

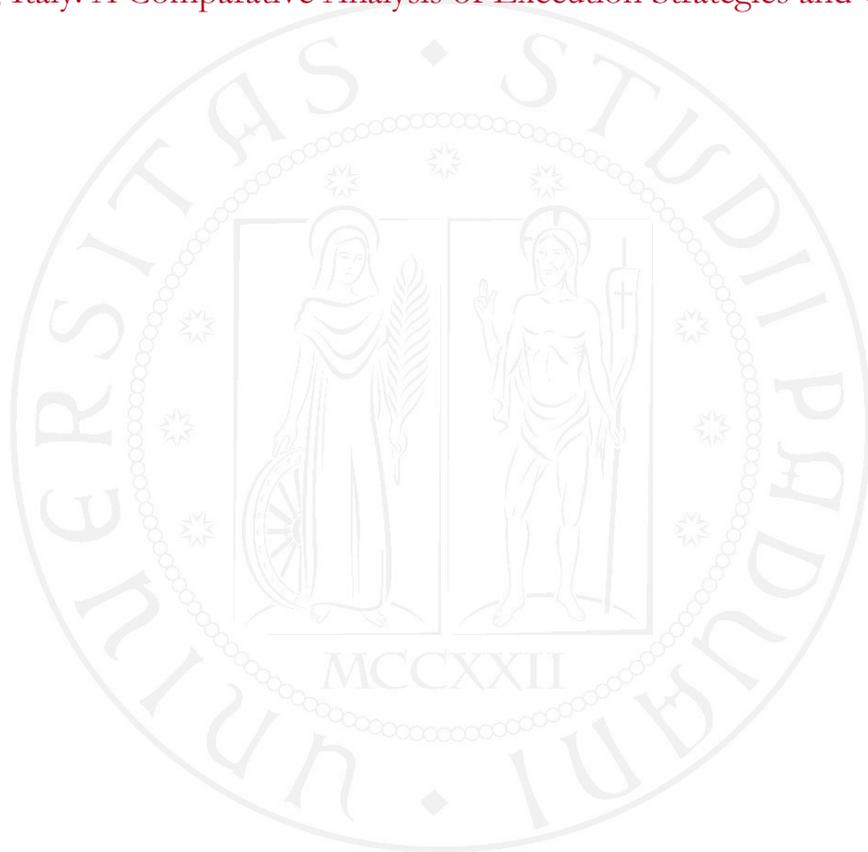


University of Padova

Department of Management and Engineering (DTG)

Master's Thesis in Management Engineering

Optimization of Water Treatment Systems for Selenium Removal in the Fiume Santo Power Plant, Sardinia, Italy: A Comparative Analysis of Execution Strategies and Cost-Efficiency.



supervisor

Prof. Lara Agostini

Company supervisor

Ing. Gianluca Castelli

Candidate

Mohsen Mardani

Academic Year

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Abstract

This thesis offers a strategic pre-execution assessment of two different methods to improve the selenium removal system at the Fiume Santo Power Plant in Sardinia, Italy. The necessity for intervention stems from a substantial rise in selenium levels in the plant's wastewater, related to the transition to a new coke source with elevated selenium content. By considering the environmental hazards and the regulatory constraints established by Italian Legislative Decree 152/2006 and European water regulations, a novel and more effective treatment method utilizing ferric sulfate, soda, and polyelectrolyte is necessary to achieve compliance.

This study aims to evaluate and compare two implementation strategies for the upgrade: a phased strategy, in which the old system is decommissioned prior to the construction of the new one, and a parallel strategy, in which the new system is developed concurrently with the ongoing operation of the existing plant. The comparison is conducted prior to actual implementation, emphasizing anticipated performance based on time, cost, risk, and environmental criteria.

Both methodologies are modeled in terms of deadlines, costs, and resource utilization using Microsoft Project, the Critical Path Method (CPM), and Excel-based simulations. Key Performance Indicators (KPIs), including the Cost Performance Index (CPI), Schedule Performance Index (SPI), and Resource Utilization Rate (RUR), are employed to facilitate the assessment. Risk exposure, procurement intricacies, environmental compliance hazards, and operational limitations are evaluated to ascertain the most sustainable and viable plan.

The study closes with a decision support framework utilizing weighted scoring and simulated scenarios, providing a systematic suggestion for project implementation. The primary objective is to aid stakeholders in making informed decisions that reconcile cost-efficiency with environmental stewardship.

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1 Introduction

The Fiume Santo Power Plant which is in Sardinia, Italy, has been playing a very critical role to provide the electricity of the region. Like many other power plants, especially in south Italy, it uses coke which is a solid carbon fuel used for energy generation. Until a few years ago, the plant sourced its coke from Russia. The coke provided from Russia included relatively low levels of selenium. High levels of selenium can cause hazardous environmental problems.[6]

However, the start of the Russia–Ukraine war, forced the plant to change suppliers. The management of the power plant has made the decision to import coke from Chile. The Chilean coke contains huge levels of selenium, and this has led to high concentration of selenium into the plant’s wastewater discharge.[6]

Selenium, especially in the form of selenite (Se IV) and selenate (Se VI), is hazardous to both aquatic ecosystems and human health.[3] The plant’s existing water treatment system, which was designed to eliminate much lower levels of selenium, is no longer sufficient. It can be also important to mention that this issue puts at risk European Union and Italian water safety rules and regulations, including those outlined in the EU Water Framework Directive and Italian Legislative Decree 152/2006.[5]

It is now clear that the Fiume Santo Power Plant must improve its water treatment system to meet environmental standards. Based on our research at WDTEC company, ferric sulfate has already been identified as the most appropriate and efficient selenium removal method. But to apply the changes and upgrade the plant, a change in the plant’s design and an increase of the capacity of the plant are necessary. All phases of the project from initiation to execution have been done by WDTEC S.R.L. Considering that the old treatment system is already running into the power plant, we have considered two different strategies for the execution phased of this improvement project.

Two project execution strategies are under evaluation:

- **Strategy 1:** Decommission the existing treatment plant, collection of the existing equipment and then build new treatment plant with higher capacity using new and existing equipment.
- **Strategy 2:** Construct the new system in parallel while keeping the old plant running, then switch over to the new part of the plant and in the meanwhile improve and upgrade the existing treatment plant.

Each option has its pros and cons. Strategy 1 may be simpler to plan and for tracking, and less costly, but could expose the plant to risks of environmental effects as they have to dispose of non-treated wastewater for a period which might have a disastrous effect on sea life. Strategy B is safer in terms of environmental considerations, but at a higher initial cost and longer construction timeline. Also, the risk of execution could be much higher because many operators would be working on the existing plant while the new sections are under construction

This thesis focuses entirely on the **strategic planning phase** of the project lifecycle. It is not intended to manage or report on actual project execution or closure. Instead, it serves as a decision-support tool to help stakeholders determine which execution strategy is most likely to succeed based on **cost, time, risk, and environmental compliance factors**.

1.1 Research Scope

The scope includes:

- Planning and project management tools such as Work Breakdown Structures (WBS), Gantt charts, and Critical Path Method (CPM).
- Estimation and simulation techniques for forecasting cost, duration, and risk (using MS project and Excel).
- Key Performance Indicators (KPIs) to help compare strategy performance before implementation.
- Legal and regulatory compliance requirements related to environmental regulations.

Execution activities such as construction management (resource and material tracking), stakeholder coordination, handover procedures, and system testing are excluded from the scope of this research as we want to make an estimation in advance to choose the best plan.

1.2 Research Objectives

This study is going to help project stakeholders at the Fiume Santo Power Plant through the critical pre-execution decision: Which execution strategy should we choose for improving our selenium removal system?

To answer this, the thesis includes the following activities with respective purposes:

1. **Conduct a Cost-Benefit Analysis**
Estimate direct and indirect costs for both strategies, including labor, materials, operational overhead, and downtime impact.
2. **Assess Project Timelines**
Use project management tools (Gantt, CPM) to develop timeline simulations for each strategy, identifying potential bottlenecks and the effect of risk considerations on the timeline.
3. **Perform Risk Analysis**
Evaluate uncertainty factors like environmental permit delays, coordination challenges, or budget overruns using qualitative and quantitative methods.
4. **Compare Key Performance Indicators (KPIs)**
Estimate each strategy against a set of KPIs including:
 - Cost Performance Index (CPI)
 - Schedule Performance Index (SPI)

- Risk Exposure Index
- Resource Utilization
- Environmental Compliance Metrics

1.3 Provide a Strategic Recommendation

Based on the simulations and KPI outcomes, recommend the most reliable, cost-effective, and regulation-aligned path forward.

2 Literature review

This chapter outlines the conceptual structure and tools for assessing the two alternative execution approaches suggested to improve the selenium elimination system at the Fiume Santo Power Plant. The discussion will relate to three critical fields: selenium removal technology, project management strategies and planning, and KPI-driven estimate approaches. The evaluation serves as the foundation to develop a practical, data-driven decision framework prior to starting the execution phase.

2.1 Chemical Processes

2.1.1 Selenium Removal Methods

Selenium is an important element; however, high levels, especially in the oxyanion forms of selenite (SeO_2^{-3}) and selenate (SeO_2^{-4}), may result in enormous ecological and health hazards.[3] Selenium pollution in thermal power plants frequently rises due to the burning of high-selenium coal or coke, resulting in greater selenium content in the wastewater from this infrastructure.[6]

The coagulation and co-precipitation with ferric sulfate are effective techniques for large-scale selenium removal methods. Ferric sulfate reacts with selenite and selenate under moderately acidic conditions (optimum pH 4.0–5.5), resulting in the creation of an insoluble iron selenide complex that can be either filtered or collected. Wang et al. (2011) found that the combination of ferric sulfate and ferrous ions achieved over 95% selenium removal by co-precipitation, underscoring its efficacy and dependability for industrial applications.[2]

Abdallah and Alam (2023) found that bio adsorbents from agricultural waste and algae biomass can effectively remove contaminants in cost-efficient, eco-friendly conditions.[4] These methods are better suited for low-flow systems than high-volume thermal power facilities.

Subsequent developments include the utilization of sophisticated hydrometallurgical techniques and nanomaterials, such as ferric oxyhydroxide flocs and magnetic nanoparticles,

which display great adsorption capacity and regeneration potential. These techniques achieved selenium elimination rates of over 90% under optimal laboratory conditions; at this point, scalability and operational costs present significant barriers. Han et al. (2009) illustrated substantial selenium removal utilizing iron oxide nanoparticles, whereas Rokkam et al. (2023) highlighted the leaching and separation techniques relevant to selenium-laden residues.[14]

Ferric sulfate was selected for the Fiume Santo plant owing to its excellent efficiency, chemical stability, and infrastructural compatibility. Although innovative technologies hold promise, ferric-based treatment remains the most economically and technically feasible solution.[6]

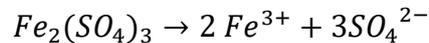
2.1.2 Detailed Reaction Mechanism for Selenium Removal using Ferric Sulfate, Soda, and Polyelectrolyte (our case)

Introduction to the process

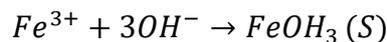
The two-section reactor of the Fiume Santo Power Plant doses sodium hydroxide (NaOH, soda) and ferric sulfate ($Fe_2(SO_4)_3$). To help sludge separation, a prepared polyelectrolyte solution is then introduced in a decanter. With an emphasis on reaction processes, process control, and operational consequences supported by existing scientific literature, each step will be covered in great chemical and engineering depth below.

Step1: Ferric sulfate addition

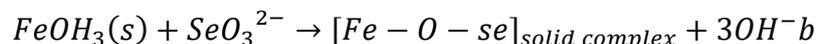
By developing precipitates with selenium ions in wastewater, ferric sulfate addition helps to remove selenium. Aqueous solution ferric sulfate dissociates as follows:



Ferric ions (Fe^{3+}) undergo rapid hydrolysis and subsequently form ferric hydroxide flocs upon pH adjustment:



Because of its great surface area, ferric hydroxide effectively adsorbs selenium species especially selenite ions (SeO_3^{2-}). This adsorption is highlighted in the paper "Removal and recovery of selenium species from wastewater [1]: Adsorption kinetics and co-precipitation mechanisms" by means of an appropriate reaction:



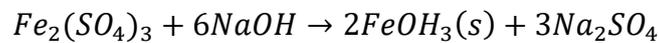
Iron-selenium is easily removed from wastewater because it forms weakly soluble solid complexes.

Step 2: Soda (NaOH) addition

Mostly for pH control, sodium hydroxide (NaOH, sometimes known as soda) is added into the second section of the reactor. Since the ideal effectiveness for selenium removal with ferric sulfate occurs within an acidic-to- neutral range (around pH 4.0–5.5), exact control of pH is necessary. Changing the pH to this optimal range helps ferric hydroxide flocs to develop and stabilize, hence greatly improving selenium capture efficiency. The paper "Dissolved-selenium removal using magnetic nanoparticles [2]: A state-of-the-art review" goes into great length on this procedure.



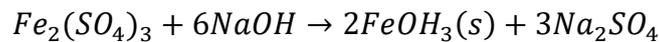
The addition preserves reaction environment stability and changes acidic conditions brought forth by ferric sulfate hydrolysis. The following summarizes the coupled reaction of sodium hydroxide and ferric sulfate producing ferric hydroxide precipitation:



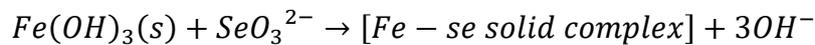
Overall reaction mechanism for selenium removal

The simplified reaction including soda dosage, ferric sulfate addition, and selenium precipitation follows:

1. Ferric sulfate dissociation and ferric hydroxide formation:



2. Selenium adsorption on ferric hydroxide:



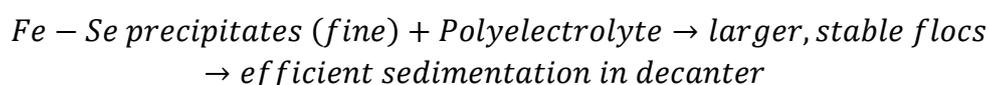
These reactions demonstrate how the combined chemical precipitation and adsorption mechanism captures and removes selenium.

Polyelectrolyte Preparation and Flocculation (Decanter)

After the reactor process, the polyelectrolyte solution made in another Poly preparator unit is added to the wastewater stream before the decanter, or clarifier. Being long-chain polymers, polyelectrolytes improve solid-liquid separation by encouraging good flocculation.

- **Mechanism:** By linking separate colloidal particles, including ferric hydroxide flocs and selenium complexes, polyelectrolytes reduce the surface charge repulsion between them. Under the effect of gravity, these bigger aggregates settle more quickly, so greatly improving the general separation efficiency.

The flocculation mechanism improved by polyelectrolytes is shown as:



These flocs settle rapidly in the decanter to produce sludge (mud), therefore separating from filtered wastewater.

Engineering Aspects: Reactors and Mixers

The reactors under description have mixers to guarantee homogenous chemical reactions.

- **Mixing in Ferric Sulfate Reactor Section:** guarantees fast and consistent distribution of ferric sulfate, hence optimizing reaction rates and ferric hydroxide generation.
- **Mixing in Soda Reactor Section:** rapidly homogenizes soda for stable reaction conditions and a good pH adjustment.

Maximizing selenium removal effectiveness by means of optimal chemical kinetics and avoidance of localized reaction conditions depends on proper mixing.[6]

Operational summary

Three stages comprise our process: chemical precipitation with ferric sulfate, pH adjustment with soda, and flocculation-enhanced solid-liquid separation with polyelectrolytes. Coordinating these phases guarantees effective selenium elimination from wastewater, so fulfilling environmental standards.

2.2 Project Strategy Models

Once the therapeutic approach is verified, focus moves to its application. Two basic approaches-decommissioning before development or building in parallel-demand analysis. Focusing just on Initiation and Planning, the thesis follows the PMBOK architecture since execution and closure lay outside the purview of current research.[7]

2.3 Planning tools: WBS, Gantt, and tools

- **Work Breakdown Structure (WBS)** divides a project into smaller, manageable units, aiding in strategy modeling and comparison.
- **Gantt Charts** provide a visual representation of activities and dependencies, showing time overlaps and bottlenecks.
- **The Critical Path Method (CPM)** is utilized to identify task sequences that dictate the overall project duration. This method proves particularly valuable in scenarios where resources are limited, or project timelines are of utmost importance.

These tools are used to simulate both strategies in a structured way.

2.4 KPI-Driven Estimation and Comparison

Key Performance Indicators (KPIs) are modeled and compared between each scenario to assist strategic decision-making. Though they are planning-level performance projections rather than based on real execution data, these KPIs [7]

2.4.1 Key KPIs and Formulas

Cost Performance Index (CPI)

$$CPI = \frac{\textit{Planned Value}}{\textit{Estimated cost}}$$

Help estimate how efficiently each strategy uses available budget.

- CPI > 1 = cost-efficient
- CPI < 1 = over budget

Schedule Performance Index (SPI)

$$SPI = \frac{\textit{Planned work}}{\textit{Sccheduled duration}}$$

Indicates whether timelines are realistic.

- SPI > 1 = ahead of schedule
- SPI < 1 = behind schedule

Resource Utilization Rate (RUR)

$$\textit{Utilization Rate} = \frac{\textit{Estimated resource use}}{\textit{Total resource availability}}$$

Predicts if resource availability can support parallel or phased execution.

Risk Exposure Index (REI)

$$\textit{Risk Exposure} = \sum (\textit{Probability} \times \textit{Impact})$$

Used to quantify the total risk each strategy carries-e.g., delays, permit risks.

Estimated Completion Ratio

$$\text{Completion Rate} = \frac{\text{Expected Work Completion}}{\text{Scheduled Work}}$$

Helps model how well the project is likely to stay on track under both strategies.

Environmental Compliance Metric

qualitative rating based on the likelihood of maintaining compliance with EU and Italian environmental standards during the transition.

These KPIs allow for **multi-criteria evaluation**, combining technical, financial, and regulatory dimensions.

2.5 Using Microsoft Project and Excel to estimate KPIs for strategy comparison

Using Key Performance Indicators (KPIs) as pre-implementation comparison guides, this thesis assesses Strategy A (phased execution) and Strategy B (parallel execution). Both strategies are modeled in Microsoft Project; planning data is transferred to Excel for computation, visualization, and comparison. This allows holistic assessment based on time, cost, resource efficiency, risk, and regulatory alignment devoid of actual progress tracking.

Cost Performance Index (CPI)

Formula: $\text{CPI} = \text{Estimated Earned Value} / \text{Estimated Cost}$

To estimate CPI:

- In Microsoft Project, both strategies are modeled with baseline cost estimates and task breakdowns. [10],[11]
- Estimated Earned Value is simulated based on planned percentage completions at given time intervals by setting status date (e.g., end of month 2, mid project).[10],[11]
- Estimated Cost is taken from the cost table based on resource assignments and task durations. [10],[11]

Schedule Performance Index (SPI)

Formula: $SPI = \text{Estimated Earned Value} / \text{Planned Value}$

SPI indicates how well the project aligns with the planned schedule in the simulation.

- Microsoft Project calculates Planned Value automatically when baselines are set.[10],[11]
- Earned Value is estimated based on expected task progress by milestone checkpoints.[10],[11]

Resource Utilization Rate (RUR)

Formula: $\text{Utilization} = \text{Estimated Work} / \text{Available Resource Capacity}$ [7]

This KPI helps predict whether Strategy B, which involves concurrent activities, might overload shared resources.

- Microsoft Project enables the assignment of team members or roles to tasks, specifying their maximum availability (for instance, 80% per week).[10],[11]
- Workload estimates are based on task durations and resource allocations.[10],[11]

Excel calculates average and peak utilization rates per resource. Gantt overlays and bar charts highlight bottlenecks or underutilization, aiding in resource balancing before execution.

Risk Exposure Index (REI)

Formula: $\text{Risk Exposure} = \sum (\text{Risk Probability} \times \text{Impact})$ [7]

Since no live risk tracking is being done, a qualitative risk matrix is created using:

- Custom fields in MS Project where each task or milestone is assigned values for estimated probability and impact.

bubble chart will be used to show risk concentration, therefore helping to guide the choice of techniques with less simulated vulnerability.

Estimated Completion Ratio

Formula: $(\text{Planned \% Complete} \times \text{Estimated Duration}) / \text{Planned Duration}$ [7]

This ratio offers a picture of predicted development based on the modeling of the task schedule.

- Microsoft Project simulated phase progress percentages using planned durations and given start and finish dates.

This allows for forecasting how each strategy might perform at key milestones, even without real data, helping predict feasibility and alignment with timelines.

Environmental Compliance Metric

This KPI is not numeric but based on qualitative assessment.

To simulate this:

- Tasks in Microsoft Project that depend on environmental permits or sensitive operations are flagged using custom text fields (e.g., “Permit Pending”).
- A checklist or rating scale (e.g., high/medium/low risk) is prepared in Excel to score overall compliance risk.

2.6 Conclusion of literature review

The important elements necessary for assessing the best approach to improve selenium elimination at the Fiume Santo Power Plant have been thoroughly examined by this section. Careful evaluation of existing selenium removal methods, strong project management methodologies, and KPI-driven analytical approaches has laid a clear basis to enable strategic, data-informed decision-making before project implementation.

Although bioremediation, advanced hydrometallurgical techniques, and nanotechnology show great promise, a comprehensive assessment of selenium removal technologies shows that ferric sulfate-based coagulation and co-precipitation always prove to be the most sensible and affordable option for major industrial uses. Research by Wang et al. (2011) [2] confirms that ferric sulfate, especially when supplemented with appropriate pH control and enough mixing, yields outstanding selenium removal efficiencies surpassing 95%. While alternative bio adsorbents and nanoparticles show promise in laboratory settings, for high-volume wastewater streams typical of thermal power plants they now present major scaling, cost, and operational complexity concerns.

Including ferric sulfate, soda, and polyelectrolytes, the complete reaction mechanism emphasizes the dependability and strength of ferric sulfate-based treatment. It emphasizes the crucial need of preserving exact reaction conditions, particularly the pH range of 4.0 to 5.5, enabled via regulated sodium hydroxide addition. Perfect ferric hydroxide production

and later selenium adsorption depend on this exact pH control. Moreover, the use of polyelectrolytes greatly increases sludge settling and separation, so improving the general wastewater clarity and regulatory compliance.

Investigating project management approaches helps to better define the strategic decisions the Fiume Santo Power Plant must make. Supported by the PMBOK framework [7], the review underlines the need of thorough planning tools such the Work Breakdown Structure (WBS), Gantt charts, and the Critical Path Method (CPM). These instruments offer methodical analysis of the two possible execution strategies, phased decommissioning against concurrent construction, regarding their relative feasibility and resource allocation consequences.

By means of measuring important aspects of project performance, the KPI-driven analytical framework enhances strategic decision-making. By using KPIs including Cost Performance Index (CPI), Schedule Performance Index (SPI), Resource Utilization Rate, Risk Exposure Index, and Environmental Compliance Metrics, objective, open, evidence-based comparisons between methods are made possible. Without actual implementation data, simulating these KPIs using tools like Microsoft Project and Excel gives decision-makers complex insights into each strategy's expected efficiency, deadlines, resource requirements, and regulatory conformity. In sophisticated industrial environments, informed decision-making depends on this forward-looking analytical capacity.

Even while novel technologies are continually evolving, ferric sulfate remains the most sensible option for selenium removal at Fiume Santo because of its cost-effectiveness, proven dependability, and infrastructure compatibility [6]. The primary challenge is not in technology but rather in the intentional selection of the most appropriate deployment strategy. Including comprehensive KPI simulations, disciplined project management planning, and rigorous chemical process evaluations, this literature review provides a well-rounded analytical basis fully matched with environmental criteria and operational reality to guide the next strategic decision-making.

Plant stakeholders can boldly choose a method that best balances operational continuity, economic efficiency, regulatory compliance, and environmental responsibility by means of this organized, multidisciplinary study. In modern industrial project planning and strategic management, such a data-driven, integrated approach embodies best practices.

3 Initiation and planning

This chapter outlines the preliminary stages of project management implemented for the selenium removal improvements at the Fiume Santo Power Plant. Concentrating solely on the Initiation and Planning phases, it delineates the project's objectives, scope, principal stakeholders, and viability. It also outlines the preparatory efforts undertaken to assess two different execution strategies, phased and parallel, prior to implementation. All exercises in this chapter are designed to facilitate an educated and systematic decision-making process.

3.1 Initiation phase

The Initiation Phase represents the fundamental stage of the project management process, establishing the scope and strategic direction of the project.[7] The Initiation Phase of the selenium removal project at the Fiume Santo Power Plant entails the explicit definition of the goals of the project, the formulation of a detailed Project Charter, the identification of stakeholders, the execution of a feasibility analysis, and the establishment of an initial risk assessment along with constraint mapping.

3.1.1 Definition of project purpose

The main goal of the project is strategic resolution of elevated selenium pollution resulting from the recent change in coke supply from Russia to Chile, the last one having much higher selenium contents.[6] As a result, this change has produced selenium levels in wastewater higher than current treatment capacity, creating problems for environmental compliance and regulation. Therefore, the main goal of the project is to determine and execution planning of an ideal strategy either a phased approach (decommissioning prior to new construction) or a parallel approach (simultaneous operation and construction) to improve the wastewater treatment capability to comply totally with the European Union's Water Framework Directive and Italian Legislative Decree 152/2006.[5]

3.1.2 Development of the Project Charter: SMART Goals, Constraints, and Assumptions

Designed at the beginning of the project, the Project Charter is a crucial instrument used to formally state the scope, goals, and presumptions of the initiative. Using SMART criteria specifically, measurable, achievable, relevant, time-bound the Project Charter for the effort at selenium removal includes:[7]

Smart goals:

- **Specific:** Set up a wastewater treatment system based on ferric sulfate to lower selenium levels below legal limits.
- **Measurable:** Under operational settings, get constant selenium removal efficiency above 95%.
- **Achievable:** Use accepted chemical precipitation techniques and current commercial processes validated by industry standards and literature.
- **Relevant:** Handle the operational and regulatory compliance problems resulting from the raw material shift directly.
- **Time-bound:** Complete strategic planning and final choice of the execution approach within the project schedules and legal limitations.

Constraints:

- Availability of resources and financial budget restrictions
- Regulatory approval timelines and compliance deadlines.
- Infrastructure restrictions at the current plant site.
- Lead times and pricing for necessary chemicals and equipment create procurement challenges.
- Limitations and responsibilities under current environmental permits.

Assumptions:

- Quick procedures of regulatory approval within expected times.
- Minimal operational disturbance, especially under the parallel execution plan

- Enough human and technical resources are provided by the company to enable operational changes and project completion.

3.1.3 Stakeholder identification and analysis

Accurate identification and management of stakeholders are essential for successful project implementation. Stakeholders are defined as individuals, groups, or organizations affected by or influencing project outcomes. Identified stakeholders for the selenium removal project at the Fiume Santo Power Plant include:

Plant management and operational staff

High influence and high interest, responsible for daily operations and directly affected by changes. The list of companies involved in our case is as follows:

- Ep Produzione (Fiume Santo)

Regulatory authorities (Environmental agencies)

High influence and significant interest, with responsibility for approving compliance with environmental standards.

- **Ministero dell’Ambiente e della Tutela del Territorio:** This Ministry has a pivotal role in coordinating national environmental protection, prevention, and remediation actions, and exercises oversight in collaboration with regional and local authoritiesDlgs_152_06.
- **Agenzia per la Protezione dell’Ambiente e per i Servizi Tecnici (APAT):** Responsible for geological surveys, soil defense, and collecting environmental data in collaboration with regional administrationsDlgs_152_06.
- **Associazione Nazionale Comuni Italiani (ANCI):** Collaborates in the collection and dissemination of environmental information, specifically focused on air pollution, water pollution, noise, electromagnetic and luminous pollution, territorial protection, sustainable development, waste management, renewable energy, and protected areasDlgs_152_06.
- **Commissione Tecnico-Consultiva per le Valutazioni Ambientali:** A commission established within the Ministry for providing technical and scientific support for Environmental Impact Assessments (VIA), Strategic Environmental Assessments (VAS), and Integrated Pollution Prevention and Control (IPPC) proceduresDlgs_152_06.

Financial sponsors and funding bodies

High influence due to budget control, with moderate interest in technical execution details.

- Ep Produzione (Fiume Santo) as behalf of (Terna driving energy)

Suppliers and subcontractors

Moderate-to-high influence and interest, instrumental in equipment procurement and installation processes. [12],[13]

- TWT (Techno Impianti SRL)/WDTEC -Engineering and design
- ARCHIMEDE (MILTONROY) _ Soda & ferric sulfate dosing pumps
- FAM (Clarified water filtration / From the primary)
- RIGHI (Q.E. MOD. MCC RIF. C.LE FIUME SANTO (Extension))
- GRUNDFOS (Centrifugal pumps P-115A/B _P-116 A/B)
- ASTRO (Tank BS-130)
- GALVOPLATING SRL (New Reactors)
- PRO-DO-MIX (New agitators)
- NOVA ROTORS (Sludge pumps)
- METTLER TOLEDO- E+H- WIKA- VEGA- SABA-STUBBE- GEMU- I.S.I_G+F (Electrical instruments)
- ON TECHNOLOGY (electrical and instrumentation installation works)
- SAFTEY ENERGY (supplying and installing electrical and instrumentation materials)
- CIMA (CIMA S.r.l. is specialized in mechanical assembly work)

Local communities and environmental advocacy groups

Lower influence but moderate-to-high interest concerning ecological impacts and compliance measures.

Stakeholders are systematically classified via a Power-Interest Matrix. This graphic instrument facilitates strategic prioritizing and focused communication planning. Stakeholders possessing substantial power and interest want rough and ongoing participation, while those with little power require regular updates and supervision.

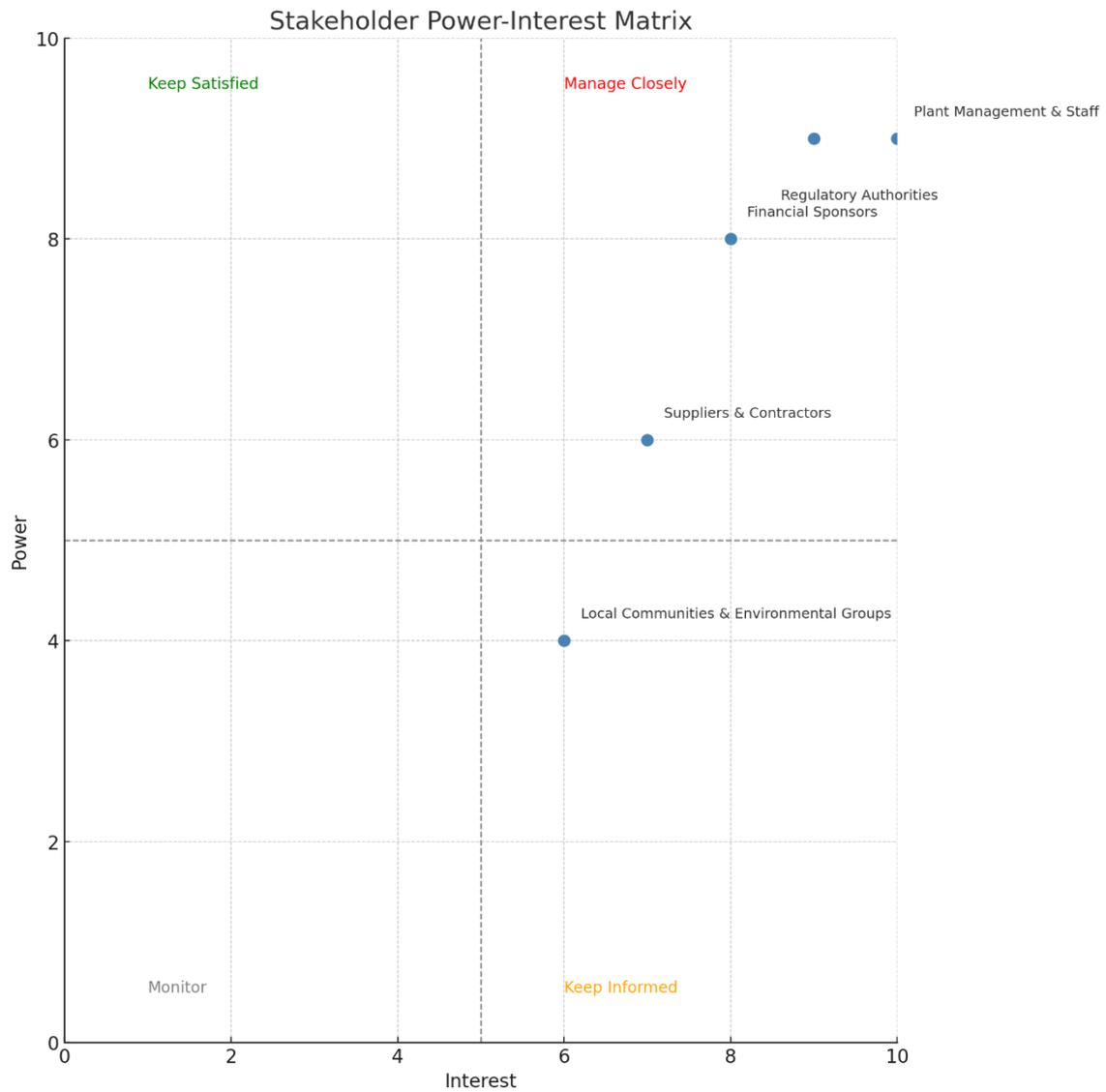


Figure 3.1- Stakeholder Power-Interest Matrix

Additional explanations for Power-Interest matrix

Manage Closely (High Power & High Interest):

- Plant Management & Staff
- Regulatory Authorities
- Financial Sponsors
- Suppliers & Contractors

Keep Informed (Low Power & High Interest):

- Local Communities & Environmental Groups

Clear definition of power and interest

- **Power:**

Power denotes the capability of stakeholders to influence or impact the project's decisions, processes, outcomes, or resources. Stakeholders possessing substantial power can profoundly affect project success via their authority, financial oversight, regulatory impact, or operational responsibilities. Regulatory authorities generally wield significant power owing to their ability to give or deny essential approvals, whereas senior management holds considerable influence due to their decision-making powers.

- **Interest:**

Interest explains how much participants in the project are worried about or involved in the goals, results, or procedures. High interest stakeholders are individuals whose welfare, goals, or duties directly depend on project results, thereby indicating great participation and concern. For instance, operational staff or plant management often have great interest since their daily activities and professional obligations mostly depend on the results of the project.

By plotting stakeholders on a Power-Interest Matrix, a project manager can identify optimal strategies for engaging stakeholders effectively.

The notions of power and interest facilitate the methodical classification and strategic management of stakeholders. This method guarantees that communication and engagement tactics are customized based on each stakeholder's capacity to impact the project and their interest in its results, hence promoting more efficient project execution and enhancing the likelihood of attaining desired objectives.

3.1.4 Feasibility Analysis (Technical, Financial, Operational)

A comprehensive feasibility analysis is crucial to assessing whether the project is viable and sustainable from technical, financial, and operational perspectives:[7]

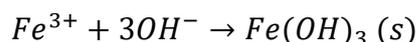
Technical feasibility analysis

The chemical feasibility of employing ferric sulfate for selenium extraction in wastewater at the Fiume Santo Power Plant is corroborated by significant experimental data present in contemporary scientific literature. Ferric sulfate ($\text{Fe}_2(\text{SO}_4)_3$) is acknowledged as a

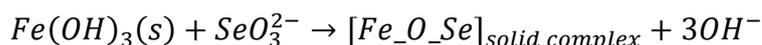
potent chemical agent for its effectiveness in adsorbing and precipitating selenium, especially as selenite ions (SeO_3^{2-}). The process of selenium removal entails a series of well-defined chemical processes. Upon contact with wastewater, ferric sulfate dissociates, releasing ferric ions (Fe^{3+}) and sulfate ions (SO_4^{2-}):



The ferric ions subsequently undergo rapid hydrolysis to form insoluble ferric hydroxide precipitates ($\text{Fe}(\text{OH})_3$):



Ferric hydroxide precipitates are well-known as very efficient adsorbents, offering substantial reactive surface areas that effectively absorb dissolved selenium compounds. Selenite ions significantly adsorb onto the surface of ferric hydroxide flocs, resulting in the formation of stable iron-selenium complexes. This adsorption can be represented by the subsequent simple chemical reaction:



Underlying the dependability and efficiency of ferric sulfate-based co-precipitation are empirical research. Especially, Okonji et al. (2020) revealed selenium removal efficiencies above 95%, therefore showing extraordinary performance in industrial wastewater treatment conditions.[1] These results demonstrate that ideal adsorption and co-precipitation fall within a controlled pH range of around 4.0 to 5.5, exactly corresponding with the suggested operational parameters of the project at the Fiume Santo Power Plant.[6]

Also, thorough kinetic analyses published in papers, the selenium adsorption onto ferric hydroxide surfaces follows a pseudo-second-order kinetic model. Under the given reaction circumstances, this kinetic profile indicates fast and effective removal, therefore supporting the relevance of ferric sulfate-based methods for reaching compliance with environment.

All things considered, a lot of research shows strong proof that ferric sulfate co-precipitation is a chemically practical and quite successful approach for selenium removal from industrial effluent. Thus, empirical data substantially supports the chemical procedure suggested for the selenium treatment at the Fiume Santo Power Plant, guaranteeing both practical application and regulatory compliance.[5]

Extensive studies have been conducted on the compatibility between the current Fiume Santo Power Plant infrastructure and the newly suggested selenium removal procedure. There are three reactors in the current arrangement; this count will be doubled to allow higher processing capability. Six reactors-each divided into two independent sections to enable separate dosing of sodium hydroxide (NaOH) and ferric sulfate ($\text{Fe}_2(\text{SO}_4)_3$)-which are

essential to the co-precipitation process-will be operational in the final renovated facility.

Likewise, there is much room for development and expansion in the decantation system. To improve sludge management and separation efficiency, the currently inadequate number of decanters-which handle expected treatment volumes-will be doubled.[6] Moreover, the physical properties and geometric layouts of both reactors and decanters will change to be effective.

The decanters used to run without agitation systems before. The suggested improvements include in the inclusion of specialized agitators linked to every reactor, therefore improving sludge generation mechanisms in the decanters. These agitators are meant to guarantee complete mixing and enable fast aggregation of precipitated solids, hence greatly enhancing sludge removal.[6]

Furthermore, the improved system requires the inclusion of more equipment to constantly monitor important operating criteria. Installations of pressure, temperature, pH, oxidation-reduction potential (Redox) monitoring instruments will guarantee exact control of process conditions. New junction boxes specifically for electrical and signal connections will be needed based on this improved instrumentation system. Furthermore, required to enable the integration of new, higher-current electrical equipment, like sludge pumps. At last, the plant's plumbing and connectivity have been overhauled. New skids have been created to provide the best flow distribution between several process units and help to integrate revised pipe networks. These rebuilt skid and pipe components are set up to improve general plant efficiency, operational flexibility, and maintenance access.

Finally, reflecting a methodical and integrated approach to capacity enhancement and operational improvement, thorough infrastructure modifications and expansions have been carefully planned to ensure complete compatibility and optimal performance of the upgraded selenium removal system.

Financial feasibility analysis

Cost estimation leveraging detailed equipment and material procurement lists, including prices and lead times

Combining digital design tools with procurement information, a systematic and data-driven strategy has been used to build a dependable and reasonable cost estimate for the selenium removal system upgrade at the Fiume Santo Power Plant. AutoCAD Plant 3D was diligently modeled the whole plant layout including the current and projected areas. This platform guaranteed a whole depiction of the integrated system by allowing the precise engineering of mechanical assemblies, instrument placements, structural layouts, and pipe paths.

Automatically created and exported into structured Excel files, instrument and equipment lists followed the 3D modeling process. Cost forecasting and itemized procurement planning emerged from these exported records. One list for process instruments such as pressure transmitters, temperature sensors, pH and Redox probes, and another for equipment such as pumps, agitators, skids, and electrical panels was created. Every list covers necessary criteria for cost analysis and supplier searching.[13]

These equipment and instrument lists were sent to several qualified vendors in cooperation with Tecno impianti S.r.l.'s Purchasing Department to request official quotes. Many components had several offers from several suppliers for the same item, which let for competitive benchmarking. Lead times especially attracted particular attention since timely delivery is a major project planning challenge. Usually, products with the quickest delivery times were given priority provided they satisfied technical requirements and compliance criteria.[12]

The purchase data were arranged into two comparison matrices-one for instruments and one for equipment-to improve traceability and openness. These records compiled supplier offers, unit pricing, projected delivery times, and any departures from technical standards. This method made a precise comparison possible not just in terms of cost but also regarding procurement viability inside the project schedule.[12],[13]

In the end, our cost estimate system offers a strong basis for scenario study and financial planning. It guarantees that budget projections are based on actual market data and supports strategic choice on building schedule and supplier selection. The dependability of cost and lead time forecasts for the whole plant upgrade has been much improved by the combination of 3D design tools with supplier involvement.

APPARECCHI - Equipment list											Sh	of
CLIENTE / Customer											5	11
DESCRIZIONE / Description												
MIGLIORAMENTO IMPIANTO ABBATTIMENTO SELENIO (IAS)												
ITEM	DESCRIZIONE Description	Our Vendor	TV/T Vendor1	N/offer	Lead Time1	Price 1 (Unitario)	TV/T Vendor2	N/offer	Lead Time2	Price 2 (Unitario)	N° SPECIFICA Data Sheet no	NOTE Remarks
P111A/B	Acqua Fangosa da TK104 a TK 115 A/B										24-7709-PDS-03	
OPTION 1												
	Pompa modello DN 10L1 Super Duplex SS / w. 1.4501	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	4790.75						
	Varia-Riduttore a satelliti IEC con motore elettrico IEC	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Cartone + Pallet - dimensioni interne: 2000x400x520 - dimensioni esterne: 2030x440x660	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Basamento acciaio inossidabile AISI 304L / w. 1.4306	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	143.25						
OPTION 2												
	Pompa modello DN 10L1 Super Duplex SS / w. 1.4501	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	4381.25						
	Varia-Riduttore a satelliti IEC con motore elettrico IEC	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Cartone + Pallet - dimensioni interne: 2000x400x520 - dimensioni esterne: 2030x440x660	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Basamento acciaio inossidabile AISI 304L / w. 1.4306	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	143.25						
P112A/B	Acqua Fangosa da TK105 a TK 115 A/B										24-7709-PDS-03	
OPTION 1												
	Pompa modello DN 10L1 Super Duplex SS / w. 1.4501	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	4790.75						
	Varia-Riduttore a satelliti IEC con motore elettrico IEC	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Cartone + Pallet - dimensioni interne: 2000x400x520 - dimensioni esterne: 2030x440x660	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Basamento acciaio inossidabile AISI 304L / w. 1.4306	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	143.25						
OPTION 2												
	Pompa modello DN 10L1 Super Duplex SS / w. 1.4501	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	4381.25						
	Varia-Riduttore a satelliti IEC con motore elettrico IEC	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Cartone + Pallet - dimensioni interne: 2000x400x520 - dimensioni esterne: 2030x440x660	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						
	Basamento acciaio inossidabile AISI 304L / w. 1.4306	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	143.25						
P113A/B	Acqua Fangosa da TK106 a TK 115 A/B										24-7709-PDS-03	
OPTION 1												
	Pompa modello DN 10L1 Super Duplex SS / w. 1.4501	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	4790.75						
	Varia-Riduttore a satelliti IEC con motore elettrico IEC	NOVA ROTORS	NOVA ROTORS	OFF-25-00782	16/20 settimane data ordine	Incluso						

Figure 3.2- Equipment list with lead time and prices for each item [12]

TI		EP FURNE SANTO		ELENCO STRUMENTI CON FORNITORI											
Clienti / Customer		FURNE SANTO S.p.A.		DESCRIZIONE / Descrizione											
MIGLIORAMENTO IMPIANTO ABBATTIMENTO SELENIO (IAS)															
YAG	SERVIZIO Service	PREZ	FOGLIO SPECIFICA Data Sheet	Size	Our Vendor	TV1 Vendor	Qty	Lead Time1	Price 1 (Elettivo)	TV1 Vendor2	Qty	Lead Time2	Price 2		
PSV-230N	potestabilvolta a TC 304	06	24-7709-ES-36		STUBBE	STUBBE-CHV 712-R	30070	null	null						
PSV-230N	potestabilvolta a TC 305	06	24-7709-ES-36		STUBBE	STUBBE-CHV 712-R	30070	null	null						
PSV-237N	potestabilvolta a TC 306	06	24-7709-ES-36		STUBBE	STUBBE-CHV 712-R	30070	null	null						
TT-1B1	trasmettitore di temperatura	60	24-7709-ES-04		E+H	SABA	null	non riusciamo a farlo	non riusciamo a farlo						
	Termoisolenzia TRD-Hienza pozzano				E+H					WKA	Q0091645-3	7-8 settimane (for all parts)	570 (for all parts)		
	738, Digihub monitor, HART®, 4...20 mA, universal programmable (FV100, 3HA)				E+H					WKA	Q0091645-3				
TT-1B1	trasmettitore di temperatura	60	24-7709-ES-04		E+H	SABA	null	non riusciamo a farlo	non riusciamo a farlo						
	Termoisolenzia TRD-Hienza pozzano				E+H					WKA	Q0091645-3	7-8 settimane (for all parts)	570 (for all parts)		
	738, Digihub monitor, HART®, 4...20 mA, universal programmable (FV100, 3HA)				E+H					WKA	Q0091645-3				
TT-1B1	trasmettitore di temperatura	60	24-7709-ES-04		E+H	SABA	null	non riusciamo a farlo	non riusciamo a farlo						
	Termoisolenzia TRD-Hienza pozzano				E+H					WKA	Q0091645-3	7-8 settimane (for all parts)	570 (for all parts)		

Figure 3.3- Instrument list with lead time and prices for each item [13]

This document provides a cost estimation for the primary equipment, instrumentation, installation, piping, and equipment removal expenses. Therefore, the calculation and quotations we have received from main suppliers propose these results:

Total instrument cost

Total cost for all electrical and mechanical instruments designed for measuring purposes—such as pressure indicators, temperature transmitters, and similar devices is as follows:

€ 202,557.94

Based on a thorough instrument list created with the help of quotes taken from multiple suppliers, the overall cost connected with instrumentation has been computed.[13] Reflecting unit pricing, delivery timeframes, and technical specifications, this list comprises all measuring devices including pressure transmitters, temperature sensors, pH and Redox probes etc. The cost estimate was based on the quotations, which let one realistically and market-aligned assess the total instrumentation required expenditure.

Total equipment cost

Total cost for all types of equipment like reactors, decanters, agitators, pumps and filters and related spare parts is as follows:[12]

€ 1,819,905.19

The overall equipment cost has been determined by using a detailed equipment list, created with the aid of official bids from many suppliers. This list comprises essential components including pumps, agitators, electrical panels, and additional mechanical systems necessary for the enhanced plant setup. The cost and delivery time of each item were assessed according to supplier proposals, facilitating a dependable and precise projection of the total equipment spending in accordance with the current market circumstances.[12]

Total plumbing cost

CIMA will execute the prefabrication and installation of thermoplastic piping systems for the selenium removal system improvement at the EP Fiume Santo power station. The project entails the provision and installation of polypropylene (PP) materials, comprising pipes, fittings, and valve components. All connections between the different pipe sections will be conducted utilizing the butt fusion welding technique, accomplished using specialized in-house equipment. This operation guarantees a secure, chemically resistant, and durable pipeline network appropriate for the conveyance of process fluids within the enhanced treatment system. The comprehensive expenses related to these operations are outlined below:

€ 140,000.00

Cost Estimation for Electrical and Instrumentation Works (ON Technology S.r.l.):

ON Technology has been engaged to execute the electrical and instrumentation installation for the extension of the selenium removal system at the EP Produzione power plant in Fiume Santo, specifically for units 3 and 4. Their tasks encompass the thorough removal of obsolete and non-functional electrical and instrumentation equipment, succeeded by the installation of new infrastructure required for the enhanced treatment process.

Their tasks specifically encompass the removal of outdated user cables, electrical and instrumentation cable trays, conduits, and outmoded lighting systems. The installation phase encompasses the affixation of new support brackets, cable trays, electrical conduits, junction boxes, and lighting fixtures. The company will install new instruments as necessary, run new cables from field devices to connecting points, execute all electrical and signal wiring, and appropriately label all cables and conductors.

This extensive scope guarantees the full renovation of the plant's electro-instrumental systems in compliance with the specifications of the new selenium treatment line. The aggregate expense for these operations is detailed below:

€ 507,605.36

NMG Italia: Cost estimate for equipment removal and scope of work

The Fiume Santo Power Plant's selenium removal system update has found the company NMG Italia as the contractor in charge of demolishing current equipment. Their scope covers the disassembly, lifting, and transportation of big industrial parts like support structures, pumps, pipes, and tanks. The removal activities of a live industrial environment (parallel approach) call for particular logistics involving crane operations, heavy-duty transportation, safety monitoring, and on-site coordination given the operational restrictions.[12],[13]

The projected hourly cost for every important activity or service engaged in the removal process is shown below:

Activity/Role	Estimated Hourly Cost (€)	Description
Mobile Crane with Operator	€125	Lifting and removal of heavy components (e.g., tanks, skids).
Truck with Crane (Camion Gru)	€100	Dual function: transport and local lifting of dismantled parts.
Flatbed Truck + Driver	€75	Transporting removed equipment offsite or to storage.
Rigger / Machinery Mover	€35	On-ground equipment handling and support for crane operations.
Safety Coordinator	€25	Ensures compliance with safety regulations and plant operating procedures.
Site Foreman / Capo Cantiere	€30	Controls site logistics, worker coordination, and interface with client team.

Table 3.1- NMG cost estimation

Therefore, the total cost for all the activities which are going to be done by NMG would come to:

€ 390/hour

Forel S.p.A. – Cost estimate for equipment positioning and scope of work

The contractor in charge of positioning and mechanical installation of new equipment for the Fiume Santo Power Plant's selenium removal system has been Forel S.p.A. Their purview includes component assembly, alignment, and placement of tanks, pumps, piping skids, support systems, and process units. To guarantee technical and safety standards are followed, these activities call for exact coordination with lifting operations, supervision, and on-site engineering presence.

Activity/Role	Estimated Hourly Cost (€)	Description
Mechanical Technician	€35	Handles assembly, anchoring, and mechanical fixing of pumps, tanks, and piping.
Skilled Welder / Fitter	€40	Required for structural frame connections, skid installations, or bracket mounting.
Rigger / Machinery Mover	€35	Assists in lifting, aligning, and setting equipment in final position.
Site Foreman / Capo Cantiere	€30	Controls the execution team and coordinates installation sequence on site.
Safety Coordinator	€25	Monitors safety compliance during equipment handling and installation.
Project Engineer (On-Site)	€40	Provides technical supervision, drawing validation, and handles interface issues.

Table 3.2- Forel S.p.A. cost estimation

Therefore, the total cost for all the activities which are going to be done by NMG would come to:

€ 205/hour

Estimated costs for all human resources present on the field (from TWT & WDTEC)

Defining and distributing the required directing human resources who will coordinate, supervise, and assist field operations will help to guarantee the efficient running of the selenium removal system upgrade. Maintaining safety standards, fixing technical problems, and making sure that installation and removal activities follow the project plan, design specifications, and legal regulations depend on these duties.[10],[11]

The main directive figures expected to be on hand in the field during operation are shown below. It offers a comprehensive picture of the human resource investment required for effective project delivery by including their different duties and projected hourly rates.

Role	Responsibility	Estimated Hourly Cost (€)
PM-PROJECT MANAGER	General coordination, schedule control, contractor interaction, and decision-making	€50
CC-CAPO CANTIERE	Supervises daily operations, coordinates field teams, manages work progress	€35
DL-DIRETTORE DEI LAVORI	ensures that all construction activities are executed in accordance with the approved project plans	€20
PE-PROJECT ENGINEER	Technical supervision, drawing validation, design-construction alignment	€40
PJ-PROCESS JUNIOR	plays a supporting role within the project execution team	€20
PS-PROCESS SENIOR	high-level technical professional responsible for overseeing the design, validation, and optimization of industrial process systems.	€45
Safety Coordinator (HSE)	Ensure compliance with health, safety, and environmental regulations	€30

Table 3.3- On-site expert cost estimation [10],[11]

SER.TEC. S.r.l., structural works quotation

Selected to provide, build, and install the structural steelwork for the selenium removal facility is SER.TEC. S.r.l. The scope covers metal buildings, grating, stair steps, and on-site hot dip galvanizing installation. Apart from VAT, the total stated cost is €187,617.20. Excluded are structural design, specific accessories, and adaptations.

€ 187,617.20

PP Pipe and Valves: Boldarino S.p.A. Supply

Providing PPH pipes, fittings, and valves for the selenium removal facility falls to Boldarino S.p.A. With a total cost of €107,796.22 (VAT included), the quotation comprises all needed materials (PN10-rated) for fluid handling systems. There is no installation; the scope just addresses supply. Every component satisfies the mechanical and chemical requirements of the project.

€ 107,796.22

WDTEC S.r.l., Engineering Cost Summary

From preliminary process analysis to 3D modeling to technical documentation preparation to design revision coordination for major systems including heating, sludge extraction, reagent dosing, and electrical box adjustments, all engineering activities for the selenium removal project have been conducted internally by WDTEC S.r.l. Development of Gantt charts, P&ID updates, and 3D models of skids and plant components constituted other chores.

€ 105,534

In conclusion, to guarantee the economic feasibility of the suggested selenium removal system upgrade at the Fiume Santo Power Plant, an extensive financial evaluation has been conducted at last. Every significant cost component including the procurement of new equipment and instrumentation depending on supplier quotes, lead times, and technical specifications has been carefully thought over. Moreover, the study has included all labor-related costs connected to on-site operations, therefore addressing both installation and removal stages.[10],[11] This covers thorough cost projections for technical and engineering staff including mechanical technicians, welders, riggers, site supervisors, project engineers, and safety coordinators. Incorporating these components helps the financial feasibility study

to show a whole and reasonable prediction of the economic needs required to effectively implement the project under both phased and parallel strategies.

Comparative cost-benefit analysis for both phased and parallel implementation approaches, assessing overall costs and financial impacts

To assess the optimal execution strategy for the selenium removal system improvement at the Fiume Santo Power Plant, a comparative cost-benefit analysis was performed between two different implementation methodologies: phased and parallel. This analysis aimed to evaluate the overall financial implications, project timeline, and operational factors related to each option.

The investigation utilized Microsoft Project to create two comprehensive planning models, one for each execution scenario. These models were employed to organize the Work Breakdown Structure (WBS), allocate resources, assign durations to activities, and estimate task costs based on supplier quotations and labor rates.[10],[11]

In the phased strategy, all activities occur at an unoccupied and non-functional workplace following the complete shutdown of the existing factory. This circumstance permits more assertive scheduling, including the potential for overtime labor, which was factored into the planning. Furthermore, due to the inability to retain or discharge untreated wastewater with elevated selenium concentrations forever, there is an urgent need for speeding up the project's completion. Consequently, both execution duration and total expenses are expected to be reduced compared to the parallel scenario, notwithstanding the initial facility downtime. In contrast, the parallel technique allows the current selenium removal facility to continue functioning while the new system is constructed in nearby locations. This configuration reduces environmental impact and permits adaptable project scheduling.[6] Nevertheless, it also presents numerous operational difficulties. The duration of each task is extended due to safety restrictions, logistical difficulties, and the necessity to coordinate with on-site personnel. The execution crew must operate with caution, frequently in restricted areas with operating machinery in proximity. These conditions not only prolong the project timeframe but also result in increased expenses associated with safety personnel, crane utilization, temporary fencing, logistical delays, and restrictions on off-hour operations.

This chapter includes several charts and tables to support the analysis. These images depict:

The comprehensive projected expense for each strategy (Operational Cost)

- Phased strategy:

Remaining cost	Cost variance
€1,002,056.00	€1,002,056.00

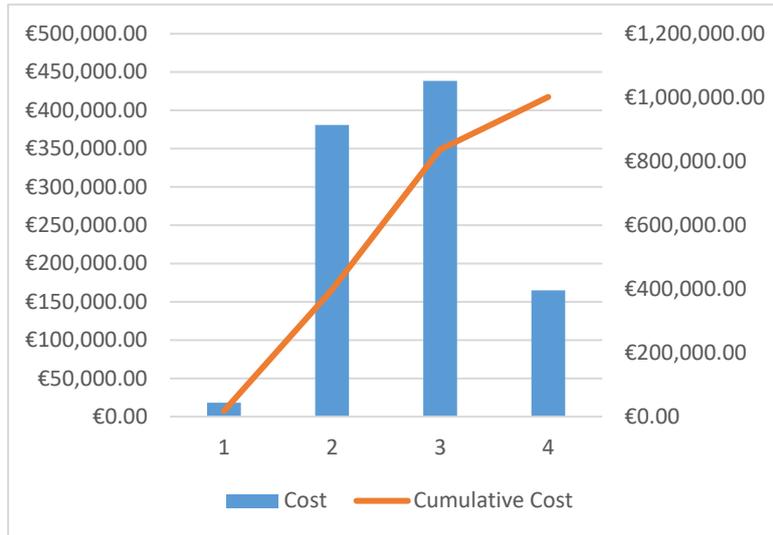


Figure 3.4- Operational cost (Phased strategy) [10]

- Parallel strategy:

Remaining cost	Cost variance
1,509,616.00 €	1,509,616.00 €

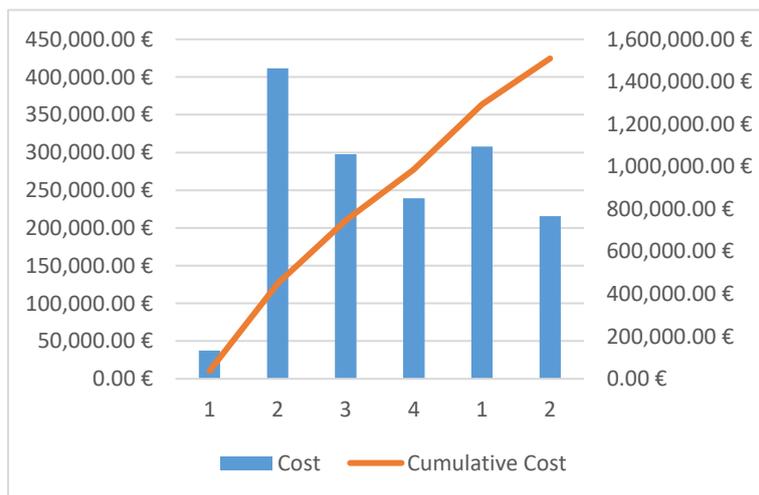


Figure 3.5- Operational cost (Parallel strategy) [11]

The comparison analysis clearly indicates that the total cost of the parallel method is roughly 50% greater than that of the phased technique.[10][11] The notable gap is mainly due to the augmented labor time, improved safety protocols, logistical limitations, and operational complexity involved in executing building tasks within an active plant setting. The phased plan advantages stem from a completely decommissioned site, facilitating quicker execution, extended shifts, and reduced coordination overhead, hence decreasing both time and expense.

The projected expenses for essential teams (installation, removal, technical oversight)

- Phased strategy

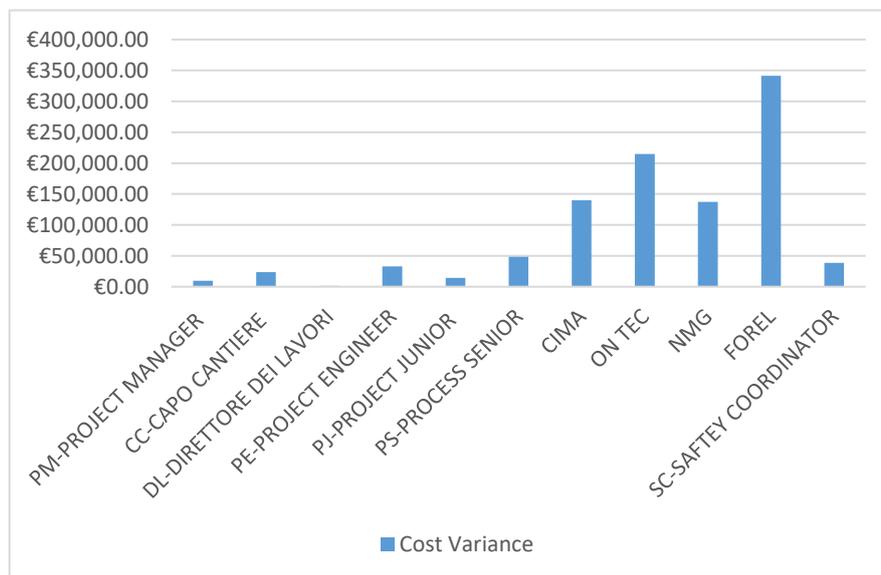


Figure 3.6- Resource cost variance (Phased strategy) [10]

Name of the resource	Cost (€)
PM-PROJECT MANAGER	€9,600.00
CC-CAPO CANTIERE	€23,520.00
DL-DIRETTORE DEI LAVORI	€1,600.00
PE-PROJECT ENGINEER	€32,960.00
PJ-PROJECT JUNIOR	€14,400.00
PS-PROCESS SENIOR	€48,600.00

CIMA	€139,920.00
ON TEC	€214,656.00
NMG	€137,280.00
FOREL	€341,120.00
SC-SAFTEY COORDINATOR	€38,400.00

Table 3.4- Resource costs [10]

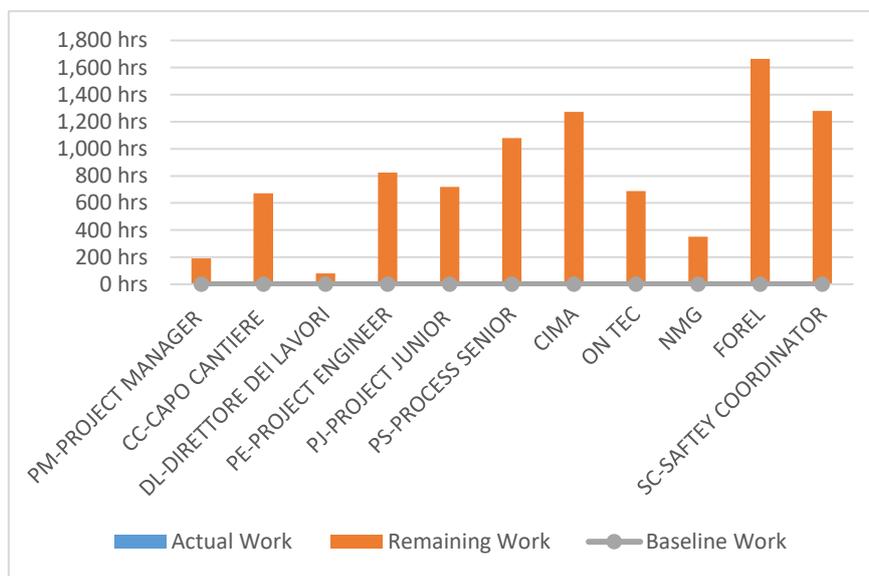


Figure 3.7- Resource stats (hour) [10]

Name of the resource	Remaining Work (hr)
PM-PROJECT MANAGER	192 hrs
CC-CAPO CANTIERE	672 hrs
DL-DIRETTORE DEI LAVORI	80 hrs
PE-PROJECT ENGINEER	824 hrs
PJ-PROJECT JUNIOR	720 hrs
PS-PROCESS SENIOR	1,080 hrs

CIMA	1,272 hrs
ON TEC	688 hrs
NMG	352 hrs
FOREL	1,664 hrs
SC-SAFTEY COORDINATOR	1,280 hrs

Table 3.5- Resource workload (hr) [10]

- Parallel strategy

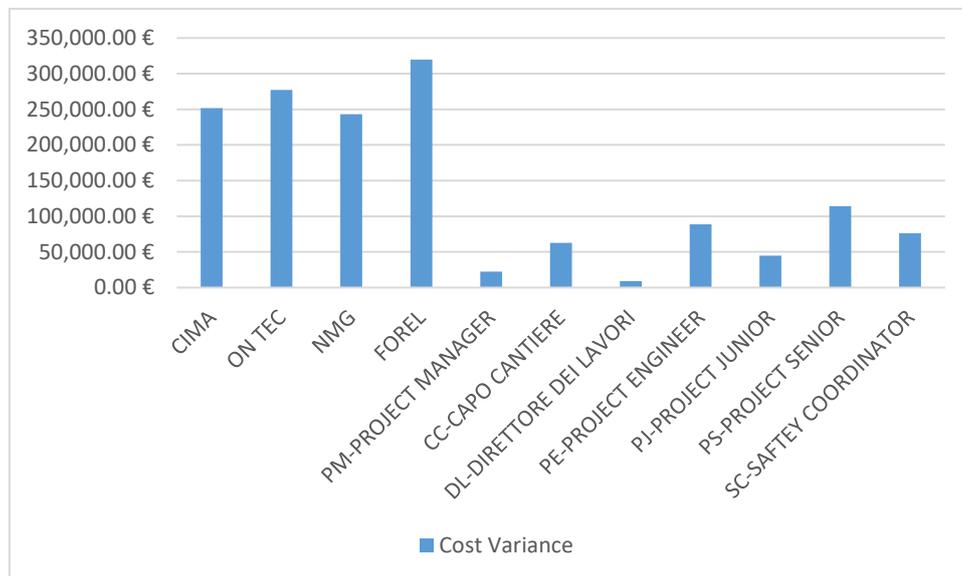


Figure 3.8- Resource cost variance (Parallel strategy) [11]

Name	Cost (€)
CIMA	251,680.00 €
ON TEC	277,056.00 €
NMG	243,360.00 €
FOREL	319,800.00 €
PM-PROJECT MANAGER	22,400.00 €
CC-CAPO CANTIERE	62,720.00 €
DL-DIRETTORE DEI LAVORI	8,960.00 €

PE-PROJECT ENGINEER	88,640.00 €
PJ-PROJECT JUNIOR	44,800.00 €
PS-PROJECT SENIOR	114,120.00 €
SC-SAFTEY COORDINATOR	76,080.00 €

Table 3.6- Resource cost variance [11]

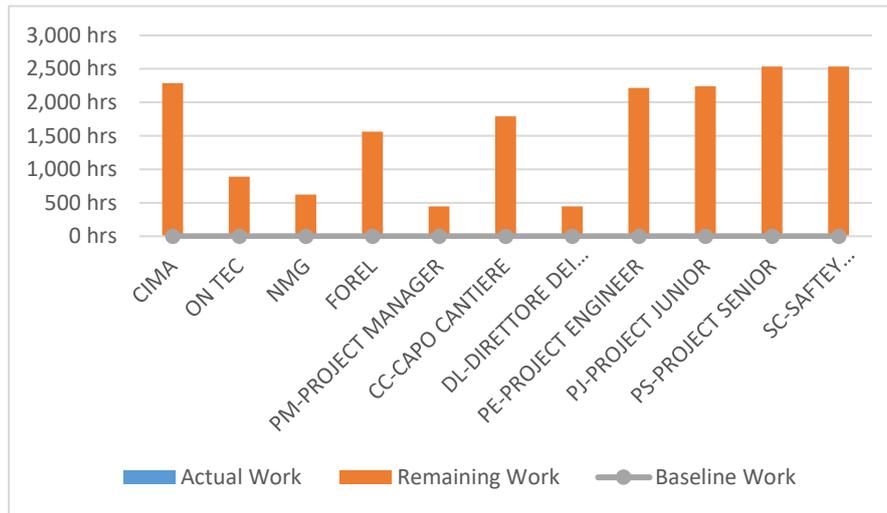


Figure 3.9- Resource stats (Parallel strategy) [11]

Name	Remaining Work (hr)
CIMA	2,288 hrs
ON TEC	888 hrs
NMG	624 hrs
FOREL	1,560 hrs
PM-PROJECT MANAGER	448 hrs
CC-CAPO CANTIERE	1,792 hrs
DL-DIRETTORE DEI LAVORI	448 hrs
PE-PROJECT ENGINEER	2,216 hrs
PJ-PROJECT JUNIOR	2,240 hrs
PS-PROJECT SENIOR	2,536 hrs
SC-SAFTEY COORDINATOR	2,536 hrs

Table 3.7- Resource workload (Parallel strategy) [11]

The comparative figures created for this study illustrate distinct differences in operating expenses between the phased and simultaneous execution strategies. A key discovery is that,

using the phased strategy, total expenses are significantly reduced, especially for field operations-due to the more straightforward, unrestricted working environment.

The expense related to NMG Group, tasked with the disposal of current equipment, is projected to be €137,280.00 in the phased plan. Conversely, the identical scope of work under the parallel strategy amounts to €243,360.00. This increase of almost double is directly associated with the prolonged duration of their work in the parallel scenario. All operations designated for this group in the parallel method are projected to necessitate roughly double the time, influenced by a fundamental 25% increase in job duration resulting from enhanced safety protocols and operational limitations. In an operational facility, teams must use heightened caution to prevent interference with current systems or jeopardizing plant people, so inevitably delaying execution.

For the ON Technology Group, which oversees the removal and installation of electrical and instrumentation systems, the cost in the phased plan is roughly €214,656.00, however in the parallel strategy it increases to €277,056.00. This increase, while less pronounced than that of the NMG Group, nonetheless shows the heightened complexity and logistical cooperation necessary in an operational context.

Furthermore, directed human resources-including safety supervisors, project engineers, and site coordinators-exhibit a significant cost escalation in the parallel method. The expense of employing a Safety Coordinator on-site is almost twice as high in the parallel model, owing to the considerably prolonged project duration and the elevated risk associated with operating near active equipment and personnel.

The observed cost escalations, seen in the comparative charts, are directly associated with the characteristics of the working environment rather than the technical scope. The procurement costs for equipment, instruments, and structures are consistent across all techniques; the difference is exclusively in the operational and labor-related elements.

A comparative analysis of financial risk exposure

This section offers a comprehensive analysis of the financial risk exposure linked to each implementation strategy-phased and parallel-for the selenium removal system upgrade at the Fiume Santo Power Plant, complementing the comparative cost-benefit evaluation. Although both methodologies seek to get the same technological result, their operational parameters markedly affect their susceptibility to unforeseen expenses, delays, and disruptions.

1.Key Risk Factors Considered

The following financial risk elements have been identified and evaluated:

- Safety-related disruptions
- Unplanned delays due to limited access or coordination conflicts

- Overtime labor requirements
- Increased supervision and safety staffing
- Damage to existing operational systems
- Regulatory penalties due to temporary environmental non-compliance
- Supplier delivery delays or installation rescheduling
- Crane, lifting, and logistics inefficiencies
- Risk contingency percentages required in budget

2. Risk Exposure Comparison Table

Risk Factor	Phased Strategy	Parallel Strategy
Safety Risk & Incident Exposure	Low – site is decommissioned	High – live plant requires careful coordination with active systems
Task Duration Uncertainty	Low – overtime possible, no access restrictions	High – limited shifts, need for slower work pace near operational zones
Environmental Compliance Risk	High – untreated selenium-rich wastewater may be temporarily discharged	Low – existing treatment system remains operational during execution
Logistics & Access Risk	Low – full control of site	High – shared space with existing operations, crane access limited
Labor Cost Escalation	Moderate – due to compressed schedule and overtime	High – extended durations, safety measures, and off-hour labor
Crane/Truck Coordination Risk	Low – easier layout and staging area	High – complicated lifting logistics within confined, active areas
Supervision & Staffing Cost Risk	Moderate – standard supervision levels	High – more HSE, site management, and interface roles needed

Damage to Existing Systems	None	High – risk of interference with live pipelines or electrical panels
Scheduling Conflict Risk	Low	High – must coordinate with ongoing plant operations
Total Risk Contingency Estimate	~5–10% of total operational cost	~15–20% of total operational cost

Table 3.8- Risk exposure comparison table (both strategies) [15]

Financial risk assessments addressing potential cost overruns, price fluctuations, and unforeseen expenditures

Any complicated industrial project such as the installation of a selenium removal system at the Fiume Santo Power Plant must include a financial risk analysis to include potential cost variations that could affect the general project budget. This part examines possible causes of cost overruns, price swings, and unanticipated expenses that could influence phased or parallel implementation plans in several ways.[15]

1. Cost overruns

Cost overruns signify the danger that real project expenditures surpass the original budget owing to underestimating, delays, or unforeseen site conditions. This project identifies potential factors contributing to cost overruns:

- Prolonged labor hours resulting from installation delays attributed to adverse weather, coordination challenges, or operations in restricted spaces (particularly in parallel method).[15]
- Augmented supervision mandates, including the necessity for full-time safety personnel and project engineers for extended durations.[15]
- Rework expenses, particularly when installations must be redone owing to technical discrepancies or misalignment with existing systems.[15]

In the parallel strategy, the expense of the removal team (NMG) escalates from €137,280 (phased) to €243,360 because of a doubling in work time. This cost escalation immediately indicates the possible risk of overruns in constrained operational conditions.

2. Price fluctuations

Price variations denote the risk of rising market pricing for materials, components, or subcontracted services during the procurement or execution phase. Due to global supply chain instability, inflation, and lead-time uncertainty, price changes are especially pertinent for:

- Electrical components (cables, panels, junction boxes) whose costs fluctuate with the copper and raw material markets.[15]
- Chemical dosing apparatus or sensors (e.g., pH and Redox probes), frequently imported and influenced by currency exchange rates.[15]
- Steel buildings and pipelines are susceptible to variations in raw material costs.[15]

During the acquisition of equipment, numerous proposals were made from vendors for equivalent items. The final options emphasized both expense and delivery time.[12],[13] In many instances, pricing variations for identical items escalated to 25%, contingent upon the source and delivery timeframe.

3. Unforeseen expenses

- Rental of emergency equipment (e.g., an extra crane necessitated by unforeseen access complications).
- Potential harm to current plant systems in the parallel method if safety parameters are not upheld.
- Environmental fines or interim wastewater storage expenses in the phased approach if the current facility is decommissioned prior to the new system's operational status.
- Insurance premiums rise because of reassessment of site safety hazards.

In the parallel strategy, supplementary fences, portable lighting, and access platforms may be necessary to segregate live areas from work zones. These were not originally included in the primary scope but can cumulatively contribute thousands of euros throughout the project duration.

Mitigation Strategies Regarded

To mitigate these risks, the financial model incorporates:

- Contingency reserves should be allocated at 5–10% for a phased approach and 15–20% for a parallel strategy.
- Incorporate a buffer in labor estimates, particularly for parallel execution, allowing for a 25% increase in time for essential activities.
- Supplier benchmarking to ensure the selection of providers with dependable delivery schedules and price consistency.
- Multi-offer procurement method that mitigates risk associated with single-supplier instability.

Final assessment

The financial risk assessment indicates that although both strategies possess inherent uncertainties, the parallel strategy subjects the project to heightened financial volatility owing to extended durations, safety limitations, and fluctuating site conditions.[15] The phased

method, albeit more urgent from a regulatory standpoint, provides a more regulated and foreseeable financial landscape, contingent upon the prior resolution of temporary wastewater management measures.

Operational feasibility

Examination of the operational impact, particularly downtime risks associated with phased implementation

The evaluation of operational impact is one of the most important factors in choosing an execution strategy for the Fiume Santo Power Plant to remove selenium, particularly in terms of downtime risks under the phased implementation method.

Under the phased approach, the current selenium removal system is completely closed before the replacement plant is built and turned on. Thanks to unrestricted access, no live disruptions, and more flexible scheduling, this provides for a simpler and faster construction process. However, it also causes a major operational gap during which the plant is unable to handle wastewater including high quantities of selenium. Two main hazards are presented by this brief stop of therapeutic activities:

1.Regulatory and environmental risk

Legal release of selenium-contaminated wastewater cannot be accomplished without a working treatment system in place. Any delay in the implementation of a project could produce:

- Concentration of untreated wastewater on-site needing temporary containment or emergency storage.
- Possible non-compliance with Italian Legislative Decree 152/2006 and EU Water Framework Directive could result in legal action or administrative fines.
- The need for temporary mobile treatment systems, which can bring operational complexity and unanticipated expenses.

2.Pressure to Quicken Implementation

The phased approach naturally necessitates the project to be finished as fast as feasible since the inability to release wastewater during the transition calls for it. This urgency shapes cost structure and planning as well:

- Tighter plans depend more on fast-track procurement, overtime, and numerous shifts.[10],[11]
- Reduced float time raises the possibility that every little delay will cause a domino impact on the project schedule.[10],[11]
- More stress on building teams could possibly affect safety and quality if not properly controlled.[15]

Still, this approach has important practical benefits as well:

1. Safety management is simplified by no interaction or interference with the current plant.[15]
2. Reduced danger of harming live systems, which in older infrastructure may be very delicate.
3. Easy task sequencing, equipment staging, and logistics driven by complete site availability.

Comparative Analysis with Parallel Strategy

On the other hand, the parallel approach lets the current selenium removal system stay functional during the building of the new plant, therefore totally removing the downtime risk. Although this lessens regulatory pressure and offers environmental continuity, it comes at the expense of longer task times, difficult safety coordination, and higher labor and supervising expenses.[11]

In conclusion, especially in relation to environmental compliance and regulatory vulnerability, the phased approach adds a great degree of operational risk connected with downtime. The project schedule must be well controlled and include contingency plans for temporary treatment or wastewater confinement to help to reduce these hazards. Although this approach is reasonably affordable in terms of direct implementation, the strategic decision-making process must carefully consider the hidden cost of downtime and non-compliance.

Assessment of resource allocation, including staffing levels, required expertise, and maintenance capabilities.

An essential element in assessing the viability and operating strategy of the selenium removal system enhancement at the Fiume Santo Power Plant is the evaluation of resource distribution. This entails a thorough assessment of workforce levels, necessary technical and managerial competencies, and the overall capacity of the project framework to facilitate the installation, coordination, and ongoing maintenance of the enhanced system.

Organizational framework and responsibilities

The project's organizational structure has been established to guarantee comprehensive technical, management, and safety oversight during all execution phases. The human resources plan encompasses the following essential positions, each designated to execute a certain strategic and operational function:

Project manager:

Accountable for comprehensive project coordination, budget management, timeline oversight, and client communication. The Project Manager is pivotal in decision-making, risk management, and monitoring progress.[7]

Capo Cantiere (Site Foreman):

Supervises daily site operations, directs technical teams, guarantees compliance with the construction timeline, and liaises with subcontractors. The Capo Cantiere functions as the principal liaison between on-site crews and project management.[7]

Construction Supervisor:

Ensure that the work is done in accordance with the authorized designs, contractual contracts, and relevant legislation. The DL oversees the site journal (Giornale dei Lavori), ensures adherence to quality standards, and approves any technical deviations.[7]

Project Engineer:

Delivers technical guidance on-site, ensures construction operations conform to engineering documentation, and resolves any design-related challenges that arise during implementation. The Project Engineer additionally assists with the commissioning process and technical documentation.[7]

Project Junior:

Supports the Project Engineer and senior team with documentation management, drawing revisions, field measurements, and fundamental supervisory responsibilities. Project Junior serves as a liaison between the design office and the construction site, facilitating prompt feedback and problem resolution.[7]

Project Senior:

An exceptionally seasoned process or mechanical engineer tasked with supervising intricate technical operations, including system integration, alignment of skids and tanks, chemical dosing logic, and commissioning procedures.[7]

Safety Coordinator (HSE Supervisor):

Oversee adherence to health and safety laws, organize safety briefings, does site inspections, and engages with subcontractors to mitigate risks—especially crucial under the concurrent strategy when existing systems continue to function.[7]

2. Considerations for allocation across strategies

The phased strategy facilitates more straightforward resource allocation. Due to the plant's shutdown, access is unlimited, job overlaps are reduced, and fewer personnel are needed concurrently. Most positions are occupied extensively for a brief period. The Capo Cantiere and Project Engineer are the most engaged, with sporadic involvement needed from the Safety Coordinator and Project Senior.[10],[11]

In the parallel strategy, the simultaneous execution of building and plant operations substantially prolongs the tenure of most directive responsibilities. Safety monitoring necessitates the full-time presence of the Safety Coordinator on-site. The Project Manager, DL, and Project Engineer are experiencing heightened workloads due to increasing coordination complexity and contact with plant operations.

3. Maintenance and post-implementation support

This project emphasizes installation and commissioning; however, the designated personnel specifically the Project Engineer and Project Senior are tasked with establishing operational procedures, maintenance access strategies, and control logic to guarantee the system's long-term functionality. Their expertise is crucial for guaranteeing that the installed equipment is maintained and adheres to future operational requirements.

The resource allocation strategy has been designed to ensure the availability of all essential technical, managerial, and safety positions, both on-site and during interactions with suppliers and stakeholders. The presence of highly qualified individuals, including the Project Manager, Site Manager, Project Director, and engineering staff, guarantees that the project is underpinned by a robust and flexible organizational structure. The plan additionally illustrates the varying requirements of the phased and parallel techniques, especially for personnel duration, safety coverage, and coordination intensity.

Scheduling analysis integrating procurement data, lead times, regulatory approval periods, and construction timelines to develop realistic project schedules

An effective and feasible project schedule must consider construction sequencing, procurement scheduling, material availability, and regulatory milestones.[7],[9] A comprehensive scheduling analysis for the selenium removal system upgrade at the Fiume Santo Power Plant has been performed using Microsoft Project, incorporating essential factors such as procurement data, supplier lead times, regulatory approval timelines, and anticipated installation durations.[10],[11]

The procurement and lead time data, elaborated upon in previous sections, was obtained from supplier quotations and organized into specific equipment and instrumentation lists. The lists encompass delivery schedules for essential items, including tanks, pumps, equipment (e.g., pH, Redox, pressure transmitters), electrical panels, junction boxes, and structural components.[12],[13] Proposals from several vendors were evaluated, and equipment with shorter lead times was preferred to mitigate project risk and facilitate timeline compression.

Additionally, the delays for regulatory approval were evaluated, including those pertaining to environmental compliance under Italian Legislative Decree 152/2006.[5] Any activity necessitating interaction with the existing facility or impacting wastewater discharge mandated collaboration with the pertinent regulatory authorities to ensure compliance and prevent delays.

From a strategic standpoint, scheduling limitations vary considerably between the two implementation methods:

The phased strategy entails the decommissioning of the current selenium treatment system, so rendering the plant incapable of processing selenium-contaminated wastewater until the new system is finalized and operational. This establishes a firm timetable, necessitating the

completion of the full project by the conclusion of 2025 to avert environmental and legal repercussions. This urgency affects procurement prioritizing and construction sequencing, resulting in numerous jobs being performed concurrently and arrangements for extra work.[10]

Conversely, the parallel technique allows the current treatment facility to function while the new system is being constructed. This alleviates the urgent obligation to adhere to a specific regulatory deadline, so rendering the building schedule more adaptable. The extended execution period is mitigated by prolonged job durations, attributable to the necessity of navigating live systems, access limitations, and heightened safety standards.

The combination of procurement timelines, material delivery projections, and execution sequences facilitated the creation of accurate and informed Gantt charts. These were employed to model project timelines, ascertain essential pathways, and optimize resource allocations efficiently. The phased approach prioritizes rapid execution and strict adherence to deadlines, whereas the parallel model entails an extended, less pressured construction schedule, with a heightened focus on safety and coordination.[11]

3.1.5 Initial risk register and constraints mapping

Proactively identifying risks and understanding constraints are critical activities during project initiation. An initial risk register qualitatively assesses potential project risks, including:

Technical Risks

Risk: Postponements in the supply of tanks, pumps, sensors (pH, Redox), and electrical panels.

Causes: Prolonged suppliers lead times, logistical difficulties, delayed acceptance of specifications.

Impact: May delay important route tasks, influencing commissioning and legal timelines.

Probability: Medium to High (considering market conditions for instrumentation and control apparatus).

How to mitigate:

- Several supplier quotations have been acquired (as we have done).
- Prioritization of equipment with minimal lead time.
- A buffer has been incorporated into the MS Project timeline for critical components.[15]

Challenges in technology integration

Risk: Incompatibility or malfunction during the integration of new automation components (e.g., sensors, PLCs, pump controllers) into the existing system using parallel technique.[15]

Causes: Design discrepancies, uncalibrated interfaces, and mismatches in communication protocols.

Consequences: May postpone commissioning and necessitate more engineering resources.

Probability: Moderate.

How to mitigate:

- assigning a Project Senior to oversee design consistency.
- Conducting pre-testing of components off-site.
- Timely collaboration with automation and instrumentation teams.[15]

Operational inefficiencies

Risk: Chemical dosing units (ferric sulfate, soda, polyelectrolyte) fail to achieve anticipated removal efficacy due to improper mixing, dosing rates, or control logic.

Causes: Inaccurate parameter calibration, unexpected water chemistry complications.

Consequences: Noncompliance, necessitating reprogramming or mechanical modifications.

Probability: Moderate

How to mitigate:

- Attendance of the Process Senior and Project Engineer throughout the initiation phase.
- Validation of process logic by laboratory experiments conducted on-site.
- Incorporation of redundant sensors for instantaneous feedback.[15]

Regulatory risks

One of the most important regulatory hazards in the framework of the phased strategy is connected to the rigorous deadline enforced by environmental compliance criteria. The facility would be unable to treat wastewater polluted with selenium since the current selenium removal plant would be closed during building. Consequently, the project is obliged to be finished by the end of 2025 to prevent possible regulatory threshold violations established by the European Union and Italian environmental authorities (e.g., Legislative Decree 152/2006).[5] Any delay in execution can subject the plant operator to administrative penalties, compliance violations, or the necessity for expensive temporary mitigating actions. Consequently, the phased strategy's regulatory schedule is not flexible and serves as a rigid constraint in both risk evaluation and planning.[15]

Financial risks

1. Budget exceeds

Labor durations were underestimated, particularly in the parallel strategy.

Revision is necessitated by technical errors or ambiguous documentation.

Urgent alterations or expedited acquisition under timing constraints.[15]

2. Price variations

- Fluctuations in raw material markets (e.g., steel for tanks, copper for wires).
- Disruptions in the global supply chain.
- Fluctuations in currency exchange rates for imported instruments.[15]

3. Risks associated with procurement and lead time

- Issues with supplier reliability.
- Absence of multi-sourcing techniques.
- Logistical constraints.[15]

Operational risks

Operational risks are those possible disturbances, inefficiencies, or hazards resulting from human constraints, interference with current operations, or unsafe working conditions during a project. Within the framework of the Fiume Santo Power Plant's selenium removal system upgrade, operational risks are very important, particularly under the simultaneous implementation model, in which building operations take place while the current treatment plant is still in use.[15]

1. Staffing shortages

The possible under allocation or lack of qualified individuals needed for the timely and safe completion of activities represents a main operational risk. Crucially important are roles including mechanical technicians, electrical experts, crane operators, and directorial staff (such as Project Engineer, Site Manager, Safety Coordinator). Especially in the parallel strategy, this danger is increased during moments of maximum workload or when several contractors are working on overlapping jobs inside limited spaces.[15]

2. Interruptions to Ongoing Operations (Parallel Strategy Only)

Under the simultaneous execution plan, buildings take place close to an active selenium removal plant. Since field teams must coordinate their efforts to prevent interfering with utilities, key plant operations, or access routes, this creates significant interference risk. Among these risks are accidental running system shutdown or bypass (such as dosing units or pump lines), Electric work causing problems with live panels, and movement of big machinery (such as skids or tanks) close to sensitive regions.[15]

3. Safety issues (under construction)

Building projects inside or near a live facility greatly complicate the process of preserving a safe workplace. Important hazards to safety consist of: Around pressurized pipelines or high-voltage panels, Operation in confined space, Crane raises in areas of common operations, possible chemical contact resulting from continuous dosage systems.[15]

Environmental risks

The Fiume Santo Power Plant's selenium removal system is motivated by the necessity to guarantee compliance with demanding environmental discharge limitations and to minimize the negative impacts of selenium on aquatic and marine ecosystems. Although trace levels of selenium are necessary, growing in the environment especially in aquatic food chains selenium becomes quite harmful.[15]

1.Process and regulatory guidelines

The project team's functional process description states that the treatment system is intended to chemically reduce and precipitate selenium using ferric sulfate and other chemicals. The technique seeks to bring selenium concentrations in expelled wastewater down to environmentally friendly levels. Normal selenium limits for surface water discharge are around 10 ppb in line with Italian Legislative Decree 152/2006 and EU water quality recommendations. We have tried to reduce the selenium amount from about 400 ppb to under 30 ppb.[5]

2.Ecological risks in selenium pollution

Particularly in systems whereby selenium enters via industrial discharges, (Fan et al., 2020, Science of the Total Environment) offers a thorough review of selenium-induced deformities and reproductive failures in fish. Particularly to early developmental stages of fish and aquatic invertebrates, long-term exposure to levels exceeding 5 µg/L in aquatic environments can cause major ecological damage.[15]

Rising selenium levels were demonstrated to stop the growth of marine phytoplankton, therefore upsetting the foundation of the aquatic food web, in the study "Effect of selenium on marine phytoplankton" (Price et al., Marine Biology, 1987). Selenium exposure showed possible damage even at low levels since it interfered with photosynthesis and metabolic enzyme performance.[15]

3.Site-specific Fiume santo risks

The Fiume Santo facility is close to estuaries and marine settings, hence there is more chance of selenium finding its way into delicate aquatic systems. Under a staged approach, whereby the current facility is closed, and the new system is under development, untreated wastewater runs a brief risk of being dumped or stored. This puts environmental hazards including Non-compliance with discharge regulations, Legal responsibility under Italian and European law as well as possible uses and Environmental damage particularly in cases of inadequate temporary systems or failing storage.

This environmental risk is much reduced in the parallel approach since the current selenium removal equipment stays operational during building. But this approach adds other operational and safety hazards covered elsewhere in the thesis.[11]

3.1.6 Summary and importance of the initiation phase

The Initiation Phase establishes the strategic groundwork for the comprehensive selenium removal system upgrading at the Fiume Santo Power Plant. In a project of this magnitude and environmental sensitivity, the beginning phase is not merely a formality; it is a crucial stage that establishes the technical direction, organizational framework, and risk profile for the whole lifecycle. This phase guarantees that all subsequent decisions conform to regulatory standards and operational objectives by clearly defining objectives, developing a structured Project Charter, and identifying all important stakeholders.

Comprehensive feasibility assessments-encompassing technical, financial, and operational aspects-facilitate a pragmatic appraisal of limitations and prospects. The risk analysis, which includes environmental, regulatory, operational, and financial vulnerabilities, guarantees that mitigation strategies are integrated from the outset. The meticulous distribution of human resources, especially for senior positions like Project Manager, Works Director, Project Engineer, and Safety Coordinator, ensures the availability of appropriate knowledge to assist in every pivotal decision on-site.

Furthermore, the scheduling framework, based on validated procurement data, feasible construction schedules, and regulatory deadlines, demonstrates that the phased and parallel strategies must be assessed not just from a financial standpoint but also for their wider project implications.

The Initiation Phase is fundamental to project success. It converts an environmental compliance requirement into a systematic, actionable strategy harmonizing schedule, cost, risk, and sustainability from the outset.

4 Planning phase

The planning stage of this project was all about coming up with two specific plans on how to upgrade the selenium removal system at the Fiume Santo Power Plant: phased and parallel. During this step, we used MS Project to make project timelines, figure out expenses, durations, and resources, and define the Work Breakdown Structure (WBS). To make sure the foundation was realistic and strategic, risk assessments, procurement planning, and technical feasibility studies were all combined. The goal was to develop a full pre-execution model that could be used to compare the two techniques in terms of time, cost, risk, and effect on the environment.

4.1 Comparative work breakdown structures (WBS)

4.1.1 Objective of WBS development

The Work Breakdown Structure (WBS) functions as a fundamental instrument in project planning by subdividing the total scope into manageable elements.[7] The purpose of creating the WBS is to explicitly outline all project outputs and tasks, assure coherence with project objectives, and enable precise scheduling, budgeting, and resource distribution. The WBS, by organizing work hierarchically, offers a distinct framework for evaluating phased and parallel execution strategies, hence enhancing management and communication throughout the project lifecycle.

4.1.2 WBS for phased execution strategy

Under a sequential and predictive approach, the phased execution plan interprets each major project phase- procurement, and construction-done before the next beginning. It lets for organized planning, risk control, and simpler tracking of dependencies. The hierarchical

breakdown of tasks particular to the staged method chosen for the selenium removal project is shown in the WBS below:

1	FIUME SANTO-EXECUTION PHASE (PHASED STRATEGY)
1.1	RIMOZIONE E DEMOLIZIONE DELLE VECCHIE APPARECCHIATURE E STRUTTURE
1.1.1	SCOLLEGAMENTO IMPIANTO ELETTRICO DAL Q.E. DEL GRUPPO FILTROPRESSA, DELLE POMPE P-121 E P123.
1.1.2	RIMOZIONE POMPE P-121A, P-121B, P-123A E P-123B
1.1.3	DEMOLIZIONE EDIFICIO FILTROPRESSA E DELLE OPERE CIVILI ANNESSE
1.1.4	DEMOLIZIONE STRUTTURE (SCALE ESCLUSE)
1.1.5	SMONTAGGIO TK-115A E TK-115B
1.1.6	RIMOZIONE REATTORE (TK111,TK112,TK113)
1.1.7	RIMOZIONE DECANTATORE TK107,TK108,TK109
1.1.8	RIMOZIONE JUNCTION BOXES
1.2	RIMOZIONE E COSTRUZIONE BAGGIOLI AREA REVAMPING-POLIPREPARATORE-TK114A/B
1.2.1	RIMOZIONE BAGGIOLI ESISTENTI IN AREA REVAMPING
1.2.2	COSTRUZIONE PLATEA PER POSIZIONAMENTO NUOVO TK-114A, TK-114B,BS-130, POMPA P-114, P114-B, TK115A,TK115B,P115A, P115B
1.2.3	COSTRUZIONE BAGGIOLI NUOVI PER TUTTE LE APPARECCHIATURE
1.2.4	RIMOZIONE DEL VECCHIO POLIPREPARATORE
1.2.5	DEMOLIZIONE COSTRUZIONE DEL VECCHIO POLIPREPARATORE
1.2.6	COSTRUZIONE NUOVI BAGGIOLI PER SOSTEGNO NUOVE PASSERELLE E DECANTATORI
1.3	APPROVVIGIONAMENTO
1.3.1	ORDINAZIONE POMPE PER SODA (DP201A/B/C/E/F/G)
1.3.2	ORDINAZIONE POMPE PER SOLFATO FERROSO (DP203A/B/C/E/F/G)
1.3.3	ORDINAZIONE GRUPPO FILTRAZIONE SU ACQUA CHIARIFICATA
1.3.4	ORDINAZIONE GRUPPO FILTRAZIONE SU ACQUA DAL PRIMARIO
1.3.5	ORDINAZIONE Q.E. MOD. MCC RIF. C.LE FIUME SANTO (AMPLIAMENTO)
1.3.6	ORDINAZIONE NUOVO TK 114A/B

1.3.7	ORDINAZIONE POMPE (P-115A/B)
1.3.8	ORDINAZIONE NUOVI TK 115 A/B
1.3.9	ORDINAZIONE BS-130
1.3.10	ORDINAZIONE POMPE P116 A/B
1.3.11	ORDINAZIONE NUOVI REATTORI
1.3.12	ORDINAZIONE AGITATORI REATTORI & DECANTATORI
1.3.13	ORDINAZIONE NUOVI DECANTATORI
1.3.14	ORDINAZIONE NUOVE POMPE P-111/112/113
1.3.15	ORDINAZIONE STRUMENTO (METTLER TOLEDO)
1.3.16	ORDINAZIONE STRUMENTO (E+H)
1.3.17	ORDINAZIONE STRUMENTO (WIKA)
1.3.18	ORDINAZIONE STRUMENTO (VEGA)
1.3.19	ORDINAZIONE STRUMENTO (SABA)
1.3.20	ORDINAZIONE STRUMENTO (STUBBE)
1.3.21	ORDINAZIONE STRUMENTO (GEMU)
1.3.22	ORDINAZIONE STRUMENTO (I.S.I_G+F)
1.4	POSIZIONAMENTO E COLLEGAMENTO DELL NUOVE APPARECCHIATURE
1.4.1	CONSEGNA AREE
1.4.1.1	COLLOCARE LO SKID DELLE POMPE DOSATRICI IN PROSSIMITA' DEL POLIPREPARATORE
1.4.1.2	REALIZZAZIONE SKID POMPE SOLFATO
1.4.1.3	REALIZZAZIONE SKID POMPE SODA
1.4.1.4	POSIZIONAMENTO SKID POMPE SOLFATO
1.4.1.5	POSIZIONAMENTO SKID POMPE SODA
1.4.1.6	POSIZIONAMENTO GRUPPO FILTRAZIONE SU ACQUA CHIARIFICATA
1.4.1.7	POSIZIONAMENTO GRUPPO FILTRAZIONE SU ACQUA DAL PRIMARIO
1.4.1.8	COLLEGARE IL QUADRO POLIPREPARATORE CON LINEA ELEETRICA
1.4.2	EDIFICIO ELETTRICO
1.4.2.1	COPERTURA QCC,QMC IN CONSERVAZIONE
1.4.2.2	AMPLIAMENTO EDIFICIO Q.E.

1.4.3	AREA TK-114 E SKID POMPE
1.4.3.1	INSTALLAZIONE STRUTTURE DI SOSTEGNO /CAMMINAMENTO
1.4.3.2	POSIZIONAMENTO NUOVO TK 114A/B E RELATIVE POMPE (P-114A/B P-115A/B)
1.4.3.3	STESURA NUOVA TUBAZIONE PER ACQUE CHIARIFICATE DAL NUOVO TK 114A/B AL TIE- IN PRESENTE SUL PIPE RACK
1.4.3.4	INSTALLAZIONE SKID POMPE DEL TK 114 A/B PROVVISORIO NELLA NUOVA AREA DESIGNATA
1.4.3.5	COLLEGAMENTO SKID POMPE P-114 A/B AL TK 114 A/B
1.4.3.6	COLLEGAMENTO LINEE FUORI SPECIFICA AL TK 114 B (PROVENIENTE DA DECANTATORE)
1.4.3.7	COLLEGAMENTO LINEE FUORI SPECIFICA AL TK101 (DALLE POMPE P-115 A/B A TK-101B)
1.4.3.8	INIZIO COLLEGAMENTO ELETTRICO DI TUTTI I DISPOSITIVI INSTALLATI
1.4.4	AREA THICKENER
1.4.4.1	POSIZIONAMENTO BS-130
1.4.4.2	POSIZIONAMENTO NUOVI TK 115 A/B
1.4.4.3	POSIZIONAMENTO NUOVO SKID POMPE P121 A/B
1.4.4.4	POSIZIONAMENTO POMPE P116 A/B
1.4.4.5	STESURA LINEA DA POMPE P116 A/B A TK101
1.4.4.6	STESURA LINEA DA P121 A/B A DEWATERING STATION
1.4.4.7	COLLEGAMENTO POMPE P121 A/B CON TK 115 A/B
1.4.4.8	COLLEGAMENTO POMPE P116 A/B CON BS130
1.4.4.9	COLLEGAMENTO ACQUE DI SFIORO TK-115A/B E CON BS 130
1.4.4.10	COLLEGAMENTO ELETTRICO NUOVE POMPE P121 A/B
1.4.4.11	COLLEGAMENTO ELETTRICO NUOVE POMPE P116 A/B
1.4.5	AREE REATTORI E DECANTATORI-SKID POMPE
1.4.5.1	POSIZIONAMENTO NUOVI REATTORI (TK111,TK111A,TK112,TK112A,TK113,TK113A)
1.4.5.2	POSIZIONAMENTO NUOVI REATTORI (TK116,TK116A,TK117,TK117A,TK118,TK118A)
1.4.5.3	INSTALLAZIONE AGITATORI REATTORI
1.4.5.4	POSIZIONAMENTO NUOVO DECANTATORI TK-104/105/106/107
1.4.5.5	POSIZIONAMENTO NUOVO DECANTATORI TK-108/109
1.4.5.6	INSTALLAZIONE AGITATORI DECANTATORI
1.4.5.7	POSIZIONAMENTO NUOVI SKID P-109/110/122/111/112/113

1.4.5.8	COLLEGAMENTO TUBAZIONE DA TK-107 A TK-114A E TK-114B
1.4.5.9	COLLEGAMENTO TUBAZIONE DA TK-108 A TK-114A E TK-114B
1.4.5.10	COLLEGAMENTO TUBAZIONE DA TK-109 A TK-114A E TK-114B
1.4.5.11	COLLEGAMENTO TUBAZIONE DA TK-104 A TK-114A E TK-114B
1.4.5.12	COLLEGAMENTO TUBAZIONE DA TK-105 A TK-114A E TK-114B
1.4.5.13	COLLEGAMENTO TUBAZIONE DA TK-106 A TK-114A E TK-114B
1.4.5.14	STESURA TUBAZIONE FANGHI DA POMPE P-109 A TK 115 A/B
1.4.5.15	STESURA TUBAZIONE FANGHI DA POMPE P-110 A TK 115 A/B
1.4.5.16	STESURA TUBAZIONE FANGHI DA POMPE P-122 A TK 115 A/B
1.4.5.17	STESURA TUBAZIONE FANGHI DA POMPE P-111 A TK 115 A/B
1.4.5.18	STESURA TUBAZIONE FANGHI DA POMPE P-112 A TK 115 A/B
1.4.5.19	STESURA TUBAZIONE FANGHI DA POMPE P-113 A TK 115 A/B
1.4.5.20	COLLEGAMENTO POMPE P-109 A TK-107
1.4.5.21	COLLEGAMENTO POMPE P-110 A TK-108
1.4.5.22	COLLEGAMENTO POMPE P-122 A TK-109
1.4.5.23	COLLEGAMENTO POMPE P-111 A TK-104
1.4.5.24	COLLEGAMENTO POMPE P-112 A TK-105
1.4.5.25	COLLEGAMENTO POMPE P-113 A TK-106
1.4.5.26	COLLEGAMENTO TK-107 A TK-111A
1.4.5.27	COLLEGAMENTO TK-108 A TK-112A
1.4.5.28	COLLEGAMENTO TK-109 A TK-113A
1.4.5.29	COLLEGAMENTO TK-104 A TK-116A
1.4.5.30	COLLEGAMENTO TK-105 A TK-117A
1.4.5.31	COLLEGAMENTO TK-106 A TK-118A
1.4.5.32	COLLEGAMENTO TK-111/112/113/116/117/118 A LINEA DI PROCESSO (TIE-IN)
1.4.5.33	COLLEGAMENTO ELETTRICO DI TUTTI I DISPOSITIVI INSTALLATI SU TK-104/105/106/107/108/109, SKID P-109/110/122/111/112/113, TK111,TK111A,TK112,TK112A,TK113,TK113A,TK116,TK116A,TK117,TK117A,TK118,TK118A
1.4.5.34	COLLEGAMENTO LINEE ARIA E ACQUA ALLE NUOVE LINEE DI IMPIANTO
1.4.6	COLLEGAMENTO TUTTI I STRUMENTI

1.4.7	COLLEGAMENTO SEGNALE A TUTTE LE APPARECCHIATURE INSTALLATE
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Table 4.1- WBS for phased strategy [10]

4.1.3 WBS for parallel execution strategy

The parallel execution strategy employs a concurrent and adaptable methodology, initiating several project phases-such as procurement and construction-prior to the complete finalization of engineering tasks. The overlap of stages seeks to reduce project time and expedite delivery, but at the cost of increased complexity and coordination difficulties. The subsequent WBS delineates the work decomposition designed for the parallel strategy of the selenium removal project.

1	FIUME SANTO-EXECUTION PHASE _Parallel
1.1	INIZIO OPERATIVITA' AREA VECCHIA
1.1.1	SCOLLEGAMENTO IMPIANTO ELETTRICO DAL Q.E. DEL GRUPPO FILTROPRESSA, DELLE POMPE P-121 E P123.
1.1.2	RIMOZIONE POMPE P-121A, P-121B, P-123A E P-123B
1.1.3	SMONTAGGIO TK-115A E TK-115B
1.1.4	DEMOLIZIONE EDIFICIO FILTROPRESSA E DELLE OPERE CIVILI ANNESSE
1.1.5	COSTRUZIONE PLATEA PER POSIZIONAMENTO NUOVO TK-114A, TK-114B, POMPA P-114, P114-B, P-115A, P-115B
1.1.6	COLLOCARE IL NUOVO POLIPREPARATORE
1.1.7	COLLOCARE LO SKID DELLE POMPE DOSATRICI IN PROSSIMITA' DEL POLIPREPARATORE
1.1.8	COLLEGARE IL QUADRO POLIPREPARATORE CON LINEA ELEETRICA PROVVISORIA
1.1.9	COLLEGARE LE POMPE DOSATRICI CON LE TIE-IN PRESENTI SUI RELATIVI REATTORI
1.1.10	COLLEGARE CON LINEA ELETTRICA PROVVISORIA LE POMPE DOSATRICI INSTALLATE
1.1.11	RIMOZIONE DEL VECCHIO POLIPREPARATORE
1.1.12	DEMOLIZIONE COSTRUZIONE DEL VECCHIO POLIPREPARATORE
1.1.13	POSIZIONAMENTO TIE-IN

1.1.14	AMPLIAMENTO EDIFICIO Q.E.
1.1.15	POSIZIONAMENTO (TEMPORANEO) NUOVO TK-114A CON RELATIVO SKID POMPE
1.1.16	COLLEGAMENTO ELETTRICO DI TUTTI I DISPOSITIVI ELETTRICI ED ELETTRONICI INSTALLATI SUL NUOVO SERBATOIO E SUL NUOVO SKID POMPE
1.1.17	COLLEGAMENTO GRUPPO POMPE- SERBATOIO
1.1.18	COLLEGAMENTO LINEA USCITA POMPE CON LINEA ESISTENTE AL TIE-IN PRESENTE SULLA LINEA IN USCITA ACQUE CHIARIFICATE ESISTENTE
1.1.19	COLLEGAMENTO LINEA ACQUA CHIARIFICATA IN ARRIVO DAI DECANTATORI AL TK-114A
1.1.20	SCOLLEGAMENTO ALIMENTAZIONE ELETTRICA DELLE POMPE DEL VECCHIO GRUPPO P114A-B E COLLEGAMENTO AL NUOVO GRUPPO POMPE
1.1.21	SCOLLEGARE TUBO ACQUE CHIARIFICATE PROVENIENTE DAI DECANTATORI E TAPPARE LINEA IN CORRISPONDENZA TIE-IN
1.1.22	SCOLLEGARE LINEA RILANCIO DELLE POMPE E TAPPARE LA LINEA STESSA IN CORRISPONDENZA DEL TIE-IN
1.1.23	SCOLLEGARE TUTTI I COLLEGAMENTI ELETTRICI ED ELETTRONICI DEI DISPOSITIVI INSTALLATI SUL SERBATOIO E SULLO SKID POMPE
1.1.24	DEMOLIZIONE E RIMOZIONE TK-114
1.1.25	SMONTAGGIO E RIMOZIONE SKID P-114
1.1.26	DEMOLIZIONE OPERE CIVILI PRESENTI SOTTO I COMPONENTI RIMOSI
1.1.27	COSTRUZIONE NUOVI BAGGIOLI DI SOSTEGNO AI DECANTATORI NUOVI E RELATIVE POMPE ASPIRAZIONE FANGHI E REATTORI
1.1.28	POSIZIONAMENTO NUOVI REATTORI
1.1.29	POSIZIONAMENTO POMPE FANGHI, NUOVI DECANTATORI
1.1.30	POSIZIONAMENTO NUOVO TK 114A E RELATIVE POMPE
1.1.31	STESURA NUOVA TUBAZIONE PER ACQUE CHIARIFICATE DAL NUOVO TK 114A AL TIE-IN PRESENTE SUL PIPE RACK
1.1.32	COLLEGAMENTO NUOVO TK 114A CON SKID POMPE ACQUE CHIARIFICATE
1.1.33	COLLEGAMENTO DEI DECANTATORI NUOVI AL NUOVO TK-114A
1.1.34	COLLEGAMENTO DEI DECANTATORI AI RELATIVI REATTORI

1.1.35	COLLEGAMENTO DEI DECANTATORI ALLE RELATIVE POMPE FANGO
1.1.36	STESURA NUOVE TUBAZIONI FANGHI DALLE POMPE DEI NUOVI DECANTATORI AI NUOVI TK115A E TK115B
1.1.37	COLLEGAMENTO LINEE ARIA E ACQUA ALLE NUOVE LINEE DI IMPIANTO
1.1.38	COLLEGAMENTO ELETTRICO DI TUTTI I DISPOSITIVI
1.1.39	COLLEGAMENTO SEGNALE A TUTTE LE APPARECCHIATURE
1.1.40	COLLEGAMENTO DEI REATTORI ALLA TIE-IN ACQUE DI PROCESSO
1.1.41	POSIZIONAMENTO NUOVI TK 115 A/B
1.1.42	POSIZIONAMENTO NUOVO SKID POMPE P121A/B
1.1.43	POSIZIONAMENTO BS 130
1.1.44	POSIZIONAMENTO POMPE P116A/B
1.1.45	STESURA LINEA DA POMPE P116 A/B A TK101
1.1.46	STESURA LINEA DA P121A/B A DEWATERING STATION
1.1.47	COLLEGAMENTO POMPE P121A/B CON TK 115 A E B
1.1.48	COLLEGAMENTO POMPE P116 A/B CON BS130
1.1.49	COLLEGAMENTO TK-115 A/B CON LINEE FANGO PROVENIENTI DAI NUOVI DECANTATORI
1.1.50	COLLEGAMENTO ACQUE DI SFIORO TK-115A/B CON BS-130
1.1.51	COLLEGAMENTO ELETTRICO NUOVE POMPE P121A/B
1.1.52	COLLEGAMENTO ELETTRICO NUOVE POMPE P116A/B
1.2	INIZIO OPERATIVITA' AREA NUOVA
1.2.1	SVUOTAMENTO TK 114 PROVVISORIO
1.2.2	SCOLLEGAMENTO ELETTRICO POMPE TK 114 PROVVISORIO

1.2.3	SCOLLEGAMENTO DI TUTTE DEL TK 114 PROVVISORIO DA TUTTE LE LINEE
1.2.4	SPOSTAMENTO TK 114 PROVVISORIO A LATO DEL NUOVO TK 114B
1.2.5	SPOSTAMENTO DELLO SKID POMPE DEL TK 114 PROVVISORIO (TK114 B)NELLA NUOVA AREA DESIGNATA
1.2.6	COLLEGAMENTO SKID POMPE DEL 114 PROVVISORIO AL TK 114 B
1.2.7	COLLEGAMENTO LINEE FUORI SPECIFICA AL TK 114 B
1.2.8	COLLEGAMENTO LINEE FUORI SPECIFICA AL TK101
1.2.9	COLLEGAMENTO ELETTRICO DELLO SKID TK 114B
1.2.10	DEMOLIZIONE PARZIALE DELLA PASSERELLA TK-107
1.2.11	SCOLLEGAMENTO ELETTRICO TK-107 E RELATIVO GRUPPO POMPE
1.2.12	SCOLLEGAMENTO ELETTRICO TK-111
1.2.13	SCOLLEGAMENTO TUBAZIONI DEL REATTORE TK-111
1.2.14	SCOLLEGAMENTO TUBAZIONI TK-107
1.2.15	RIMOZIONE TK-107
1.2.16	RIMOZIONE TK-111
1.2.17	TAGLIO TUBO ACQUA CHIARIFICATA DA TK-108 E TK-109
1.2.18	SMONTAGGIO TUBO ACQUA CHIARIFICATA TK-108 E TK-109
1.2.19	ADATTARE TUBO ACQUE CHIARIFICATE TK-108- E TK-109 PER SCARICO IN TK-114A
1.2.20	MONTAGGIO TUBO ACQUE CHIARIFICATE DA TK-108- E TK-109 PER SCARICO IN TK-114A
1.2.21	POSIZIONAMENTO NUOVO REATTORE TK-111
1.2.22	ADEGUAMENTO OPERE CIVILI PER ALLOGGIAMENTO NUOVO DECANTATORE TK-107
1.2.23	POSIZIONAMENTO NUOVO DECANTATORE TK-107

1.2.24	POSIZIONAMENTO POMPE P-109A/B
1.2.25	COLLEGAMENTO TUBAZIONE DA TK-107 A TK-114A E TK-114B
1.2.26	STESURA TUBAZIONE FANGHI DA POMPE P-109A/B A TK107
1.2.27	COLLEGAMENTO POMPE P-109A/B A TK-107
1.2.28	COLLEGAMENTO TK-107 A TK-111
1.2.29	COLLEGAMENTO TK-111 A LINEA DI PROCESSO
1.2.30	COLLEGAMENTO ELETTRICO DI TUTTI I DISPOSITIVI INSTALLATI SU TK-111, TK-107, SKID P-109A/B
1.2.31	RIMOZIONE PASSERELLA ESISTENTE
1.2.32	SCOLLEGAMENTO DI TUTTI GLI IMPIANTI COLLEGATI AI REATTORI TK-112 E TK-113
1.2.33	SCOLLEGAMENTO DI TUTTI GLI IMPIANTI DEI DECANTATORI TK-108 E TK-109
1.2.34	SCOLLEGAMENTO SKID P-110A/B E P-122A/B (PARTE ESISTENTE)
1.2.35	RIMOZIONE VECCHIO TK-108 E VECCHIO TK-109
1.2.36	RIMOZIONE VECCHI REATTORI TK-112 E TK-113
1.2.37	RIMOZIONE SKID P-110A/B E P-122A/B
1.2.38	POSIZIONAMENTO NUOVI REATTORI TK-112 E TK-113
1.2.39	ADEGUAMENTO OPERE CIVILI ESISTENTI PER ALLOGGIAMENTO NUOVI DECANTATORI TK-108 E TK-109
1.2.40	POSIZIONAMENTO NUOVO TK-108 E NUOVO TK-109
1.2.41	POSIZIONAMENTO NUOVI SKID P-110A/B E P-122 A/B
1.2.42	COLLEGAMENTO TUBAZIONE DA TK-108 A TK-114A E TK-114B
1.2.43	COLLEGAMENTO TUBAZIONE DA TK-109 A TK-114A E TK-114B
1.2.44	STESURA TUBAZIONE FANGHI DA POMPE P-110A/B A TK 115A/B

1.2.45	STESURA TUBAZIONE FANGHI DA POMPE P-122 A/B A TK 115A/B
1.2.46	COLLEGAMENTO POMPE P-110 A TK-108
1.2.47	COLLEGAMENTO POMPE P-122 A TK-109
1.2.48	COLLEGAMENTO TK-108 A TK-112
1.2.49	COLLEGAMENTO TK-109 A TK-113
1.2.50	COLLEGAMENTO TK-112 E TK 113 A LINEA DI PROCESSO
1.2.51	COLLEGAMENTO ELETTRICO DI TUTTI I DISPOSITIVI INSTALLATI SU TK-108, TK-109, A/B SKID P-110A/B, SKID P-122A/B, TK-112, TK-113

Table 4.2- WBS for parallel strategy [11]

4.1.4 Structural differences and implications

The Work Breakdown The logic and structure of the two execution strategies vary greatly. Task breakdown under the phased approach is arranged according to separate, sequential project phases engineering, procurement, and construction. This is feasible since the building works are section by section in a linear sequence, therefore enabling a defined, phase-based framework in which every stage can be finished before the next starts.[10]

By contrast, the parallel approach rejects such stepwise planning. The planning process entails hopping from one segment to another since the nature of activities overlaps, particularly between procurement and construction. Consequently, the task structure gets more scattered and dependent on one another, which calls for an adaptable WBS. The parallel technique is more time-efficient but also more complicated to regulate since this difference has major consequences for scheduling, coordination, and resource management.[11]

4.1.5 Summary comparison

An analysis of the WBS structures for both methodologies distinctly reveals that the parallel strategy encompasses a considerably greater quantity of jobs. This is mainly attributable to the concurrent disassembly of existing components while new parts are being installed in various portions of the plant. In contrast to the phased strategy, which organizes activities sequentially, the parallel approach necessitates the division of work into smaller, overlapping tasks to facilitate simultaneous execution. Moreover, the average duration of jobs is typically extended under the parallel strategy, as they must be executed while the old plant continues to operate. This imposes further constraints concerning safety standards and access restrictions, rendering security considerations more rigorous and planning more intricate.

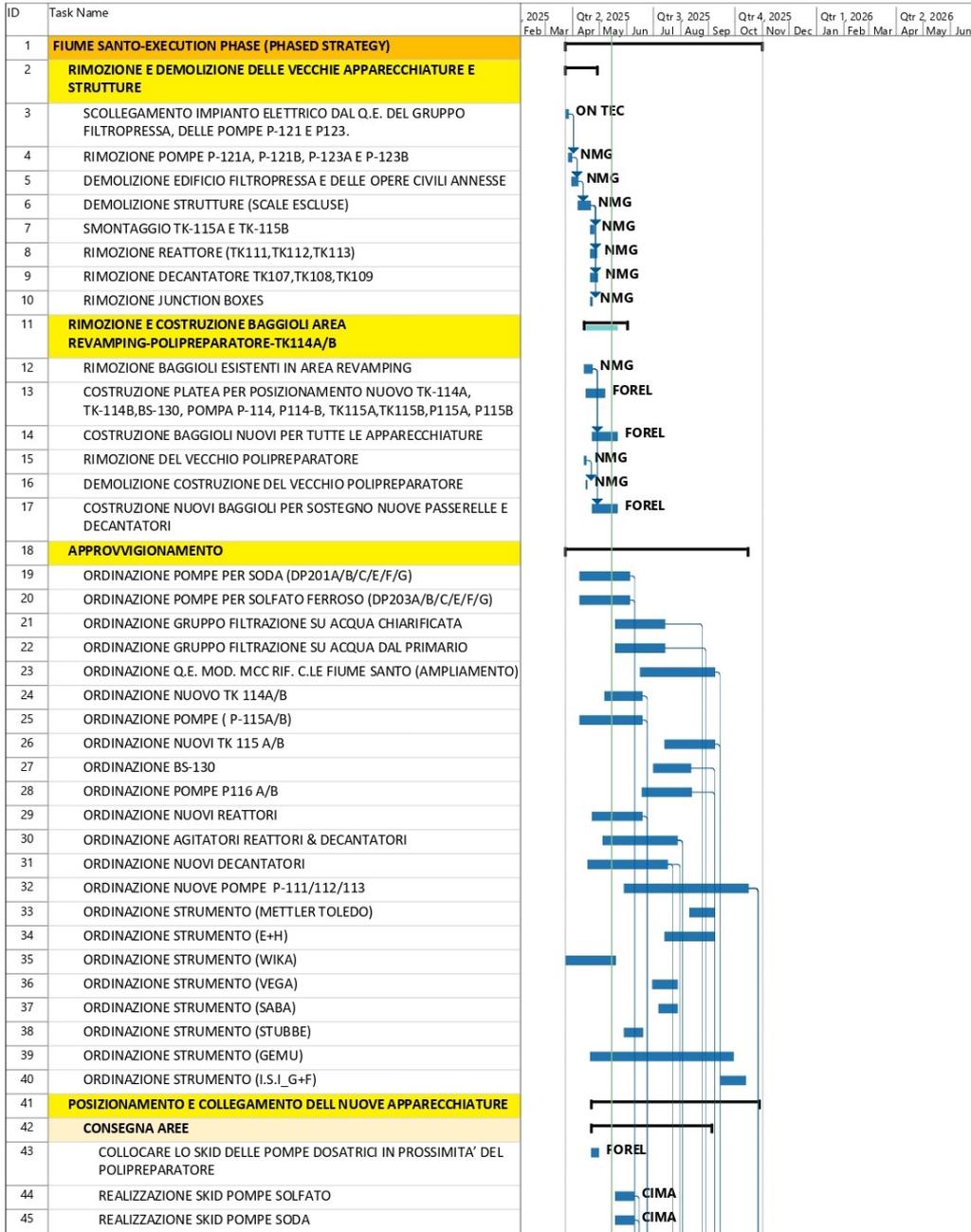
4.2 Indicative scheduling and critical path analysis

4.2.1 Introduction to scheduling tools

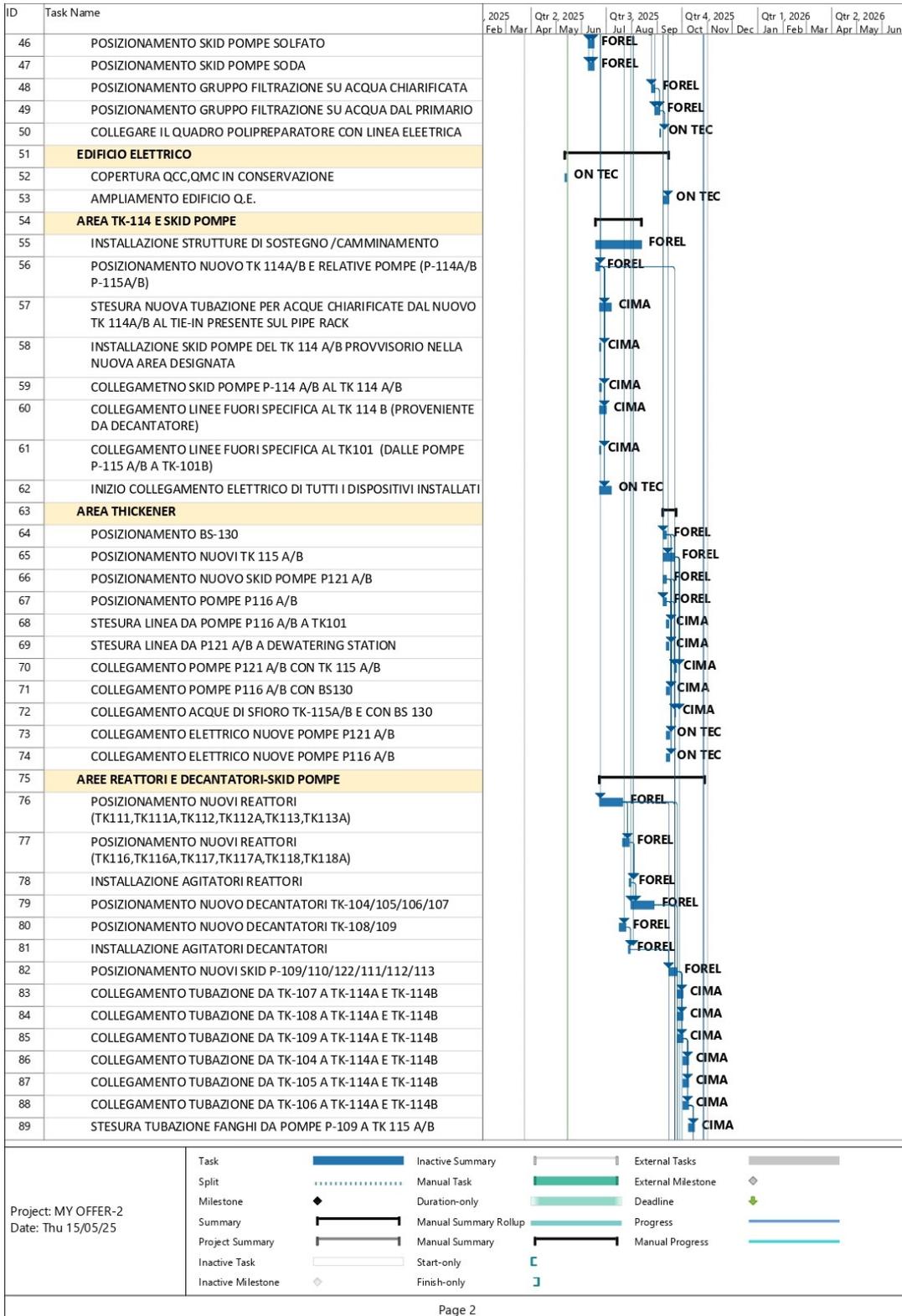
Microsoft Project was chosen for the planning and scheduling of this project because of its sophisticated capacity to control challenging schedules and resource allocation. Features of the program include Gantt charts, task dependencies, critical path analysis, and resource leveling qualities especially helpful for visualizing execution plans, spotting scheduling threats, and best use of resources. Given the uncertainties and interdependencies in the execution phase of this project, MS Project's adaptability also permitted scenario comparison and iterative updates-which were very vital.[10],[11]

4.2.2 Gantt chart for phased execution

Using Microsoft Project, a Gantt chart has been created to offer a visual representation of the scheduling plan for the project. Across the execution period, the chart lists the main chores, their durations, start and end dates, dependencies, and benchmarks. The task structure was broken down, the critical path was found, and resource availability was matched with the expected flow of events thanks in great part to this instrument. This Gantt chart shows the comprehensive project schedule and provides a basis for examining the scheduling possibilities covered in the thesis.[10]



Project: MY OFFER-2 Date: Thu 15/05/25	Task		Inactive Summary		External Tasks
	Split		Manual Task		External Milestone
	Milestone		Duration-only		Deadline
	Summary		Manual Summary Rollup		Progress
	Project Summary		Manual Summary		Manual Progress
	Inactive Task		Start-only		
Inactive Milestone		Finish-only			



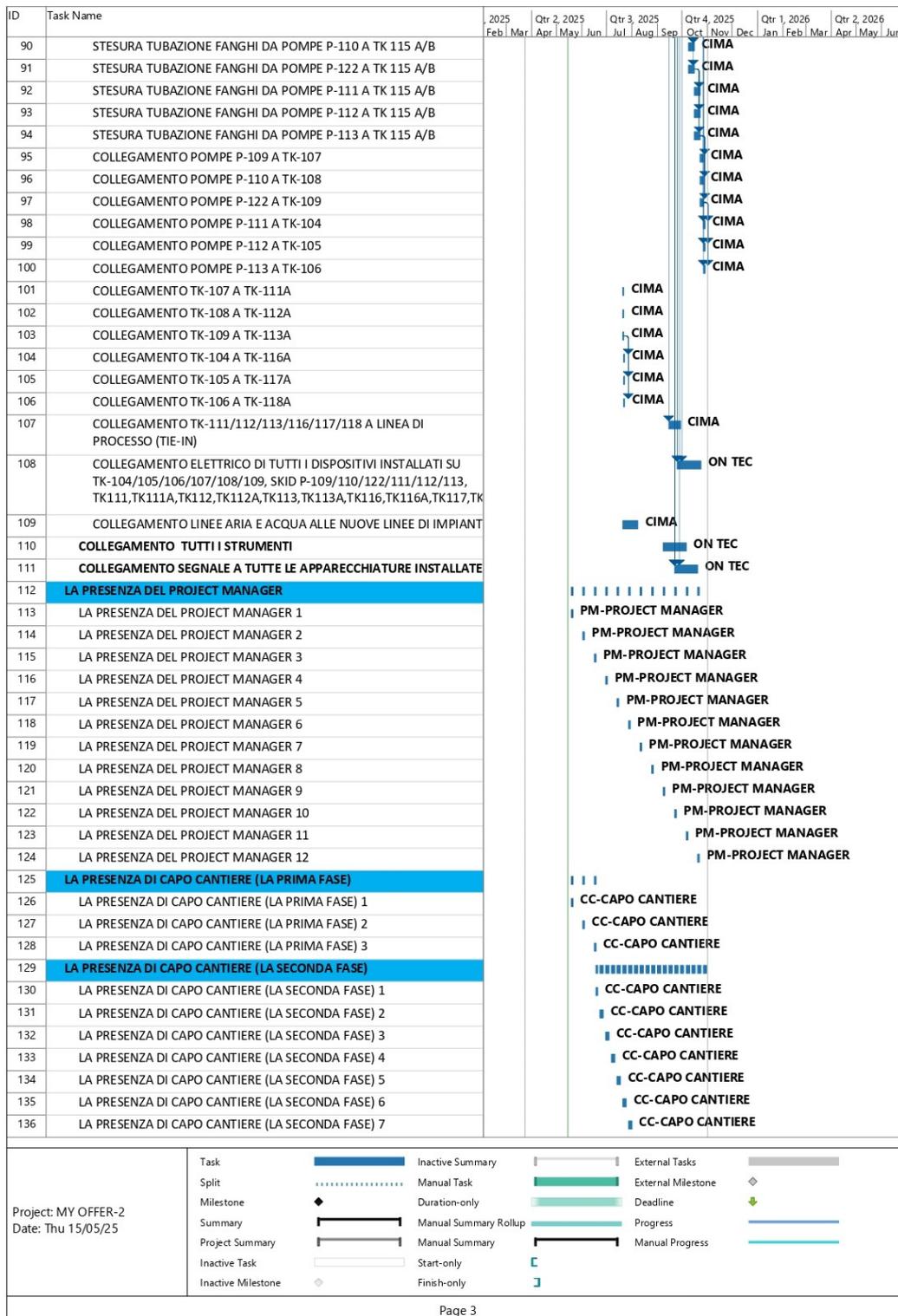
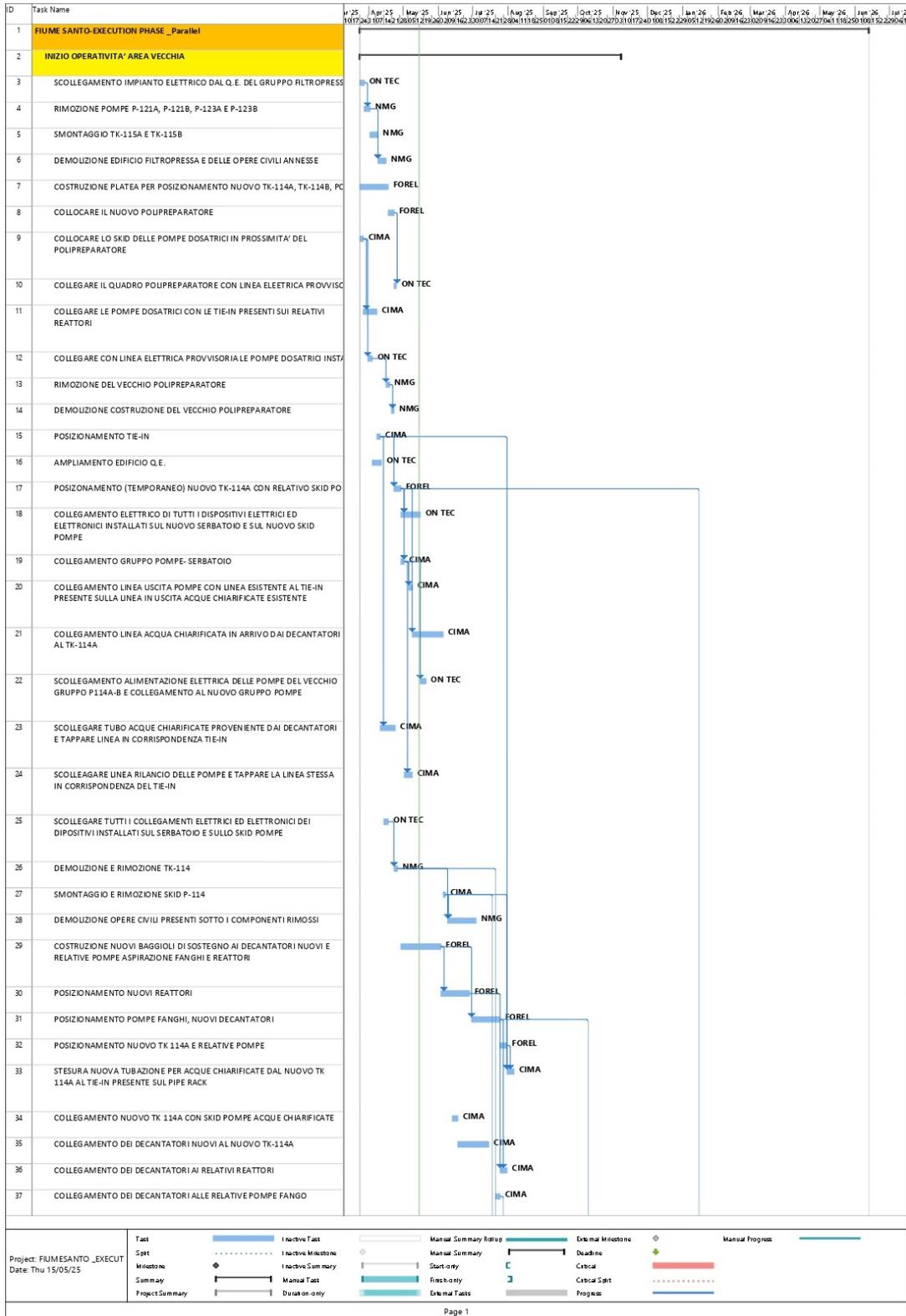


Figure 4.1- WBS for phased strategy [10]

4.2.3 Gantt chart for parallel execution

Using Microsoft Project, a Gantt chart has been created to offer a visual representation of the scheduling plan for the project. Across the execution period, the chart lists the main chores, their durations, start and end dates, dependencies, and benchmarks. The task structure was broken down, the critical path was found, and resource availability was matched with the expected flow of events thanks in great part to this instrument. This Gantt chart shows the comprehensive project schedule and provides a basis for examining the scheduling possibilities covered in the thesis.[11]



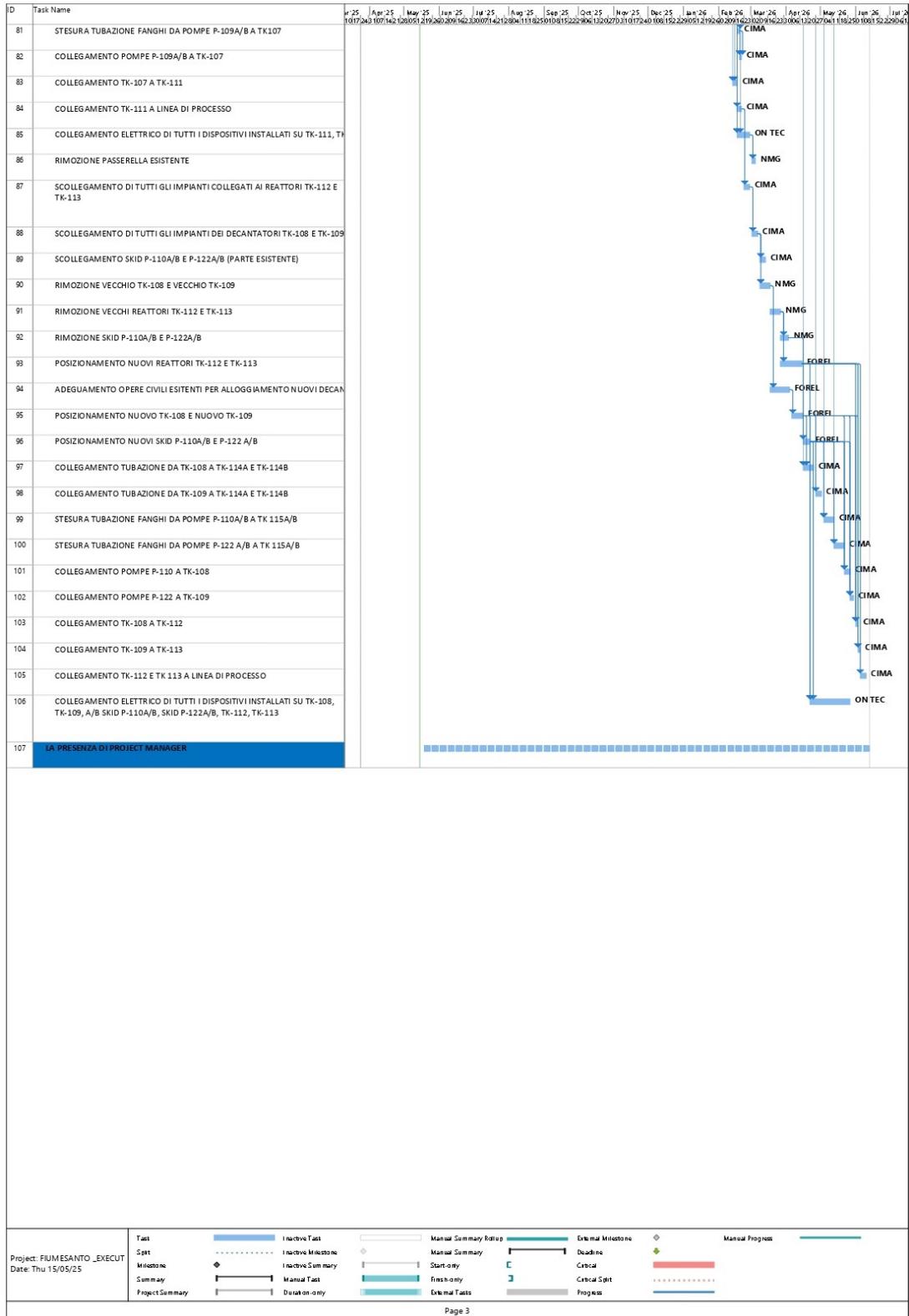


Figure 4.2- WBS for parallel strategy [11]

4.2.4 Timeline comparison and flexibility

Emphasizing general duration and scheduling flexibility, this part contrasts the project schedules for the phased and parallel techniques. Regulatory restrictions force the project to be finished by the end of 2025, yet thanks to complete site access and the possibility to work overtime the project gains from quicker execution. While the current facility is operational in the parallel strategy, the timeframe is more flexible since limited access and safety restrictions affect work durations. These variations are graphically shown on the following charts.



Figure 4.3- Timeline (phased strategy) [10]

Starting on March 24, 2025, the phased approach is expected to finish by October 2025, therefore guaranteeing completion well before the end-of- year legislative deadline. This schedule provides almost two months of buffer to handle the commissioning of the new selenium removal system and absorb any possible delays, so managing the controlled shutdown of the current facility. Minimizing environmental risk and guaranteeing compliance with discharge criteria during the transition phase depend on this buffer.

Though the parallel approach is also expected to start on March 24, 2025, unlike the phased approach it offers more scheduling flexibility since the present selenium removal facility is running all during the building phase. This offers greater attention to synchronization and safety and lets quick execution be slower. The project is expected to be completed by June



Figure 4.4- Timeline (parallel strategy) [11]

9, 2026, which will enable extended work periods and easing of the need to meet a strict statutory deadline during construction. While this approach lowers environmental risk, it also requires more thorough on-site management and resource allocation.

4.3 Cost estimation and budgeting framework

4.3.1 Cost categories: Direct and indirect

Category	Type	Examples Specific to This Project
Equipment Supply	Direct	Tanks, pumps, dosing units, agitators, skids
Instrumentation	Direct	pH/Redox sensors, transmitters, control panels, junction boxes
Civil Works	Direct	Foundation works, structural supports, pipe racks
Mechanical Works	Direct	Piping installation, valve mounting, system assembly
Electrical Works	Direct	Cable laying, lighting installation, electrical connections
Labor & Contractors	Direct	NMG (removal), ON Technology (installation), welders, riggers
Project Management	Indirect	Project Manager, coordination meetings, technical supervision
Engineering Services	Indirect	Project Engineer, Project Junior/Senior, design revisions
HSE Supervision	Indirect	Safety Coordinator, site access management
Site Overheads	Indirect	Temporary fencing, lighting, toilets, containers
Insurance & Permits	Indirect	Construction insurance, regulatory fees, environmental approvals

Contingency	Indirect	Risk buffer for delays, rework, unexpected site issues
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Table 4.3- Cost categories [12],[13]

4.3.2 Baseline budget for phased strategy

Microsoft Project has been used for task-based resource allocation and scheduling to project the whole cost of the phased implementation method [10]. Labor, supervision, and on-site operations among other connected expenses for execution come to €1,002,056.00. Equipment, instrumentation, engineering, removal, and installation taken together cost €3,071,015.91, as previously described. For the phased approach, the whole baseline budget is thus roughly €4,073,071.91.[10],[12],[13]

4.3.3 Baseline cost for parallel strategy

Using Microsoft Project, the project cost has been calculated under the parallel execution strategy with consideration for extra safety and coordination needs as well as longer task times. The intricacy of operating in an active plant setting causes the execution-related expenses which come to €1,509,616.00 to be noticeably greater. The overall cost of equipment, instrumentation, engineering, removal, and installation stays €3,071,015.91 as with the phased approach.[11],[12],[13]

This yields the parallel strategy's overall baseline budget of roughly €4,580,631

4.3.4 Budget risk exposure and comparison

While the parallel approach is much higher at €4,580,631, the overall projected cost for the phased plan is €4,073,071.91. The phased approach is more economical, but it is limited by a rigorous legislative timetable. Although the parallel approach gives more scheduling freedom, its higher operational complexity raises both financial risk and execution costs.[10],[11]

4.4 Preliminary resource allocation and levelling

4.4.1 Identification of key resources

Resource	Role / Responsibility
PM – Project Manager	Oversee overall project execution, timeline, budget control, and client coordination.
CC – Capo Cantiere	Manage day-to-day site operations, supervise teams, ensure progress and task alignment.

DL – Direttore dei Lavori	Verifies that construction aligns with project specs, documents progress, ensures compliance.
PE – Project Engineer	Provides technical supervision, solves design issues, supports on-site decisions.
PJ – Project Junior	Assists technical staff with documentation, measurements, and on-site drawing updates.
PS – Process Senior	Oversees process design, system integration, and supports commissioning of critical systems.
CIMA	Contractor involved in mechanical/electrical execution or integration works (assumed role).
ON TEC	Contractor responsible for electrical and instrumentation system installation.
NMG	Contractor responsible for dismantling and removing existing equipment.
FOREL	Contractor for mechanical installation of new equipment, such as tanks and pumps.
SC – Safety Coordinator	Ensures compliance with HSE standards, performs site inspections, manages safety protocols.

Table 4.4- Key resources and the roles [10],[11]

4.4.2 Resource loading and levelling for strategies

Every activity related to resource loading and leveling has been completed depending on the tasks allocated to every position inside the project. The distribution of hours represents the real technical supervision needed throughout the phased and parallel approaches as well as the operational needs. This covers internal (e.g., Project Manager, Project Engineer, Safety Coordinator) as well as outside contractors (e.g., NMG, ON Technology, FOREL).[10],[11]

Workloads have been distributed based on project sequencing and execution restrictions, therefore guaranteeing a reasonable and equitable use of resources throughout time. Particularly focused on minimizing overallocation and spotting periods of maximum demand is identification of the distribution of work hours for every important role engaged in the project execution is compiled in the resource table below.

Phased Strategy			
Name	Start	Finish	Remaining Work
PM-PROJECT MANAGER	Mon 19/05/25	Wed 22/10/25	192 hrs
CC-CAPO CANTIERE	Mon 19/05/25	Fri 31/10/25	672 hrs
DL-DIRETTORE DEI LAVORI	Mon 19/05/25	Wed 16/07/25	80 hrs
PE-PROJECT ENGINEER	Mon 19/05/25	Thu 30/10/25	824 hrs
PJ-PROJECT JUNIOR	Mon 23/06/25	Mon 27/10/25	720 hrs
PS-PROJECT SENIOR	Wed 23/04/25	Mon 27/10/25	1,080 hrs
CIMA	Mon 19/05/25	Wed 29/10/25	1,272 hrs
ON TEC	Mon 24/03/25	Fri 24/10/25	688 hrs
NMG	Thu 27/03/25	Tue 29/04/25	352 hrs
FOREL	Wed 16/04/25	Thu 25/09/25	1,664 hrs
SC-SAFTEY COORDINATOR	Mon 24/03/25	Fri 31/10/25	1,280 hrs

Table 4.5- Resource workload and working hours (Phased strategy) [10]

Parallel Strategy			
Name	Start	Finish	Remaining Work
PM-PROJECT MANAGER	Mon 19/05/25	Tue 02/06/26	448 hrs
CC-CAPO CANTIERE	Mon 19/05/25	Thu 11/06/26	1,792 hrs
DL-DIRETTORE DEI LAVORI	Mon 19/05/25	Mon 08/06/26	448 hrs
PE-PROJECT ENGINEER	Mon 19/05/25	Tue 09/06/26	2,216 hrs
PJ-PROJECT JUNIOR	Mon 23/06/25	Fri 12/06/26	2,240 hrs
PS-PROJECT SENIOR	Mon 24/03/25	Tue 09/06/26	2,536 hrs
CIMA	Mon 24/03/25	Tue 09/06/26	2,288 hrs
ON TEC	Mon 24/03/25	Tue 26/05/26	888 hrs
NMG	Fri 28/03/25	Thu 02/04/26	624 hrs
FOREL	Mon 24/03/25	Tue 21/04/26	1,560 hrs
SC-SAFTEY COORDINATOR	Mon 24/03/25	Tue 09/06/26	2,536 hrs

Table 4.6- Resource workload and working hours (Parallel strategy) [11]

4.4.3 Comparison of both strategies in terms of resource allocation

- Exactly twice their hours in the phased method, the Safety Coordinator (SC) and Process Senior (PS) responsibilities both attain 2,536 hours in the parallel strategy.
- From ~700–800 hours in phased to > 2,200 hours in parallel, Project Junior (PJ) and Project Engineer (PE) similarly nearly treble their commitment.
- Reflecting the higher coordination effort in an active plant setting, the Project Manager (PM) and Direttore dei Lavori (DL) likewise display more than twice the time commitment in the parallel strategy.
- Under the parallel approach, external contractors including NMG, ON TEC, and FOREL all deal with longer terms and far more work. NMG's workload rises from 352 hours to 624 hours, for instance, and CIMA's from 1,272 hours to 2,288 hours.

- While the parallel strategy stretches until June 2026 and calls for 8 more months of resource deployment, the phased strategy ends by October 2025.

In terms of individual effort as well as project length, the parallel approach results in a rather larger resource demand. This reflects the more complicated operations inside a live facility that call for more careful execution, closer collaboration, and ongoing safety monitoring. Conversely, although more time-limited, the phased approach lets people be used more effectively and concentratedly, therefore lowering the overall working hours and related expenses. This contrast emphasizes that, although the parallel approach provides operational continuity, it has a far larger human resource and cost load, which must be carefully considered in the choice of the ultimate strategy.

4.5 Selection of planning methodology

4.5.1 Overview of planning styles

The two main planning techniques under consideration for the implementation phase—adaptive (parallel) and predictive (phased)—are described in this part. Although adaptive planning lets for overlapping activities and more flexibility, predictive planning uses a sequential, regimented approach. Their qualities are judged according to the requirements and limitations of the project.

4.5.2 Predictive (phased) execution characteristics

Under the predictive (phased) approach, the project is broken out into precisely specified phases, each finished before the next starts. Particularly appropriate for projects with safety-critical activities and a need for minimum disturbance, this approach offers better control over hazards, resources, and interfaces with the current plant.[10]

4.5.3 Adaptive (parallel) execution characteristics

The adaptive (parallel) approach is distinguished by simultaneous completion of several chores over several parts of the plant. This strategy seeks to shorten the total project lifetime while nevertheless adding more coordination complexity, more resource demands, and more danger of interfering with current operations.[11]

4.6 Conclusion

Chapter 4 provided a critical and orderly assessment of the Initiation and Planning Phases of the selenium removal project at the Fiume Santo Power Plant. The chapter started by describing the strategic relevance of the project driven by environmental and regulatory issues related to high selenium concentrations in wastewater resulting from a change in raw material sources.

Under the Initiation Phase, a SMART-based Project Charter tightly defined the extent of the project. By means of the Power-Interest Matrix, a comprehensive stakeholder study guaranteed consistency in stakeholder influence and participation initiatives. The feasibility analysis showed that co-precipitation based on ferric sulfates is both financially reasonable and technically feasible. Procurement planning established a strong basis from thorough modeling using AutoCAD Plant 3D and vendor quotations.[12],[13] Under the phased method especially, a multi-dimensional risk analysis including environmental, operational, regulatory, and financial issues stressed the project's sensitivity to execution timing and compliance duties.

Built on this basis, the Planning Phase examined two opposing approaches: phased (predictive) and parallel (adaptive) execution. Though with significant operational downtime, it was demonstrated through thorough Work Breakdown Structures (WBS) and Gantt chart schedules for each technique that the phased strategy offers cheaper costs, less coordination problems, and less safety hazards.[10],[11] With project staff hours almost tripling in numerous important positions, the parallel approach guarantees operational continuity but results in greatly higher execution costs, lengthier timeframes, and resource intensity.

The study of resource allocation underlined the various needs of human capital for every strategy. Although the phased approach allows focused, shorter-term resource utilization, the parallel approach calls for continuous involvement especially for technical control and safety. Finally, the cost and financial risk analyses showed that although both approaches have same capital expenses, the working environment and scheduling complexity causes a major difference in operational and labor costs.

These comparative assessments give the project team a strong decision-making tool to match regulatory compliance, financial limits, safety issues, and stakeholder expectations with the execution strategy. Eventually, the chapter emphasizes the phased approach as, given strict respect for regulatory deadlines and strategies for interim wastewater management during downtime, it is more beneficial in terms of cost control and risk predictability.

5 Comparative strategic analysis of execution scenarios

5.1 Strategy A: Phased execution (Decommission first)

5.1.1 Cost breakdown

The staged approach, the project's overall estimated cost is €4,073,071.91; this includes €3,071,015.91 for equipment, instrumentation, engineering, removal, and installation plus €1,002,056.00 for execution-related costs computed using Microsoft Project. The most significant cost categories will be summarized in the section that follows, therefore offering a clear picture of the distribution of the project budget.[10]

Cost category	Cost value (€)
Equipment and instrumentation	2,965,481.91
Engineering & design	105,534
Labors, contractors & supervision	1,002,056
Total	4,073,071.91

Table 5.1 Cost breakdown (Phased strategy) [10]

5.1.2 Timeline projection

In line with environmental rules, the phased execution plan is set to start on March 24, 2025, and finish by October 31, 2025, therefore guaranteeing completion before the year ends. The overall length includes a 2-month buffer to let the old and new systems flow smoothly and to cover any possible delays.[10]

The program follows a limited and carefully regulated timeline due to the total closure of the current selenium removal facility during this period; so, well-coordinated work sequencing and possible usage of overtime are necessary to keep advancement.

The timeline showing this chronology is as follows:



Figure 5.1 Timeline projection of the phased strategy [10]

5.1.3 Resource allocation

Since the project must be finished before the end of 2025, the phased approach results in an intense and highly focused total effort. High demand for critical roles especially the Project Engineer, Capo Cantiere, and Safety Coordinator, who are needed on-site for long daily hours to guarantee that progress stays on schedule results from this constricted timescale.[10]

Previously shown in the resource overview table, the total working hours for every role show those in danger of overallocation under this approach. Charts and tables will be included in the part that follows graphically show the distribution of the workload and point out any general resource overheads.[10]

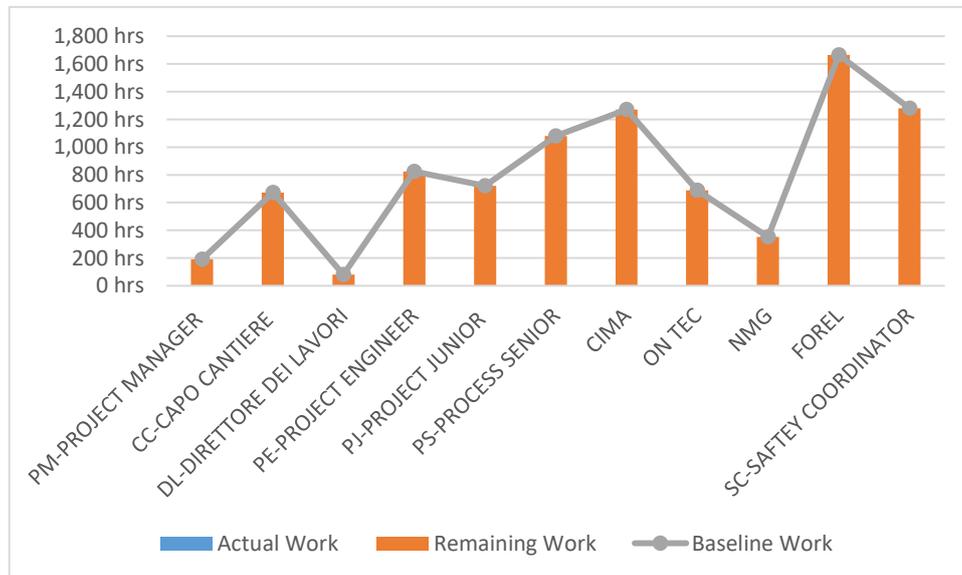


Figure 5.2 Total working hours for each resource (resource status) [10]

Name of resource	Work hour
PM-PROJECT MANAGER	192 hrs
CC-CAPO CANTIERE	672 hrs
DL-DIRETTORE DEI LAVORI	80 hrs
PE-PROJECT ENGINEER	824 hrs
PJ-PROJECT JUNIOR	720 hrs
PS-PROCESS SENIOR	1,080 hrs
CIMA	1,272 hrs
ON TEC	688 hrs
NMG	352 hrs
FOREL	1,664 hrs
SC-SAFTEY COORDINATOR	1,280 hrs

Table 5.2 Total working hours of resources (Phased strategy) [10]

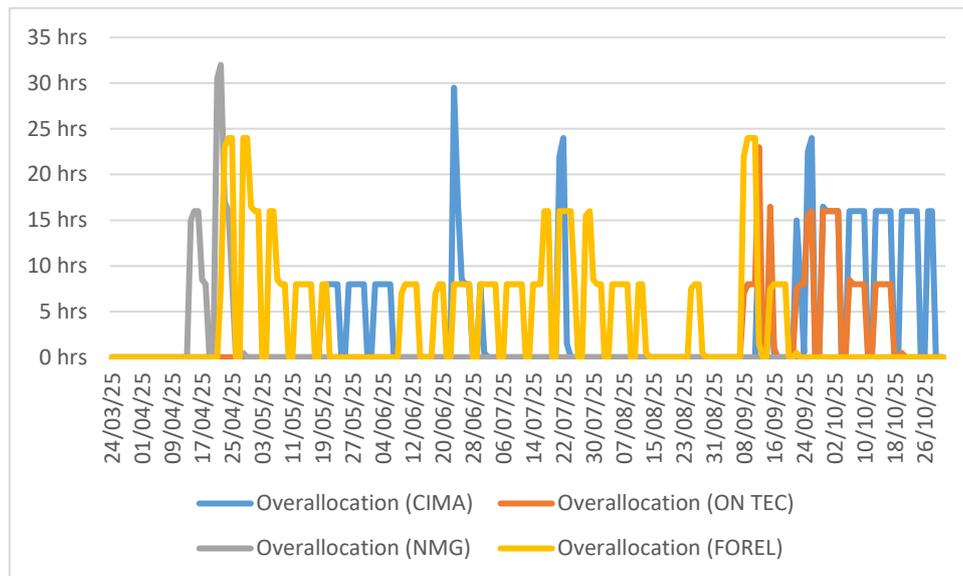


Figure 5.3 Overallocated resources (Phased strategy) [10]

5.1.4 Risk exposure

The staged execution plan calls for decommissioning the current selenium removal system and carrying out all building operations within a constrained period. Although this guarantees easier logistics and more site accessibility, it also brings hazards that should be considered while assessing the viability of the project.[15],[10]

Risk Category	Risk Level	Description
Technical	Moderate	Risk of delays or integration issues; mitigated through buffer and planning.
Operational	Low	Simplified site conditions reduce safety and interference risks.
Regulatory	High	Strict deadline: delay could result in non-compliance with discharge regulations.
Financial	Moderate	Risk of overtime or emergency costs if timeline slips.

Table 5.3 Risk exposure of phased strategy [10]

5.1.5 Environmental impact

The current selenium removal plant is totally closed under the phased approach before the replacement system starts running. This method increases a major environmental risk during the transitory period even if it streamlines site management and execution. Particularly, any delay in finishing the new system could cause untreated wastewater with high selenium levels to leak into the surroundings.[15]

This is especially important considering the proximity of the plant to delicate maritime habitats. As the research emphasizes, even low levels of selenium can result in bioaccumulation in aquatic life, therefore upsetting the food chain and causing long-term ecological damage.

The phased strategy's project timeline contains a built-in buffer period and a rigorous deadline (31 October 2025) to help to offset this, but if delays arise the danger of regulatory non-compliance stays great. Therefore, even if the phased approach is operationally efficient and reasonably cost-effective, it causes notable short-term environmental exposure during the building stage.[10]

5.2 Strategy B: Parallel execution

5.2.1 Cost breakdown

Under the parallel approach, the project's overall projected cost is €4,580,631.91 comprising €3,071,015.91 for equipment, instrumentation, engineering, removal, and installation plus €1,509,616.00 for execution-related expenditures as computed using Microsoft Project. The important cost categories will be shown in a summary table in the next part, so clearly illustrating the way resources are distributed using this approach.[11]

Cost category	Cost value (€)
Equipment and instrumentation	2,965,481.91
Engineering & design	105,534
Labors, contractors & supervision	1,509,616.00
Total	4,580,631.91

Table 5.4 Cost breakdown of parallel strategy [11]

5.2.2 Timeline projection

Starting on March 24, 2025, the parallel execution technique is intended to finish by June 2026. Since the current selenium removal technology stays operational all during the building process, this method provides more scheduling freedom than the staged approach. Safety concerns, limited site access, and the necessity to integrate building activities with continuous plant operations all help to explain lengthier task times.[11]

The following figure will display the entire parallel strategy timeline:



Figure 5.4 Timeline projection (Parallel strategy) [11]

5.2.3 Resource allocation

Although the overall effort is spread over a longer period in the parallel strategy, the extended timeline and more complexity of working in an active plant setting cause the total working hours to be much higher. Longer term involvement in key roles such the Safety Coordinator, Process Senior, and Project Engineer guarantees constant coordination, safety compliance, and technical oversight.[11]

Already shown in the resource overview table is the growing manpower requirement over time. Charts and tables in the part that follow will show the distribution of work hours and point out areas of possible overall resource overallocation during the running process.[11]

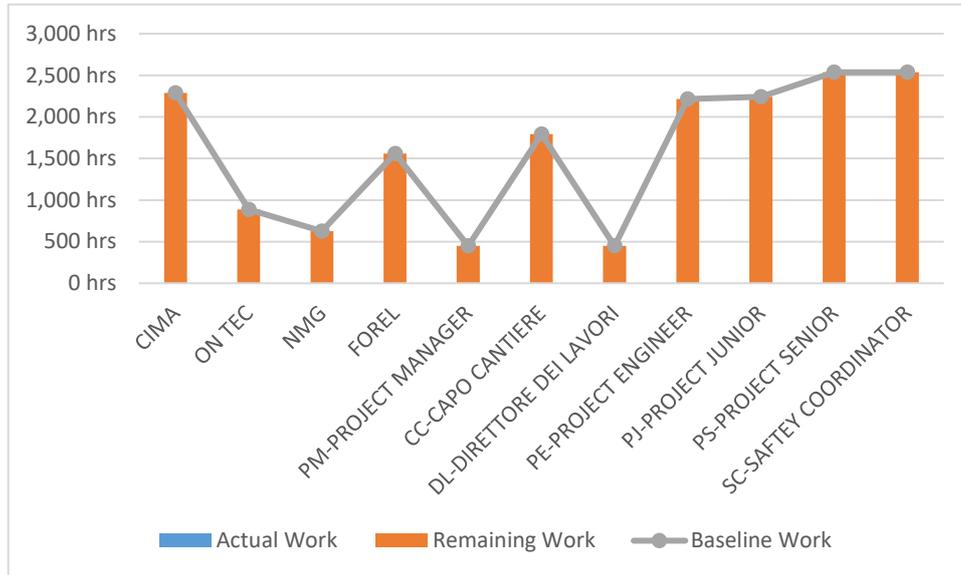


Figure 5.5 Total working hours for each resource (Parallel strategy) [11]

Name of resource	Work hour
PM-PROJECT MANAGER	448 hrs
CC-CAPO CANTIERE	1,792 hrs
DL-DIRETTORE DEI LAVORI	DL-DIRETTORE DEI LAVORI
PE-PROJECT ENGINEER	2,216 hrs
PJ-PROJECT JUNIOR	2,240 hrs
PS-PROCESS SENIOR	2,536 hrs
CIMA	2,288 hrs
ON TEC	888 hrs
NMG	624 hrs
FOREL	1,560 hrs
SC-SAFTEY COORDINATOR	2,536 hrs

Table 5.5 Total working hours for each resource (Parallel strategy) [11]

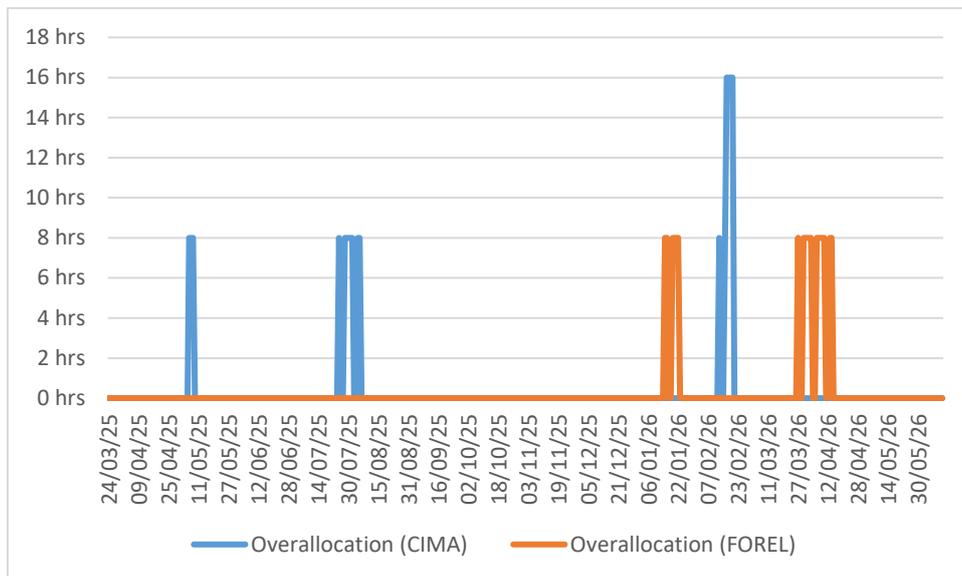


Figure 5.6 Overallocated resources (Parallel strategy) [11]

5.2.4 Risk exposure

Due to lengthier execution durations, safety restrictions, and complicated coordination in a live environment, the parallel method increases technical, operational, and financial risks while lowering regulatory risk by maintaining the current plant running. These elements greatly raise the need for oversight, the use of resources, and cost uncertainty. [15]

Risk Category	Risk Level	Description
Technical	High	Integration challenges and extended task durations.
Operational	High	Safety risks and access limitations in an active plant.
Regulatory	Low	Existing system ensures continuous compliance.
Financial	High	Increased labor, supervision, and overhead due to extended timeline.

Table 5.6 Risk exposure of different categories of parallel strategy [15]

5.2.5 Environmental impacts

By guaranteeing constant functioning of the current selenium removal plant during the building of the new system, the parallel approach greatly lowers environmental risk. This method guarantees complete regulatory compliance and stops the release of treated selenium-rich wastewater into the environment by preventing any disturbance of treatment. Consequently, despite its increased cost and complexity, the parallel approach provides a steadier changeover.[15]

5.3 KPI-based comparison

5.3.1 Cost performance index (CPI) [7],[9]

Phased strategy:

Even in the planning phase when no real tracking is conducted, the Cost Performance Index (CPI) evaluates cost efficiency by matching the Planned Value (PV) with the entire Baseline Cost. The equation is:

$$CPI_{est} = \frac{PV (Planned\ value)}{Baseline\ Cost}$$

Under the phased plan, the Baseline Cost is €1,002,056 whereas the Planned Value (PV) at a given milestone (status date: 01/08/2025) is €552,350. Following the formula:[7],[9]

$$CPI_{est} = \frac{552,350}{1,002,056} \approx 0.55$$

It means that, at this point, the budgeted work is projected to have finished about 55% of the total budget (baseline cost). Although this is not a performance indicator yet, it clarifies budget allocation and enables early planning and cash flow forecasting for the phased implementation, in which timing and cost efficiency are crucial since the predetermined completion deadline dictates.[10]

Parallel strategy:

The Cost Performance Index (CPI) can be approximated in planning phase analysis by means of the ratio of Planned Value (PV) to Baseline Cost, therefore enabling an evaluation of the predicted lifetime budget consumption. The recipe is:[11]

$$CPI_{est} = \frac{PV}{Baseline\ Cost}$$

Under the parallel strategy, the Baseline Cost is €1,509,616 and the Planned Value (PV) is €751,360 at the status date of 01/10/2025-about halfway through the project. Following the formula:[11]

$$CPI_{est} = \frac{751,360}{1,509,616} \approx 0.50$$

The predicted Cost Performance Index (CPI) at their respective midpoints is 0.55 for the phased approach (based on a Present Value of €552,350 as of 01/08/2025) and 0.50 for the parallel plan (with a Present Value of €751,360 as of 01/10/2025). This signifies that by mid-execution, a little greater percentage of budgeted work is scheduled for completion in the phased strategy, illustrating its more condensed timeline and assertive execution tempo. Conversely, the parallel technique distributes expenses more uniformly across an extended timeframe. The contrast emphasizes that the phased technique prioritizes expenditure and advancement initially, whilst the parallel strategy facilitates a more incremental allocation of costs corresponding to its prolonged implementation timeline.[11]

5.3.2 Schedule performance index (SPI)

As of right now, actual development and expenses are not recorded in planning. Thus, using the ratio of planned value at a certain status date to the entire baseline cost, both CPI and SPI are approximated. CPI is numerically exactly at this point but has various conceptual uses: CPI shows cost distribution; SPI matches schedule advancement. In conclusion, they are the same in our case. [10],[11]

5.3.3 Resource utilization rate (RUR)

The Resource Utilization Rate (RUR) is a key project management indicator that measures how efficiently each resource's available time is being allocated to planned project work. It helps project managers assess whether human resources are being overloaded, underutilized, or optimally planned during the execution phase.[7],[9]

$$RUR = \left(\frac{\text{Planned Work Hours}}{\text{Available Work Hours}} \right) \times 100$$

***Planned Work Hours** = Remaining work assigned to the resource.

***Available Work Hours** = Number of working days × working hours/day.

Phased strategy

For the phased strategy, the project duration is **160 working days**, and we assume a standard 8-hour workday, resulting in:[10]

$$\text{Available Hours} = 160 \times 8 = 1,280 \text{ hrs per resource}$$

Therefore, using the data we have extracted from MS project for each resource we would have the results as follows:

Resource	Planned Work (hrs.)	Available Work (hrs)	RUR (%)
PM – Project Manager	192	1,280	15.0%
CC – Capo Cantiere	672	1,280	52.5%
DL – Direttore dei Lavori	80	1,280	6.3%
PE – Project Engineer	824	1,280	64.4%
PJ – Project Junior	720	1,280	56.3%
PS – Process Senior	1,080	1,280	84.4%
CIMA	1,272	1,280	99.4%
ON TEC	688	1,280	53.8%
NMG	352	1,280	27.5%
FOREL	1,664	1,280	130.0%
SC – Safety Coordinator	1,280	1,280	100.0%

Table 5.7 Resource utilization rate (Phased strategy) [10]

- Most internal resources PM, DL, and PJ are underused and provide capacity or flexibility to handle schedule changes.
- Well-balanced roles such as Process Senior and CIMA indicate reasonable and demanding workloads.
- With an overallocation of 130%, FOREL points towards a possible load balancing requirement, risk of delay, or scheduling conflict.
- The Safety Coordinator is very busy, suggesting a vital part in this stage of the project.

Parallel strategy:

Assuming that the project duration is 320 days and the standard working hours per day are 8 hours, therefore:[11]

$$\text{Available Working Hours} = 320 \times 8 = 2,560 \text{ hours per resource}$$

Therefore, using the data we have extracted from MS project for each resource we would have the results as follows:[11]

Resource	Planned Work (hrs.)	Available Work (hrs)	RUR (%)
PM – Project Manager	448	2,560	17.5%
CC – Capo Cantiere	1,792	2,560	70.0%
DL – Direttore dei Lavori	448	2,560	17.5%
PE – Project Engineer	2,216	2,560	86.6%
PJ – Project Junior	2,240	2,560	87.5%
PS – Process Senior	2,536	2,560	99.1%
CIMA	2,288	2,560	89.4%
ON TEC	888	2,560	34.7%
NMG	624	2,560	24.4%
FOREL	1,560	2,560	60.9%
SC – Safety Coordinator	2,536	2,560	99.1%

Table 5.8 Resource utilization rate (Parallel strategy) [11]

Key points:

- Most key roles like Process Senior, Project Engineer, Project Junior, and Safety Coordinator are highly utilized (>85%), indicating critical involvement throughout the project.[11]
- Project Manager and Works Director show lower utilization (~17.5%), suggesting supervisory involvement rather than continuous site presence.[11]
- Contractors like CIMA and FOREL are efficiently loaded (60–90%), while NMG and ON TEC show lower usage, indicating shorter or more specialized tasks.[11]

Comparison of both strategies in terms of RUR

Resource	Planned Work (phased)	Planned Work (Parallel)	RUR (%) - Phased	RUR (%) - Parallel
PM – Project Manager	192	448	15.0%	17.5%
CC – Capo Cantiere	672	1,792	52.5%	70.0%
DL – Direttore dei Lavori	80	448	6.3%	17.5%
PE – Project Engineer	824	2,216	64.4%	86.6%
PJ – Project Junior	720	2,240	56.3%	87.5%
PS – Process Senior	1,080	2,536	84.4%	99.1%
CIMA	1,272	2,288	99.4%	89.4%
ON TEC	688	888	53.8%	34.7%
NMG	352	624	27.5%	24.4%
FOREL	1,664	1,560	130.0%	60.9%
SC – Safety Coordinator	1,280	2,536	100.0%	99.1%

Table 5.9 Resource utilization rate (Comparison of both strategies) [10],[11]

Key points:

- The parallel strategy leads to significantly increased workloads across nearly all jobs due to the prolonged timetable and additional complexity of operating within an active plant.[10],[11]
- Roles such as Project Engineer, Project Junior, and Process Senior are employed at over 85–99% in the parallel strategy, in contrast to 50–65% in the phased method.[10],[11]
- The Safety Coordinator is fully engaged in both initiatives, underscoring their essential role irrespective of the method employed.[10],[11]
- FOREL is mostly situated (130%) within the phased method, indicating a potential risk that necessitates modification, whereas in the parallel approach, its load is better equilibrated (60.9%).[10],[11]
- In contrast, the Project Manager and Works Director exhibit low RURs in both instances, as their roles are predominantly supervisory rather than full-time.[10],[11]

Conclusion (RUR)

This comparison confirms that while the phased strategy is more efficient in resource usage, it requires tighter coordination and mitigation of overload risks, particularly for critical contractors like FOREL. The parallel strategy, though smoother in execution, demands more hours and sustained engagement, especially from engineering and safety teams.

5.3.4 Risk exposure index

The Risk Exposure Index (REI) is a quantitative tool used to assess the overall level of risk in a project by evaluating the likelihood and impact of each identified risk. It is calculated using the formula:[7]

$$\text{Risk Exposure} = \text{Probability} (1 - 5) \times \text{Impact} (1 - 5)$$

This method provides a clear and structured way to compare risk profiles between strategies. In this project, REI is applied to both the phased and parallel execution strategies to evaluate risks related to technical complexity, operational environment, regulatory pressure, and financial uncertainty.

Risk Category	Phased Strategy (P × I = RE)	Parallel Strategy (P × I = RE)
Technical Risk	3 × 3 = 9	4 × 4 = 16
Operational Risk	2 × 2 = 4	4 × 5 = 20
Regulatory Risk	4 × 5 = 20	1 × 2 = 2
Financial Risk	3 × 4 = 12	4 × 4 = 16
Total REI	45	54

Table 5.10 REI calculations (both strategies) [10],[11]

- The phased method exhibits elevated regulatory risk (20) because of the cessation of the current treatment facility and tight completion timelines.
- The parallel strategy entails elevated technical, operational, and financial risks, resulting in a superior overall REI of 54, in contrast to 45 for the phased approach.
- This illustrates the intricacy of doing construction within an operational plant setting, necessitating enhanced coordination, oversight, and safety protocols.
- Conversely, although the phased technique is logistically more straightforward, its primary weakness is associated with regulatory deadlines and environmental compliance during the plant's inactivity.

5.3.5 Environmental compliance metric

Phased strategy:

Under the phased execution plan, the current selenium removal technology is turned off during the new plant building. This raises a major danger of non-compliance, particularly in case the project is postponed. Selenium-rich effluent may be dumped without enough treatment during this time, so breaking environmental guidelines. Although this approach is quick and straightforward, it provides no buffer for environmental variances should schedules go apart. Thus, unless rigorous contingency actions (such as faster schedules or temporary treatment systems) are taken, the environmental compliance risk is categorized as high.[15]

Parallel strategy:

Conversely, the parallel technique entails developing the new system while the current treatment facility continues to operate without interruption. This method guarantees that selenium concentrations in the effluent are consistently regulated during the project. The uninterrupted treatment procedure substantially mitigates the danger of environmental non-compliance, even in the event of delays in the new system. Consequently, the parallel strategy exhibits enhanced performance regarding environmental compliance, aligning more effectively with long-term sustainability and regulatory reliability objectives.[15]

5.4 Visual tools (Comparison table, bubble matrix, weighted scoring)

5.4.1 Comparison table

Criterion	Phased Strategy	Parallel Strategy
Total Estimated Cost	€4,073,071.91	€4,580,631.91
Project Duration	160 days (Mar–Oct 2025) + 2 months buffer	320 days (Mar 2025 – June 2026)
Regulatory Compliance Risk	High due to temporary shutdown	Low due to continuous treatment
Operational Complexity & Risk	Low	High working around active systems
Environmental Sustainability	Risk of untreated discharge if delayed	Continuous treatment maintained
Risk Exposure Index (REI)	45	54

Table 5.11 Comparison table (both strategies) [10],[11]

This comparison elucidates the principal trade-offs between the two strategies: the phased strategy is more economical and expedient but entails greater risks regarding compliance and sustainability, whereas the parallel strategy, albeit more expensive and time-consuming, offers enhanced assurance against environmental and operational risks.

5.4.2 Bubble matrix

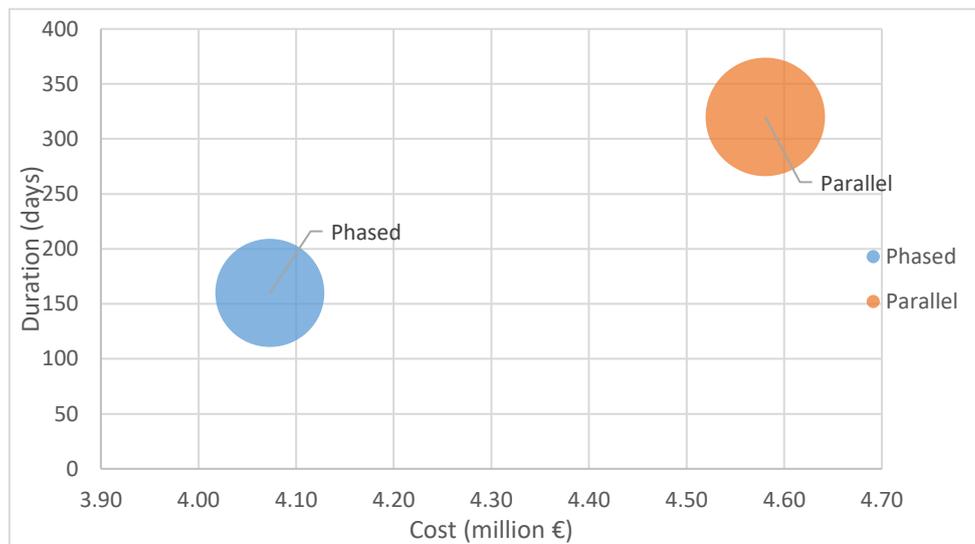


Figure 5.7 Bubble matrix [15]

- The phased technique is characterized by reduced costs and shorter timelines, however accompanied by a significant risk factor.[15]
- The parallel technique incurs higher costs and time requirements but demonstrates improved compliance and operational safety.[15]

5.4.3 Weighted scoring with sustainability priority

Using a weight scoring system has helped to improve decision-making. This model underlines the need for environmental preservation, which is quite significant for this project. The criteria represent regulatory pressure and values of stakeholders.

- Environmental Sustainability: 35%
- Duration: 25%
- Cost: 20%
- Regulatory Risk: 10%

- Operational Risk: 10%

Criterion	Scoring Rationale
Cost	Phased (9): Cheaper (€4.07M). Parallel (6): Higher cost (€4.58M).
Duration	Phased (9): 160 days (faster). Parallel (6): 320 days (slower due to active plant operations).
Regulatory Risk	Phased (5): High risk if the timeline slips. Parallel (9): Low risk thanks to continuous treatment.
Operational Risk	Phased (8): No interference with live systems. Parallel (6): More complexity and safety concerns during construction.
Environmental Sustainability	Phased (5): Downtime could lead to selenium discharge. Parallel (9): Maintains treatment throughout construction, ensuring full compliance and sustainability.

Table 5.12 Scoring criteria and rationale (Scale:1-10) [15]

Criterion	Weight	Phased Score	Phased Weighted	Parallel Score	Parallel Weighted
Cost	0.20	9	1.80	6	1.20
Duration	0.25	9	2.25	6	1.50
Regulatory Risk	0.10	5	0.50	9	0.90
Operational Risk	0.10	8	0.80	6	0.60
Environmental Sustainability	0.35	5	1.75	9	3.15
Total	1.00	—	7.10	—	7.35

Table 5.13 weighed scoring table [15]

The weighted scoring approach, emphasizing sustainability, regulatory compliance, and risk reduction, slightly favors the parallel plan (7.35) over the phased strategy (7.10). The phased

strategy is competitive because of its reduced cost and expedited timetable, whereas the parallel alternative offers a more comprehensive environmental and regulatory framework. This scoring model underscores that the optimal method is contingent upon stakeholder interests, specifically the relative importance of budget efficiency against long-term risk management.

5.5 Final assessment

This chapter proposed a thorough comparative study that evaluates the two execution strategies-Phased and Parallel- using several project indicators, such as cost, time, risk exposure, environmental compliance, and resource allocation. The results demonstrate that each technique offers a unique array of benefits and drawbacks corresponding to various project priorities.

The incremental approach is evidently more beneficial for overall expenses and implementation schedule. With a total expenditure of around €4,073,071.91, which encompasses €1,002,056 in execution-related costs, it is identified as the most economical option. Furthermore, the project timeline is considerably abbreviated — 160 working days, in addition to a two-month contingency to address possible delays and facilitate the transition. This technique guarantees a more concentrated deployment of human and technical resources, resulting in elevated utilization rates and facilitating streamlined on-site coordination, as buildings occur on a cleared site devoid of interruption from concurrent operations.

This method entails significant regulatory and environmental hazards. The complete shutdown of the current selenium removal system during construction may lead to untreated selenium-laden wastewater being released if there are any project delays. This presents significant compliance and sustainability issues, particularly considering the stringent environmental rules pertaining to selenium emissions. The necessity of adhering to strict deadlines imposes considerable strain on scheduling, necessitating meticulous planning and minimum allowance for delays.

The parallel strategy, despite its higher expense of about €4,580,631.91, which includes €1,509,616 in operational execution expenses, provides superior environmental safety and regulatory compliance. Since the existing plant remains active throughout the project, the risk of environmental breaches is minimized. The prolonged project timeframe of 320 working days facilitates enhanced flexibility, diminishing the probability of quality or safety sacrifices due to scheduling pressures. Furthermore, it distributes the resource task more equitably, reducing peak demand constraints on staff.

Notwithstanding its benefits, the parallel technique entails increased operational complexity. Collaborating with an operational facility necessitates enhanced safety protocols and may result in diminished efficiency on specific operations. Moreover, the extended timeframe

subjects the project to greater concerns, encompassing potential price volatility and heightened administrative expenses.

Despite its benefits, the parallel technique entails increased operational complexity. Collaborating with an operational facility necessitates enhanced safety protocols and may result in diminished efficiency on specific operations. Moreover, the extended timeframe subjects the project to greater concerns, encompassing potential price volatility and heightened administrative expenses.

A weighted scoring approach was used to facilitate objective decision-making; environmental sustainability was given significant attention (35%), followed by time (25%), and cost (20%). This model suggests that, mostly because of its better environmental performance and regulatory stability, the parallel method obtained a somewhat higher total score (7.35) than the phased strategy (7.10).

Despite the phased method's competitiveness stemming from its economic efficiency and temporal advantage, the ultimate recommendation favors the parallel technique. This recommendation is motivated by its congruence with long-term environmental accountability, diminished compliance risks, and a more resilient implementation framework that alleviates the risk of unexpected delays. In conclusion, if the project's paramount concern is stringent cost and time management inside a meticulously organized timetable, the phased technique may be deemed suitable. Nonetheless, considering the environmental and legal sensitivities associated with selenium treatment, the parallel strategy presents a more sustainable and secure approach moving ahead.

6 Simulation and scenario modeling

6.1 Methodology

This chapter's simulation technique is entirely grounded in the planning and cost analysis conducted in this thesis, aimed at comparing the phased and parallel execution strategies for the selenium removal system at the Fiume Santo Power Plant. The research emphasizes the assessment of each plan for timing, resource allocation, and cost-effectiveness, utilizing exclusively authentic data obtained from procurement, workload estimation, and project scheduling.

The timeline simulations were conducted in Microsoft Project, resulting in the creation of comprehensive Gantt charts and WBS structures for both techniques. The phased strategy involved a project plan synchronized with a stringent regulatory deadline mandating completion by 31 October 2025,[10] with an approximate two-month buffer to accommodate final transitions and contingencies. The parallel technique permitted greater flexibility, with the project timeline extended to June 2026, indicating diminished time constraints since the present system remains operational throughout construction.[11]

Labor expenses and human resource planning were informed by both internal and external data. The labor hours of essential field personnel (Project Manager, Site Supervisor, Project Engineers, etc.) were calculated based on actual job allocations and durations extracted from MS Project and aligned with hourly/daily cost rates.[10],[11] Correspondingly, proposals obtained from subcontractors - including NMG (removal), Forel (installation), and On Technology (electrical work) - were incorporated into both the phased and parallel plans.

No false delay percentages or speculative variance simulations were used; rather, the entire simulation is grounded in definitive planning and procurement assumptions established throughout the thesis. Resource loading and leveling were manually modified to align with the real operating logic of the two methods, especially in the parallel approach, where more stringent safety limits and the need for operational continuity led to extended job durations.

The key inputs used in this simulation include:

- Completed equipment and instrumentation lists with actual supplier data, including costs and lead times.[12],[13]
- Current work calendars include human resource schedules for both internal and external teams.[10],[11]
- Execution timelines and regulatory limitations, particularly for incremental implementation.[10],[11]

- Output from MS Project encompass baseline cost, projected value (PV), and computed performance indices such as Cost Performance Index (CPI) and Schedule Performance Index (SPI).[10],[11]
- Considerations for field logistics include restricted area, crane accessibility, and the necessity for meticulous coordination with concurrent operations during simultaneous execution.

This realistic and constraint-aware simulation setup provides a solid foundation for the upcoming analysis of outcomes, where execution costs, timeline pressure, and operational risks will be compared under both strategies.

6.2 Simulation

The planning, scheduling, and procurement data created and evaluated over this thesis determines the whole result of the simulation phase. Under real planning limitations, the simulations concentrate on comparing the two execution strategies - phased and parallel - in terms of cost, timing, resource utilization, and overall project pressure; they do not include fictitious variability.

The phased strategy indicates that the project will commence on 24 March 2025 and is anticipated to conclude by 31 October 2025, according to environmental regulatory deadlines.[5] The program incorporates a two-month buffer to accommodate unexpected delays and the transition between the existing and new treatment systems. This technique necessitates the cessation of the current treatment system during building, resulting in a tightly constrained timeframe and the aggressive allocation of all resources. This method guarantees expedited execution but necessitates more concentrated staff, prolonged working hours, and effective coordination among suppliers and contractors.[10]

Conversely, the parallel approach commences on 24 March 2025 and continues until 12 June 2026.[11] This method enables the current plant to stay functional during the construction and testing of the new system. Consequently, scheduling exhibits increased flexibility; yet the duration of individual tasks is extended due to the necessity of adhering to stringent safety protocols and coordinating activities within an operational industrial setting. Activities such as installation and removal frequently necessitate crane access, careful maneuvering, and monitored shifts to prevent disruption to the operational facility and its staff.

The total execution cost for the phased strategy was determined in MS Project to be €1,002,056.00, whereas the parallel strategy amounted to €1,509,616.00, indicative of the prolonged duration, supplementary safety protocols, and logistical intricacies associated with concurrent operations. The whole project expenditure, encompassing procurement, engineering, installation, and subcontractor proposals, is projected to be €4,073,071.91 for the phased approach and €4,580,631.91 for the parallel approach.[10],[11]

Performance metrics, including the Cost Performance Index (CPI) and Schedule Performance Index (SPI), were utilized to evaluate efficiency. The CPI for the phased method is 0.55, whereas for the parallel strategy it is 0.50, according to the intended value (PV) obtained at critical status dates (1 August 2025 and 1 October 2025, respectively). The data indicates that both strategies necessitate significant expenditure early in implementation; however, the phased strategy demonstrates somewhat greater cost efficiency in the midway owing to its condensed schedule and targeted execution methodology.[10],[11]

Furthermore, Resource Utilization Rates (RUR) examined were examined for every method considering the project length and total remaining work hours. Once more, reflecting the intensity of execution needed within a constrained period, the RUR for most field teams and management staff is much greater in the phased plan. Although the parallel approach offers reduced peak workloads but spans availability over a longer period, the same resources are more equally distributed.

The results of these simulations serve as the foundation for the subsequent comparison analysis, where trade-offs between time, cost, risk, and environmental impact will be evaluated utilizing visual tools and weighted scoring models. The results indicate that the phased method provides a more concise and potentially cost-effective execution timeframe, whereas the parallel strategy guarantees operational continuity, reduced regulatory risk, and seamless integration, albeit with extended execution duration and heightened complexity.

6.3 Decision framework

This section employs a structured decision-making framework to facilitate strategic decision-making regarding the optimal execution approach for upgrading the selenium removal system at the Fiume Santo Power Plant. The methodology utilizes the outcomes of the simulation and comparative analysis, employing a KPI-based weighted scoring model to evaluate the phased and parallel solutions across the fundamental characteristics of project success: cost, length, risk exposure, and environmental sustainability.

As outlined in Chapter 5, a detailed scoring table was created to evaluate both strategies based on key performance indicators (KPIs). The significance of each KPI was determined according to project priorities and stakeholder sensitivity, with the most emphasis placed on environmental sustainability (35%), followed by project duration (25%), risk exposure (20%), and cost efficiency (20%). These weights represent the plant's essential duty to comply with environmental discharge requirements, while also ensuring the project is completed within acceptable schedule and cost parameters.[15]

The scores used in the weighted model were derived from simulation results and real data, including Total cost of execution and procurement, estimated project duration based on Gantt charts, Resource utilization levels and performance indexes (CPI, SPI), Operational

risk exposure, especially in terms of plant interference and safety, Regulatory pressure and downtime risk (especially for phased execution).[10],[11]

The results of the weighted scoring unequivocally demonstrated that the parallel strategy [11], although incurring greater overall expenses and requiring a longer implementation timeframe, excels in environmental compliance and operational resilience.[5] The capacity to sustain uninterrupted treatment operations during the development phase markedly diminishes environmental and regulatory risks, deemed the paramount success factor for this project. The parallel strategy offers enhanced flexibility in scheduling and resource allocation, hence increasing resilience against variables like procurement delays or field coordination challenges.

In contrast, the phased technique exhibits enhanced performance for cost and time efficiency. [10] The project's condensed timetable and substantial resource allocation facilitate earlier completion and reduced expenses. Nonetheless, this incurs heightened regulatory risk, particularly in the event of project delays, along with the operational difficulty of decommissioning the current system prior to the readiness of the new one.[15]

The parallel approach performs better, from a resilience standpoint. Under uncertainty, it has a strategic benefit since it allows one to absorb delays without immediate operational or legal consequences. Though more costly, it guarantees a safer change with less chance of project failure or compliance penalties.

In conclusion, the decision framework advocates for parallel strategy as the more robust and strategically coherent choice, especially where sustainability and compliance are emphasized. The phased plan is a feasible option if cost reduction and expedited completion are the primary priorities. Nonetheless, every choice must be guided by the client's risk tolerance and long-term operating objectives.[10],[11],[5],[15]

7 Strategic discussion and broader implications

7.1 Practical implications for industrial projects

This thesis provides significant insights for industrial project planning, especially in environmentally controlled industries like energy and wastewater treatment. The comparison of phased versus simultaneous execution strategies underscores the significant impact that pre-implementation strategy decisions can have on regulatory compliance, operational risk, and cost efficiency.

The phased technique displayed distinct benefits regarding reduced costs and abbreviated timescales, rendering it appealing for projects with constrained budgets or pressing deadlines. Nonetheless, it presents considerable regulatory risk if delays arise, owing to the total cessation of the current treatment system. This exposes the plant to potential non-compliance with legal discharge restrictions, a risk that may surpass short-term savings in highly regulated environments.[10],[15],[5]

The parallel approach guarantees constant environmental compliance, on the other hand, since the current plant stays operating during building. However, because old and new systems coexist, this gain comes with increased operational expenses, more resource use, and logistical complexity. These trade-offs highlight the need of precisely coordinating technical planning, environmental priorities, and financial resources.

Another significant aspect is the necessity of early procurement integration in strategy planning. This project involved the selection of equipment and instrumentation depending on lead times, which directly impacted the project's feasibility and scheduling. This emphasizes how timely procurement data can avert delays and facilitate pragmatic planning. The study underscores the need to assess various methods in the pre-execution phase, including technologies such as MS Project, cost simulations, and KPI scoring. This systematic comparison facilitates informed decision-making for complicated industrial upgrades and promotes long-term sustainability objectives.

Key Aspect	Phased Strategy	Parallel Strategy	Implication
Cost Efficiency	Lower execution cost (\approx €1M)	Higher execution cost (\approx €1.5M)	Budget constraints favor phased, but

			only if compliance risks are manageable.
Timeline	Shorter (Mar–Oct 2025) with 2-month buffer	Longer (Mar 2025–June 2026)	Phased preferred for urgent deadlines; parallel better for flexibility.
Regulatory Compliance	Risk of non-compliance if delayed	Continuous compliance ensured	Projects with strict environmental rules benefit from a parallel approach.
Operational Risk	Minimal (no overlapping operations)	High (construction near working plant)	Higher safety management is needed in parallel; the phased is operationally simpler.
Procurement and Planning	Simplified coordination due to the empty work area	Complex due to simultaneous old/new system	Early procurement planning is essential in both cases to avoid lead-time delays.
Strategic Insight	Highlights of trade-off between speed and environmental risk	Emphasizes the importance of continuity and regulatory foresight	Comparing strategies early supports better decision-making under uncertainty.

Table 7.1 The strategies' conditions and implications [10],[11],[15]

7.2 KPI-driven strategic planning

This thesis utilized Key Performance Indicators (KPIs) not just to assess execution outcomes but also as decision-making instruments during the planning phase. This methodology facilitated the assessment of the two strategies-phased and parallel-prior to execution, ensuring that cost, time, and environmental priorities were distinctly comprehended and quantified.[7],[10],[11]

The Cost Performance Index (CPI) and Schedule Performance Index (SPI) indicated enhanced cost and time management in the phased strategy, attributed to its concentrated

schedule and absence of operational disruptions. Simultaneously, the parallel strategy, albeit less effective in terms of CPI/SPI, provided superior environmental compliance and continuity during implementation.[7],[10],[11]

The Resource Utilization Rates (RUR) indicated increased labor intensity in the phased plan, resulting in possible overloads. Conversely, resource utilization in the parallel technique was distributed but incurred higher overall hours.[7],[10],[11]

Significantly, KPIs facilitated the quantification of trade-offs: a phased approach is more time- and cost-efficient, whereas a parallel approach mitigates environmental and regulatory risks. This illustrates how KPI-based planning enables project teams to compare intricate options with clarity-a technique relevant to numerous industrial infrastructure enhancements.

KPI	Phased Strategy	Parallel Strategy	Insight
CPI (Cost Performance)	Higher (more efficient use of budget)	Lower (due to extended timeline and resource costs)	Phased is more cost-efficient
SPI (Schedule Performance)	Higher (faster execution with tight planning)	Lower (delays from safety and coexistence issues)	Phased finishes earlier, suits strict deadlines
RUR (Resource Utilization)	Higher (more intense and concentrated work)	Lower (spread over longer time)	Parallel lowers overload risk but requires longer staff engagement
Environmental Compliance	Risk of non-compliance during downtime	Continuous compliance maintained	Parallel strategy ensures legal and ecological safety
Strategic Use of KPIs	Scenario-driven choice of optimal plan	Pre-execution decisions supported by KPI evidence	KPI-based planning supports smarter decisions before work begins

Table 7.2 Summary of KPIs and related insights for both strategies [10],[11],[5]

7.3 Long-term sustainability and regulatory alignments

A key finding of this thesis is that strategic planning for infrastructure enhancements, particularly for environmental treatment systems, must be congruent with long-term sustainability objectives and regulatory requirements. The choice between phased and parallel

execution tactics for the Fiume Santo Power Plant extends beyond mere immediate costs or schedules.

The parallel technique, although more costly to operate,[11] provides a considerable benefit regarding sustainability and environmental stewardship.[5] By preserving the current selenium treatment system throughout development, the facility prevents the release of untreated wastewater, so ensuring ongoing adherence to the standards set forth in Italian Legislative Decree 152/2006.[5] This continuous operation mitigates the potential of ecological harm and reinforces the company's dedication to environmental stewardship.

The phased technique, although economically beneficial, [10] creates a temporary treatment gap that may result in selenium discharges over the authorized limits. This not only jeopardizes environmental integrity [5] but may also lead to reputational harm or legal repercussions if delays transpire. This method may only be appropriate when stringent environmental rules may be suspended or when alternative treatment options are accessible. This analysis confirms that sustainability must be regarded as a fundamental factor in strategic assessments, rather than a secondary consideration. By incorporating KPIs pertaining to environmental performance and compliance at the first planning phase, the project team quantified the extensive impacts of each scenario, illustrating that initial expenditures in concurrent execution might result in long-term regulatory and reputational advantages.

This methodology exemplifies a model for other industrial initiatives characterized by stringent regulatory frameworks and elevated public accountability. The thesis underscores the importance of proactive, sustainability-oriented planning in infrastructure projects within both the public and private sectors.

8 Conclusion and recommendations

8.1 Summary of strategic assessment

This thesis has conducted a comparative strategic assessment of two potential execution strategies—phased and parallel—for upgrading the selenium removal system at the Fiume Santo Power Plant. The study was designed as a pre-implementation analysis to determine the most appropriate strategy before execution. No physical implementation or real-time monitoring was performed; rather, the study depended on planning simulations, KPI analyses, risk evaluations, and resource modeling.

The phased technique entails initially dismantling the current treatment system prior to constructing the new one.[10] This method provides financial benefits and a reduced overall duration. The total expected cost for the phased strategy, derived from simulations in MS Project and cost estimation tools, is €4,073,071.91, encompassing both execution-related expenses and material acquisition. [10] Resource Utilization Rates (RUR) and Schedule Performance Index (SPI) reflect a focused yet effective deployment of the personnel, albeit accompanied by an increased operational burden within a compressed timetable. The phased method has regulatory and environmental hazards, especially if the completion deadline is not adhered to, as the facility is prohibited from discharging untreated selenium-contaminated water beyond 2025 in accordance with environmental rules.[5]

The parallel technique, conversely, involves constructing the new treatment system while maintaining the functionality of the present one. This guarantees ongoing adherence to environmental standards yet leads to extended execution times and markedly increased resource and coordination demands. The overall projected expenditure for this method amounts to €4,580,631.91, [11] chiefly attributable to extended labor involvement, safety measures, and the requirement for specialized apparatus (e.g., cranes, monitoring systems) inside an operational plant setting. Notwithstanding the increased expenses, the parallel strategy demonstrates superior performance in environmental sustainability and mitigation of regulatory risk. KPI-based analysis indicated reduced overloading of vital resources, however at the expense of cost and time efficiency.[7],[11]

Both approaches employed Key Performance Indicators (KPIs) including the Cost Performance Index (CPI), Schedule Performance Index (SPI), Resource Utilization Rate (RUR), and environmental compliance indicators to quantify strategic trade-offs.[7],[9] A

weighted scoring system was implemented, prioritizing environmental sustainability, followed by time and money, to align with the project's strategic and ethical aims.

This chapter consolidated the information from previous analyses and simulations to facilitate an informed, data-driven decision between phased versus parallel execution. The evaluation indicates that strategy selection should not depend exclusively on cost or time measures but must also consider multifaceted risks and long-term sustainability objectives. This underscores the significance of strategic project planning, wherein methods such as simulation modeling and KPI forecasting are essential, particularly in projects subject to stringent environmental constraints and regulatory deadlines, as exemplified in this study.

8.2 Final recommendation and justification

This report suggests the parallel strategy as the most suitable option following a thorough comparative assessment of the two suggested execution strategies-phased and parallel-for the selenium removal upgrade at the Fiume Santo Power Plant.

This advice stems from the strategic focus of environmental preservation, which has always been the main goal of the project. The phased approach naturally implies a time of environmental non-compliance even if it is linked with a reduced total cost (€4,073,071.91) and a shorter project length. Wastewater polluted with selenium would be dumped without sufficient treatment during this period, therefore exposing the facility to ecological risk, legal infringement, and damage to reputation. Any unanticipated delays could stretch this exposure and raise legal and financial risk even with a two-month buffer.

Conversely, the parallel technique, although more costly (€4,580,631.91) and operationally intricate, guarantees uninterrupted wastewater treatment during the whole construction phase. The current system stays in operation until the new system is fully operational (although the existing system is not efficient enough and that is the reason we are improving that), ensuring more compliance with environmental standards and adhering to the limits established by Italian Legislative Decree 152/2006 and European environmental directives. This continuous adherence demonstrates a heightened congruence with the plant's long-term sustainability objectives and social responsibility obligations.

From a technical performance standpoint, KPI assessments further substantiate this recommendation:

- The Cost Performance Index (CPI) and Schedule Performance Index (SPI) values for the phased method are more advantageous in isolation, signifying more cost efficiency and expedited execution.[7],[10]
- The Cost Performance Index (CPI) and Schedule Performance Index (SPI) values for the phased method are more advantageous in isolation, signifying more cost efficiency and expedited execution.[7],[11]
- The weighted scoring methodology, prioritizing sustainability, placed the parallel strategy higher due to its greater performance in environmental measures and reduced exposure to legal and reputational threats.[15]

It is essential to acknowledge that funding availability continues to be a significant limitation. In situations with constrained financial resources and potential regulatory leniency, the phased technique may still be contemplated, however as a final option. This strategy, however, must be supplemented by comprehensive contingency planning and maybe interim treatment systems to mitigate environmental damage.

Ultimately, this thesis underscores that infrastructure projects of this nature, especially those involving pollution control, must be evaluated not just on operational cost and timeline, but on their impact on public health, environmental integrity, and regulatory compliance. Based on this holistic assessment, the parallel strategy is recommended as the more resilient and responsible execution pathway.

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