	1	1
15FF+30 d 20FF;527;490		980	7 d	Servente / Ajudante(200%)	124 d	As Soon As Possible	####	1	1
12SS		1591.57	197 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	####	1	0
12SS		1371.37	197 d	Servente / Ajudante(200%)	82 d	As Soon As Possible	####	1	0
		0	7 d		40 d	As Soon As Possible	####	0	0
16FF;15FF 223SS+14 d		295.8	7 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	####	1	1
		0	0 d		159 d	As Soon As Possible	####	0	0
15SS+30 d 63SS;50SS;29SS		636.09	0 d	Servente / Ajudante(200%)	103 d	As Soon As Possible	####	1	1
15SS+30 d 63SS;24;50SS		636.09	38 d	Servente / Ajudante(200%)	103 d	As Soon As Possible	####	1	1
23 25FF		146.3	142 d	Servente / Ajudante(200%)	12 d	As Soon As Possible	####	1	1
24FF		277.83	142 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	####	1	0
29FF 42FF		1024.6	68 d	Servente / Ajudante(200%)	40 d	As Soon As Possible	####	1	1

Fig. 4.4 - Example of what the missing logic point is looking for in the project's schedule from Case Study 1.

The goal was to identify the tasks that had predecessors and successors, so any task missing one of these was going to be considered as tasks with missing logic.

Since the author is initially analyzing the baseline, all the incomplete tasks referred to are meant to be all the tasks in the project, because, at the time of the analysis, it is considered that the project has not yet started.

The following formula was applied to this assessment:

$$\% \text{ Missing Logic} = \frac{\text{Number of tasks missing logic}}{\text{Number of incomplete tasks}} * 100 \quad (1.1)$$

"Missing logic" leads to a static schedule - activity dates are not automatically changed, making it difficult to adapt to changing project circumstances. However, schedules are supposed to be dynamic, they need to be able to change as project situations do. The factor that controls a schedule's degree of flexibility and dynamicity is schedule logic.

For this study case, 312 tasks were identified, and of these, 200 were missing logic by not having predecessors and successors - concluding that 64.10% of the tasks did not comply with the missing logic point, clearly exceeding the 5% margin allowed by the DCMA guideline. It is important to mention that two of the tasks included in the missing logic tasks will be start tasks and end tasks, so even though these are included in the 200 tasks, they should not be considered. With that, the value is updated,

identifying 198 missing logic tasks and getting a percentage of 63.46%, yet still failing to meet the metric.

4.2.2.2. Leads

This metric determines which links in the predecessors' relationships have a negative lag (lead). The DCMA guideline doesn't allow any leads in the schedule, as they alter the total float of the schedule and can cause conflicts in resources.

For this second point of the guideline, there's also a formula to use, which is the following:

$$\% \text{ Leads} = \frac{\text{Number of logic links with negative lag}}{\text{Number of logic links}} * 100 \quad (1.2)$$

Since for this metric, the formula refers to the number of connections as the comparison quantity, it was necessary to make this count, so the approach adopted in Excel by the author is shown in figure 3.4. In this, it was possible to separate all the links presented in the schedule in order to obtain the total link quantity of all the tasks with predecessors.

The figure 4.5 below shows the separation done with the predecessor's links, and the same was made with the successors, counting the total links. The total number of links was 751.

ADAPT

Predecessors	Predecessors				
546SS+10 d	546SS+10 d				
5	5				
5	5				
7SS;6SS	7SS	6SS			
5SS	5SS				
5	5				
12SS	12SS				
12SS	12SS				
15FF+30 d	15FF+30 d				
12SS	12SS				
12SS	12SS				
16FF;15FF	16FF	15FF			
15SS+30 d	15SS+30 d				
15SS+30 d	15SS+30 d				
77FF;79FF;82FF;88FF;85FF	77FF	79FF	82FF	88FF	85FF
97	97				
77FF;79FF;82FF;88FF;85FF	77FF	79FF	82FF	88FF	85FF
77FF;79FF;82FF;88FF;85FF	77FF	79FF	82FF	88FF	85FF
79	79				
106SF;115SF;111SF;113SF	106SF	115SF	111SF	113SF	
107SF	107SF				

Fig. 4.5 - Link counting with separation of all links in Case Study 1.

Now for the metric evaluation, in this case study any links with the “-” indication (example in figure 4.6) meant that there was a negative lag in that link. Ideally, there should not be any negative lags in the project's schedule, since it leads to poor coordination of the following tasks.



Predecessors	Successors	Prod./day	Total Slack	Resource Names	Duration (d.calend.)	Constraint Type	Cost	tasks count
			586 d			Start No Earlier Than	####	
	546;549;551;552;553;548		0 d			Start No Earlier Than	####	1
		0	0 d		253 d	As Soon As Possible	####	0
		0	0 d		166 d	As Soon As Possible	####	0
546SS+10 d	10SS;41;555SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante[200%]	33 d	As Soon As Possible	####	1
5 9SS		22.2	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
5 9SS		52.27	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
29FF	42FF	1024.6	68 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
		0	0 d		159 d	As Soon As Possible	####	0
		0	0 d		159 d	As Soon As Possible	####	0
	22SS 26FF;33FF-10 d;164FF	1279.25	0 d	Servente / Ajudante[400%]	159 d	As Soon As Possible	####	1
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d	Camião Basculante VOL	40 d	As Soon As Possible	####	0
29FF-10 d	34;35SS	2353.73	101 d		19 d	As Soon As Possible	####	1

Fig. 4.6 - Example of the negative lag indicated in the predecessor's relationships on the project's schedule for Case Study 1.

After careful analysis, the author concluded that there was a link with a negative lag in the predecessor's relationships, meaning that the project does not meet the second metric, "leads", which has zero tolerance. Since this metric is compared to the total number of links in the schedule, it had a 0.13% compared to all links.

Although the author is dealing with a zero-tolerance check, this percentage is very low, leading to this point being almost fulfilled.

4.2.2.3. Lag

The third point of the guideline consists of the opposite of what was analyzed in the second one - now the check refers to the positive lag in the predecessor's relationships, i.e. the waiting time between activities.

For this check, positive lag is allowed, but the limit of relationships with positive lag should not exceed the 5% mark. Next is the formula used to identify it:

$$\% \text{ Positive Lags} = \frac{\text{Number of links with positive lag}}{\text{Number of Logic Links}} * 100 \quad (1.3)$$

In this scenario, the positive lag was represented in the schedule with the "+" symbol. Next is figure 4.7 with an example of this case.



Predecessors	Successors	Prod./day	Total Slack	Resource Names	Duration (d.calend.)	Constraint Type	Cost	tasks count
			586 d			Start No Earlier Than	####	
	546;549;551;552;553;548		0 d			Start No Earlier Than	####	1
		0	0 d		253 d	As Soon As Possible	####	0
		0	0 d		166 d	As Soon As Possible	####	0
546SS+10 d	10SS;41;555SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante[200%]	33 d	As Soon As Possible	####	1
5 9SS		22.2	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
5 9SS		52.27	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
29FF 42FF		1024.6	68 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
		0	0 d		159 d	As Soon As Possible	####	0
		0	0 d		159 d	As Soon As Possible	####	0
22SS	26FF;33FF-10 d;164FF	1279.25	0 d	Servente / Ajudante[400%]	159 d	As Soon As Possible	####	1
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d	Camião Basculante VOL	40 d	As Soon As Possible	####	0
29FF-10 d	34;35SS	2353.73	101 d		19 d	As Soon As Possible	####	1

Fig. 4.7 - Example of the positive lag indicated in the predecessor's relationships on the project's schedule for Case Study 1.

After this check, and considering all links associated with this project, the conclusion is that there are 21 links in the predecessor's relationships with a positive lag, which leads to 2.80% of all links - in this case, the point has been met.

4.2.2.4. Schedule Relationships

For this metric, it is taken in consideration the type of link relationships present in the schedule. As mentioned before, there are four dependency types of link relationships:

- **Finish to Start (FS):** This is the most common type of relationship, in which the completion of one activity prevents the start of another related activity. One clear illustration is that installing wall frames cannot begin until the floor installation task has been finished;
- **Start to Start (SS):** In this type of relationship, one activity cannot begin until the other has. As an illustration, demolition cannot start until the safety plan has been implemented;
- **Start to Finish (SF):** This is a type of relationship not as common and occurs when one action can not end until the start of another. Most scheduling guidelines restrict and find confusing this kind of relationship. Master schedulers are usually the ones who use the SF relationship, which is a useful tool throughout a project's proposal and early planning phases. Then, utilizing the more commonly used FS, SS, and FF relationships, detailed planners take the schedule and translate the SF relationships into more comprehensible network logic;
- **Finish to Finish (FF):** In this relationship, one activity cannot end until another that is related to it has. One straightforward illustration would be that report editing cannot be finished before report drafting is finished.

For this scenario, the FS relationship should be the most seen in the schedule - at least 90% of the links in the schedule should be the type Finish To Start. The formula used for this metric is shown next.

$$\% \text{ FS Relationships} = \frac{\text{Number of logic links with FS Relationships}}{\text{Number of logic links}} * 100 \quad (1.4)$$

In this case of study, the method used for getting the number of logic links with FS relationships was by discarding the other types of relationships (which are all indicated in the schedule) and comparing the Finish to Start ones with the total number of links. Next in figure 4.8 is an example of what was shown in the schedule. Every FS relationship was indicated only with numbers, while the other types of links had letters associated with those numbers.



Predecessors	Successors	Prod./day	Total Slack	Resource Names	Duration (d.calend.)	Constraint Type	Cost	tasks count
			586 d			Start No Earlier Than	####	
	546;549;551;552;553;548		0 d			Start No Earlier Than	####	1
		0	0 d		253 d	As Soon As Possible	####	0
		0	0 d		166 d	As Soon As Possible	####	0
546SS+10 d	10SS;41;555SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante[200%]	33 d	As Soon As Possible	####	1
5 9SS		22.2	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
5 9SS		52.27	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
29FF	42FF	1024.6	68 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
		0	0 d		159 d	As Soon As Possible	####	0
		0	0 d		159 d	As Soon As Possible	####	0
22SS	26FF;33FF-10 d;164FF	1279.25	0 d	Servente / Ajudante[400%]	159 d	As Soon As Possible	####	1
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d	Camião Basculante VOL	40 d	As Soon As Possible	####	0
29FF-10 d	34;35SS	2353.73	101 d		19 d	As Soon As Possible	####	1

Fig. 4.8 - Example of how FS Relationships appear on the schedule in Case Study 1.

In this evaluation, the conclusion was that only 55.26% of all links had FS relationships, meaning that this metric was not accomplished. Having a lot of other kinds of relationships such as Start-to-Start or Finish-To-Finish can cause too much float and be harder to track down and justify.

4.2.2.5. Hard Constraints

In the fifth point of the DCMA's guideline, the hard/soft constraints were analyzed.

Additional requirements on dates that specify the significance of particular dates in the project's existence are known as constraints. For this evaluation, the soft constraints are not as crucial to evaluate as hard constraints. This happens because with soft constraints negative total float can be generated, but they will never break the logic of the network.

Next are the soft constraints considered in MS Project for the analysis of this metric:

- As Soon As Possible (ASAP);
- As Late As Possible (ALAP);
- Start No Earlier Than (SNET);
- Finish No Earlier Than (FNET).

When it comes to hard constraints, these are much more problematic in terms of logic dependency relationships. Dates in the schedule may be fixed by hard constraints in a way that disrespects the network logic. The four hard constraint types considered in MS Project are the following:

- Start No Later Than (SNLT);
- Must Finish On (MNO);
- Finish No Later Than (FNL);
- Must Start On (MSO).

The evaluation was done in Excel and they were represented as in the next figure 4.9.



Predecessors	Successors	Prod./day	Total Slack	Resource Names	Duration (d.calend.)	Constraint Type	Cost	tasks count
			586 d			Start No Earlier Than	####	
	546;549;551;552;553;548		0 d			Start No Earlier Than	####	1
		0	0 d		253 d	As Soon As Possible	####	0
		0	0 d		166 d	As Soon As Possible	####	0
546SS+10 d	10SS;41;555SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante[200%]	33 d	As Soon As Possible	####	1
5 9SS		22.2	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
5 9SS		52.27	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
29FF 42FF		1024.6	68 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####	1
		0	0 d		159 d	As Soon As Possible	####	0
		0	0 d		159 d	As Soon As Possible	####	0
22SS	26FF;33FF-10 d;164FF	1279.25	0 d	Servente / Ajudante[400%]	159 d	As Soon As Possible	####	1
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d		40 d	As Soon As Possible	####	0
		0	101 d	Camião Basculante VOL	40 d	As Soon As Possible	####	0
29FF-10 d	34;35SS	2353.73	101 d		19 d	As Soon As Possible	####	1

Fig. 4.9 - Example of Constraints shown in the schedule from Case Study 1.

It is important to mention that for other project planning tools, the constraint types can have different designations.

For this point of the assessment check, no more than 5% of the constraints in the project should have hard constraints - although, any hard constraint is highly discouraged. The formula to obtain this relation is the following:

$$\%Hard\ Constraints = \frac{Total\ Number\ of\ Tasks\ with\ Hard\ Constraints}{Total\ Number\ of\ Incomplete\ Tasks} * 100 \quad (1.5)$$

There weren't any hard constraints in this case study, meaning this metric was accomplished.

4.2.2.6. High Float

The High Float metric consists of analyzing if there are tasks with a total float greater than 44 working days - two months (figure 4.10). Intuitively, a high float (slack) is viewed favorably since it gives the schedule a good margin. However, a very high float could be a sign of missing predecessor and/or successor relationships.



Quant	Un	Duration	Start	Finish	Predecessors	Successors	Prod./day	Total Slack	Resource Names	Duration (d.calend.)	Constraint Type	Cost	tasks count
		0 d	Tue 29/11/22	Tue 29/11/22				586 d			Start No Earlier Than	###	
		0 d	Mon 15/01/24	Mon 15/01/24		546;549;551;552;553;548		0 d			Start No Earlier Than	###	1
		181 d	Mon 29/01/24	Mon 07/10/24			0	0 d		253 d	As Soon As Possible	###	0
		120 d	Mon 29/01/24	Fri 12/07/24			0	0 d		166 d	As Soon As Possible	###	0
127950	m2	25 d	Mon 29/01/24	Fri 01/03/24	546SS+10 d	10SS;41;55SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante[200%]	33 d	As Soon As Possible	###	1
666	m3	30 d	Mon 04/03/24	Fri 12/04/24	5 9SS		22.2	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	###	1
1568	m2	30 d	Mon 04/03/24	Fri 12/04/24	5 9SS		52.27	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	###	1
30738	m2	30 d	Mon 12/08/24	Fri 20/09/24	29FF 42FF		1024.6	68 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	###	1
		115 d	Mon 15/04/24	Fri 20/09/24			0	0 d		159 d	As Soon As Possible	###	0
		115 d	Mon 15/04/24	Fri 20/09/24			0	0 d		159 d	As Soon As Possible	###	0
147114	m3	115 d	Mon 15/04/24	Fri 20/09/24	22SS 26FF;33FF-10 d;164FF		1279.25	0 d	Servente / Ajudante[400%]	159 d	As Soon As Possible	###	1
		30 d	Mon 19/08/24	Fri 27/09/24			0	101 d		40 d	As Soon As Possible	###	0
		30 d	Mon 19/08/24	Fri 27/09/24			0	101 d		40 d	As Soon As Possible	###	0
		30 d	Mon 19/08/24	Fri 27/09/24			0	101 d	Camião Basculante VOL	40 d	As Soon As Possible	###	0
35306	m2	15 d	Mon 19/08/24	Fri 06/09/24	29FF-10 d 34;35SS		2353.73	101 d		19 d	As Soon As Possible	###	1
15366	m2	15 d	Mon 09/09/24	Fri 27/09/24	33		1024.4	107 d		19 d	As Soon As Possible	###	1
68007	m2	30 d	Mon 19/08/24	Fri 27/09/24	33SS 37		2266.9	101 d		40 d	As Soon As Possible	###	1
		1 d	Mon 30/09/24	Mon 30/09/24			0	101 d	Servente / Ajudante[200%]	1 d	As Soon As Possible	###	0
52	m3	1 d	Mon 30/09/24	Mon 30/09/24	35 39		52	101 d		1 d	As Soon As Possible	###	1

Fig. 4.10 - Representation of total float in the schedule from Case Study 1.

With this in mind, the analysis to be carried out for this metric consisted of checking the float of the project's tasks, with a margin no greater than 5% for high float tasks. The formula used for this point is:

$$\% \text{ High Float} = \frac{\text{Total Number of Incomplete Tasks with High Float}}{\text{Total Number of Incomplete Tasks}} * 100 \quad (1.6)$$

After a thoughtful evaluation of this metric, the author came to the conclusion that 97.76% of all tasks have a float greater than 44 days - far exceeding the stipulated limit. This means that, in this project, the majority of its activities function as "dangling" activities that aren't adequately integrated into the schedule.

4.2.2.7. Negative Float

Total float is the amount of time that an activity can be delayed without causing the project as a whole to be delayed. Positive and zero total float are acceptable. Negative float, on the other hand, indicates that the schedule is already behind, which is problematic while planning is still ongoing. Tasks with a total float less than zero are captured by the negative total float metric (float identified in figure 4.10). A transparent note of explanation and a negative total float mitigation plan should accompany tasks with negative float.

Next is the formula used to identify the percentage of negative float in the case study:

$$\% \text{ Negative Float} = \frac{\text{Total Number of Incomplete Tasks with Negative Float}}{\text{Total Number of Incomplete Tasks}} * 100 \quad (1.7)$$

This assessment fails if any task with a negative float appears in the project. This means there is zero tolerance in this metric. In this case study, the author didn't find any negative float, meaning this metric is met.

4.2.2.8. High Duration Tasks

Any task that takes longer than 44 working days (or two months) is considered a high-duration task. Tasks that take an excessive amount of time could make it difficult to see the current situation and progress of the schedule. Project management and administrative chores, as well as long-term lead procurement operations, are examples of work that fall beyond this category. Next is figure 4.11 showing how the High Duration tasks were found in the schedule.



Quant	Un	Duration	Start	Finish	Predecessors	Successors	Prod./day	Total Stack	Resource Names	Duration (d.calend.)	Constraint Type	Cost	tasks count
		0 d	Tue 29/11/22	Tue 29/11/22				586 d			Start No Earlier Than	####	
		0 d	Mon 15/01/24	Mon 15/01/24		546,549;551;552;553;548		0 d			Start No Earlier Than	####	
		181 d	Mon 29/01/24	Mon 07/10/24			0	0 d		253 d	As Soon As Possible	####	0
		120 d	Mon 29/01/24	Fri 12/07/24			0	0 d		166 d	As Soon As Possible	####	0
127950	m2	25 d	Mon 29/01/24	Fri 01/03/24	546SS+10 d	10SS;41;55SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante(200%	33 d	As Soon As Possible	####	1
666	m3	30 d	Mon 04/03/24	Fri 12/04/24	5 9SS		22.2	227 d	Servente / Ajudante(200%	40 d	As Soon As Possible	####	1
1568	m2	30 d	Mon 04/03/24	Fri 12/04/24	5 9SS		52.27	227 d	Servente / Ajudante(200%	40 d	As Soon As Possible	####	1
30738	m2	30 d	Mon 12/08/24	Fri 20/09/24	29FF 42FF		1024.6	68 d	Servente / Ajudante(200%	40 d	As Soon As Possible	####	1
		115 d	Mon 15/04/24	Fri 20/09/24			0	0 d		159 d	As Soon As Possible	####	0
		115 d	Mon 15/04/24	Fri 20/09/24			0	0 d		159 d	As Soon As Possible	####	0
147114	m3	115 d	Mon 15/04/24	Fri 20/09/24	22SS 26FF;33FF-10 d;164FF		1279.25	0 d	Servente / Ajudante(400%	159 d	As Soon As Possible	####	1
		30 d	Mon 19/08/24	Fri 27/09/24			0	101 d		40 d	As Soon As Possible	####	0
		30 d	Mon 19/08/24	Fri 27/09/24			0	101 d		40 d	As Soon As Possible	####	0
		30 d	Mon 19/08/24	Fri 27/09/24			0	101 d	Camião Basculante VOL	40 d	As Soon As Possible	####	0
35306	m2	15 d	Mon 19/08/24	Fri 06/09/24	29FF-10 d 34;35SS		2353.73	101 d		19 d	As Soon As Possible	####	1
15366	m2	15 d	Mon 09/09/24	Fri 27/09/24	33		1024.4	107 d		19 d	As Soon As Possible	####	1
68007	m2	30 d	Mon 19/08/24	Fri 27/09/24	33SS 37		2266.9	101 d		40 d	As Soon As Possible	####	1
		1 d	Mon 30/09/24	Mon 30/09/24			0	101 d	Servente / Ajudante(200%	1 d	As Soon As Possible	####	0
52	m3	1 d	Mon 30/09/24	Mon 30/09/24	35 39		52	101 d		1 d	As Soon As Possible	####	1

Fig. 4.11 - Duration of the tasks in the schedule from Case Study 1.

High or long-duration tasks come with the following downsides:

- They increase the difficulty of measuring discrete progress;
- They raise the probability that in-process work may need to be modified;
- The critical path can be distorted by them;
- The negative lag relationship modifier affects them more easily.

The percentage permitted for this metric is no greater than 5%, and its formula is the following:

$$\% \text{ High Duration} = \frac{\text{Total Number of Incomplete Tasks with High Duration}}{\text{Total Number of Incomplete Tasks}} * 100 \quad (1.8)$$

After the author's analysis, the percentage of high duration for this project was 58.97%, leading to difficulties in managing the schedule's progress and current state, and not meeting the metric's needs.

4.2.2.9. Invalid Dates

According to the invalid dates assessment, unfinished tasks shouldn't include real (completed work) dates in the future or anticipated (future work) dates in the past. Everything on the left side of the status date should be complete, and everything on the right side should be incomplete, if the schedule has been updated correctly. This metric threshold is zero.

For the evaluation of this point, every date on the project was analyzed, comparing the start and finish dates. Next, in figure 4.12 is an example of what is shown in the excel.

ADAPT

ID	Outline Level	Work fronts	Item	Activities	Quant	Un	Duration	Start	Finish	Predecessors	Successors	Prod. day	Total Slack
1	1			ASSINATURA CONTRATO			0 d	Tue 26/11/22	Tue 26/11/22				586 d
2	1			CONSIGNAÇÃO			0 d	Mon 15/01/24	Mon 15/01/24		546,549,551,552,553,548		0 d
3	1		R.01	Terrassemgeiro			181 d	Mon 26/01/24	Mon 07/04/24				0 d
4	2		R.01.01	Trabalhos preparatórios			120 d	Mon 26/01/24	Fri 12/07/24				0 d
5	3	Troço 2	R.01.01.01	Desmatamento, incluindo derrube de árvores, desbasteamento, limpeza do terreno	127950	m2	25 d	Mon 26/01/24	Fri 01/03/24	54655+10 d	1055;41;5555;55855;6;7;35755;15	5118	0 d
6	3	Troço 1, 2 e 3	R.01.01.02	Demolição de construções (incluindo muros)	680	m3	30 d	Mon 04/03/24	Fri 12/04/24	5 955		22,2	227 d
7	3	Troço 1, 2 e 3	R.01.01.03	Demolição de muros	1980	m2	30 d	Mon 04/03/24	Fri 12/04/24	5 955		52,27	227 d
26	3	Troço 1, 2 e 3	R.01.02.07	Regularização de taludes de aterro	30738	m2	30 d	Mon 12/08/24	Fri 20/09/24	26FF 42FF		1024,6	66 d
27	2		R.01.03	Escavação em empréstimo			118 d	Mon 15/04/24	Fri 26/09/24			0	0 d
28	3		R.01.03.01	Escavação em empréstimo em terreno de qualquer natureza e colocação em aterro			118 d	Mon 15/04/24	Fri 26/09/24			0	0 d
29	4	Troço 1	R.01.03.01.01	Carga, transporte, espalhamento e compactação	147114	m3	115 d	Mon 15/04/24	Fri 20/09/24	22SS 26FF 33FF-10 d;164FF		1279,25	0 d
30	2		R.01.04	Leito do pavimento, incluindo tratamento ou fornecimento, e colocação dos materiais			30 d	Mon 19/08/24	Fri 27/09/24			0	101 d
31	3		R.01.04.03	Em aterros de solos/ Em escavações ou perfis mistos em solo			30 d	Mon 19/08/24	Fri 27/09/24			0	101 d
32	4			Em material granular			30 d	Mon 19/08/24	Fri 27/09/24			0	101 d
33	5	Troço 1	R.01.04.01.03.04	Aterro com 0,20m	35306	m2	15 d	Mon 19/08/24	Fri 06/09/24	26FF-10 d 34,3555		2353,73	101 d
34	5	Troço 1	R.01.04.03.05.03	Escavações ou perfis mistos em solo com 0,15 m	15366	m2	15 d	Mon 09/09/24	Fri 27/09/24	33		1024,4	107 d
35	5	Troço 1	R.01.04.03.05.04	Escavações ou perfis mistos em solo com 0,2 m	68007	m2	30 d	Mon 19/08/24	Fri 27/09/24	3355 37		2266,9	101 d
36	2		R.01.05	Trabalhos em condições particulares			1 d	Mon 26/09/24	Mon 26/09/24			0	101 d
37	3	Troço 2	R.01.05.02	Preparação de taludes de aterro para posterior alargamento	52	m3	1 d	Mon 20/09/24	Mon 30/09/24	35 39		52	101 d
38	2		R.01.06	Trabalhos complementares			5 d	Tue 01/10/24	Mon 07/10/24			0	101 d
39	3	Troço 2	R.01.06.01	Máscaras drenantes	384	m3	5 d	Tue 01/10/24	Mon 07/10/24	37		76,8	101 d
40	2		R.01.09	Outros Trabalhos			145 d	Mon 04/03/24	Fri 26/09/24			0	112 d
41	3	Troço 1, 2 e 3	R.01.09.01	Remoção de redes de vedações existentes e respectivos postes	1906	m	60 d	Mon 04/03/24	Fri 24/05/24	5		31,77	197 d
42	3	Troço 1, 2 e 3	R.01.09.02	Proteção de taludes de aterro novos através da colocação na face dos taludes de agregado rochoso não frável até 1,0m altura a partir da base do tal	2862	m2	10 d	Mon 05/03/24	Fri 20/03/24	26FF 218,93		286,2	66 d

Fig. 4.12 - Example of start and finish dates shown in the schedule and their evaluation in Case Study 1.

For this assessment, there is no defined formula, since it consists of comparing dates; In this study case, the project didn't have any invalid dates, accomplishing this metric.

4.2.2.10. Resources

Although resource loading is not mandatory, the DCMA stipulates that resources must be fully loaded if they are provided. So, it's all or nothing. If a schedule has resources, then every task in that schedule that has a duration longer than zero needs to have corresponding resource hours or costs – the case study shown in the next figure 4.13. For confidentiality reasons, the values are not shown, but for this evaluation, the important thing is that values are given for all the cells, which can be seen from the cardinal symbol assigned to each cell.

ADAPT

Start	Finish	Predecessors	Successors	Prod./day	Total Slack	Resource Names	Duration (d.calend.)	Constraint Type	Cost
Tue 29/11/22	Tue 29/11/22				586 d			Start No Earlier Than	####
Mon 15/01/24	Mon 15/01/24		546;549;551;552;553;548		0 d			Start No Earlier Than	####
Mon 29/01/24	Mon 07/10/24			0	0 d		253 d	As Soon As Possible	####
Mon 29/01/24	Fri 12/07/24			0	0 d		166 d	As Soon As Possible	####
Mon 29/01/24	Fri 01/03/24	546SS+10 d	10SS;41;555SS;558SS;6;7;557SS;12	5118	0 d	Servente / Ajudante[200%]	33 d	As Soon As Possible	####
Mon 04/03/24	Fri 12/04/24	5 9SS		22.2	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####
Mon 04/03/24	Fri 12/04/24	5 9SS		52.27	227 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####
Mon 12/08/24	Fri 20/09/24	29FF 42FF		1024.6	68 d	Servente / Ajudante[200%]	40 d	As Soon As Possible	####
Mon 15/04/24	Fri 20/09/24			0	0 d		159 d	As Soon As Possible	####
Mon 15/04/24	Fri 20/09/24			0	0 d		159 d	As Soon As Possible	####
Mon 15/04/24	Fri 20/09/24	22SS	26FF;33FF-10 d;164FF	1279.25	0 d	Servente / Ajudante[400%]	159 d	As Soon As Possible	####
Mon 19/08/24	Fri 27/09/24			0	101 d		40 d	As Soon As Possible	####
Mon 19/08/24	Fri 27/09/24			0	101 d		40 d	As Soon As Possible	####
Mon 19/08/24	Fri 27/09/24			0	101 d	Camião Basculante VOL	40 d	As Soon As Possible	####
Mon 19/08/24	Fri 06/09/24	29FF-10 d	34;35SS	2353.73	101 d		19 d	As Soon As Possible	####
Mon 09/09/24	Fri 27/09/24	33		1024.4	107 d		19 d	As Soon As Possible	####
Mon 19/08/24	Fri 27/09/24	33SS 37		2266.9	101 d		40 d	As Soon As Possible	####
Mon 30/09/24	Mon 30/09/24			0	101 d	Servente / Ajudante[200%]	1 d	As Soon As Possible	####
Mon 30/09/24	Mon 30/09/24	35 39		52	101 d		1 d	As Soon As Possible	####
Tue 01/10/24	Mon 07/10/24			0	101 d	Servente / Ajudante[200%]	7 d	As Soon As Possible	####
Tue 01/10/24	Mon 07/10/24	37		76.8	101 d		7 d	As Soon As Possible	####

Fig. 4.13 - Resources shown in the project's schedule (costs) in Case Study 1.

In this metric, the formula utilized is the following:

$$\% \text{ Missing Resources} = \frac{\text{Total No of Incomplete Tasks w/ Missing Resources}}{\text{Total Number of Incomplete Tasks}} * 100 \quad (1.9)$$

The percentage of Missing Resources in the schedule of a project should be zero.

For this case, it was included in the schedule-associated costs, meaning the author could do the evaluation of this metric; With this, the outcome was positive, meaning that all tasks had the respective cost associated with them, passing this assessment.

4.2.2.11. The Critical Path Test

The integrity of network logic, and specifically the critical path, is examined using the critical path test. According to the critical path test, the amount of intentional schedule slippage that is included as part of the test should directly affect how long the project takes to complete. If not, the schedule lacks logic. The absence of predecessors and/or successors is a condition that leads to broken logic.

With this said, the evaluation carried out by the author consisted of assessing the variation in the total project duration in MS Project when a deviation was made in an activity that belonged to the schedule's critical path. With this in mind, and as shown in figure 4.14, a critical activity was selected and a value of 100 days more was used as the deviation. The expected result would be an extra 100 days in the total duration of the project, and subsequent figure 4.15 shows that when this change is made, the total duration of the project complies with the requirement.

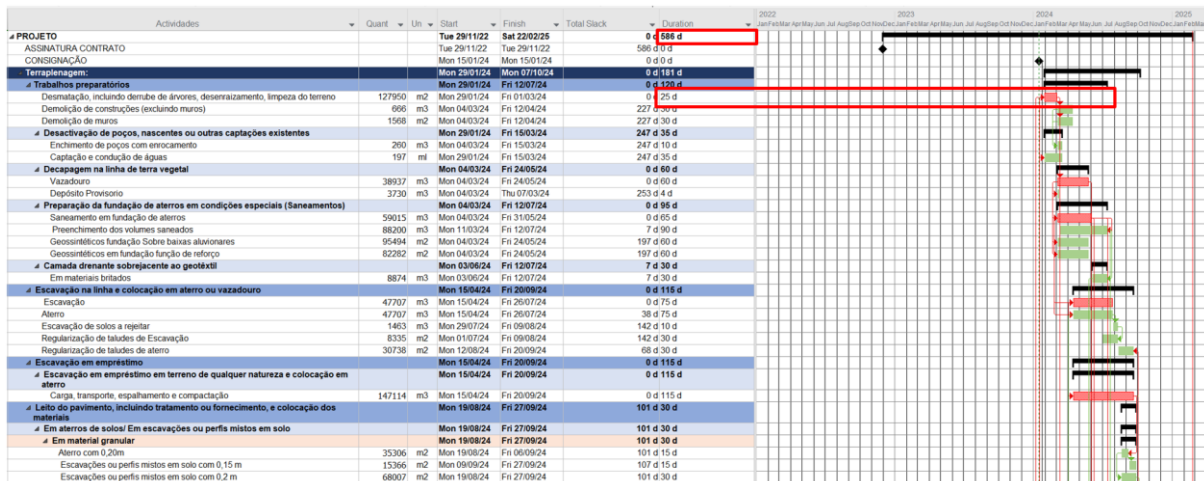


Fig. 4.14 - Selection of Task for Critical Path Test in Case Study 1.

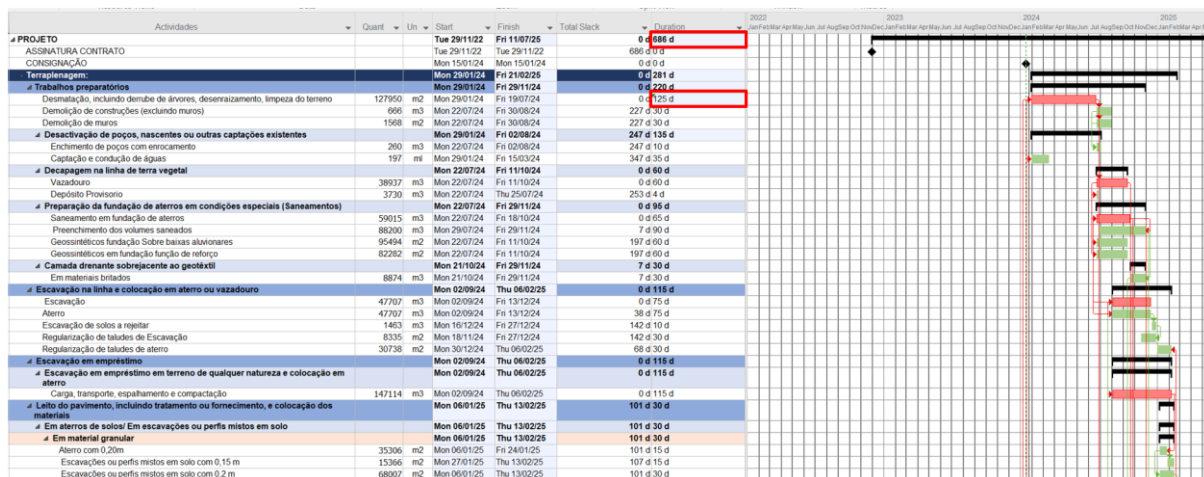


Fig. 4.15 - Results of the critical Path Check in Case Study 1.

Since for this point of the DCMA the result can only be PASS or NO PASS, it is determined that for this requirement the schedule complies with the request.

This point could have a different impact if an analysis was made during the course of the work, since this point will be very relevant in order to understand whether throughout the work, due to the dependencies established for the activities and if there are fluctuations in the duration of tasks, there continues to be a logical relationship between the duration that the final task should have and the task that is being evaluated at the time of the check-in point 12.

4.2.3. SUMMARIZE

To summarize, below is a figure with the brief analysis and a developed tool to synthesize what was made and explained above (figure 4.16), with the ones shown with a red background not complying with the metric and the ones in green complying. In this way, it is possible to see what needs to be improved in order to satisfy the points of the DCMA.

	LOGIC	LEADS	LAG	SCHEDULE RELATIONSHIPS	HARD CONSTRAINTS	HIGH FLOAT	NEGATIVE FLOAT	HIGH DURATION TASKS	INVALID DATES	RESOURCES	CRITICAL PATH CHECK
total	198	1	21	415	0	305	0	184	0	312	
target	<=5%	0%	<=5%	>=90%	<=5%	<=5%	<=5%	<=5%	0%	0%	
	63.46%	0.13%	2.80%	55.26%	0.00%	97.76%	0.00%	58.97%	0.00%	0.00%	OK
	PRED & SUC	NEGATIVE LAG	POSITIVE LAG	FS RELATIONSHIPS	HARD CONSTRAINTS	FLOAT GREATER THAN 44 DAYS	FLOAT LESS THAN ZERO	DURATION GREATER THAN 44 DAYS	INVALID DATES	ASSOCIATED €€ OR HOURS	PASS?
	198	1	21	415	0	305	0	184	0	312	PASS

Fig. 4.16 - Summary of the DCMA 14-Point evaluation check for Case Study 1.

4.3. CASE OF STUDY NO. 2 – BASELINE ANALYSIS

4.3.1. PROJECT SUMMARY

As a second case study aimed at analyzing the baseline with the DCMA 14-Point Assessment Check, the author used a project that consisted of two independent towers, one designated for use as a hotel and the other for tourist apartments. These towers are connected by a central structure that houses social and support facilities for the entire complex. Additionally, there is a basement level dedicated to parking. Seventy-two tourist apartments, ranging in typology from T1 to T3, are located in the northern section, while the entire southern section is devoted to the hotel, which has nine floors and 206 rooms. Next is figure 4.17 with the project section.



Fig. 4.17 – Project section for case study 2.

The aim is to compare the analysis carried out in the two case studies in order to gain a better insight into how a construction project work schedule should be organized so that it complies with the requirements of the DCMA.

This schedule has already been designed to be more efficient, and an improvement has been made right from the start - with this, it is hoped to obtain better results than in the first case, since it has already been organized more carefully.

4.3.2. ANALYSIS

As in the first case, the 1-10 and 12 points of DCMA 14-Point will also be used to assess the project baseline. Initially, there was the need to determine how many tasks were in this schedule, and since this was a different project from the first case and, because of that, the schedule's organization was different, the author had to find a different way of counting the project's tasks. The next figure 4.18 represents a part of this schedule's second case.

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Task Mode	Task Name	Actual Start	% Complete	Actual Finish	Total Slack	Start	Finish	Baseline Duration	Baseline Start	Baseline Finish	Predecessors	Successors / ID	Outline Level	Constraint Type		
Auto Scheduled	Início da empreitada	20/07/2021	100%	20/07/2021	0 days	20/07/2021	20/07/2021	0 days	20/07/2021	20/07/2021		18	2	2 Start No Earlier Than		
Auto Scheduled	Conclusão da empreitada	NA	0%	NA	0 days	31/12/2024	31/12/2024	0 days	31/12/2024	31/12/2024	24,28,27,498,59,62,75,76,600,592,591,588,587,586,581,577,598,1078,1076,647,159,162,175,176,409,412,425,436,259,262,275,276,209,212,225,226,359,362,375,376,389,312,325,326,459,462,475,476,109,507,112,125,126,640,641,627,697,680,693,694,1047,1030,1043,1044	3	2	2 As Soon As Possible		
Auto Scheduled	Aprovações	09/01/2024	0%	NA	120 days	09/01/2024	22/03/2024	51 days	09/01/2024	22/03/2024		4	2	2 As Soon As Possible		
Auto Scheduled	Hotel	09/01/2024	0%	NA	120 days	09/01/2024	22/03/2024	51 days	09/01/2024	22/03/2024		5	3	3 As Soon As Possible		
Auto Scheduled	Pisos	11/01/2024	0%	NA	45 days	11/01/2024	22/03/2024	49 days	11/01/2024	22/03/2024		6	4	4 As Soon As Possible		
Auto Scheduled	Tetos metálicos	11/01/2024	100%	11/01/2024	0 days	11/01/2024	11/01/2024	0 days	11/01/2024	11/01/2024		7	5	5 Start No Earlier Than		
Auto Scheduled	Definição dos tetos/iluminação dos corredores	NA	0%	NA	45 days	22/03/2024	22/03/2024	0 days	22/03/2024	22/03/2024	82FF+10 days	79	8	5 Start No Earlier Than		
Auto Scheduled	Cobertura	09/01/2024	0%	NA	136 days	09/01/2024	29/02/2024	35 days	09/01/2024	29/02/2024		9	4	4 As Soon As Possible		
Auto Scheduled	Solução de impermeabilização da cobertura	09/01/2024	100%	09/01/2024	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024		572	10	5 As Soon As Possible		
Auto Scheduled	TMM Casinhoto	NA	0%	NA	92 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024		580,579	11	5 Start No Earlier Than		
Auto Scheduled	Maciços dos painéis acústicos	NA	0%	NA	136 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024		591	12	5 Start No Earlier Than		
Auto Scheduled	Maciços dos chillers	29/02/2024	100%	29/02/2024	0 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024		581	13	5 Start No Earlier Than		
Auto Scheduled	Piso Dr	NA	0%	NA	0 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024		1264	14	3 As Soon As Possible		
Auto Scheduled	Teto acústico	NA	0%	NA	0 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024		1074	15	4 Start No Earlier Than		
Auto Scheduled	Piso 0	14/02/2024	100%	14/02/2024	0 days	14/02/2024	14/02/2024	0 days	14/02/2024	14/02/2024		16	3	3 As Soon As Possible		
Auto Scheduled	Iluminação	14/02/2024	100%	14/02/2024	0 days	14/02/2024	14/02/2024	0 days	14/02/2024	14/02/2024		1201,1202,1264,1199	17	4	4 Start No Earlier Than	
Auto Scheduled	DEMOIÇÕES	18/08/2021	100%	29/03/2022	0 days	18/08/2021	29/03/2022	160 days	18/08/2021	29/03/2022		2	20	2 Start No Earlier Than		
Auto Scheduled	ESTRUTURAS	30/09/2022	61%	NA	60,6 days	30/09/2022	30/09/2024	645 days	30/09/2022	30/09/2024		3	19	2 As Soon As Possible		
Manually Scheduled	ESTRUTURA DE BETÃO ARMADO	30/03/2022	99%	NA	0 days	30/03/2022	07/02/2024	260 days	30/03/2022	07/02/2024	18	30,1082,1066,34,36,1111	20	3	3 As Soon As Possible	
Auto Scheduled	ESTRUTURA DE MADEIRA	09/01/2024	0%	NA	9,4 days	09/01/2024	16/08/2024	149,6 days	09/01/2024	16/08/2024		21	3	3 As Soon As Possible		
Manually Scheduled	Aprovação da preparação da cobertura	09/01/2024	100%	09/01/2024	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024		23F5+30 days	22	4	4 As Soon As Possible	
Auto Scheduled	1ª Fase - Estrutura Cobertura	NA	0%	NA	-44 days	22/02/2024	13/06/2024	75 days	22/02/2024	13/06/2024		22F5+30 days	1118,24	23	4	4 As Soon As Possible
Auto Scheduled	2ª Fase - Revestimento de tetos	NA	0%	NA	9,4 days	14/06/2024	16/08/2024	44 days	14/06/2024	16/08/2024	23,1200F5-22 days,1199F5-22 days,1202FF+22 days,3	24	4	4 As Soon As Possible		
Auto Scheduled	ESTRUTURAS METÁLICAS	09/01/2024	0%	NA	60,6 days	09/01/2024	30/09/2024	181 days	09/01/2024	30/09/2024		25	3	3 As Soon As Possible		
Manually Scheduled	Aprovação da preparação de Obra	09/01/2024	100%	09/01/2024	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024		27F5+30 days	26	4	4 Start No Earlier Than	
Auto Scheduled	Estrutura Showcooking	NA	0%	NA	201,6 days	22/02/2024	06/03/2024	10 days	22/02/2024	06/03/2024	28F5+30 days	3	27	4	4 As Soon As Possible	
Auto Scheduled	Escadas Metálicas	08/07/2024	0%	NA	60,6 days	08/07/2024	30/09/2024	60 days	08/07/2024	30/09/2024	32	3	28	4	4 As Soon As Possible	
Auto Scheduled	VARANDAS E FACHADAS PRÉ-FABRICADAS	29/03/2023	70%	NA	53 days	29/03/2023	05/07/2024	325 days	29/03/2023	05/07/2024		29	3	3 As Soon As Possible		
Manually Scheduled	Varandas e Painéis	29/03/2023	100%	03/10/2023	0 days	29/03/2023	03/10/2023	135 days	29/03/2023	03/10/2023	20	31F5+130 days,32,654,1094,1004	30	4	4 As Soon As Possible	
Auto Scheduled	Torre A - Alçados Norte e sul	09/04/2024	5%	NA	53 days	09/04/2024	22/05/2024	30 days	09/04/2024	22/05/2024	30F5+130 days	4,954,904,854,854	31	4	4 As Soon As Possible	
Auto Scheduled	Torre B - Alçados Nascente	NA	0%	NA	53 days	23/05/2024	05/07/2024	30 days	23/05/2024	05/07/2024	28,498,507,516,04,754,704	31	525,534,543,552,561,570	32	4	4 As Soon As Possible
Auto Scheduled	QUARTO MODELO / APARTAMENTO MODELO	29/03/2023	100%	23/08/2023	0 days	29/03/2023	23/08/2023	105 days	29/03/2023	23/08/2023		3	33	2	2 As Soon As Possible	

Fig. 4.18 - Extract from the project's schedule of the Case Study 2.

For this case study, the approach used by the author to get the number of tasks in the project's schedule was by considering every task that contained predecessors and/or successors. If there weren't either, the tasks count would get 0, otherwise it would get 1. Counting all the 1s in this evaluation, the sum was the total number of tasks in this schedule. Next is a part of the evaluation done in Excel (figure 4.19).



Task Name	Total Slack	Start	Finish	Baseline Duration	Baseline Start	Baseline Finish		Predecessors	Successors	ID	Outline Level	Constraint Type	PRED	SUC	PRED&SUC	TASKS
Início da empreitada	0 days	20/07/2021	20/07/2021	0 days	20/07/2021	20/07/2021			18	2	2	Start No Earlier Than	0	1	0	1
Conclusão da empreitada	0 days	31/12/2024	31/12/2024	0 days	31/12/2024	31/12/2024	24;28;27;498;59;62;75;76;600;592;591;588;587;586;581;577;598;1078;1076;647;159;162;175;176;409;412;425;426;259;262;275;276;209;212;225;226;359;362;375;376;309;312;325;326;459;462;475;476;109;507;112;125;126;640;641;627;697;680;693;694;1047;1030;1043;104...		3	2	As Soon As Possible	1	0	0	1	
Aprovações	120 days	09/01/2024	22/03/2024	51 days	09/01/2024	22/03/2024			4	4	2	As Soon As Possible	0	0	0	0
Hotel	120 days	09/01/2024	22/03/2024	51 days	09/01/2024	22/03/2024			5	5	3	As Soon As Possible	0	0	0	0
Pisos	45 days	11/01/2024	22/03/2024	49 days	11/01/2024	22/03/2024			6	6	4	As Soon As Possible	0	0	0	0
Tetos metálicos	0 days	11/01/2024	11/01/2024	0 days	11/01/2024	11/01/2024		82FF+10 days	7	5	Start No Earlier Than	0	1	0	1	
Definição dos tetos/iluminação dos corredores	45 days	22/03/2024	22/03/2024	0 days	22/03/2024	22/03/2024			79	8	5	Start No Earlier Than	0	1	0	1
Cobertura	136 days	09/01/2024	29/02/2024	35 days	09/01/2024	29/02/2024			9	4	As Soon As Possible	0	0	0	0	
Solução de impermeabilização da cobertura	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024			572	10	5	As Soon As Possible	0	1	0	1
TMM Casinhoto	92 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024			580;579	11	5	Start No Earlier Than	0	1	0	1
Maciços dos painéis acústicos	136 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024			591	12	5	Start No Earlier Than	0	1	0	1
Maciços dos chillers	0 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024			581	13	5	Start No Earlier Than	0	1	0	1
Piso 0+	0 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024			1264	14	3	As Soon As Possible	0	1	0	1
Teto acústico	0 days	29/02/2024	29/02/2024	0 days	29/02/2024	29/02/2024			1074	15	4	Start No Earlier Than	0	1	0	1
Piso 0	0 days	14/02/2024	14/02/2024	0 days	14/02/2024	14/02/2024			16	3	As Soon As Possible	0	0	0	0	
Iluminação	0 days	14/02/2024	14/02/2024	0 days	14/02/2024	14/02/2024		1201;1202;1264;1199	17	4	Start No Earlier Than	0	1	0	1	
DEMOLIÇÕES	0 days	18/08/2021	29/03/2022	160 days	18/08/2021	29/03/2022		2	20	18	2	Start No Earlier Than	1	1	1	1
ESTRUTURAS	60.6 days	30/03/2022	30/09/2024	645 days	30/03/2022	30/09/2024			3	19	2	As Soon As Possible	0	1	0	1
ESTRUTURA DE BETÃO ARMADO	0 days	30/03/2022	07/02/2024	260 days	30/03/2022	07/02/2024		18	30;1082;1066;34;36;1111	20	3	As Soon As Possible	1	1	1	1
ESTRUTURA DE MADEIRA	9.4 days	09/01/2024	16/08/2024	149.6 days	09/01/2024	16/08/2024			21	3	As Soon As Possible	0	0	0	0	
Aprovação da preparação da cobertura	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024			23F5+30 days	22	4	As Soon As Possible	0	1	0	1
1ª Fase - Estrutura Cobertura	-44 days	22/02/2024	13/06/2024	75 days	22/02/2024	13/06/2024		22F5+30 days	1118;24	23	4	As Soon As Possible	1	1	1	1
2ª Fase - Revestimento de tetos	9.4 days	14/06/2024	16/08/2024	44 days	14/06/2024	16/08/2024	23;1200F5-22 days;1199F5-22 days	1201FF+22 days;1202FF+22 days;3	24	4	As Soon As Possible	1	1	1	1	

Fig. 4.19 - Task Count of the Schedule for Case Study 2.

With this evaluation, the conclusion was that there were 868 tasks in the schedule.

For the next points mentioned, the explanation is the same as in the first case.

4.3.2.1. Missing Logic

Doing the same evaluation as in the first case, and utilizing the evaluation done to get the number of tasks of this schedule (figure 4.20), the author considered missing logic tasks the ones without predecessors and successors.



Predecessors	Successors	ID	Outline Level	Constraint Type	PRED	SUC	PRED&SUC	TASKS
	18	2	2	Start No Earlier Than	0	1	0	1
24;28;27;498;59;62;75;76;600;592;591;588;587;586;581;577;598;1078;1076;647;159;162;175;176;409;412;425;426;259;262;275;276;209;212;225;226;359;362;375;376;309;312;325;326;459;462;475;476;109;507;112;125;126;640;641;627;697;680;693;694;1047;1030;1043;104...		3	2	As Soon As Possible				
		4	2	As Soon As Possible	1	0	0	1
		5	3	As Soon As Possible	0	0	0	0
		6	4	As Soon As Possible	0	0	0	0
	82FF+10 days	7	5	Start No Earlier Than	0	1	0	1
	79	8	5	Start No Earlier Than	0	1	0	1
		9	4	As Soon As Possible	0	0	0	0
	572	10	5	As Soon As Possible	0	1	0	1
	580;579	11	5	Start No Earlier Than	0	1	0	1
	591	12	5	Start No Earlier Than	0	1	0	1
	581	13	5	Start No Earlier Than	0	1	0	1
	1264	14	3	As Soon As Possible	0	1	0	1
	1074	15	4	Start No Earlier Than	0	1	0	1
		16	3	As Soon As Possible	0	0	0	0
	1201;1202;1264;1199	17	4	Start No Earlier Than	0	1	0	1

Fig. 4.20 - Example of what the missing logic point is looking for in the project's schedule in Case Study 2.

The tasks with missing links identified were 55, meaning that 6.34% of the total number of tasks didn't have a predecessor and successor. Since this metric only allows a threshold of 5% or less, this point of the assessment check wasn't fulfilled. As in the first case study, two tasks were removed due to the fact that they were start and end tasks, and therefore missed both predecessor and successor. This resulted in 53 links with missing logic and a percentage of 6.11%, Still not meeting this requirement.

4.3.2.2. Leads

For the Leads metric, it was important that with this evaluation there weren't any leads present in the schedule (zero-tolerance), so the evaluation was made looking at the predecessor's links that had a negative sign "-". This evaluation was very similar to the first case since they both showed leads in the same way. Next is an example of the schedule's leads (figure 4.21).

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Predecessors	Successors	ID	Outline Level	Constraint Type	PRED	SUC	PRED&SUC	TASKS
	18	2	2	Start No Earlier Than	0	1	0	1
2	20	18	2	Start No Earlier Than	1	1	1	1
	3	19	2	As Soon As Possible	0	1	0	1
18	30;1082;1066;34;36;1111	20	3	As Soon As Possible	1	1	1	1
		21	3	As Soon As Possible	0	0	0	0
	23FS+30 days	22	4	As Soon As Possible	0	1	0	1
22FS+30 days	1118;24	23	4	As Soon As Possible	1	1	1	1
23;1200FS-22 days;1199FS-22 days	1201FF+22 days;1202FF+22 days;3	24	4	As Soon As Possible	1	1	1	1
		25	3	As Soon As Possible	0	0	0	0
	27FS+30 days	26	4	Start No Earlier Than	0	1	0	1
26FS+30 days	3	27	4	As Soon As Possible	1	1	1	1

Fig. 4.21 - Example of the negative lag indicated in the predecessor's relationships on the project's schedule in Case Study 2.

For this metric evaluation, the author had to determine the total number of links in the schedule and do a similar method as in the first case, all the links were separated in Excel, getting the total number of 2562. Since there were some links with leads (a total of 56 links with negative lags), that means this point of the assessment was not fulfilled, with a percentage of 2.19% when compared to all links accounted for.

4.3.2.3. Lag

For this third point of the assessment, the author looked for links with positive lag in the predecessor's links, and just like the previous metric, the author searched for all predecessor's links with the "+" symbol, just as shown in the next figure 4.22.



Predecessors	Successors	ID	Outline Level	Constraint Type	PRED	SUC	PRED&SUC	TASKS
	18	2	2	Start No Earlier Than	0	1	0	1
2	20	18	2	Start No Earlier Than	1	1	1	1
	3	19	2	As Soon As Possible	0	1	0	1
18	30;1082;1066;34;36;1111	20	3	As Soon As Possible	1	1	1	1
		21	3	As Soon As Possible	0	0	0	0
	23FS+30 days	22	4	As Soon As Possible	0	1	0	1
22FS+30 days	1118;24	23	4	As Soon As Possible	1	1	1	1
23;1200FS-22 days;1199FS-22 days	1201FF+22 days;1202FF+22 days;3	24	4	As Soon As Possible	1	1	1	1
		25	3	As Soon As Possible	0	0	0	0
	27FS+30 days	26	4	Start No Earlier Than	0	1	0	1
26FS+30 days	3	27	4	As Soon As Possible	1	1	1	1

Fig. 4.22 - Example of the positive lag indicated in the predecessor's relationships on the project's schedule in Case Study 2.

The threshold for this metric is 5% or less, and after the positive lag links were identified there were 11 of these links. Compared to all links in this schedule, the percentage obtained was 0.43%, meeting the requisites of this point of the assessment check.

4.3.2.4. Schedule Relationships

The goal for this metric evaluation was to determine how many Finish To Start (FS) links were in the schedule of this case study, and the goal was to get a percentage equal to or greater than 90% compared to all links associated with this case. For this situation, the schedule's links were organized by putting letters next to the number of the task to identify the type of relationship for each link, but some of them didn't have any letters associated. The author considered as FS relationships the links identified with the "FS" letters (and this is the difference from the organization done in the first case) and also the links without letters. As an example of the Finish To Start relationships, the next figure 4.23 shows how they appeared in the schedule's project.



Predecessors	Predecessors				
24;28;27;498;59;62;75;76;600;592;591;588;587;586;581;577;598;1078;1076;647;159;162;175;176;409;412;425;426;259;262;275;276;209;212;225;226;359;362;375;376;309;312;325;326;459;462;475;476;109;507;112;125;126;640;641;627;697;680;693;694;1047;1030;1043;104...	24	28	27	498	59
2	2				
18	18				
22FS+30 days	22FS+30 days				
23;1200FS-22 days;1199FS-22 days	23	1200FS-22 days	1199FS-22 days		
26FS+30 days	26FS+30 days				
32	32				
20	20				
30FS+130 days	30FS+130 days				

Fig. 4.23 - Example of how FS Relationships appear on the schedule in Case Study 2.

After the author's evaluation, the conclusion was that 99.22% of all links in the schedule had FS relationships, meaning that almost all links in this study case's schedule had this type of relationship, thus complying with this metric.

4.3.2.5. Hard Constraints

In this fifth point, the aim was to determine if there were any hard constraints in this project, and if so the number of them should not exceed 5% of all tasks in the project. The constraints are shown in figure 4.24, where the column with the information about the constraint's type was evaluated.



Predecessors	Successors	ID	Outline Level	Constraint Type	PRED	SUC	PRED&SUC	TASKS
	18	2	2	Start No Earlier Than	0	1	0	1
2	20	18	2	Start No Earlier Than	1	1	1	1
	3	19	2	As Soon As Possible	0	1	0	1
18	30;1082;1066;34;36;1111	20	3	As Soon As Possible	1	1	1	1
		21	3	As Soon As Possible	0	0	0	0

Fig. 4.24 - Column showing Constraints in the schedule from Case Study 2.

In conclusion, there weren't any hard constraints in this schedule, meaning that this metric was accomplished.

4.3.2.6. High Float

The next metric consists of analyzing the float of each task in the schedule (figure 4.25), where each task should not have a slack greater than 44 days (2 months of work). This metric has a limit of 5% or

less of tasks with a float greater than 44 days compared to the total number of tasks present in this project.

ADAPT

Task Name	Actual Start	% Complete	Actual Finish	Total Slack	Start	Finish	Baseline Duration	Baseline Start	Baseline Finish	Predecessors	Successors ID
Início da empreitada	20/07/2021	100%	20/07/2021	0 days	20/07/2021	20/07/2021	0 days	20/07/2021	20/07/2021		18 2
DEMOLIÇÕES	18/08/2021	100%	29/03/2022	0 days	18/08/2021	29/03/2022	160 days	18/08/2021	29/03/2022	2	20 18
ESTRUTURAS	30/03/2022	61% NA		60,6 days	30/03/2022	30/09/2024	645 days	30/03/2022	30/09/2024		3 19
ESTRUTURA DE BETÃO ARMADO	30/03/2022	99% NA		0 days	30/03/2022	07/02/2024	260 days	30/03/2022	07/02/2024	18	30;1082;1066;34;36;1111 20
ESTRUTURA DE MADEIRA	09/01/2024	0% NA		9,4 days	09/01/2024	16/08/2024	149,6 days	09/01/2024	16/08/2024		21
Aprovação da preparação da cobertura	09/01/2024	100%	09/01/2024	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024		23F5+30 days 22
1ª Fase - Estrutura Cobertura	NA	0% NA		-44 days	22/02/2024	13/06/2024	75 days	22/02/2024	13/06/2024	22F5+30 days	1118;24 23
2ª Fase - Revestimento de tectos	NA	0% NA		9,4 days	14/06/2024	16/08/2024	44 days	14/06/2024	16/08/2024	23;1200F5-22 days;1199F5-22 days	1201FF+22 days;1202FF+22 days;3 24
ESTRUTURAS METÁLICAS	09/01/2024	0% NA		60,6 days	09/01/2024	30/09/2024	181 days	09/01/2024	30/09/2024		25
Aprovação da preparação de Obra	09/01/2024	100%	09/01/2024	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024		27F5+30 days 26
Estrutura Showcooking	NA	0% NA		201,6 days	22/02/2024	06/03/2024	10 days	22/02/2024	06/03/2024	26F5+30 days	3 27
Escadas Metálicas	NA	0% NA		60,6 days	08/07/2024	30/09/2024	60 days	08/07/2024	30/09/2024	32	3 28
VARANDAS E FACHADAS PRÉ-FABRICADAS	29/03/2023	70% NA		53 days	29/03/2023	05/07/2024	325 days	29/03/2023	05/07/2024		29
Varandas e Paineis	29/03/2023	100%	03/10/2023	0 days	29/03/2023	03/10/2023	135 days	29/03/2023	03/10/2023	20	31F5+130 days 30
Torre A - Alçados Norte e sul	09/04/2024	5% NA		53 days	09/04/2024	22/05/2024	30 days	09/04/2024	22/05/2024	30F5+130 days	32;654;1054;100 4;954;904;854;8 04;754;704 31

Fig. 4.25 - Total Slack/Float for each task in the schedule

After careful evaluation, 390 tasks were found to have a float greater than 44 days, meaning 44.93% of all tasks in the schedule have a high float, not meeting the requirement of this point.

4.3.2.7. Negative Float

To analyze the negative float, the author used the same information indicated in figure 4.25, where the goal for this metric was to find any negative float. To confirm that this metric was met, a threshold of 5% or less was taken into account as a requirement.

With that being said, the evaluation took action with the information in the “Total Slack” column shown in figure 4.25, concluding that there weren’t any tasks with negative float (0%), meeting the requirements of the metric.

4.3.2.8. High Duration Tasks

For the High Duration Tasks metric, the author had to take in consideration the Baseline Duration to analyze the requirements of this point, as shown in figure 4.26 below. For its evaluation, the goal was to get 5% or fewer tasks with high duration, meaning, 44 days or 2 working months dedicated to a single task.

ADAPT

Task Name	Actual Start	% Complete	Actual Finish	Total Slack	Start	Finish	Baseline Duration	Baseline Start	Baseline Finish	Predecessors	Successors ID
Início da empreitada	20/07/2021	100%	20/07/2021	0 days	20/07/2021	20/07/2021	0 days	20/07/2021	20/07/2021		18 2
DEMOLIÇÕES	18/08/2021	100%	29/03/2022	0 days	18/08/2021	29/03/2022	160 days	18/08/2021	29/03/2022	2	20 18
ESTRUTURAS	30/03/2022	61% NA		60,6 days	30/03/2022	30/09/2024	645 days	30/03/2022	30/09/2024		3 19
ESTRUTURA DE BETÃO ARMADO	30/03/2022	99% NA		0 days	30/03/2022	07/02/2024	260 days	30/03/2022	07/02/2024	18	30;1082;1066;34;36;1111 20
ESTRUTURA DE MADEIRA	09/01/2024	0% NA		9,4 days	09/01/2024	16/08/2024	149,6 days	09/01/2024	16/08/2024		21
Aprovação da preparação da cobertura	09/01/2024	100%	09/01/2024	0 days	09/01/2024	09/01/2024	0 days	09/01/2024	09/01/2024		23F5+30 days 22
1ª Fase - Estrutura Cobertura	NA	0% NA		-44 days	22/02/2024	13/06/2024	75 days	22/02/2024	13/06/2024	22F5+30 days	1118;24 23
2ª Fase - Revestimento de tectos	NA	0% NA		9,4 days	14/06/2024	16/08/2024	44 days	14/06/2024	16/08/2024	23;1200F5-22 days;1199F5-22 days	1201FF+22 days;1202FF+22 days;3 24

Fig. 4.26 - Part of the schedule showing the Baseline Duration taken into consideration in Case Study 2.

After thoughtful evaluation, the author concluded that 453 tasks exceed the requirement, meaning that 52.19% of all tasks had high duration. With this outcome, the metric was not met in this case.

4.3.2.9. Invalid Date

Similar to the first case, the way to assess whether the metric regarding invalid dates was to compare the start and end dates of each task, in order to confirm that the end date of each would always be equal to or later than the start date indicated in the schedule. The tolerance for this metric is 0%, so after the evaluation was done there shouldn't be any invalid dates in this study case. Below is a figure (4.27) of a small excerpt from this analysis, where 0 is shown for those that meet the requirement and 1 is shown if there were invalid dates.



Baseline Start	Baseline Finish	
20/07/2021	31/12/2024	0
20/07/2021	20/07/2021	0
31/12/2024	31/12/2024	0
09/01/2024	22/03/2024	0
09/01/2024	22/03/2024	0
11/01/2024	22/03/2024	0
11/01/2024	11/01/2024	0
22/03/2024	22/03/2024	0
09/01/2024	29/02/2024	0
09/01/2024	09/01/2024	0
29/02/2024	29/02/2024	0
29/02/2024	29/02/2024	0

Fig. 4.27 - Evaluation of Invalid Dates in the Schedule for Case Study 2.

After its evaluation, the author concluded that there weren't any invalid dates in this schedule, meaning that this metric was fulfilled.

4.3.2.10. Resources

This metric evaluated should be about the resources associated with the schedule, but since this information has not been integrated into the schedule in this case and this metric is not mandatory, the resources metric has not been assessed.

4.3.2.11. Critical Path Check

For the last point to be evaluated, the author carried out an evaluation of the schedule's critical path, where similarly to case study 1, a duration of 100 days was added to a critical task in the schedule (as shown in figure 4.28), in order to confirm that it met the requirement of affecting the entire project in the sense of increasing its total duration by 100 days.

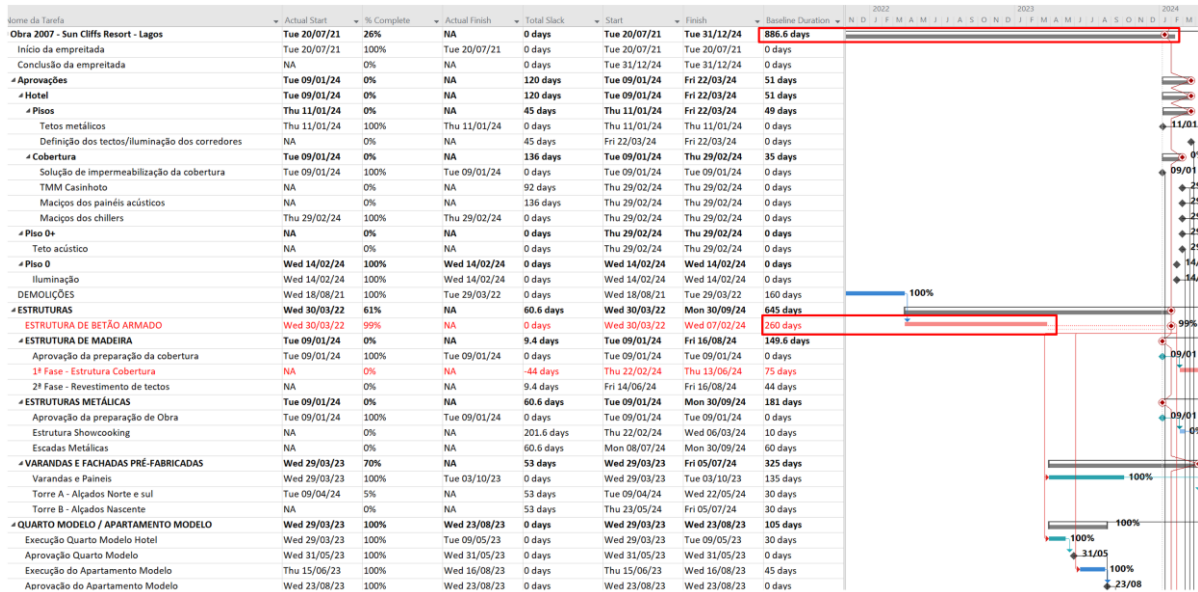


Fig. 4.28 - Selection of task for critical path test in case study 2.

With this check, and as can be seen in figure 4.29, it is concluded that the total project duration has been affected, thus fulfilling the requirement of the critical path check and passing the evaluation.

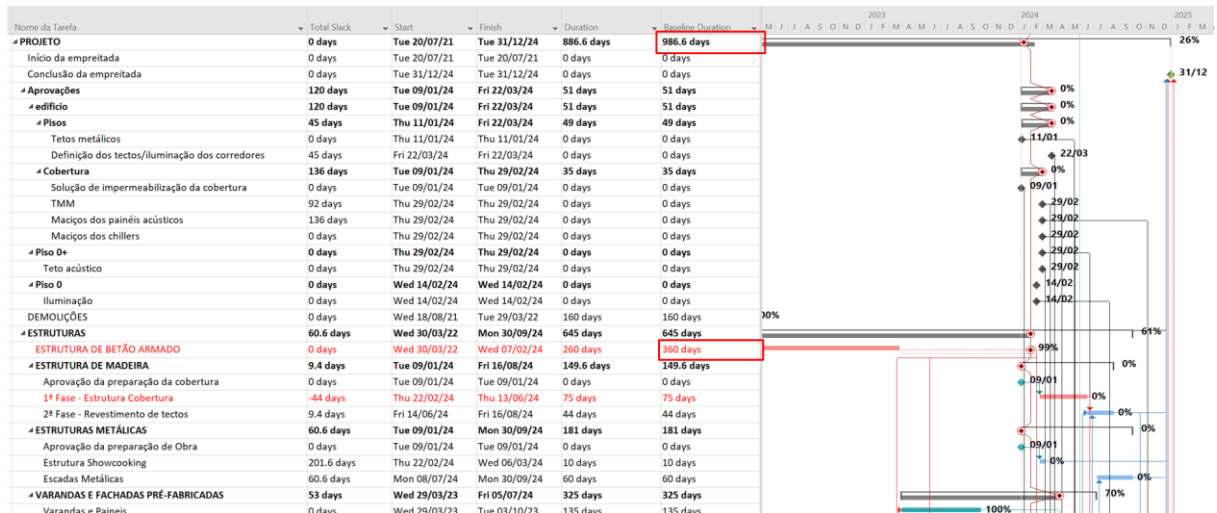


Fig. 4.29 - Results of the Critical Path Check in Case Study 2.

4.3.3. SUMMARIZE

In summary, figure 4.30 below provides a concise overview of the analysis discussed earlier, with the same overview shown in the first case, done with the tool developed for the first case. The “resources” are presented in blue to indicate that it couldn’t be evaluated.

	LOGIC	LEADS	LAG	SCHEDULE RELATIONSHIPS	HARD CONSTRAINTS	HIGH FLOAT	NEGATIVE FLOAT	HIGH DURATION TASKS	INVALID DATES	RESOURCES	CRITICAL PATH CHECK
total	815	56	11	2542	0	390	0	453	0	0	
target	<=5%	0%	<=5%	>=90%	<=5%	<=5%	<=5%	<=5%	0%	0%	
	6.11%	2.19%	0.43%	99.22%	0.00%	44.93%	0.00%	52.19%	0.00%	0.00%	OK
	PRED & SUC	NEGATIVE LAG	POSITIVE LAG	FS RELATIONSHIPS	HARD CONSTRAINTS	FLOAT GREATER THAN 44 DAYS	FLOAT LESS THAN ZERO	DURATION GREATER THAN 44 DAYS	INVALID DATES	ASSOCIATED €€ OR HOURS	PASS?
	815	56	11	2542	0	390	0	453	0	0	PASS

Fig. 4.30 - Summary of the DCMA 14-Point evaluation check for Case Study 2.

With this, the author concludes that for this second case, the baseline analysis outcome was more positive, and even in the metrics that weren't met, the values obtained didn't stray too far from the required limits. In this sense, it can be said that the organization of the second case's schedule took much more care, and was more thought out in terms of efficiently organizing its tasks.

It's worth mentioning that in this analysis, the author developed this helpful tool with Excel, so that in the future it would be possible to evaluate other work schedules using the same tool. In this way, any schedule needing analysis would be analyzed much faster and quicker, thus enabling much more efficient analysis of the schedule's health check.

4.4. CONCLUSIONS

After thoroughly examining two case studies to assess their compliance with DCMA requirements, it is evident that Case Study 1 is notably deficient. This case study exhibits a high incidence of tasks without predecessors and successors, as well as problematic relationships between activities, with high float and durations. Given that Case Study 1 will serve as the foundation for the subsequent chapter, a comprehensive redesign of its activities and interrelations is imperative. This redesign should aim to optimize the project schedule to ensure full compliance with the requirements identified in this chapter.

Regarding case 2, it is significantly more structured and well-planned, as previously mentioned, demonstrating a greater effort in executing the schedule. This highlights the importance of investing time and effort into scheduling, as evidenced by the more rigorous schedule produced for case study 2.

In the forthcoming chapter, the author will commence by restructuring the schedule using the "Work Breakdown Structure" concept previously discussed. This will involve logically and coherently planning the tasks, followed by an evaluation using the 14-point DCMA assessment checklist. This analysis will determine the validity of the revised schedule and assess whether the modifications will yield long-term benefits in the context of constructing work schedules for future projects.

5

WBS AND SCHEDULE DEVELOPMENT

5.1. CASE OF STUDY NO. 1 – APPROACH

5.1.1. ACTION PLAN

As the initial step in the process of optimizing the schedule for the first case study, it is imperative for the author to thoroughly review all available technical specifications. This comprehensive examination ensures that the subsequent modifications are executed in a well-considered and methodical manner. By carefully assessing these materials, the author will be able to identify areas for improvement and devise strategies to enhance the efficiency of the project's schedule. This systematic approach ensures that any adjustments align with the requirements outlined in the DCMA 14-Point Assessment Check.

Following this initial review, a preliminary analysis of the project was conducted using the project plans and descriptions of the respective specialties. This analysis aimed to gain a comprehensive understanding of the logical sequencing required for the project and how tasks could be effectively subdivided to optimize the schedule's efficiency. By delineating the logical phasing of the project and strategically organizing its tasks, the aim is to streamline project execution and improve overall performance.

It is pertinent to note that the values obtained from the baseline analysis of this case study served as the foundation for subsequent investigations. Any modifications made during this process were carefully considered to ensure they addressed the most pertinent issues and contributed to the project's overall success.

In order to think of a good subdivision of the project's tasks, the concept of Work Breakdown Structure was applied: The process of breaking down a project's total amount of work into a number of easier-to-manage, hierarchical tasks is called work breakdown structure, or WBS. While maintaining achievable tasks, the amount of detail should reflect the project's overall scope. Usually, the WBS is designed using a top-down approach. The WBS's upper levels are broken down into logical work groups, which are then followed by the level below that, and so forth. This makes it possible to schedule the lowest-level WBS component and to estimate, control, and manage its cost [78]. Next is an example (figure 5.1) of a typical WBS, using a “family tree” structure.

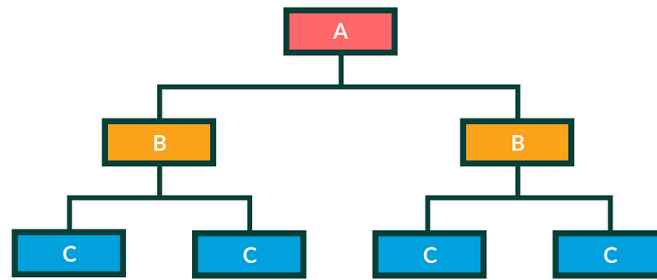


Fig. 5.1 - Example of WBS [79].

Although the tree view is the most typical view of the Work Breakdown Structure, it is also possible to find a WBS with a horizontal hierarchical list. This type of WBS generator offers a practical method for assigning numbers to tasks and subtasks. Although the representations change, the breakdown's basic structure remains the same [79].

With that said, the work relating to case study 1 is divided into 3 different sections, each of which will have different works. In order to carry out a more in-depth study of the schedule for case study 1, the author has chosen to focus on the first section, which is shown in the following figure 5.2. This section involves the widening and resurfacing of an existing road and the construction of an overpass approximately 50 meters long and 17 meters wide, designed to create a new access from this main road to a local conglomerate. Also, two exit and entrance ramps will be constructed, leading to the existing communication route. These ramps will be built on embankments, each featuring a traffic circle to direct traffic towards section 2 of the project, which will not be presented in this chapter. Additionally, two parallel roads will be improved that follow the existing road.

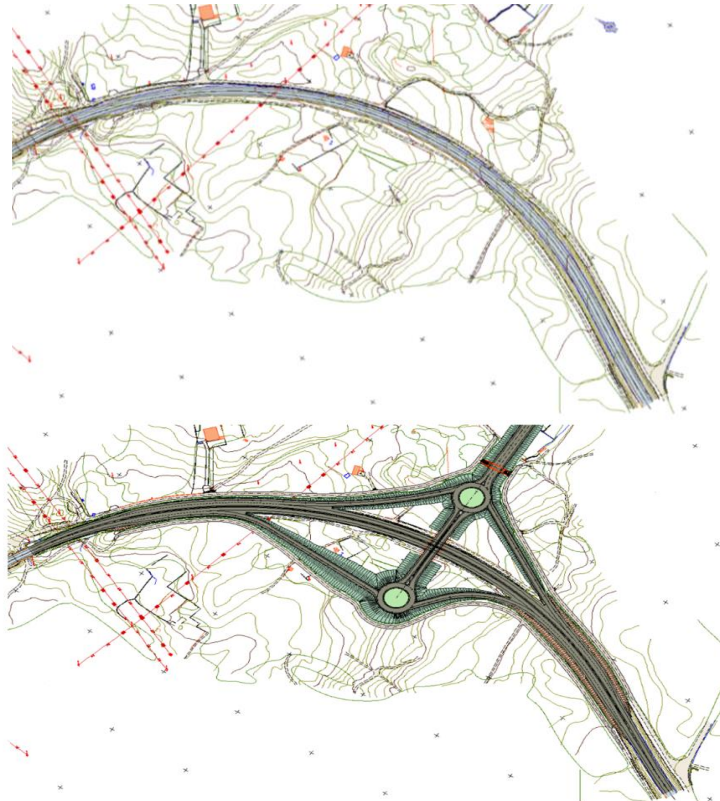


Fig. 5.2 – Project Plan – Initially current situation, and below is the project proposal.

The section chosen to carry out this task optimization would include different specialties: earthworks, drainage, pavement, ancillary works, signage, and safety equipment, and a structure work - an overpass.

It should be noted that in order to carry out the project in this section, there will have to be new construction work and rehabilitation of existing roads as well as widening them, as mentioned before. In this way, the logic taken into account to make a division that made sense in terms of the tasks to be carried out took into account the different procedures to be taken into consideration throughout the section, as well as the need to divert traffic on existing roads so as not to interrupt it completely. Therefore, in addition to the tasks considered for the project, it is necessary to devise a follow-up to these tasks so that they can be carried out while maintaining the possibility of road transport passing through. With that said, the excerpt under study was subdivided as follows:

- Traffic Circle 1;
- Branch road 1A;
- Branch road 1B;
- Branch road 2A;
- Branch road 2B;
- Traffic Circle 2;
- Parallel road 1;
- Parallel road 2;
- Structure Work – Overpass;
- Existing Lane - Right Side;
- Existing Lane - Left Side;

It is important to mention that six different links have been indicated for the entire project, including traffic circles, junctions, and connecting roads, and for this section of the project under study only link 1 is presented, which represents the unlevelled junction between two roads, which as mentioned above coincides with the overpass.

Below is figure 5.3 with the same plan as before, now captioned with the descriptions mentioned above.

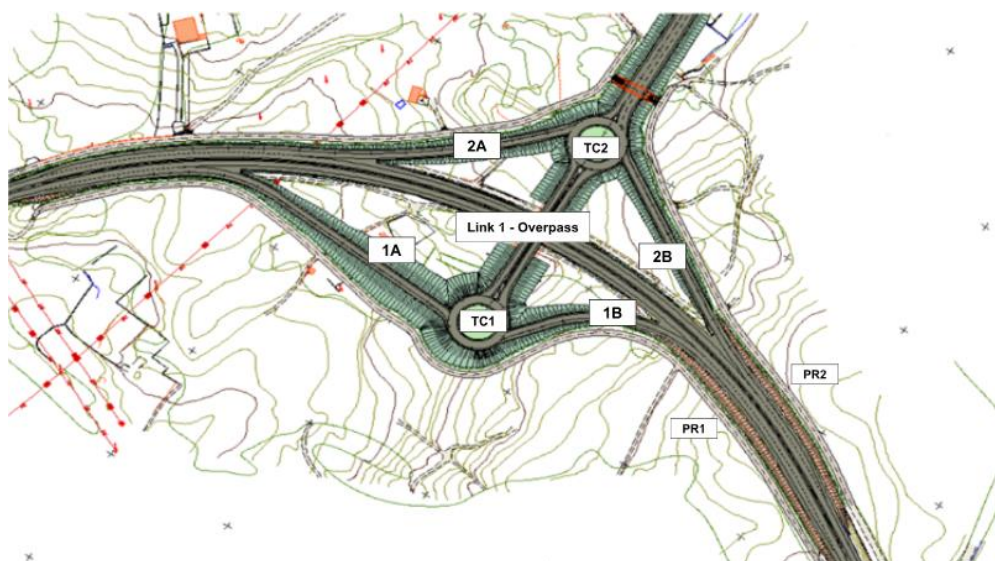


Fig. 5.3 - Identification of the Subdivisions.

With regard to the phasing designed to avoid traffic constraints, the idea was to first build branches 1 and 2, as well as the respective traffic circles and the widening of the existing road. In this way, when the branches and traffic circles were finished, traffic could be diverted through them, by using the extension of the main itinerary to access the new branches, while the rest of the work followed. Parallel roads could also be started at the same time as the branches. These works will all be included in the first phase - phase 1. Parallel paths could also be used to support construction during phase 1.

As for the overpass, it could go ahead as soon as phase 1 is finished – this will be phase 2. In parallel with phase 2, the rehabilitation of the existing main road could begin (phase 3), with the accesses for equipment and machinery for both phases being made directly through the end of the section being rehabilitated, via the existing main route. It is important to mention that during the execution of phase 2 and phase 3, the foreman would have to take safety measures when carrying out work with regard to the tasks located under the overpass.

Below is figure 5.4 representing the three different phases taken into consideration.

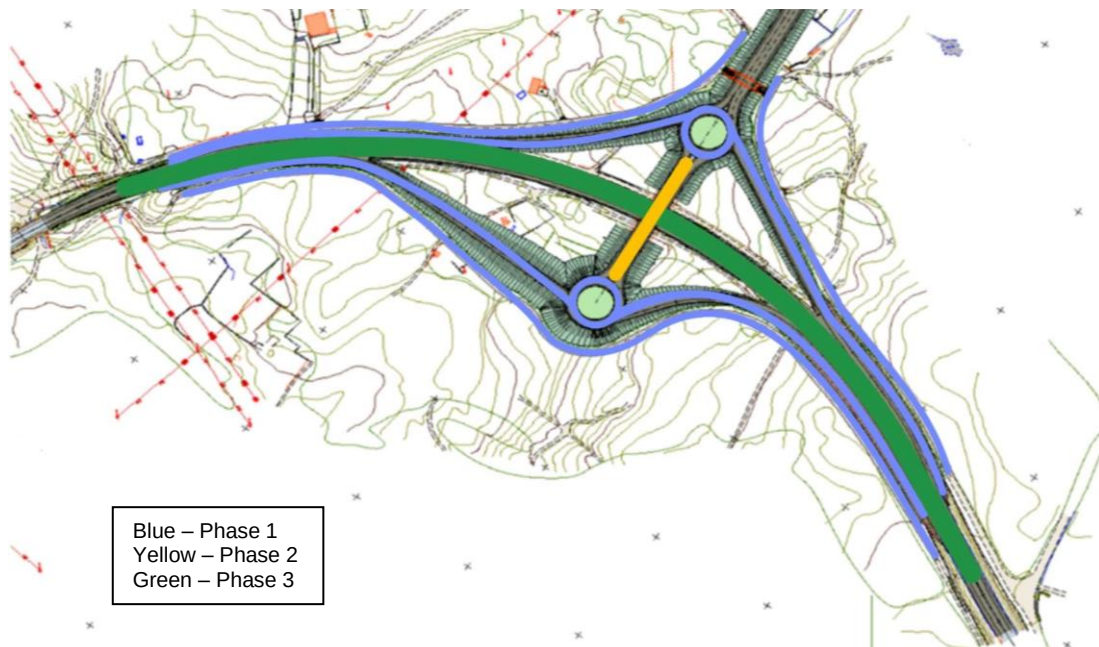


Fig. 5.4 - Phasing of the project.

5.1.2. WORK BREAKDOWN STRUCTURE

With the help of the Bill of Quantities and the Method Statements for each project specialty, a WBS was created with the help of Excel. Next is the way that the WBS was thought out for this case scenario, including all the aspects mentioned before. The different levels indicated represent the different levels of detail, where level 1 is the overall project, level 2 is the section of the project to which it refers, level 3 is the key stage of the project and the following represents the major and minor deliverables.

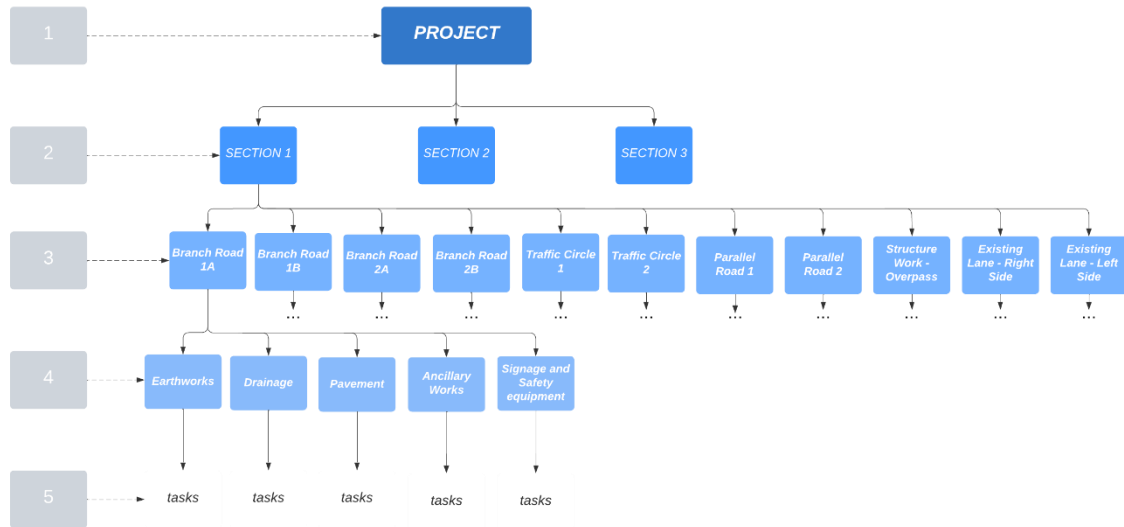


Fig. 5.5 – Organization of the WBS levels for case study 1.

Below is an excerpt (figure 5.6) from the horizontal division of tasks created, where at each level the tasks became more and more specific.

WBS	1	2	3	4	5	6	7	Duration	Un	Quant	Rendim
1	PROJETO										
2		TROÇO 1									
3			Lado Direito -								
4			Plataforma Existente								
5				Terraplenagens							
5					Desmatamento, incluindo desenraizamento, limpeza e abate de árvores ou arbustos			1	m2	3282	5118
5					Demolição de Muros			2	m2	86.00	52.27
5					Remoção de redes de vedações existentes e respectivos postes			25	m	810	31.77
5					Decapagem de terra vegetal com colocação em vazadoiro definitivo			2	m3	1558.00	648.95
5					Saneamento de aterros em zona aluvionar com 1,5 m de espessura			1	m3	231	907.92
5					Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura			1	m3	244	907.92
5					Preenchimento dos Volumes Saneados com enrocamento grosso insensível à água			1	m3	615	980.00
5					Preenchimento dos Volumes Saneados com agregados britados			1	m3	780	980.00
5					Camada Drenante com espessura de 0,50 m			4	m3	1304	295.80
5					Geossintético sobre aterros em zona aluvionar			1	m2	1654	1591.57
5					Geossintético com função de reforço			3	m2	4501	1371.37
5					Colocação de agregado rochoso não friável até 1,0m altura a partir da base do talude, com 0,5m de espessura			2	m2	602	286.2
5					Escavação na linha com meios mecânicos			9	m3	5901.535	636.09
5					Aterro			9	m3	5901.535	636.09
5					Carga e transporte dos materiais da escavação, incluindo espalhamento e compactação dos materiais			1	m3	307.94	1279.25

Fig. 5.6 – WBS Excerpt with Different Levels.

In addition to subdividing the tasks, they were assigned their productivity as well as their quantities and, consequently, their durations (dividing the quantities by the task efficiency, and if this value is less than 1, give the value one), the latter being measured in days. To obtain the quantities, it was taken into account that for this section a relationship would be made as to the fraction that it would have in relation to the total project, in order to obtain coherent quantity values.

With this excerpt of the WBS, it can be seen that one of the divisions adopted for this excerpt was to separate the existing lane into two (right and left sides of the lane with individual tasks, where above only the tasks on the right side are shown in the figure 5.6). This division was made in order to better

control the duration of the tasks to be done. The figure also shows the tasks assigned to this section in relation to the earthworks project to be carried out.

It is important to note that in order to obtain the values presented for each task, the information included in the project description was used, as well as the bill of quantities and the original schedule, as mentioned above.

The same process was devised and adapted to the specifics of the project for all subdivisions of the section, thus obtaining a horizontally hierarchical WBS with logical reasoning that was compatible with factors such as site conditions, project complexity, and stakeholder preferences.

5.1.3. TASK LINKS - USING CANDY SOFTWARE

Having completed this important step of creating a WBS, it was necessary to start thinking about the links between the project's tasks: Firstly, and given that the Work Breakdown Structure was done in Excel (thus facilitating the process of dividing up the tasks), it was necessary to transfer this information to the Candy software.

To make this process easier, the information was first transferred to MS Project, and then the file was transferred via an XML file to the Candy software.

With this said, a heading was created to include the process to be executed. Next is the first view (figure 5.7) of the software, and how the process was started.

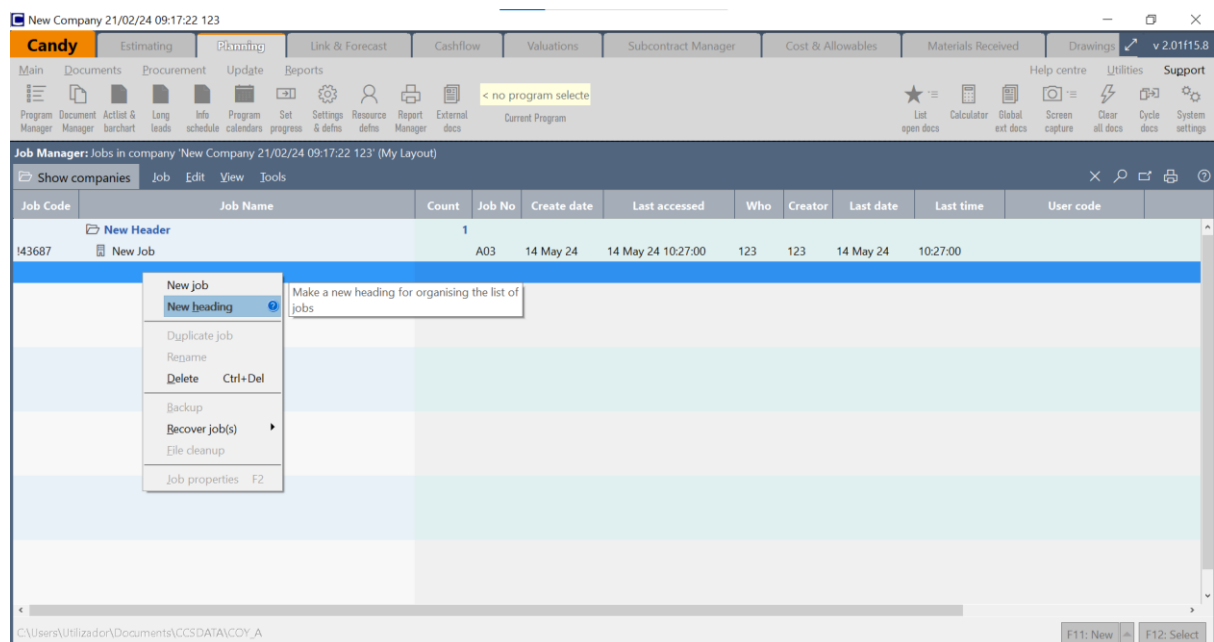


Fig. 5.7 – Creating a Heading on Candy.

The author had then to go to the Program Manager in order to initiate the process. From there, it is possible to create, copy, and remove different work programs that are often required throughout the duration of a contract. In the same task, for instance, it could have the Contract Program, the Contract Program with the first advance, etc. Thus, it would be necessary to import the above-mentioned XML file with the information about the project's tasks, as shown in the next figure 5.8.

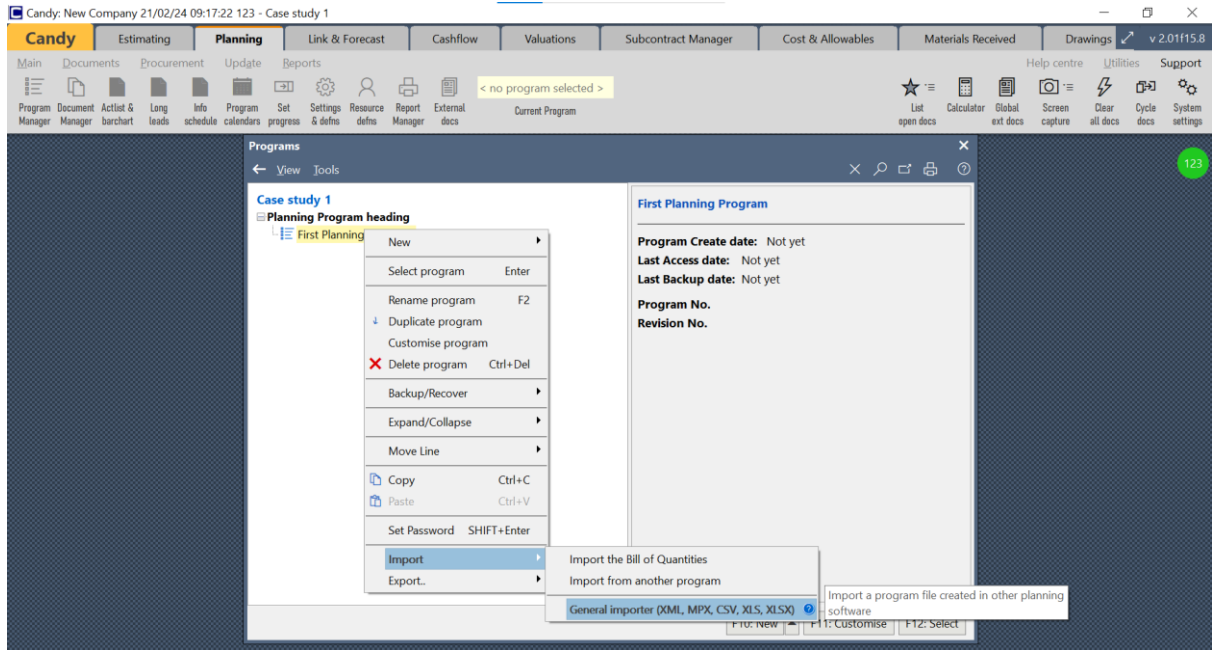


Fig. 5.8 – Importation Method from XML File to the Software.

After importing the file, it would be necessary to make the needed adaptations to the fields to be included in the software to make the task links. Candy allows the user to add fields directly from other software (in this case, MS Project) to make other software's fields compatible with Candy fields. The fields shown in the following figure represent task quantities, units, and performance. Below is figure 5.9 where are shown the three fields included.

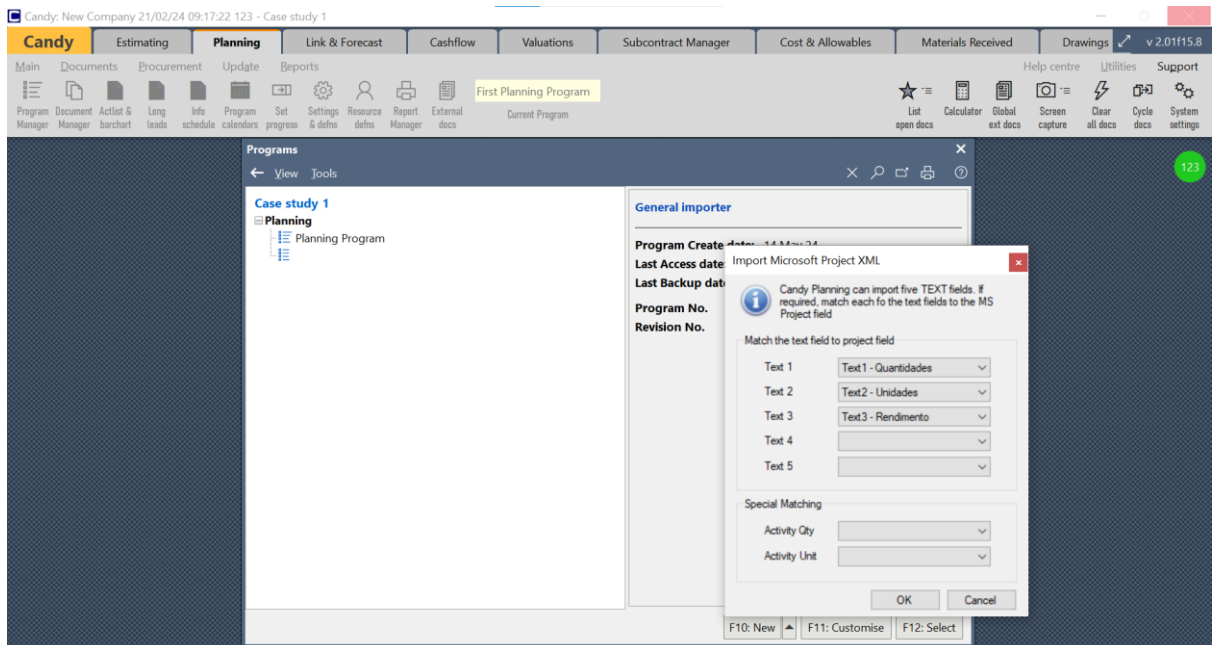


Fig. 5.9 – Importing the Fields needed.

Then, after the tasks had been added to the program, a new window appeared indicating all the information that came from the file (figure 5.10), and it should be noted that this table provides information on the previously defined start date of the work, as well as the working days (five days a week) and daily hours (eight hours).

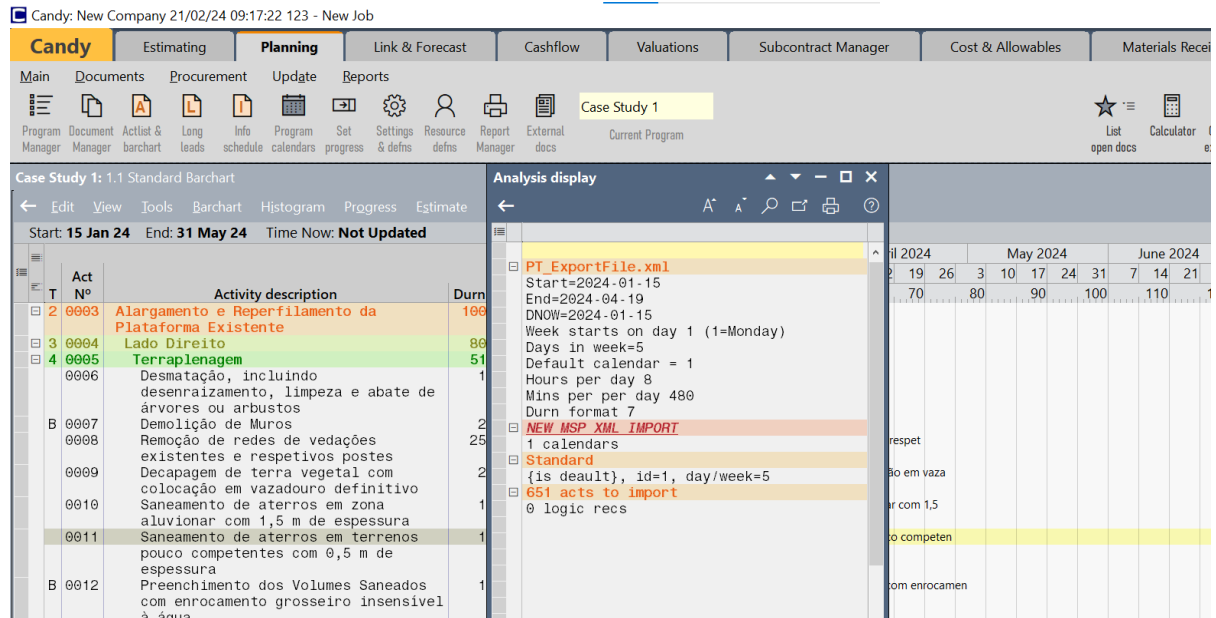


Fig. 5.10 – Schedule Information.

The author began to determine the type of chart he wanted to obtain visually, and with what information. Candy has the possibility of displaying various types of planning documents, including bar charts, time-location diagrams, activity lists, resources, progress, and program pricing.

In order to make the necessary schedule, the author intends to use a bar chart, opting to use the standard bar chart. Next is shown in figure 5.11 the barchart creation in the software.

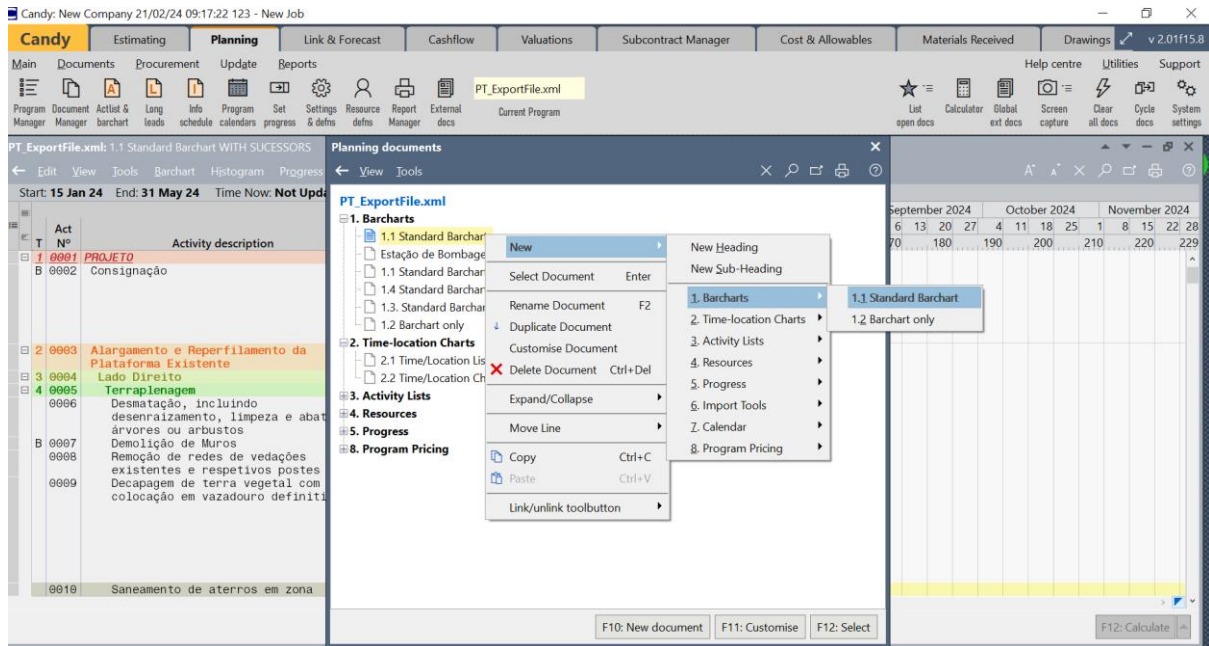


Fig. 5.11 – Barchart Creation.

Candy allows the user to customize the diagram the user selects, so in order to work on the links between the project's tasks, the author chose to work with successors, as shown below in figure 5.12, but keeping in mind that throughout the development of this schedule, the author would have to check if the activities were being left to predecessors and successors.

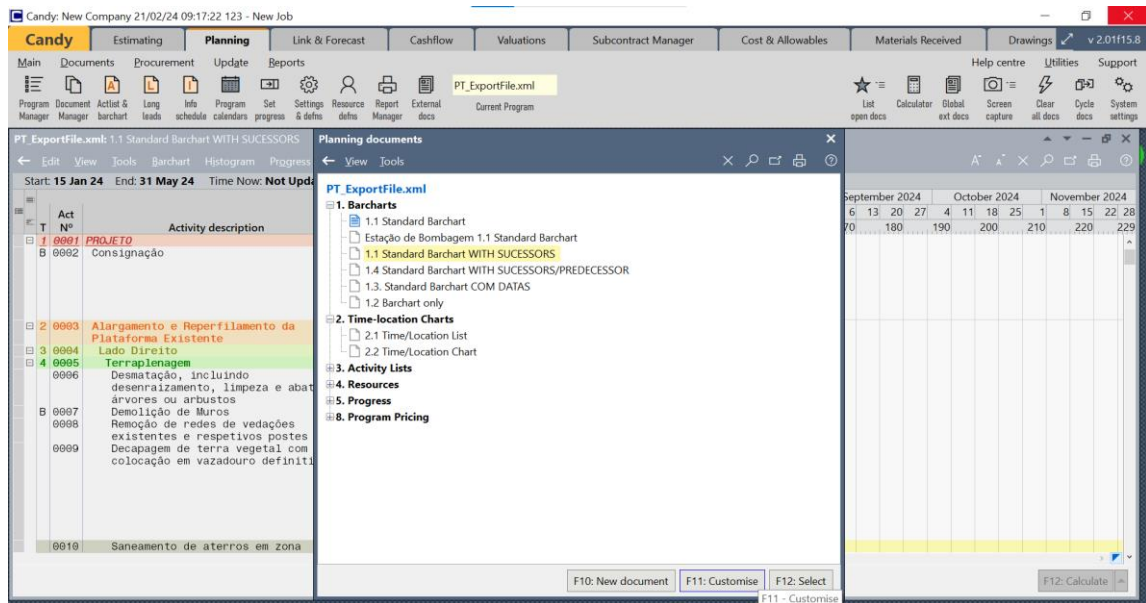


Fig. 5.12 – Successors in Barchart.

Next is figure 5.13 showing all the fields the author has chosen to display in the diagram, which must necessarily include successors and/or predecessors as well as their leads and lags and link duration, the

duration of the tasks, and their description, and the float, type, and numbering of the activities. The calendar code has been left on by default.

When we refer to the activity type, this means that this field determines and establishes the behavior of the activities. The following are examples of available types of Candy:

- B – Bar type or incompletely linked activity
- S – Target start activity
- s – Contractual start activity
- E – Target end activity
- e – Contractual end activity
- F – Activity floats through its free float
- V – Activity only uses free float
- H – Activity works through non-working days
- T – Tied activity (hammock)
- K – Key activity
- M – Marked activity

The activity number column can have numbers (1 to 9) that represent a section header's hierarchical level. Activities of the B and blank types are automatically assigned based on the logic links that lead to and from the activity. This field will be important later when analyzing the schedule again with the 14-point DCMA guideline, as far as constraints are concerned.

Apart from these, it is at the user's discretion whether they want to see any other fields, and the information selected for this case will suffice for this purpose. In figure 5.13 below, the author has assigned the consignment task the type “S”, considering it to be a target start activity.

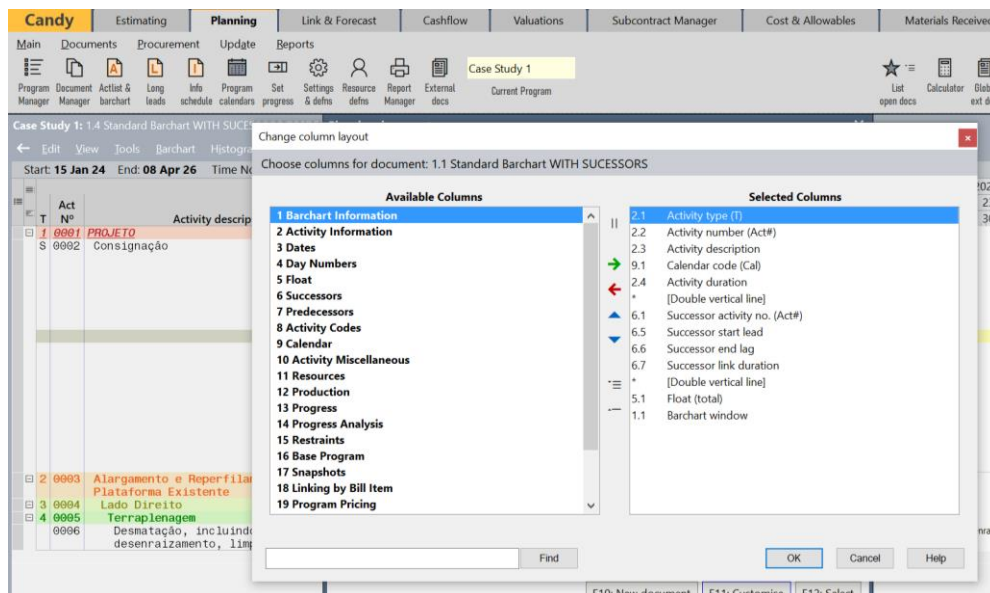


Fig. 5.13 – Customization of the Document.

Immediately before starting the process of making links between tasks, it is wise to think about the calendar: given the geographical area where the work will take place, it is advisable to indicate in the software which days there will be work and, therefore, which will not be a working day for the work,

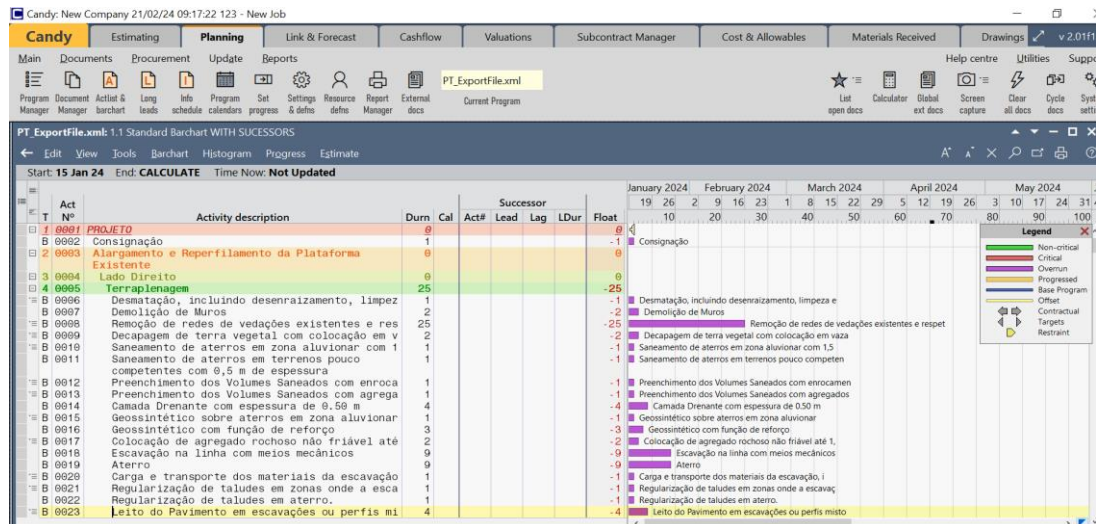


Fig. 5.16 – Schedule Presentation without Links

To begin the process of assigning links in Candy software, it is essential to understand that the software supports only Finish-to-Start (FS) relationship types. This means that one task must be completed before the next one can start. However, Candy allows for the inclusion of leads and lags to adjust the timing between linked tasks, if necessary.

To optimize the schedule, the approach involved carefully thinking through coherent Finish-to-Start links, ensuring that all tasks were logically connected to both predecessors and successors. This way, each task had clear dependencies, creating a comprehensive and interconnected schedule. While the primary method in Candy focuses on associating successors to tasks, it was equally important to monitor the links to predecessors. This ensured that activities were properly aligned and that each task's completion was accurately reflected in the sequence of events.

Ideally, the objective was to have no tasks with incomplete links, ensuring a seamless flow of activities from start to finish. However, it was recognized that in some instances, it might not be feasible to create both predecessors and successors for certain tasks. This is because some tasks, by their nature, are initial and terminal activities and do not logically lead to subsequent tasks. Despite these challenges, the aim was to maintain as complete a linkage system as possible, promoting a well-organized and efficient project schedule. Figure 5.17 shows an excerpt from the schedule developed, with some links made between its tasks.

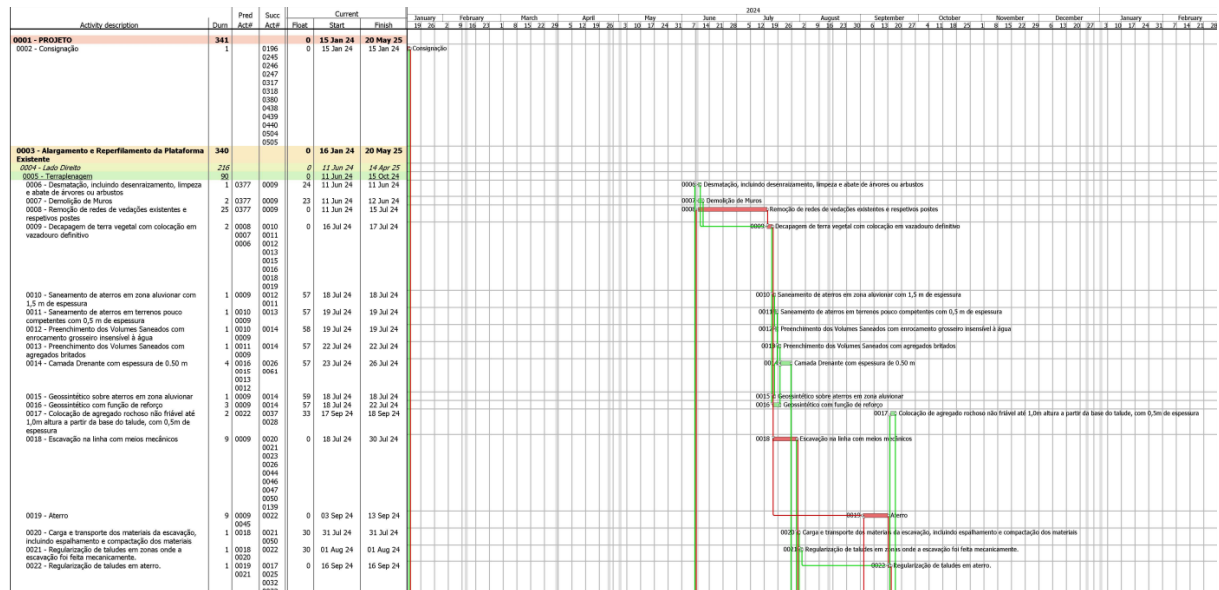


Fig. 5.17 - Schedule excerpt with links.

Ideally, all the task links were designed to maintain a duration and float of equal to or less than 44 working days. This effort was made to comply with the stringent requirements of the Defense Contract Management Agency (DCMA) guidelines. However, achieving this standard was not always feasible due to the inherent dependencies on preceding tasks, as seen in the figure above.

In many cases, the sequential nature of project activities created challenges. Certain tasks were heavily dependent on the completion of prior activities, which extended their duration beyond the desired threshold of no more than 44 working days. These dependencies necessitated careful consideration and adjustment to ensure that the overall project schedule remained as efficient as possible, while still adhering to the DCMA guidelines wherever feasible.

Despite these obstacles, every effort was made to minimize the duration and float of the activities. The goal was to optimize the project schedule and ensure compliance with the DCMA standards, recognizing that some degree of flexibility was necessary to accommodate the complex interdependencies inherent in the project.

With that said, and after finalizing the organization of the schedule, it is possible to observe that the date of completion of the work does not coincide with the date initially imposed for the completion of the work, and both dates of completion are shown in the following figure 5.18.

Activity description	Durn	Pred Act#	Succ Act#	Current		
				Float	Start	Finish
0001 - PROJETO	341			0	15 Jan 24	20 May 25
0002 - Consignação	1		0196	0	15 Jan 24	15 Jan 24

Activities				Quant	Un	Start	Finish
PROJETO						Tue 29/1/22	Sat 22/02/25
ASSINATURA CONTRATO						Tue 29/1/22	Tue 29/1/22
CONSIGNAÇÃO						Mon 15/01/24	Mon 15/01/24

Fig. 5.18 - Finish dates comparison (first presenting the new schedule and below the original schedule).

It is possible to conclude that this difference is due to the lack of information on available resources such as labor, and equipment for the respective work, and with this information, some activities would be more overlapping with each other. With this, and considering the developed schedule a coherent and logical schedule, it will be necessary to make an iteration in order to meet this deadline.

A second iteration of the schedule was therefore drawn up to improve the phasing of the tasks in order to meet the imposed deadline. The measure taken to meet this requirement was to assume that some tasks on the critical path would have a higher productivity, thus leading to activities with shorter durations. In addition, the author took into account what was required by the DCMA and considered working better on the float of some activities, so that these values would be reduced. The approach used was to allow some activities with float (not on the critical path) to increase their duration, thus reducing these float values. In addition, the author took the opportunity to visually improve the schedule, organizing the phasing of the section in a logical way (phases 1, 2, and 3).

With that said, below is figure 5.19 with an excerpt from the next iteration of the schedule developed, now complying with the imposed date and with the reduced float. The entire schedule is attached to this document, in annex A.

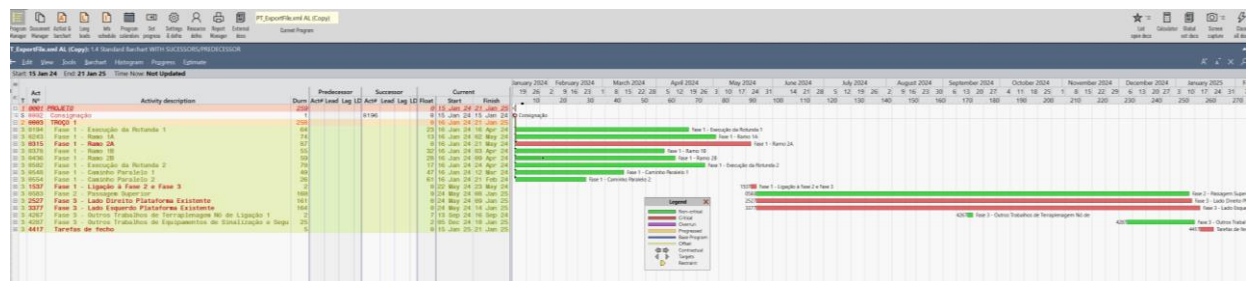


Fig. 5.19 - Schedule, second iteration.

5.2. COMPARISON

As a final note on the schedule created, below is figure 5.20 showing an excerpt from the new schedule compared to the original, which shows the subdivision of the tasks relating to the project's earthworks, and where the main differences can be seen visually.

3	3377	Fase 3 - Lado Esquerdo Plataforma Existente	164	R.01	Terraplenagem:
4	3357	Terraplenagens	81	R.01.01	Trabalhos preparatórios
	3397	Desmatção, incluindo desmatamento, limpeza e abate de árvores ou arbustos	1	R.01.01.01	Desmatção, incluindo derrube de árvores, desmatamento, limpeza do terreno
	3487	Demolição de Muros	5	R.01.01.02	Demolição de construções (excluindo muros)
	3417	Remoção de redes de vedações existentes e respectivos postes	2	R.01.01.03	Demolição de muros
	3427	Decapagem de terra vegetal com colocação em vazadouro		R.01.01.04	Desativação de poços, nascentes ou outras captações existentes
				R.01.01.04.01	Enchimento de poços com enrocamento
				R.01.01.04.02	Captação e condução de águas
	3437	Saneamento de aterros em zona aluvionar com 1,5 m de espessura	1	R.01.01.05	Decapagem na linha de terra vegetal
	3447	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	1	R.01.01.05.01	Vazadouro
	3457	Preenchimento dos Volumes Saneados com enrocamento grosseiro insensível à água	1	R.01.01.05.02	Depósito Provisorio
	3467	Preenchimento dos Volumes Saneados com agregados britados	1	R.01.01.06	Preparação da fundação de aterros em condições especiais (Saneamentos)
	3477	Camada Drenante com espessura de 0,50 m	4	R.01.01.06.02	Saneamento em fundação de aterros
				R.01.01.06.03	Preenchimento dos volumes saneados
	3487	Geossintético sobre aterros em zona aluvionar	1	R.01.01.06.04.01	Geossintéticos fundação Sobre bacias aluvionares
	3497	Geossintético com função de reforço	3	R.01.01.06.04.02	Geossintéticos em fundação função de reforço
	3587	Escavação na linha com meios mecânicos	9	R.01.01.07	Camada drenante sobrejacente ao geotêxtil
				R.01.01.07.04	Em materiais britados
	3517	Aterro	9	R.01.02	Escavação na linha e colocação em aterro ou vazadouro
				R.01.02.01	Escavação
				R.01.02.03.01	Aterro
				R.01.02.05	Escavação de solos a rejeitar
	3527	Carga e transporte dos materiais da escavação, incluindo espalhamento e compactação dos materiais	6	R.01.02.06.01	Regularização de taludes de Escavação
	3537	Regularização de taludes em zonas onde a escavação foi feita mecanicamente.	5	R.01.02.07	Regularização de taludes de aterro
	3547	Regularização de taludes em aterro.	1	R.01.03	Escavação em empréstimo
				R.01.03.01	Escavação em empréstimo em terreno de qualquer natureza e colocação em aterro
				R.01.03.01.01	Carga, transporte, espalhamento e compactação
	3557	Leito do Pavimento em escavações ou perfis mistos em solo	4	R.01.04	Leito do pavimento, incluindo tratamento ou fornecimento, e colocação dos materiais
				R.01.04.03	Em aterros de solos/ Em escavações ou perfis mistos em solo
					Em material granular

Fig. 5.20 - Schedule's comparison (left side new schedule, right side original schedule).

It can be seen that the way in which the tasks are subdivided in the new schedule proves to be more cohesive and personalized to the work front being worked on since the consolidation of all the earthworks in the original schedule makes it more difficult to understand which tasks correspond to which section of the project. In addition, the original schedule has an excessive subdivision of levels, so each task has the appropriate characteristics for the task to be carried out in the new schedule, preventing excessive subgrouping.

5.3. CONCLUSIONS

Using the Candy software, it was possible to obtain a new schedule for case study 1 so that it had a new structure and logic with coherent phasing, and ideally could meet the requirements of the DCMA 14-point assessment check. However, even with this concept in mind when developing this work schedule, a new analysis will have to be carried out in order to confirm whether the effort to optimize this schedule has been in a positive direction, thus confirming whether it meets the requirements of DCMA 14-Point. Therefore, in the next chapter, an analysis will be carried out, now of the new schedule for case study 1, in order to analyze its compliance with the initial requirement. This process will become less time-consuming due to the development of the Excel tool in the initial assessment of the two case studies analyzed initially, and could therefore be an advantage in future projects.

6

NEW SCHEDULE AND ITS ANALYSIS

6.1. INTRODUCTION

In this chapter, the author conducts an analysis similar to that presented in Chapter 4, exclusively for case 1, in order to validate the capacities of DCMA 14 as a tool to improve existing schedule plans.

At this stage, the work undertaken to optimize a schedule for a real civil engineering project has been carefully thought out and idealized. The aim is to demonstrate that through the requirements of the DCMA, it is possible to optimize and improve the way work schedules are developed, thereby providing significant advantages for future projects.

Thus, the author reanalyzes the first ten points of the DCMA 14-Point assessment checklist, as well as point 12, to prove that the new schedule has been modified in an improved manner. This process involves a detailed review of each of these points, ensuring that all implemented improvements comply with the required standards.

6.2. BASELINE ANALYSIS

6.2.1. SUMMARY

In order to start the process of assessing compliance with DCMA requirements, it was necessary to export the information from the schedule developed in Candy software to an Excel sheet, so as to easily assess the desired data. In the software it is possible to easily export the file, directly obtaining an Excel file with all the project information included. The explanations for each point given in Chapter 4 will all apply to this analysis, including their formulas.

It is important to add that for this analysis the author will continue to consider that this will be a baseline analysis, and all tasks represent the "incomplete tasks" since in this sense no task has yet been performed.

6.2.2. ANALYSIS

Initially, and as was done in the analysis of the previous case studies, it will be necessary to start the process by determining the total number of tasks present in the schedule. Since this step differs from project to project, the approach adopted for this case had to be designed to exclude the headings of each group and subgroup of tasks, by subtracting all the lines that showed the level they represented. For example, below is figure 6.1 of some of the tasks in the excel sheet, and each subgroup shows its level

of detail - these are not directly the tasks to be counted, so you quickly realize that you get the real count of tasks by removing the lines that show numbers in the type column.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Successor Activity Number	Current Float	Current Start	Current Finish	COUNT ALL LINES IN SCHEDULE	COUNT ALL HEADINGS	TASK COUNT	PRED & SUC
1	0001	PROJETO	259			0	15 Jan 24	21 Jan 25				
S	0002	Consignação	1		0196	0	15 Jan 24	15 Jan 24	1	0	1	0
					0245				0	0	0	0
					0246				0	0	0	0
					0247				0	0	0	0
					0317				0	0	0	0
					0318				0	0	0	0
					0380				0	0	0	0
					0438				0	0	0	0
					0439				0	0	0	0
					0440				0	0	0	0
					0504				0	0	0	0
					0505				0	0	0	0
					0553				0	0	0	0
					0556				0	0	0	0
2	0003	TROÇO 1	258			0	16 Jan 24	21 Jan 25	1	1	0	0
3	0194	Fase 1 - Execução da Rotunda 1	64			23	16 Jan 24	16 Apr 24	1	1	0	0
4	0195	Terraplenagem	27			23	16 Jan 24	22 Feb 24	1	1	0	0
	0196	Desmatção, incluindo desenraizamento, limpeza e abate de árvores ou arbustos	1	0002	0197	23	16 Jan 24	16 Jan 24	1	0	1	1
					0198				0	0	0	0
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196	0199	23	17 Jan 24	18 Jan 24	1	0	1	1
					0200				0	0	0	0
					0202				0	0	0	0
					0203				0	0	0	0
					0204				0	0	0	0
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196	0199	24	17 Jan 24	17 Jan 24	1	0	1	1
					0200				0	0	0	0
					0202				0	0	0	0
					0204				0	0	0	0
					0203				0	0	0	0
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198	0200	23	19 Jan 24	22 Jan 24	1	0	1	1
				0197	0585				0	0	0	0
					0586				0	0	0	0
					0587				0	0	0	0
	0200	Preenchimento dos Volumes Saneados com agregados britados	3	0198	0201	23	23 Jan 24	25 Jan 24	1	0	1	1
				0199	0585				0	0	0	0
				0197	0586				0	0	0	0
					0587				0	0	0	0

Fig. 6.1 - Task count of the new schedule.

After making this distinction, it was concluded that this schedule included 539 tasks.

With the necessary information, the evaluation of the respective points of the DCMA began and is presented below.

6.2.2.1. Missing Logic

Similarly to the practical cases, the evaluation for the first point of the DCMA was made by accounting for the activities that had predecessors and successors. In figure 6.2 it is possible to observe that it is visually easy to identify the tasks that present both or not, and through an Excel "countif" formula it was possible to obtain which activities had logic, thus concluding what percentage of tasks did not meet the requirement. The goal would be not to exceed the threshold of 5% of tasks with missing logic.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Successor Activity Number	Current Float	Current Start	Current Finish	COUNT ALL LINES IN SCHEDULE	COUNT ALL HEADINGS	TASK COUNT	PRED & SUC
1	0001	PROJETO	259			0	15 Jan 24	21 Jan 25				
S	0002	Consignação	1		0196	0	15 Jan 24	15 Jan 24	1	0	1	0
					0245				0	0	0	0
					0246				0	0	0	0
					0247				0	0	0	0
					0317				0	0	0	0
					0318				0	0	0	0
					0380				0	0	0	0
					0438				0	0	0	0
					0439				0	0	0	0
					0440				0	0	0	0
					0504				0	0	0	0
					0505				0	0	0	0
					0553				0	0	0	0
					0556				0	0	0	0
2	0003	TROÇO 1	258			0	16 Jan 24	21 Jan 25	1	1	0	0
3	0194	Fase 1 - Execução da Rotunda 1	64			23	16 Jan 24	16 Apr 24	1	1	0	0
4	0195	Terraplenagem	27			23	16 Jan 24	22 Feb 24	1	1	0	0
	0196	Desmatção, incluindo desenraizamento, limpeza e abate de árvores ou arbustos	1	0002	0197	23	16 Jan 24	16 Jan 24	1	0	1	1
					0198				0	0	0	0
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196	0199	23	17 Jan 24	18 Jan 24	1	0	1	1
					0200				0	0	0	0
					0202				0	0	0	0
					0203				0	0	0	0
					0204				0	0	0	0
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196	0199	24	17 Jan 24	17 Jan 24	1	0	1	1
					0200				0	0	0	0
					0202				0	0	0	0
					0204				0	0	0	0
					0203				0	0	0	0
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198	0200	23	19 Jan 24	22 Jan 24	1	0	1	1
				0197	0585				0	0	0	0
					0586				0	0	0	0
					0587				0	0	0	0
	0200	Preenchimento dos Volumes Saneados com agregados britados	3	0198	0201	23	23 Jan 24	25 Jan 24	1	0	1	1
				0199	0585				0	0	0	0
				0197	0586				0	0	0	0
					0587				0	0	0	0

Fig. 6.2 - Predecessors and Successors counting.

After this count, the total number of tasks with missing logic was 2, concluding that 0.37% of all tasks are without predecessors and successors, thus meeting the requirement of no more than 5% of the point. It's important to note that the activities that are missing logic should not be included in this concept, since the first and last tasks that were considered don't naturally have a predecessor or successor. This means that all tasks that can have predecessors and successors comply with this point, concluding that there are 0% of tasks with missing logic.

6.2.2.2. Leads

For the second point of the Assessment, it is important to remember that for this evaluation, links in the predecessor's relationships with leads (negative lag) should not be presented, as these lead to changes in the total float of the project. In the development of the schedule, due attention was paid to this aspect. Candy's information subdivision allows the separation of all leads in a column, so the evaluation to be made consisted of checking if any value was indicated in this column. Below is figure 6.3 with this column highlighted.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Predecessor Lead	Predecessor Lag	Successor Activity Number	Current Float	Current Start	Current Finish	COUNT ALL LINES IN SCHEDULE	COUNT ALL HEADINGS	TASK COUNT
1	0001	PROJETO	259					0	15 Jan 24	21 Jan 25			
S	0002	Consignação	1				0196	0	15 Jan 24	15 Jan 24	1	0	1
							0245				0	0	0
							0246				0	0	0
							0247				0	0	0
							0317				0	0	0
							0318				0	0	0
							0380				0	0	0
							0438				0	0	0
							0439				0	0	0
							0440				0	0	0
							0504				0	0	0
							0505				0	0	0
							0553				0	0	0
							0556				0	0	0
2	0003	TROÇO 1	258					0	16 Jan 24	21 Jan 25	1	1	0
3	0194	Fase 1 - Execução da Rotunda 1	64					23	16 Jan 24	16 Apr 24	1	1	0
4	0195	Terraplenagem	27					23	16 Jan 24	22 Feb 24	1	1	0
	0196	Desmatção, incluindo desmatamento, limpeza e abate de árvores ou arbustos	1	0002			0197	23	16 Jan 24	16 Jan 24	1	0	1
							0198				0	0	0
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196			0199	23	17 Jan 24	18 Jan 24	1	0	1
							0200				0	0	0
							0202				0	0	0
							0203				0	0	0
							0204				0	0	0
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196			0199	24	17 Jan 24	17 Jan 24	1	0	1
							0200				0	0	0
							0202				0	0	0
							0204				0	0	0
							0203				0	0	0
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198			0200	23	19 Jan 24	22 Jan 24	1	0	1
				0197			0585				0	0	0
							0586				0	0	0
							0587				0	0	0
	0200	Preenchimento dos Volumes Saneados com agregados britados	3	0198			0201	23	23 Jan 24	25 Jan 24	1	0	1
				0199			0585				0	0	0
				0197			0586				0	0	0

Fig. 6.3 - Leads counting in the new schedule.

As mentioned earlier, this point is evaluated by comparing the total number of links with leads with the total number of project links. Thus, and due to the line separation that Candy makes for each connection, it was only necessary to make a count of all the links made from predecessors and successors, thus obtaining a total number of 2104 links.

With that being said, there was not any link with negative lag, thus this metric was accomplished.

6.2.2.3. Lag

Now to evaluate the next metric, it's taking into consideration all links that have a positive lag. For this point, there was a tolerance of 5% for this evaluation. In the same way that Candy separates leads into an individual column, the same happens with lags. Thus, in the same way that the previous metric was evaluated, the same procedure was done in Excel. Next, in figure 6.4 is the column referring to the schedule lags highlighted.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Predecessor Lead	Predecessor Lag	Successor Activity Number	Current Float	Current Start	Current Finish	COUNT ALL LINES IN SCHEDULE	COUNT ALL HEADINGS	TASK COUNT
1	0001	PROJETO	259					0	15 Jan 24	21 Jan 25			
S	0002	Consignação	1				0196	0	15 Jan 24	15 Jan 24	1	0	1
							0245				0	0	0
							0246				0	0	0
							0247				0	0	0
							0317				0	0	0
							0318				0	0	0
							0380				0	0	0
							0438				0	0	0
							0439				0	0	0
							0440				0	0	0
							0504				0	0	0
							0505				0	0	0
							0553				0	0	0
							0556				0	0	0
2	0003	TROÇO 1	258					0	16 Jan 24	21 Jan 25	1	1	0
3	0194	Fase 1 - Execução da Rotunda 1	64					23	16 Jan 24	16 Apr 24	1	1	0
4	0195	Terraplenagem	27					23	16 Jan 24	22 Feb 24	1	1	0
	0196	Desmatção, incluindo desmatamento, limpeza e abate de árvores ou arbustos	1	0002			0197	23	16 Jan 24	16 Jan 24	1	0	1
							0198				0	0	0
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196			0199	23	17 Jan 24	18 Jan 24	1	0	1
							0200				0	0	0
							0202				0	0	0
							0203				0	0	0
							0204				0	0	0
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196			0199	24	17 Jan 24	17 Jan 24	1	0	1
							0200				0	0	0
							0202				0	0	0
							0204				0	0	0
							0203				0	0	0
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198			0200	23	19 Jan 24	22 Jan 24	1	0	1
				0197			0585				0	0	0
							0586				0	0	0
							0587				0	0	0
	0200	Preenchimento dos Volumes Saneados com agregados britados	3	0198			0201	23	23 Jan 24	25 Jan 24	1	0	1
				0199			0585				0	0	0
				0197			0586				0	0	0

Fig. 6.4 – Lags counting of the new schedule.

Since this metric is analyzed by comparing links with lag in the same way as leads, the percentage to be presented would be between links with lag and the total number of links in the project. Thus, a total of 0 connections with lag were obtained, clearly complying with this metric.

6.2.2.4. Schedule Relationships

To evaluate this metric, it is important to remember that Candy only works with Finish-to-Start and Finish-to-Finish link relationships. The latter could only be performed using lags, otherwise it would not be possible to make this distinction. Taking this into account, and knowing that previously in the evaluation of the point “Lags” none was identified, it is possible to conclude that all the connections made for this schedule are Start-to-Finish, thus concluding that the total percentage of connections had this connection. Since the requirement of this metric is the existence of at least 90% of Start-to-Finish connections concerning all connections, it is concluded that 100% of the connections are of this nature.

6.2.2.5. Hard Constraints

As mentioned in Chapter 5, Candy's "activity type" field is assigned to each task, if necessary, its behavior and, consequently, if there were any restrictions to be indicated. Thus, knowing that only in the initial task was assigned the information of being a "contractual start activity" task, this would have the difference of being a task with a soft constraint "Start No Earlier Than" (SNET), while the others would have the soft constraint "As Soon As Possible" (ASAP). Thus, and taking into account that this metric evaluates the existence of hard constraints associated with the project, it is possible to verify in

figure 6.5 that none has been assigned to the schedule, thus fulfilling the requirement of not more than 5% of tasks with hard constraints.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Predecessor Lead	Predecessor Lag	Successor Activity Number	Current Float	Current Start	Current Finish	COUNT ALL LINES IN SCHEDULE	COUNT ALL HEADINGS	TASK COUNT	PRED & SUC	CONSTRAINTS
1	0001	PROJETO	259					0	15 Jan 24	21 Jan 25					
S	0002	Conservação	1				0196	0	15 Jan 24	15 Jan 24	1	0	1	0	Start No earlier Than
							0245				0	0	0	0	
							0246				0	0	0	0	
							0247				0	0	0	0	
							0317				0	0	0	0	
							0318				0	0	0	0	
							0380				0	0	0	0	
							0438				0	0	0	0	
							0439				0	0	0	0	
							0440				0	0	0	0	
							0504				0	0	0	0	
							0505				0	0	0	0	
							0553				0	0	0	0	
							0556				0	0	0	0	
2	0003	TROÇO 1	258					0	16 Jan 24	21 Jan 25	1	1	0	0	
3	0194	Fase 1 - Execução da Rotunda 1	64					23	16 Jan 24	16 Apr 24	1	1	0	0	
4	0195	Terraplenagem	27					23	16 Jan 24	22 Feb 24	1	1	0	0	
	0196	Desmatamento, incluindo deslenraizamento, limpeza e abate de árvores ou arbustos	1	0002			0197	23	16 Jan 24	16 Jan 24	1	0	1	1	As Soon As Possible
							0198				0	0	0	0	
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196			0199	23	17 Jan 24	18 Jan 24	1	0	1	1	As Soon As Possible
							0200				0	0	0	0	
							0202				0	0	0	0	
							0203				0	0	0	0	
							0204				0	0	0	0	
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196			0199	24	17 Jan 24	17 Jan 24	1	0	1	1	As Soon As Possible
							0200				0	0	0	0	
							0202				0	0	0	0	
							0204				0	0	0	0	
							0203				0	0	0	0	
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198			0200	23	19 Jan 24	22 Jan 24	1	0	1	1	As Soon As Possible
							0585				0	0	0	0	
							0586				0	0	0	0	
							0587				0	0	0	0	
	0200	Preenchimento dos Volumes Saneados com agregados britados	3	0198			0201	23	23 Jan 24	25 Jan 24	1	0	1	1	As Soon As Possible

Fig. 6.5 - Constraints added to the new schedule.

Some activities present the “B” type, where in this case it means that they are missing logic – missing predecessors or successors.

6.2.2.6. High Float

With regard to the metric of high float, it is important to remember that it consists of tasks float that exceed 44 days of work - coinciding with two months of work. Thus, an analysis was carried out in this sense in order to prove that it was possible to create connections in such a way that the maximum limit required by the DCMA is not exceeded, which is no more than 5% of the total tasks of the project.

Despite efforts to minimize very high task float, there were instances where this could not be avoided due to task dependencies. For example, in the developed schedule, the parallel paths exhibit high float. This occurs because these tasks are part of phase one, and once completed, they connect to a milestone that subsequently links to the next two phases. Consequently, this subgroup of tasks has increased float due to the waiting period between the completion of the parallel paths and the continuation of the remaining work in phase one.

Thus, the analysis was carried out, obtaining a number of 11 tasks with high float, and subsequently a percentage of 2.04% of tasks with high float, thus passing this point of the DCMA and making it easier to manage the schedule’s progress and current state. Next is figure 6.6 showing the column with the total float information.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Predecessor Lead	Predecessor Lag	Successor Activity Number	Current Float	Current Start	Current Finish	COUNT ALL LINES IN SCHEDULE	COUNT ALL HEADINGS	TASK COUNT	PRED & SUC	TASKS DURATIONS	TASKS FLOAT
1	0001	PROJETO	259					0	15 Jan 24	21 Jan 25						
5	0002	Conservação	1				0196	0	15 Jan 24	15 Jan 24	1	0	1	0	1	0
							0245				0	0	0	0		
							0246				0	0	0	0		
							0247				0	0	0	0		
							0317				0	0	0	0		
							0318				0	0	0	0		
							0380				0	0	0	0		
							0438				0	0	0	0		
							0439				0	0	0	0		
							0440				0	0	0	0		
							0504				0	0	0	0		
							0505				0	0	0	0		
							0553				0	0	0	0		
							0556				0	0	0	0		
2	0003	TROÇO 1	258					0	16 Jan 24	21 Jan 25	1	1	0	0		
3	0194	Fase 1 - Execução da Rotunda 1	64					23	16 Jan 24	16 Apr 24	1	1	0	0		
4	0195	Terraplenagem	27					23	16 Jan 24	22 Feb 24	1	1	0	0		
	0196	Desmatamento, incluindo desmatamento, limpeza e abate de árvores ou arbustos	1	0002			0197	23	16 Jan 24	16 Jan 24	1	0	1	1	1	23
							0198				0	0	0	0		
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196			0199	23	17 Jan 24	18 Jan 24	1	0	1	1	2	23
							0200				0	0	0	0		
							0202				0	0	0	0		
							0203				0	0	0	0		
							0204				0	0	0	0		
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196			0199	24	17 Jan 24	17 Jan 24	1	0	1	1	1	24
							0200				0	0	0	0		
							0202				0	0	0	0		
							0204				0	0	0	0		
							0203				0	0	0	0		
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198			0200	23	19 Jan 24	22 Jan 24	1	0	1	1	2	23
				0197			0585				0	0	0	0		
							0586				0	0	0	0		
							0587				0	0	0	0		
	0200	Preenchimento dos Volumes Saneados com agregados britados	3	0198			0201	23	23 Jan 24	25 Jan 24	1	0	1	1	3	23

Fig. 6.6 - Total float analysis of the new schedule.

6.2.2.7. Negative Float

This aspect of the DCMA involves examining the schedule for any negative float, with zero tolerance for this metric. The presence of a negative float indicates that the project is already behind schedule. This analysis was carried out by selecting the float that appeared negative in the respective column, thus concluding that there was no negative float associated with any task in the schedule, meaning that this metric has been met. This metric was also evaluated with the information indicated in the figure above 6.6.

6.2.2.8. High Duration Tasks

For this eighth metric, the duration of the tasks was the focus of evaluation. The goal would be to obtain no more than 5% of tasks with a duration of more than 44 working days, so as not to lose sight of the progress of each activity. The approach in the execution of the schedule in order to avoid high durations was through the division of activities, leading to smaller durations for each one of them. The different work fronts also allowed the duration values to be lower, as the quantities of each task were distributed proportionally across each front. Next is figure 6.7 identifying the duration column in Excel, counting the tasks that had a high duration, and comparing them with the total number of tasks.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Predecessor Lead	Predecessor Lag	Successor Activity Number	Current Float	Current Start	Current Finish	COUNT ALL LINES IN SCHEDULE	COUNT ALL HEADINGS	TASK COUNT	PRED & SUC	TASKS DURATIONS	TASKS FLOAT
1	0001	PROJETO	259					0	15 Jan 24	21 Jan 25						
5	0002	Consignação	1				0196	0	15 Jan 24	15 Jan 24	1	0	1	0	1	0
							0245				0	0	0	0		
							0246				0	0	0	0		
							0247				0	0	0	0		
							0317				0	0	0	0		
							0318				0	0	0	0		
							0380				0	0	0	0		
							0438				0	0	0	0		
							0439				0	0	0	0		
							0440				0	0	0	0		
							0504				0	0	0	0		
							0505				0	0	0	0		
							0553				0	0	0	0		
							0556				0	0	0	0		
2	0003	TROÇO 1	258					0	16 Jan 24	21 Jan 25	1	1	0	0		
3	0194	Fase 1 - Execução da Rotunda 1	64					23	16 Jan 24	16 Apr 24	1	1	0	0		
4	0195	Terraplenagem	27					23	16 Jan 24	22 Feb 24	1	1	0	0		
	0196	Desmatção, incluindo desmatamento, limpeza e abate de árvores ou arbustos	1	0002			0197	23	16 Jan 24	16 Jan 24	1	0	1	1	1	23
							0198				0	0	0	0		
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196			0199	23	17 Jan 24	18 Jan 24	1	0	1	1	2	23
							0200				0	0	0	0		
							0202				0	0	0	0		
							0203				0	0	0	0		
							0204				0	0	0	0		
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196			0199	24	17 Jan 24	17 Jan 24	1	0	1	1	1	24
							0200				0	0	0	0		
							0202				0	0	0	0		
							0204				0	0	0	0		
							0203				0	0	0	0		
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198			0200	23	19 Jan 24	22 Jan 24	1	0	1	1	2	23
				0197			0585				0	0	0	0		
							0586				0	0	0	0		
							0587				0	0	0	0		
	0200	Preenchimento dos Volumes Saneados com agregados britados	3	0198			0201	23	23 Jan 24	25 Jan 24	1	0	1	1	3	23

Fig. 6.7 - Tasks duration evaluation is done for the new schedule.

After this count, it is possible to conclude that 0 tasks have a high duration, leading to a percentage of 0% in relation to the total number of tasks. Thus, it is concluded that this metric was met since it did not exceed the 5% limit of this point.

6.2.2.9. Invalid Dates

For this point in the assessment, invalid dates were analyzed. With this, the metric aims to evaluate if there are no finish dates to end before the start of the same activity - because if it did, there would be no coherence in terms of deadlines in the schedule. The tolerance for this metric is 0%.

Below is figure 6.8 which shows an excerpt of the start and end dates of the respective tasks.

Type	Activity Number	Activity description	Duration	Predecessor Activity Number	Predecessor Lead	Predecessor Lag	Successor Activity Number	Current Float	Current Start	Current Finish	CHECK INVALID DATES
1	0001	PROJETO	259					0	15 Jan 24	21 Jan 25	0
S	0002	Consignação	1				0196	0	15 Jan 24	15 Jan 24	0
							0245				0
							0246				0
							0247				0
							0317				0
							0318				0
							0380				0
							0438				0
							0439				0
							0440				0
							0504				0
							0505				0
							0553				0
							0556				0
2	0003	TROÇO 1	258					0	16 Jan 24	21 Jan 25	0
3	0194	Fase 1 - Execução da Rotunda 1	64					23	16 Jan 24	16 Apr 24	0
4	0195	Terraplenagem	27					23	16 Jan 24	22 Feb 24	0
	0196	Desmatção, incluindo desenraizamento, limpeza e abate de árvores ou arbustos	1	0002			0197	23	16 Jan 24	16 Jan 24	0
							0198				0
	0197	Decapagem de terra vegetal com colocação em vazadouro	2	0196			0199	23	17 Jan 24	18 Jan 24	0
							0200				0
							0202				0
							0203				0
							0204				0
	0198	Decapagem de terra vegetal com colocação em depósito provisório	1	0196			0199	24	17 Jan 24	17 Jan 24	0
							0200				0
							0202				0
							0204				0
							0203				0
	0199	Saneamento de aterros em terrenos pouco competentes com 0,5 m de espessura	2	0198			0200	23	19 Jan 24	22 Jan 24	0
				0197			0585				0
							0586				0

Fig. 6.8 - Invalid dates analysis of the new schedule.

Similar to the cases analyzed in a previous chapter, all start and end dates were compared, respectively. With this, it was concluded that there were no invalid dates in the schedule, thus complying with the metric.

6.2.2.10. Resources

For DCMA metric number 10, it is analyzed whether resources (if they are assigned to the project) are assigned to all tasks. These resources can represent hours or costs. Due to the size of the project and for confidentiality reasons, it was not possible to associate this information with the new schedule. As this is a non-mandatory point of the DCMA, it was therefore not included in this analysis.

6.2.2.11. The Critical Path Test

This last metric consists of analyzing the integrity of network logic, also relating to the lack of logic associated with the schedule tasks. By applying a deviation in the duration of a task present in the critical path, it is supposed to lead to the same deviation in the total duration of the project. Thus, this analysis was performed in Candy (figure 6.9), making the change to the task presented in the following figure. Tasks marked in red are critical tasks in the schedule.

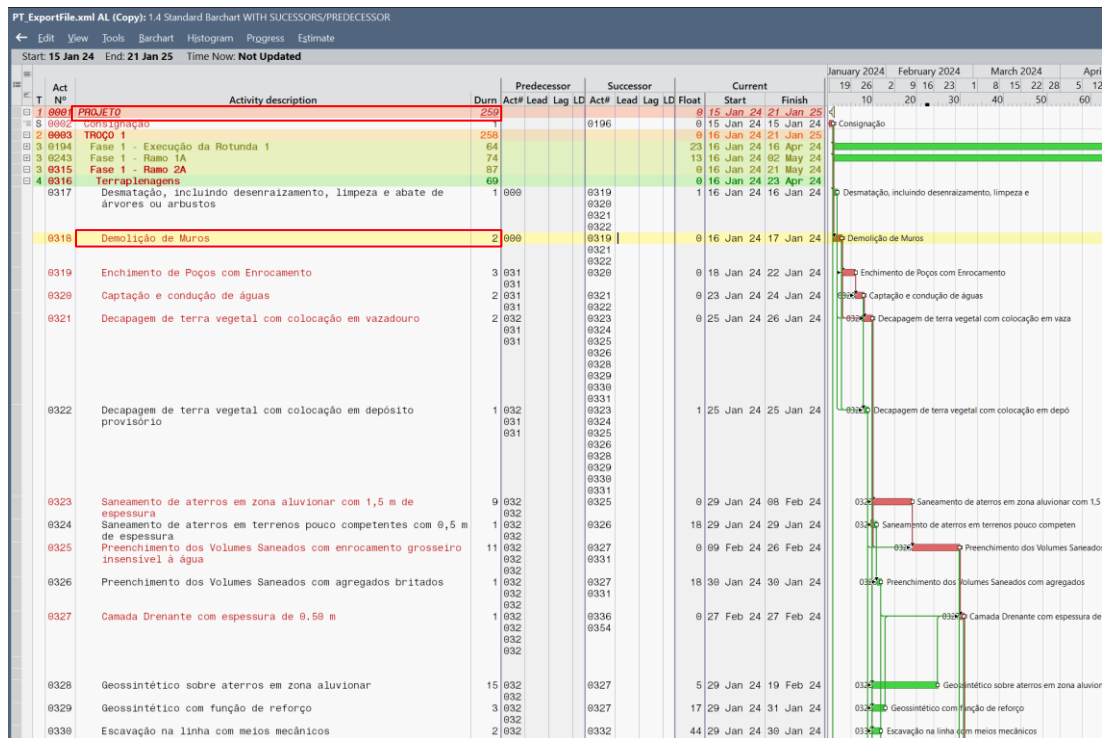


Fig. 6.9 - Selection of critical activity on Candy.

The results obtained are shown in figure 6.10.

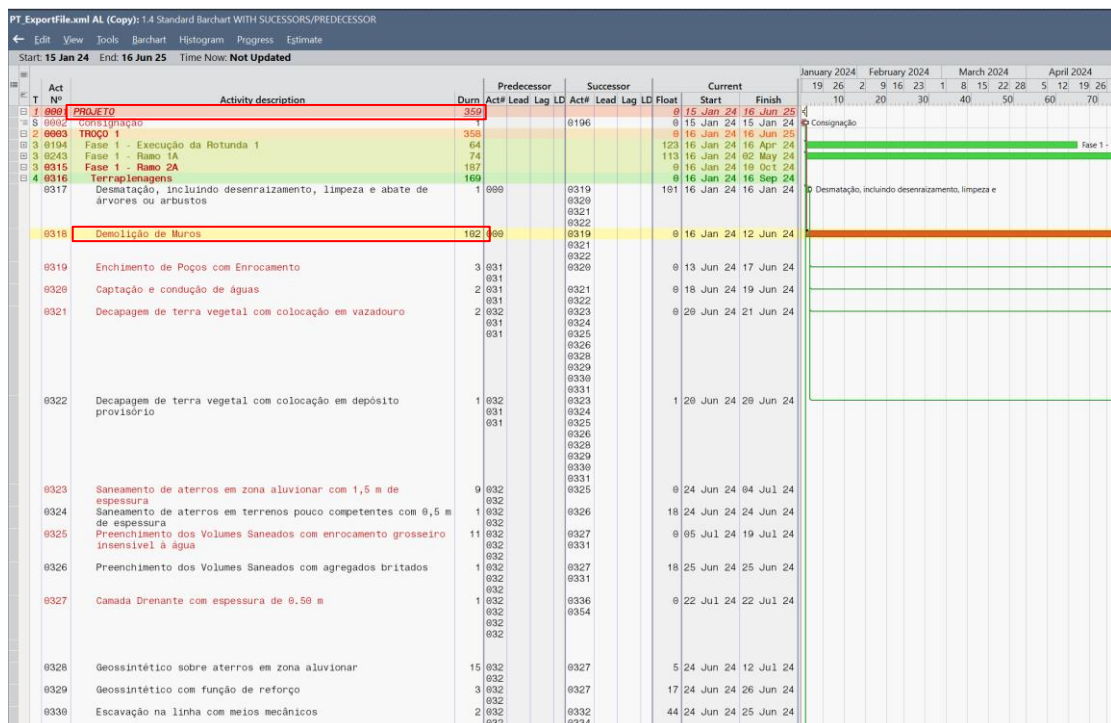


Fig. 6.10 - Critical path check for the new schedule.

With the results obtained, it is possible to conclude that the schedule complies with this metric.

6.2.3. SUMMARIZE

In short, after a detailed analysis of the points addressed above, it is possible to conclude that all the criteria were duly met. The application of the DCMA requirements allowed for the creation of a coherent and logical work schedule. This process resulted in the significant optimization of work schedules, ensuring better organization and efficiency in the execution of projects. Therefore, the use of DCMA criteria has proven to be a valuable tool for the development of more effective and well-structured work schedules. Below is figure 6.11 showing all the points evaluated, using the Excel tool previously developed, that could quickly demonstrate if all criteria were accomplished.

	LOGIC	LEADS	LAG	SCHEDULE RELATIONSHIPS	HARD CONSTRAINTS	HIGH FLOAT	NEGATIVE FLOAT	HIGH DURATION TASKS	INVALID DATES	CRITICAL PATH CHECK
total	0	0	0	2104	0	11	0	0	0	
target	<=5%	0%	<=5%	>=90%	<=5%	<=5%	<=5%	<=5%	0%	
	0.00%	0.00%	0.00%	100.00%	0.00%	2.04%	0.00%	0.00%	0.00%	OK
	PRED & SUC	NEGATIVE LAG	POSITIVE LAG	FS RELATIONSHIPS	HARD CONSTRAINTS	FLOAT GREATER THAN 44 DAYS	FLOAT LESS THAN ZERO	DURATION GREATER THAN 44 DAYS	INVALID DATES	PASS?
	0	0	0	2104	0	11	0	0	0	PASS

Fig. 6.11 - Excel tool with DCMA metrics evaluation of the new schedule.

6.3. CONCLUSIONS

This in-depth examination of the completed work shows that the optimized schedule effectively complied with all of the strict restrictions established by the DCMA. Following these guidelines to the letter shows that the final schedule is more logical and cohesive. This accomplishment emphasizes how crucial it is to adhere to the DCMA's recommended practices for project management, and following the DCMA guidelines made sure that each component of the schedule was carefully examined and compared to industry standards, which produced a work schedule that was reliable as well as efficient.

In summary, the analysis shows clearly that a more coherent and well-built project schedule might be produced by adhering to the DCMA criteria. This strategy follows the best practices that are necessary for the project's successful execution and conclusion.

7

CONCLUSION

7.1. FINAL CONCLUSIONS

Throughout this dissertation, the author presented a study on the optimization of scheduling and planning processes, based on the DCMA 14-Point assessment, the tool the author developed in excel, and the development of schedules using Candy Software.

This successful outcome was supported by the strategic use of advanced tools and adherence to thorough criteria, which resulted in a suitable schedule. In particular, the DCMA 14-Point Assessment and the Candy software were essential in offering a strong framework for creating a new schedule for Case Study 1. These resources not only improved the author's comprehension and skills in the complex process of building project planning, but also provided a methodical approach for that.

Through the utilization of Candy software, the author was able to execute a thorough scheduling process that made sure every aspect of the project was well-planned. This procedure was further strengthened by the DCMA 14-Point Assessment, which provided a thorough checklist to confirm the schedule's viability and integrity. This evaluation made sure that important components, like task dependencies and float, were carefully considered and optimized.

The planning process improved the author's understanding of managing and scheduling construction projects by offering valuable insights and learning experiences. Not only was Case Study 1's schedule optimized through the effective use of these tools and standards but the assessment tool developed by the author has been used by the company in other projects and services.

Additionally, the optimized schedule is evidence of how well-organized approaches and sophisticated tools, for project planning, work. It emphasizes how crucial it is to conduct in-depth analysis and make ongoing improvements in order to create schedules that are not only efficient and flexible but also achievable as well as realistic. The author is certain that the knowledge gained during the preparation of this dissertation will be useful for its career, and the author's expectation that what was developed and presented may be used as a useful guide by others for upcoming initiatives, encouraging best practices and cultivating an excellent culture in building project management.

7.2. IMPORTANCE OF SCHEDULE PLANNING

The significance of schedule planning within the construction industry cannot be overstated. As a foundational element of project management, effective schedule planning ensures that projects are completed on time, within budget, and to the highest quality standards. Despite its critical role, planning often does not receive the attention or investment it deserves. To enhance the success of construction

projects, it is imperative that the industry recognizes the importance of clear, detailed, and strategic schedule planning.

Moreover, robust schedule serves as the master plan for the entire project, guiding all activities from inception to completion. It provides a clear and coherent framework that facilitates efficient resource allocation, timely task execution, and proactive risk management. By outlining the sequence of activities and establishing realistic timelines, a well-constructed schedule plan minimizes uncertainties and enhances project predictability. This clarity is crucial for aligning all stakeholders, including contractors, subcontractors, suppliers, and clients, ensuring that everyone is on the same page and working towards common goals.

With that said, investing in schedule planning is essential for several reasons. Firstly, it improves project predictability and reliability, allowing project managers to forecast completion dates accurately and plan for contingencies effectively. This reduces uncertainty and enhances stakeholder confidence. Secondly, effective schedule planning contributes to cost efficiency by optimizing resource use and minimizing wastage. Given the financial implications of cost overruns in the construction industry, this is a critical advantage.

Furthermore, schedule planning promotes innovation and continuous improvement. By analyzing past projects and incorporating lessons learned, schedule planners can develop more sophisticated methodologies and best practices, driving overall industry advancement. However, to fully realize these benefits, the construction industry must invest in training and development for schedule planners, adopt advanced scheduling tools and technologies, and foster a culture that values meticulous planning.

In conclusion, the clarity and precision of a schedule plan are vital to the success of construction projects. A clear schedule plan not only provides a roadmap for project execution but also ensures that all stakeholders are aligned and informed. Recognizing schedule planning as a strategic function that requires specialized skills and expertise is essential.

By committing resources to the development and implementation of clear, detailed, and strategic schedule plans, the construction industry can achieve greater efficiency, innovation, and overall project success. The future of construction depends on our ability to plan effectively, and investing in this critical area will yield significant long-term benefits for the industry.

7.3. FUTURE WORKS

As main proposal for future works enhanced by this dissertation, the focus can be oriented to the phases of the schedule control process during effective construction, which can be defined as the actions to perform a continuous analysis and improvement of the schedule plan established during the baseline phase of the project.

By applying a structured guideline to the initial schedule, this research has laid a strong foundation for effective project management. However, to ensure ongoing success, it is essential to maintain a dynamic approach to scheduling throughout the development of the construction work.

Given the time constraints for this dissertation, it was not feasible to conduct an in-depth analysis of the entire project, or multiple projects. Such a comprehensive study would be particularly interesting, as it would allow for the examination of various optimization and improvement options. Furthermore, it would enable the application and evaluation of different schedule health check and schedule quality check methods. This broader analysis would also facilitate the comparison of these methods across

different types of projects, providing deeper insights into their effectiveness and applicability in diverse scenarios.

With this, the primary interest will be in regularly reviewing the schedule as the construction progresses and adjusting as necessary. This continuous monitoring will allow for the identification of any deviations or emerging issues that may require schedule modifications. By doing so, it will be possible to pinpoint the critical factors that need these changes, providing valuable insights into the aspects of scheduling that are most influential in maintaining project schedules and efficiency.

Additionally, the ability to extend this study throughout the duration of a construction project will significantly enhance the management of the entire project. By keeping the schedule under constant review and promptly addressing any mistakes that arise, the overall project management process will be more resilient and adaptive. This proactive approach will facilitate smoother operations, minimize delays, and ensure that the project stays on track.

Through this extended analysis, this dissertation and their future developments, on the execution phase, aim to contribute to the development of best practices for schedule management in construction projects. The findings will offer practical recommendations for improving schedule robustness and flexibility, ultimately leading to more successful project outcomes.

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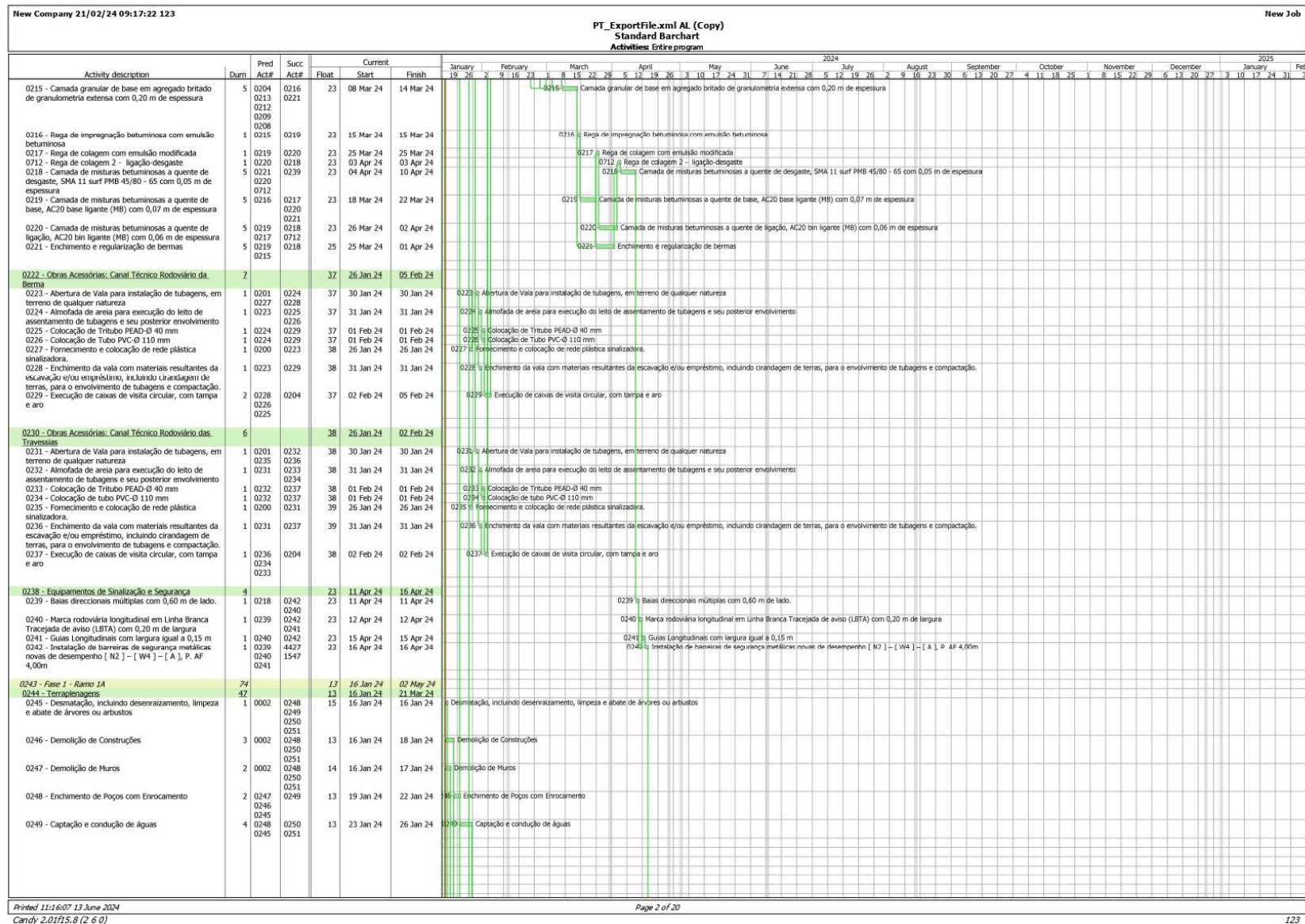
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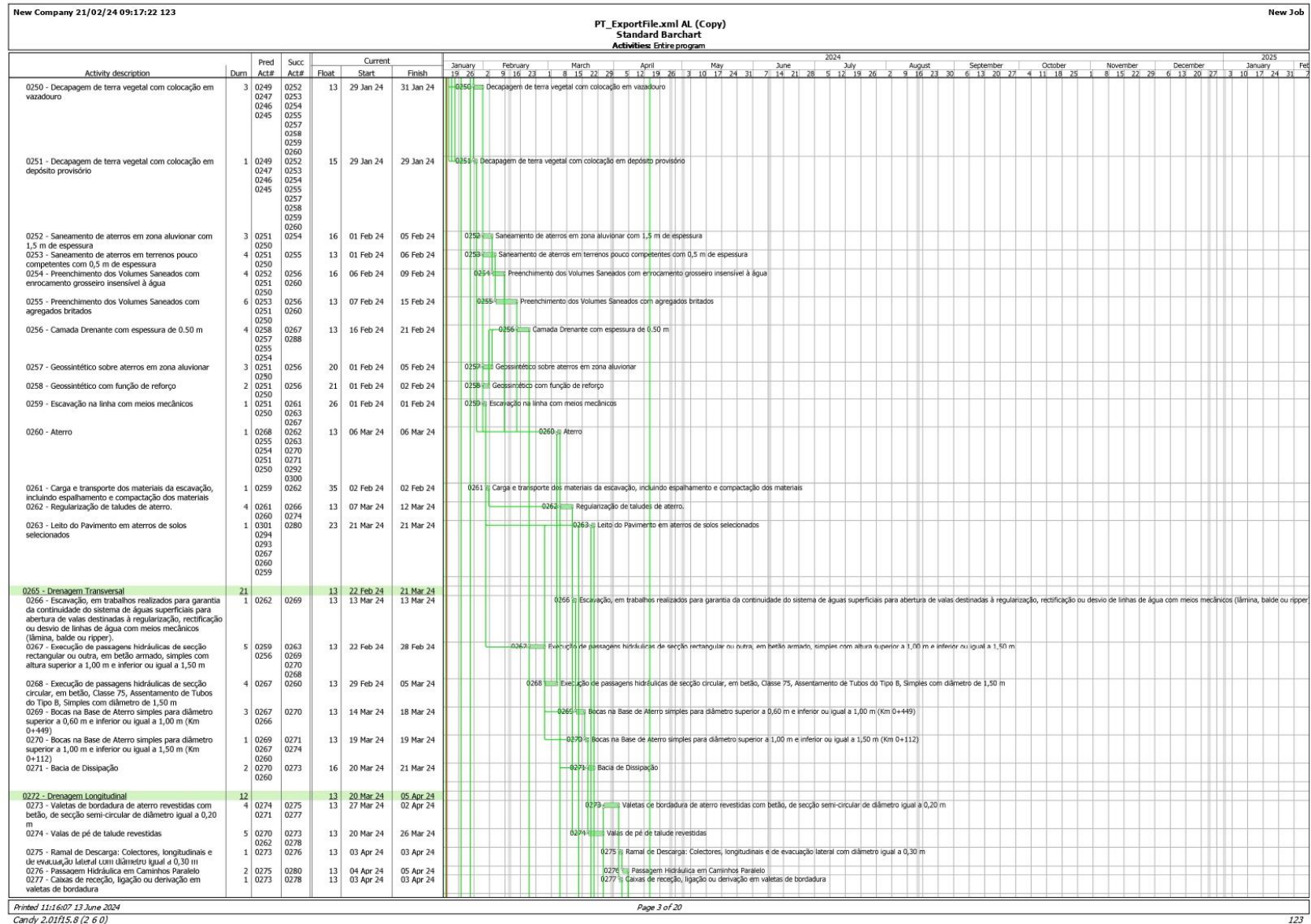
ANNEX

ANNEX A- SCHEDULE DEVELOPED IN CANDY

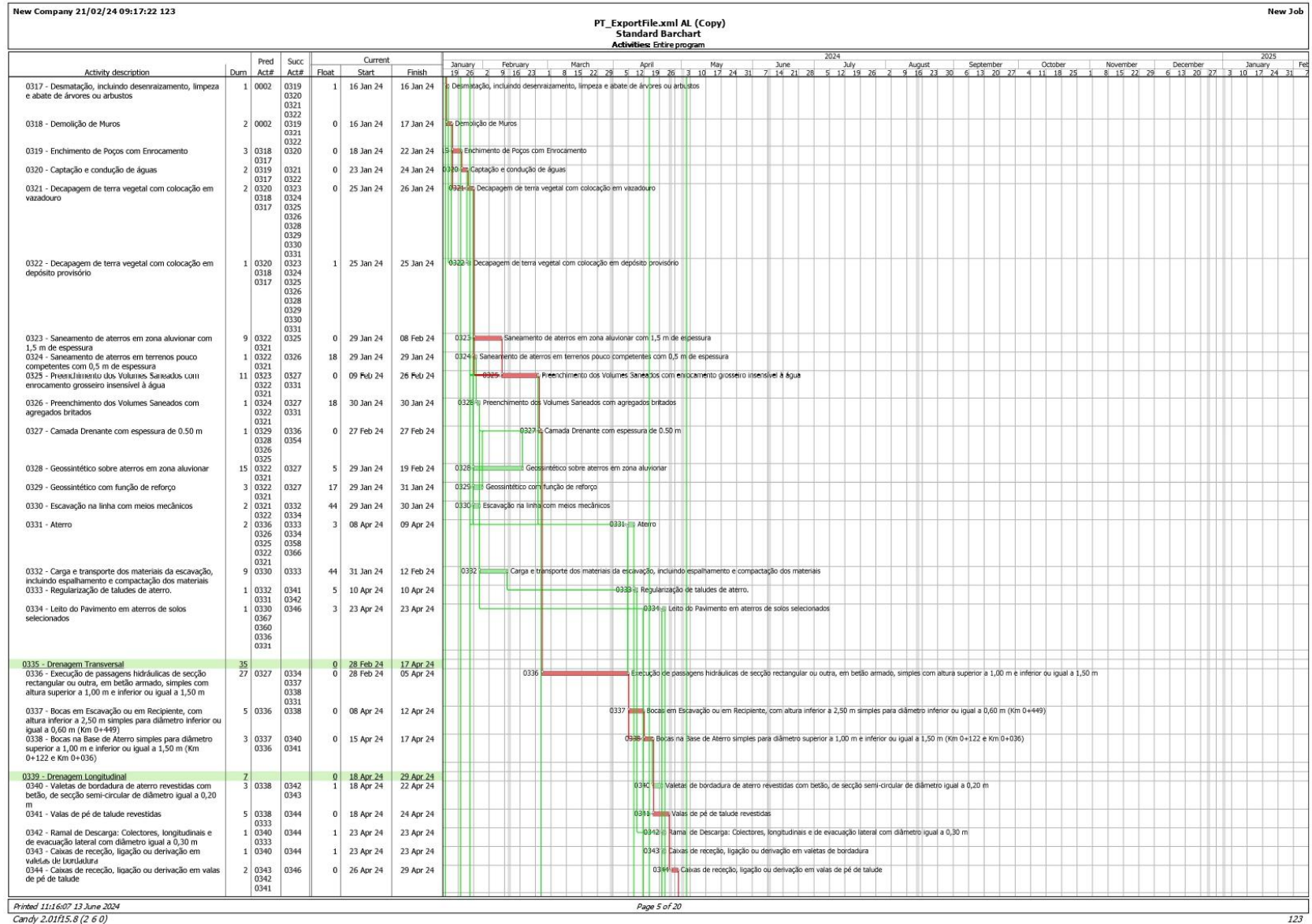
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Process Development for DCMA 14-Point Schedule Health Check and Progress Monitoring



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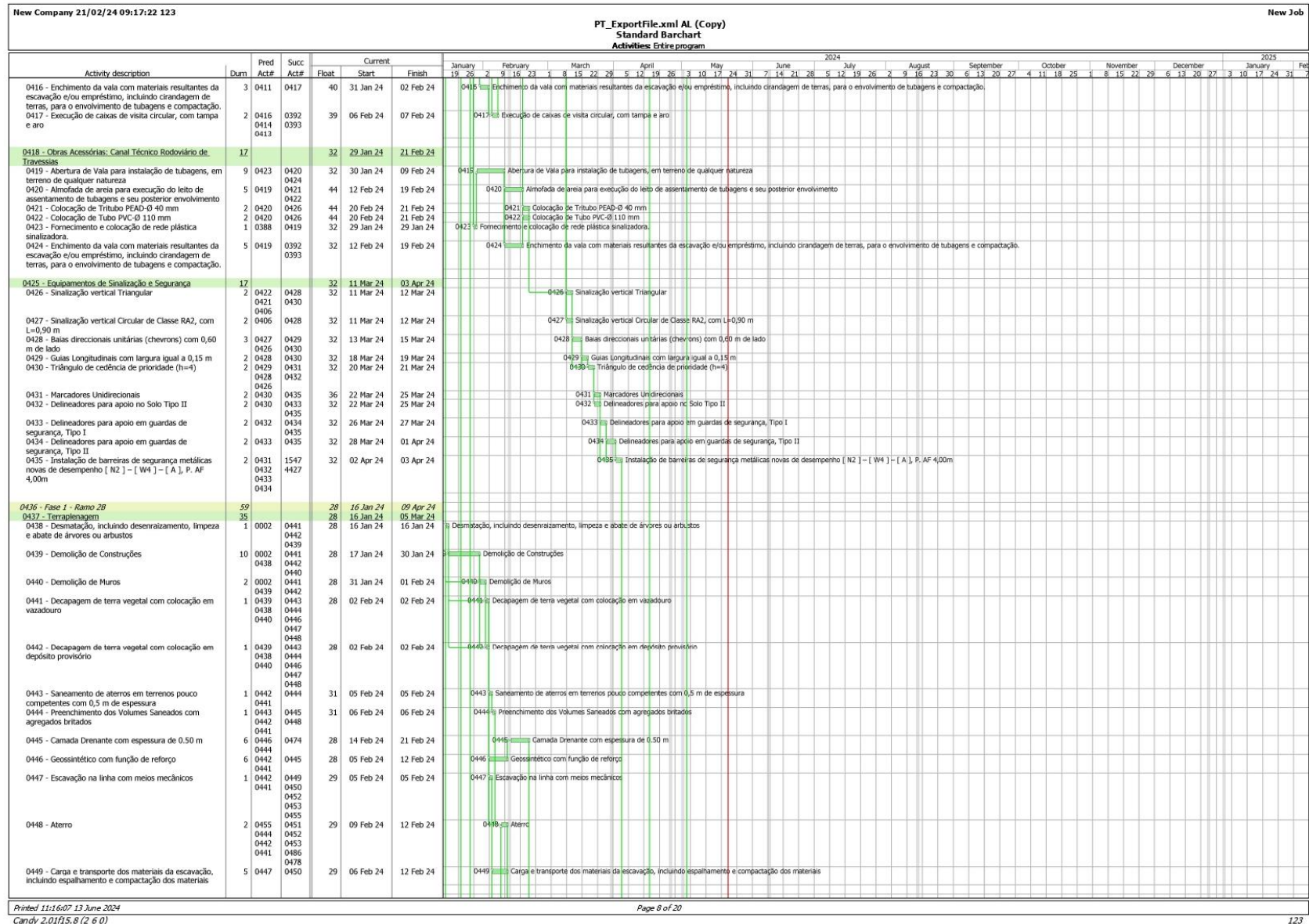
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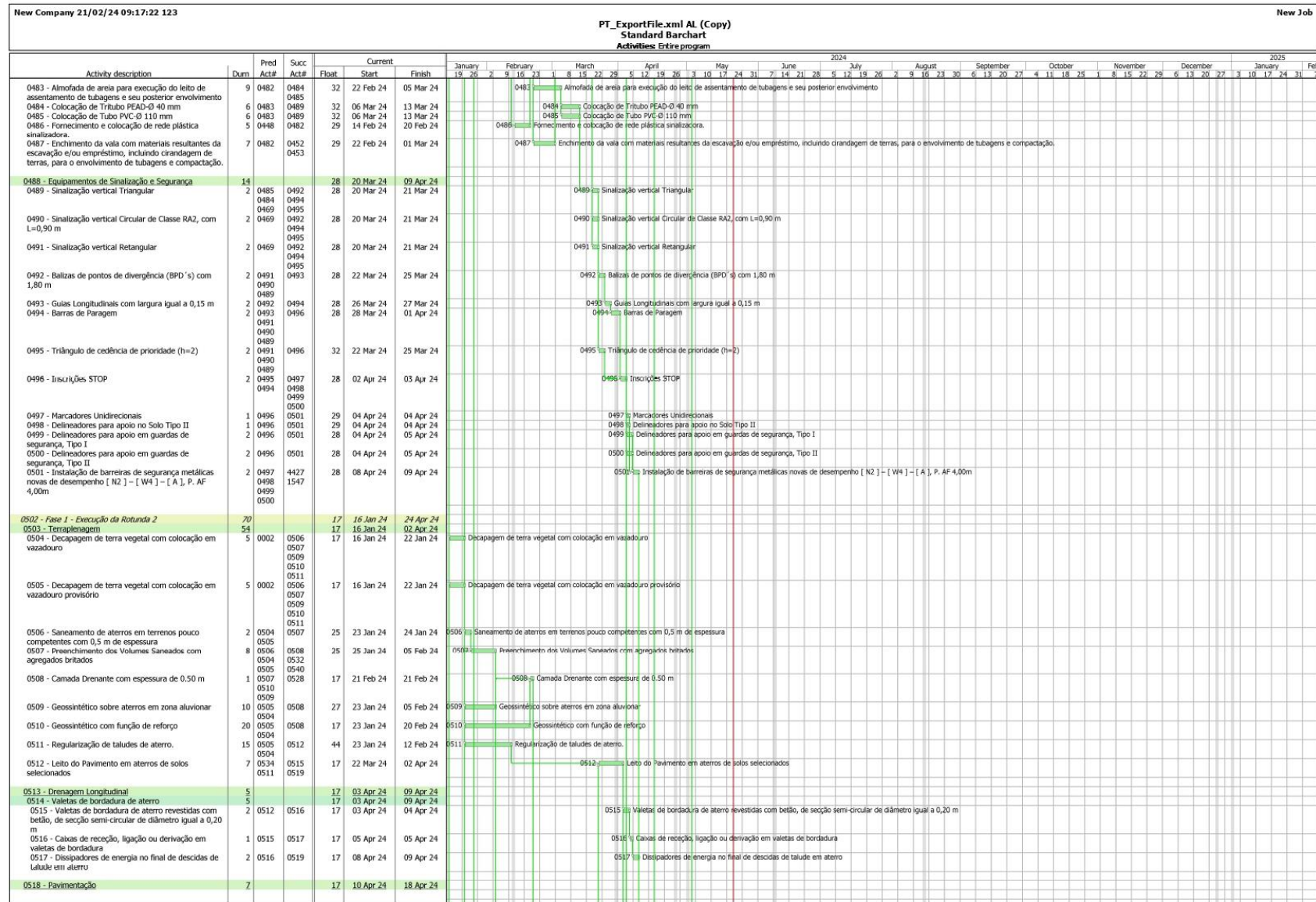
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