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Optimising Core Process Technology System Delivery in Global Capacity Expansions: Identifying and Mitigating Critical Success Factors and Risks.

Uranium **E**nrichment **Co**mpany

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Management Summary

Uranium Enrichment Company (Urenco), an international supplier of uranium enrichment services, aims to increase its capacity to meet growing demand. The availability of Core Process Technology (CPT), the key process equipment and critical systems required to initiate the uranium enrichment process, is critical to this goal. The action problem is: "*Urenco faces challenges in mitigating supply chain-related risks to ensure the timely delivery and installation of CPT systems globally, which is crucial to achieving its capacity target of* [redacted] *SWU by 2032"*. The main research question is: ***"How can Urenco manage supply chain-related risks to ensure the timely delivery and installation of Core Process Technology systems in global capacity expansions?"*** Using the DMAIC methodology, the problem is broken down into Define, Measure, Analyse, Improve, and Control. Data is collected through semi-structured interviews and Urenco's intranet, involving six key stakeholders: CPT Procurement, Asset Management, Design Authority, Research & Development, Project Management, and the Supplier. The data is processed using techniques and models from (Theisens, 2016), such as Process Flow Diagrams, Gantt charts, and Bottom-Up Affinity Diagramming, along with the CSF Framework, Reverse Risk Analysis, Risk Score Calculation, Business Case, Scenario Analysis, and Sensitivity Analysis.

A process model is established to understand CPT system delivery in global capacity expansions and to lay the foundation for further phases. The interdependent Commodity- and the Expansion Process run in parallel to ensure delivery. The Commodity Process secures long-term supplier commitment, while the Expansion Project Process details project-specific activities and decisions.

Twelve Critical Success Factors (CSFs), essential for the timely delivery and installation of CPT systems, are identified through a hybrid approach, incorporating elements of Grounded Theory. This ensures that the CSFs emerged directly from the data. The CSFs are grouped into four clusters (Supplier Relationship Management, Enterprise Planning, Dialogue Specification and Scope, and Stakeholder Transparency) based on common themes and stakeholder roles. Their impact is quantified using stakeholder criticality assessments, process interdependencies, and the distinction between strategic and tactical-operational impacts, providing a reasonable approximation of potential delays. CSFs are translated into risks using Reverse Risk Analysis and stakeholder discussions. A risk is defined as a potential negative consequence if a CSF is not properly managed. This process identified ten key risks, of which stakeholder misalignment is the most critical. This risk is significant due to its high probability (80%) and impact (12-18 months), affecting both processes, and the identified inconsistencies and overlapping responsibilities.

The proposed solution involves regular cross-functional handover meetings and feedback mechanisms between the Commodity Team and the Project Expansion Team. These meetings, structured at strategic, innovative, and operational levels, ensure alignment by addressing progress and challenges. This initiative aims to reduce the risk of misalignment, lower the overall risk score, and provide financial benefits. The business case assesses risks, costs, and benefits for both worst and best-case scenarios. The solution reduced the total risk score by 12,18% (best-case) and 11,65% (worst-case), with net benefits of €11.019,44 (best case) and €10.424,25 (worst-case) after implementation costs of €2.658,70. Sensitivity analysis showed potential net benefits of up to €1,987.71. This improvement reduces the probability of delays and increases the likelihood of meeting the two-year project delivery deadline, supporting Urenco's capacity goals by 2032.

Acknowledgements

Hereby, I present my master's thesis entitled "Optimising Core Process Technology System Delivery in Global Capacity Expansions: Identifying and Mitigating Critical Success Factors and Risks". This thesis is the final part of my master's programme in Industrial Engineering & Management at the University of Twente. I am grateful for this opportunity, which has been both challenging and rewarding. Despite the complexity of independently researching such a multifaceted topic, the experience has been invaluable.

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Annemie Sprokkereef,

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Glossary of Terms

The following glossary provides clarity on abbreviations used throughout this research. These abbreviations are essential for understanding the concepts and discussions presented in the following chapters. They will be referred to where necessary to ensure consistency and understanding.

Abbreviation	**Full term**
A&C	Acceptance & Commissioning
AM	Asset Management
ATP	Acceptance Test Plan
BMS	Behavioural, Management and Social Sciences
CAPEX	Capacity Expansional
CO2	Carbon Dioxide
CPT	Core Process Technology
CS	Corporate Services
CSF	Critical Success Factor
DA	Design Authority
DMAIC	Define Measure Analyse Improve Control
ETC	Enrichment Technology Company
FM	Facility Management & Site
GC	Gas Centrifuge
HS&E	Health Safety Environment
LB	Lower Bound
MIT90	Massachusetts Institute of Technology
MWE	Megawatt Electric
R&D	Research & Development
SCRM	Supply Chain Risk Management
SRM	Supplier Relationship Management
SWU	Separative Work Unit
UB	Upper Bound
UD	Urenco Deutschland
UF6	Uranium Hexafluoride
UNL	Urenco Netherlands
URENCO	Uranium Enrichment Company
UUK	Urenco United Kingdom
UUSA	Urenco United States of America

Key Definitions

The following key definitions provide clarity on important terms used throughout this research. These definitions are essential for understanding the concepts and discussions presented in the following chapters. They will be referred to where necessary to ensure consistency and understanding.

Term	Definition
Core Process Technology	The key process equipment and critical systems required to initiate the uranium enrichment process.
Critical Success Factor	A specific element, condition, or variable that is essential to the success of an organisation of project (Wuni & Shen, 2020).
Impact	The consequences or effects of an event when it occurs (Aveng, 2010).
Likelihood	The probability that a particular event will occur (Aveng, 2010).
Risk	The probability of the occurrence of an adverse event caused by a specific cause, with a negative impact on the achievement of organisational objectives (Aveng, 2010).
Supply Chain	A network of organisations, people, activities, information, and resources involved in supplying a product or service to a consumer. Supply chain activities transform natural resources, raw materials, and components, into a finished product that is delivered to the end customer (Chopra & Sodhi, n.d.).
Supply chain risk	The potential for disruptions in the supply of goods and services, which can stem from various sources such as supplier issues, market characteristics, geopolitical tensions, and natural disasters. Supply risk can affect the timely delivery and quality of essential components, impacting the overall efficiency and success of supply chain operations (Zsidisin, 2003).

1. Problem Statement and Research Approach

Chapter introduction

This chapter describes Urenco, an international supplier of uranium enrichment services, which faces capacity challenges in its upscaling activities due to supply chain-related risks for Core Process Technology. This technology includes the key systems and critical components required to implement Gas Centrifuge technology for uranium enrichment services. The chapter outlines the action problem faced by Urenco and the main research question to be answered. Based on the DMAIC methodology, this main research question is divided into five phases: Define, Measure, Analyse, Improve, and Control. In addition, this chapter covers the data collection methods and the techniques & models used to process the data for each sub-research question. Finally, the scope & conditions, project schedule, and the report structure are provided.

The chapter is divided into the following sections:

- *Section 1.1: **Urenco** – Introduces Urenco, the uranium enrichment process, Core Process Technology, and the Supply Chain of Core Process Technology.*
- *Section 1.2: **Motivation of Research** – Includes the necessity of this research and the problem to be addressed.*
- *Section 1.3: **Research Methodology** – Introduces the DMAIC methodology.*
- *Section 1.4: **Research Objective & Research Questions** – Formulates the research objective, research question, and sub-research questions based on DMAIC methodology.*
- *Section 1.5: **Data Collection Method** – Describes the data collection methods.*
- *Section 1.6: **Scope & Conditions** – Defines the main points about the research scope.*
- *Section 1.7: **Project Schedule** – Outlines the essence of the research planning.*
- *Section 1.8: **Report Structure** – Organises the research into chapters and the corresponding titles.*

1.1. Urenco

Uranium Enrichment Company (Urenco) is an international supplier of uranium enrichment services and fuel cycle products for the civil nuclear industry. Urenco's vision is of a sustainable net zero world, in which carbon-free energy is provided to enrich the future. To achieve this vision, Urenco's mission is to deliver trusted and innovative nuclear services and solutions. By leveraging expertise and advanced gas centrifuge technology, Urenco enrich Uranium Hexafluoride (UF6) to international specifications, ensuring a sustainable chain reaction. The isotopic composition of UF6 is not conductive to sustaining a chain reaction.

Urenco has a 50-year history as a leading nuclear services technology company and is the only company in the world which operate enrichment facilities in four countries: Urenco Netherlands (UNL) in Almelo, Urenco Deutschland (UD) in Gronau, Urenco United states of America (UUSA) in Eunice, Urenco United Kingdom (UUK) in Capenhurst. Urenco serves more than 50 customers in 19 countries worldwide who provide low carbon electricity through nuclear generation.

The primary processes at Urenco include Marketing/Sales & Customer Requirements, Outline Planning, Logistics (Planning), Operations, Logistics (execution), and Customer Fulfilment. This research is conducted by Urenco's

Procurement Department, which provides services that deliver value through global and regional strategic sourcing initiatives and the acquisition of goods and services, necessary to support Urenco's operations. This involves identifying suppliers, negotiating contracts, ensuring quality standards, and managing vendor relationships to optimise organisational value. The primary focus of Urenco's procurement function is to mitigate supply risk and enhance shareholder value through procurement expertise and supplier relationship management.

The main responsibilities of the Procurement Department consist of four categories, in descending order of globality: Core Process Technology (CPT), Corporate Services (CS), Facility Management & Site (FM), and Capacity Expansional (Capex). This research is part of the former, Core Process Technology (CPT), and is carried out for Urenco Global, thus all four enrichment facilities (UNL, UD, UUSA, UUK). The overall management system of Urenco can be found in Appendix A. Urenco's employees are clearly represented in the organisation chart found in Appendix B.

1.1.1. Uranium Enrichment Process

The uranium enrichment process starts with UF6, which is converted into a gas. This gas is fed into a Gas Centrifuge (GC) which spins at high speed, creating a centrifugal force. This force pushes the heavier UF6 molecules (containing uranium-238) towards the outer edge of the GC, while the lighter UF6 molecules (containing uranium-235) remain closer to the centre. The gas with the higher concentration of uranium-235 is collected and sent to the next GC for further enrichment. This process is repeated in a series of GCs until the desired level of enrichment is achieved. The enriched uranium (higher in uranium-235) is used in nuclear reactors, while the remaining uranium-238 (depleted uranium) is stored or processed. This method uses the mass difference between the isotopes for effective separation (MODULE 4.0: GAS CENTRIFUGE, 2009).

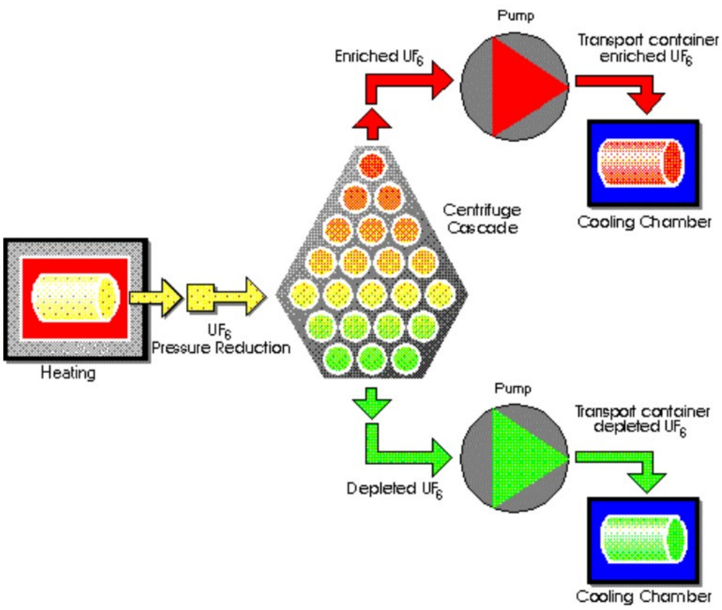

Figure 1: Schematic of Gas Centrifuge Cascade Arrangement process (MODULE 4.0: GAS CENTRIFUGE, 2009)

Figure 1 shows a schematic of a GC cascade and Figure 2 visualises a generic layout for a gas centrifuge facility. Multiple GCs in parallel, known as a cascade, are used to meet throughput requirements, allowing for modular and incremental implementation to begin before the entire plant is completed or to meet additional needs (MODULE 4.0: GAS CENTRIFUGE, 2009).

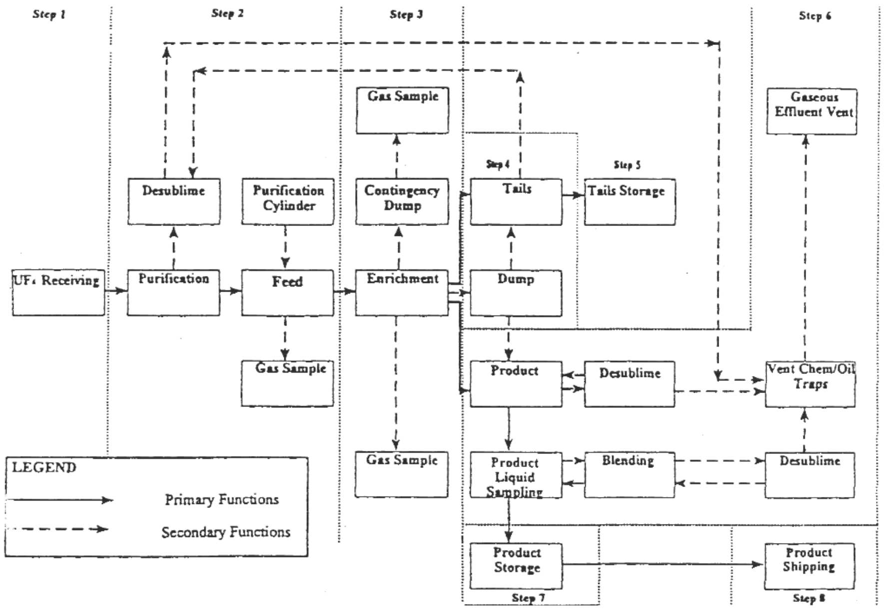

Figure 2: Visualised block diagram of steps in Gas Centrifuge process (MODULE 4.0: GAS CENTRIFUGE, 2009)

1.1.2. Core Process Technology

To implement GC technology for uranium enrichment, several key systems and critical components defined as 'Core Process Technology' (CPT) are essential. CPT is a specific technology, designed in collaboration between Urenco and its suppliers, to interface with the Cascade Header Pipework & Centrifuges, supplied by Enrichment Technology Company (ETC). Since centrifuge information is classified and beyond Urenco's control, it is treated as black box.

CPT systems work together to ensure the operation of GC technology for uranium enrichment (MODULE 4.0: GAS CENTRIFUGE, 2009). An example of a CPT system is the 'feed system', that prepares and supplies UF6 gas to the GCs (Figure 2). This system includes storage tanks, heaters to convert UF6 to gas, and pipework to transport the gas. For a detailed breakdown of CPT systems required to ensure the operation of GC technology for uranium enrichment, please refer to Section 3.2.

'Non-Core' includes all process equipment and systems, infrastructure and services required indirectly to implement GC technology. Related interfaces include building fit-out, site preparation & building construction, and outside battery limits (connections). Non-core is beyond the scope of the research. Figure 3 shows the framework of interfaces required to build a uranium enrichment facility.

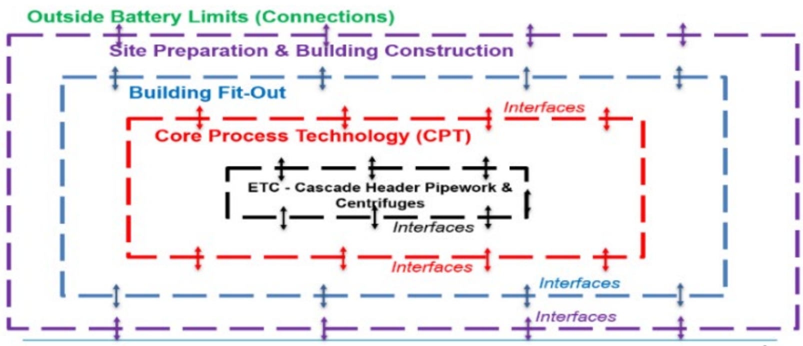

Figure 3: Framework of interfaces required to build an uranium enrichment facility

1.1.3. Supply Chain for Core Process Technology

The supply chain for CPT systems is critical to the success of Urenco's enrichment activities. As discussed in Section 1.1.2., CPT is a specific technology developed in collaboration between Urenco and its suppliers. This collaboration is essential because these systems must integrate seamlessly to ensure the effective operation of the GC technology for uranium enrichment. The complexity and interdependence of these systems make the supply chain vital, as the timely delivery and installation of these systems is essential to maintain and improve enrichment activities.

Urenco relies heavily on reliable and qualified suppliers for this specific technology. There are only a limited number of suppliers worldwide capable of supplying these systems, resulting in limited availability and expertise. This dependence on a small number of suppliers creates significant risks. Delays, quality issues, or geopolitical tensions can disrupt the supply of critical CPT systems. Given the critical role of the supply chain in ensuring the availability of CPT systems, it is essential to understand and manage these risks. This research focuses on identifying and mitigating supply chain risks to ensure the timely delivery and installation of CPT systems. Chapter 2 considers the theoretical framework and literature on supply chain risk management, which provides a basis for understanding and addressing these risks.

1.2. Motivation of Research

The demand for future supplies of enriched uranium has increased significantly in recent years for two reasons:

1. The war between Ukraine and Russia in 2022 can be largely attributed to this phenomenon since western countries do not want to be dependent on Russia for enriched uranium. Therefore, countries switched to Urenco or a competitor for demand for enriched uranium.
2. Nuclear energy is crucial for the climate agreement because it is a stable and carbon-neutral energy source. It helps reduce greenhouse gas emissions, which is essential to meet climate goals. In addition, nuclear energy can support the growing demand for electricity without additional carbon dioxide (CO2) emissions (IAEA (International Atomic Energy Agency) Department of Nuclear Energy, 2032). Urenco's vision (Section 1.1.) aligns with this: a sustainable, net-zero world in which carbon-free energy is provided to enrich the future (Urenco, 2024).

Urenco's purpose to meet this growing demand is ***"to expand its operational capacity from the current amount of* [redacted] *SWU to* [redacted] *SWU by 2032".*** To achieve this, Urenco must maintain its current operating capacity through annual preventive maintenance and refurbishment activities, such as the replacement and maintenance of Gas Centrifuges (GCs) and the refurbishment of old enrichment facilities (MODULE 4.0: GAS CENTRIFUGE, 2009).

However, preventive maintenance can at most maintain current capacity and is, hence, not sufficient for the increasing demand. Significant expansions across multiple sites are essential to meet the [redacted] SWU target by 2032. Figure 4 illustrates the projected cumulative capacity flow required for these expansions, showing the capacity flow with and without refurbishment, and the impact of each site expansion.

- **Necessity of expansions:** Without significant expansions, Urenco risks failing to meet future demand, which could negatively affect its market position and financial performance. Expansion of operational capacity is essential to remain competitive and meet supply commitments.
- **Realism of 2032 target:** Achieving the 2032 target requires addressing several strategic risks that could impede progress. The increase in enriched uranium capacity is highly dependent on the availability of CPT systems. Therefore, risks associated with CPT can significantly hinder Urenco's ability to meet its capacity target. These risks include uncertainties related to the operating systems for uranium enrichment activities, political issues, and regulatory challenges. In addition, operating at four different sites in different countries adds complexity due to different legal and regulatory frameworks.

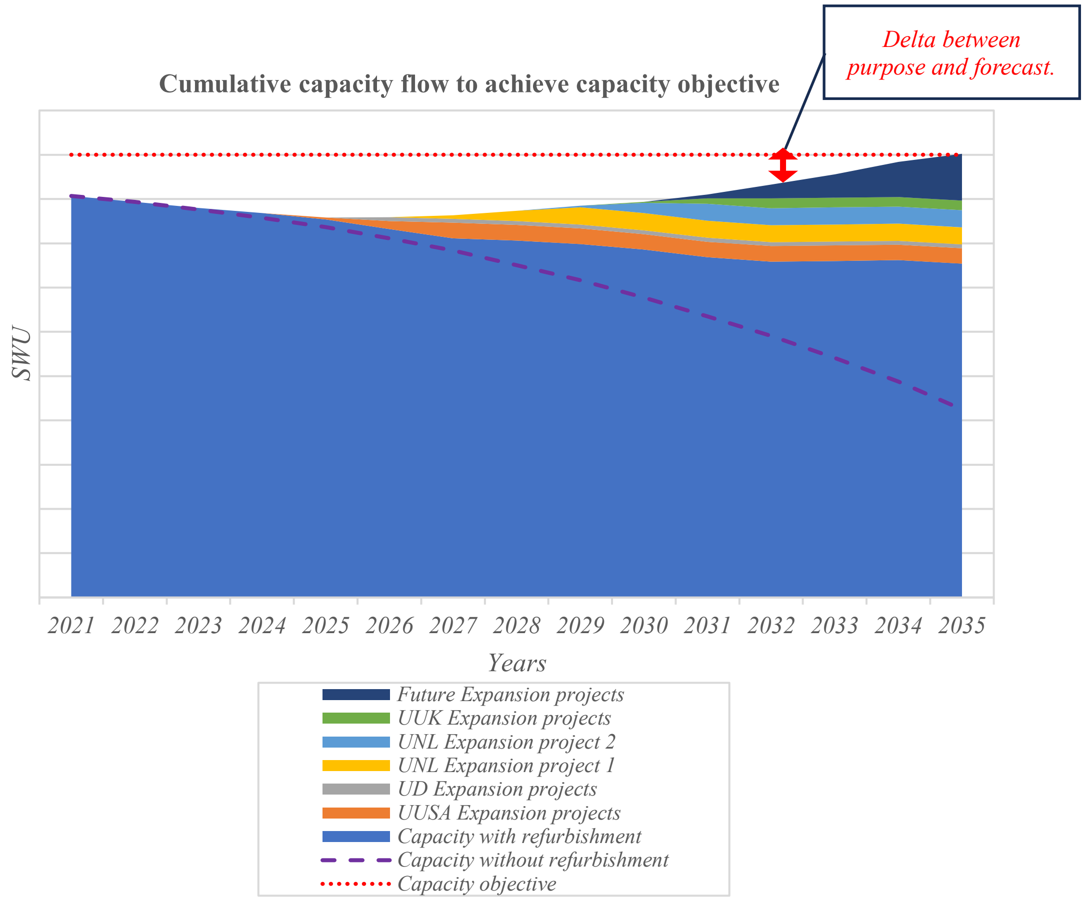

Figure 4: Cumulative capacity flow of various capacity expansions

The main reason that conveys the necessity of this research as shown in the figure:

Urenco will not achieve its projected capacity target by 2032, but rather by 2035. Therefore, none of the expansion projects can afford (further) delay, highlighting the importance of the investigation. Faced with this, the **action problem** is: "*Urenco faces challenges in mitigating supply chain-related risks to ensure the timely delivery and installation of CPT systems globally, which is crucial to achieving its capacity target of* [redacted] *SWU by 2032".*

1.3. Research Methodology

A methodology for extensive problem-solving processes is Define-Measure-Analyse-Improve-Control (DMAIC) (Table 1). DMAIC is an improvement method to improve, optimise and stabilise existing processes within an organisation and is "applicable for a wide range of well-to semi-structured problems" (De Mast & Lokkerbol, 2012), (Theisens, 2016). DMAIC breaks down a problem-solving task into a sequence of generic subtasks, represented and defined by five phases: Define, Measure, Analyse, Improve, and Control. In the Define-phase, the problem and its parameters are clarified. The Measure-phase quantifies the problem. The Analyse-phase identifies the cause. The Improve-phase involves a solution. The Control-phase maintains the solution. This model is considered useful for the following reasons:

- It provides a *structured and systematic approach* to problem solving.
- It focuses on *identifying and implementation of improvements*.
- It requires the *involvement of various stakeholders* throughout the process which ensures the diverse perspectives are included and that there is broad support for the final solutions.

Table 1: DMAIC methodology (Theisens, 2016)

DMAIC-phases	Theory
Define	Definition of the problem
Measure	Operationalising the problem
Analyse	Identification of the cause of the problem
Improve	Implementation and verification of the solution
Control	Maintaining the solution

The application of the DMAIC-methodology facilitates the identification of supply chain-related risks for CPT systems and propose a solution to ensure the timely delivery and installation of CPT systems during global capacity expansions. The DMAIC phases guiding the sequential progression of the research. Each DMAIC phase yields specific outputs, which are then evaluated in consultation with the supervisor to serve as input for subsequent phases. This iterative process ensures a comprehensive examination of the research problem, allowing for informed decision-making at each stage.

1.4. Research Objective & Research Questions

The action problem is transformed into a research objective: *"To manage supply chain-related risks to ensure the timely delivery and installation of CPT systems in global capacity expansions".* The main research question to achieve this research objective is as follows: ***"How can Urenco manage supply chain-related risks to ensure the timely delivery and installation of Core Process Technology systems in global capacity expansions?"***

Based on the DMAIC-methodology mentioned in Section 1.3., sub-research questions are formulated to answer the main research question (Table 2). The expected answers to all sub-research questions contribute to the main research question's overall answer enabling the research objective to be achieved (De Mast & Lokkerbol, 2012).

The Define-phase describes the process pertaining to the process of delivering and installing CPT systems in global capacity expansions. The Measure-phase identifies and maps Critical Success Factors (CSF) in the process. This are factors that are critical to ensure the success of the timely delivery and installation of CPT systems in global capacity expansions. The Analysis-phase examines supply chain-related risks associated with the CSFs and maps these risks to the process. The final Improve- & Control-phase investigates and propose a solution to reduce the criticality of CPT system delivery in global capacity expansions.

Table 2: Sub-research questions, methods, techniques & models, and deliverables

Note: for detailed explanations of the techniques & models mentioned in this table, please refer to Chapter 2.

Sub-research questions	**Data collection methods**	**Techniques & models**	**Deliverables**
Define			
1. What does the process of delivering and installing CPT systems in global capacity expansions entail?	-Semi-structured interviews with key stakeholders. - Urenco's intranet.	- Process Flow Diagram. -Gantt charts.	-Process of CPT system delivery in global capacity expansions.
Measure			
2.a. What are the Critical Success Factors to achieve the timely delivery and installation of CPT systems in global capacity expansions? 2.b. Where do these Critical Success Factors fit within the process?	-Semi-structured interviews with key stakeholders.	-Bottom-Up affinity diagramming. -Grounded Theory. -Critical Success Factors framework. -Impact calculation -Critical Success factor mapping.	-Critical Success Factors. -Critical points in process.
Analyse			
3. What are the supply chain-related risks associated with the Critical Success Factors?	-Semi-structured interviews with key stakeholders.	-Reverse risk analysis. -Risk score calculation -Risk mapping.	-Supply chain-related risks for CPT systems within critical points. -Risks in process.
Improve & Control			
4. What solutions can reduce and control the criticality of CPT system delivery in global capacity expansions?	-Semi-structured interviews from Define-, Measure- and Analyse-phase with key stakeholders.	-Process adjustment. -Business case -Scenario analysis -Sensitivity analysis	- Risk advice

1.5. Data Collection Method

Since the process of CPT system delivery in global capacity expansions has no direct connections in the literature, data collection involves semi-structured interviews and Urenco's intranet (Table 2). Semi-structured interviews use pre-established questions and allow for follow-up questions to gain deeper insights. Prior to the commencement of the interviews, the interviewer explains the purpose of the interview. Responses are analysed and validated to ensure accuracy and consistency, leading to reliable conclusions (Leen & Mertens, 2017). Urenco's intranet enables access to information about Urenco's company structure, corporate identity, policies & procedures. The literature is used to find suitable techniques and models applicable in this research.

A Stakeholder Analysis determines the key stakeholders (Figure 5), inspired by the work of (Brugha & Varvasovszky, 2000), which highlights the significance of stakeholder influence and interest. The Category Management Lead (company supervisor) and the researcher assess stakeholders based on their influence and interest. This research involves both individual and group stakeholders.

- **Individual stakeholders**: the Category Management Lead, the Head of Procurement, and the CPT supplier.
- **Group stakeholders** the Project Expansion Team and the Commodity Team. Chapter 3 (Define) explains the required context for both teams. Please refer to Appendix C and D for function descriptions.
    - Functions in the **Project Expansion Team**: Construction, Engineering, Health Safety Environment (HS&E), Quality, Acceptance & Commissioning (A&C), Design, Procurement & Contracting, and Project Management.
    - Functions in the **Commodity Team**: Research & Development (R&D), Design Authority (DA), CPT Procurement, and Asset Management (AM).

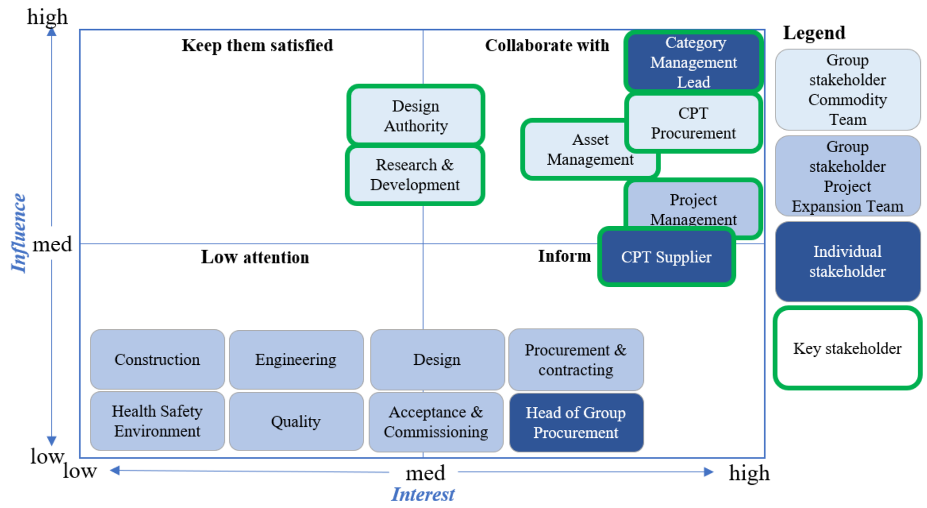

Figure 5: Stakeholder Analysis

Key stakeholders, highlighted with a green border in Figure 5 include CPT Procurement, Asset Management, Design Authority, Research & Development, Project Management, CPT supplier and the Category Management Lead. Four key points clarify the rationale behind their selection:

1. **Selection of Key Stakeholders:** the seven key stakeholders have the most interest and influence. This ensures maximum impact and deep insights, as they are more likely to actively participate and collaborate.

However, it is important to note that the Category Management Lead supervises this research, guiding the process. Therefore, the analysis primarily focuses on the **six stakeholders** who consider issues to be critical. Table 12 provides further evidence that these stakeholders consider issues to be critical.

2. **Strategical Perspective and Data Validity:** key stakeholders, mainly from the Commodity Team, provide essential strategic insight to understand the broader implications of an expansion project. Project Management, while having less influence on strategic decisions, is deeply interested in the success of the project. A CPT supplier is included as a key stakeholder due to their role in delivering CPT systems and their close involvement with both the Commodity Team and the Project Expansion Team (as become visible in the process model in Figure 16). This ensures that they provide valuable input into both the strategic and operational aspects of the project.
3. **Exclusion of Certain Stakeholders**: some stakeholders, typically from the Project Expansion Team, have a very specific and limited perspective on a single expansion project. Their lack of interest or influence could limit the breadth and depth of the analysis, so they are excluded.
4. **Use of Stakeholder Analysis in Research**: the results of the stakeholder analysis guide the selection of interviews, ensuring a comprehensive and representative view of perspectives within Urenco. The **six** key stakeholders are involved throughout the DMAIC-methodology through semi-structured interviews. This ensures interrelated stages and coherent contributions.

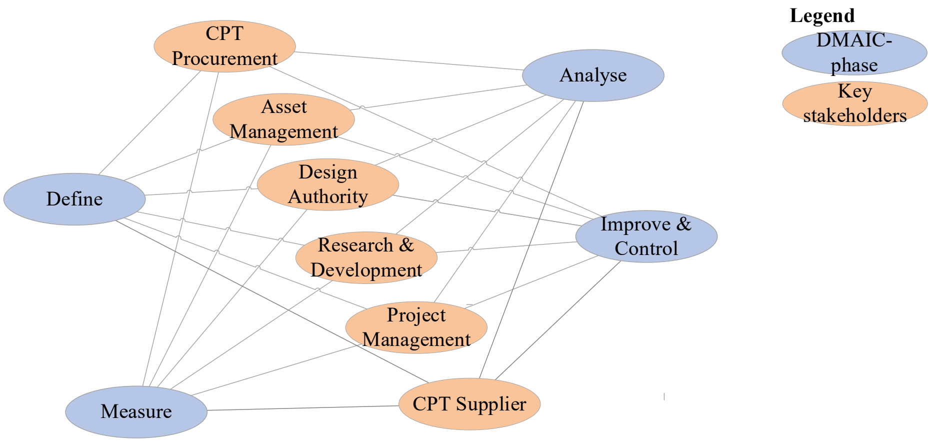

Figure 6: Coherence of stakeholder engagement with each chapter

1.6. Scope & Conditions

This research focuses on the timely delivery and installation of CPT systems in global capacity expansions. The research includes systems beyond the CPT interface. Table 3 outlines the items includes and excluded. Research success depends on sufficient information, stakeholder cooperation, and supervisor approval of the research question. For confidentiality, the research does not include supplier names or technical / commercial company information.

1.7. Project Schedule

At the start of this research, detailed planning is undertaken for each phase of the DMAIC methodology. The planning for each phase is based on an estimate of the complexity and scope of the tasks involved. Simpler tasks, such as setting up the basics and defining processes, are thought to require fewer weeks, while more complex tasks, such as analysing risks and measuring CSFs, are allocated more weeks to allow for thorough analysis and evaluation. An overview of the original project schedule and the actual project schedule can be found in Appendix E. For a detailed discussion of these challenges and the actions taken, see Chapter 7.

1.8. Report Structure

Table 3 structures the research in the order of the chapters and the corresponding titles.

Table 3: Reading guide research

Chapter nr.	**Chapter title**
1	Problem Statement and Research Approach
2	Theoretical and Literature Framework
3	Define
4	Measure
5	Analyse
6	Improve & Control
7	Discussion
8	Conclusion
Bibliography	
Appendices	

Chapter conclusion

This chapter outlined Urenco's capacity challenges in scaling up its uranium enrichment activities due to supply chain-related risks for Core Process Technology (CPT). Capacity expansion is highly dependent on the availability of CPT, and risks may hinder achieving the capacity target of [redacted] *SWU by 2032. Addressing these risks is critical to avoid delays pushing this target to 2035. The action problem is identified as: "Urenco faces challenges in mitigating supply chain-related risks for CPT systems to ensure the timely delivery and installation of CPT systems globally, which is crucial to achieving its capacity target of* [redacted] *SWU by 2032". In addition, this chapter outlined the DMAIC methodology, which divides the problem-solving task into five phases: Define, Measure, Analyse, Improve, and Control. The main research question guiding this investigation is: "How can Urenco manage supply chain-related risks to ensure the timely delivery and installation of Core Process Technology systems in global capacity expansions?" Data collection methods include semi-structured interviews and information from Urenco's intranet. Key stakeholders include CPT Procurement, Asset Management, Design Authority, Research & Development, Project Management, and the CPT supplier.*

To address the action problem, Chapter 2 establishes a theoretical and literature framework. It explores the relevant literature field of Supply Chain Risk Management (SCRM), providing the necessary context and insights to develop risk mitigation strategies.

2. Theoretical and Literature Framework

Chapter introduction

This chapter provides a theoretical and literature framework to address the action problem. It explores the relevant literature field of Supply Chain Risk Management (SCRM) and provides the necessary context and insight to develop risk mitigation strategies. The chapter integrates the perspectives within SCRM - Risk Identification, Risk Assessment, and Risk Mitigation - into the DMAIC methodology. Each DMAIC phase is linked to these perspectives to provide a structured and systematic approach to managing risk within the supply chain. For each DMAIC phase, the chapter discusses the relevant literature, techniques, and models, highlighting their necessity and essence.

The chapter is divided into the following sections:

- *Section 2.1: **Literature field of Supply Chain Risk Management -** provides a context for the research by exploring the broader literature field of Supply Chain Risk Management (SCRM).*
- *Section 2.2: **Methodological approaches within Supply Chain Risk Management –** Represents the relevant literature, and techniques & models, integrated into the DMAIC methodology associated with the SCRM perspectives.*

2.1. Literature field of Supply Chain Risk Management

For a better understanding of the terms used in this research, see the Key Definitions on page 12. These definitions are essential for comprehending the concepts and discussions presented in the following sections. These terms are underlined in this chapter for emphasis.

- Supply Chain Risk Management (SCRM): SCRM focuses on identifying, assessing, and managing risks within the supply chain (6Sigma.us, 2024). SRCM is a crucial research area because of the increasing complexity and vulnerability of modern supply chains. Globalisation, geopolitical risks, and reliance on external suppliers make supply chains susceptible to disruption. Effective risk management is essential to ensure the continuity and resilience of supply chains (Moody's Analytics Supplier Risk Solutions, 2023). The key challenges within SCRM include identifying potential risks, assessing the likelihood and impact of these risks, and developing strategies to mitigate these risks. The aim of SCRM is to reduce vulnerability of supply chains and increase resilience through proactive and reactive risk management strategies.
- SCRM definitions: Academics defined supply chain risk management from numerous perspectives (Aqlan & Lam, 2016). defines SCRM as "a systematic and phased approach for recognising, evaluating, ranking, mitigating, and monitoring potential disruptions in supply chains". (Jüttner et al., 2003) defined SCRM as "the identification and management of risks for the supply chain, through a coordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole". However, (Tang, 2006) offers a broader definition by focussing on its generic processes as "the management of supply chain risks through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity". *Although definitions of SCRM vary, there are some common elements*. All definitions emphasise the importance of identifying and managing risk. Table 4 shows the way authors differ in key focus on SCRM.
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Table 4: Key focus of SCRM for different authors

Author	Key focus
(Aqlan & Lam, 2016)	The structured and step-by-step nature of SCRM.
(Jüttner et al., 2003)	The process of risk identification and management.
(Tang, 2006)	The need for cooperation and coordination within the supply chain.

- Perspectives within literature field of SCRM*:* It is important to explore the different perspectives within this field of literature. SCRM covers a wide range of approached and methods, which can be divided into three main perspectives: risk identification, risk assessment, and risk mitigation strategies (Shojaei & Haeri, 2019). These perspectives provide a structured framework to evaluate the existing literature and understand how different researchers approach these aspects. Table 5 provide for each perspective its definition and its importance for SCRM.

Table 5: Perspectives within literature field SCRM

Perspectives	Definition	Importance for SCRM
1. Risk identification	The process of identifying potential risks within a supply chain. This includes the systematic recognition of events or conditions that could negatively impact supply chain performance (Shojaei & Haeri, 2019).	Proactively addresses vulnerabilities, preventing disruptions and protecting reputation (McGrath, 2023).
2. Risk assessment	The process of evaluating and quantifying identified risks to determine their likelihood and impact. This includes analysing the potential impact of risks and prioritising them according to their severity and likelihood of occurrence (Shojaei & Haeri, 2019).	Ensures efficient resource allocation by prioritising significant risks, enhancing preparedness and resilience (ACSM, n.d.).
3. Risk mitigation strategies	The measures and strategies developed and implemented to reduce or eliminate the impact of identified risks. This includes preventive measures and reactive measures (Shojaei & Haeri, 2019).	Minimises impact of risks, ensures operational continuity, reduces losses, and improves supply chain resilience (SCRG, n.d.).

- Specific relevance of SCRM in this research: Urenco faces the challenge of mitigating supply chain-related risks for Core Process Technology (CPT) systems that may impede the timely delivery and installation of CPT systems in global capacity expansions. SRCM provides the methods and strategies to effectively manage this complexity and vulnerability. By using SCRM, Urenco can:
  - **Identify Specific Risks**: SCRM helps systematically identify supply chain-related risks for CPT systems specific to Urenco's operations. By identifying these risks early, Urenco can take proactive measures to prevent disruptions (6Sigma.us, 2024).
  - **Assess and Mitigate Risks**: SCRM provides methods for assessing the likelihood and impact of identified risks, as well as risk management strategies. This enables Urenco to take effective action

against supply chain-related risks for CPT systems. Understanding which risks pose the greatest threat and how to mitigate them is critical to the success of Urenco's operations (McGrath, 2023).

- **Increase Resilience and Continuity**: By implementing effective risk management strategies, Urenco is better able to manage supply chain-related risks for CPT systems and ensure timely delivery and installation of systems, even in a complex and dynamic environment (Spanier, 2021).

2.2. Methodological Approaches within SRCM

This section provides an overview of the most important and relevant literature that forms the foundation for this research. The selection of literature is based on its direct relevance and contribution to the core of the research. Literature specific to minor details or specific issues is discussed in the relevant sections of the report where it is applied.

The different phases of the DMAIC methodology are linked to the perspectives within SCRM. Each perspective within SCRM (Risk Identification, Risk Assessment, Risk Mitigation) is applied to the relevant DMAIC phases to provide a structured and systematic approach for identifying, assessing, and mitigating risks within the supply chain.

- **Define**: This phase focuses on **Risk Identification**. The goal is to gain a clear understanding of the process and information flows, so that potential risks can be identified at each step of the process.
- **Measure**: This phase encompasses both **Risk Identification and Risk Assessment**. Identifying Critical Success Factors (CSF) and quantifying their impact in terms of delays are crucial to understanding and assessing risks.
- **Analyse**: This phase focuses on both **Risk Identification and Risk Assessment**. Identifying risks within the CSFs and quantifying the likelihood of these risks occurring are essential to determine which risks have the greatest impact.
- **Improve & Control**: These phases focus on **Risk Mitigation**. Developing solutions to reduce risks and ensuring the effectiveness of these solutions are crucial to maintaining the continuity and efficiency of the process.

2.2.1. Define – Risk Identification

1. Literature Review:
   - (Gaudenzi & Borghesi, 2006): This study emphasises the importance of a systematic approach to identify all possible risks. This is relevant for understanding the various steps and information flows within the CPT system delivery process.
   - (Theisens, 2016): This study designs specific techniques and models that seamlessly fit into each step of the DMAIC methodology, from defining problems to implementing improvements. This ensures a consistent and effective approach throughout the entire research project.

2. Techniques & Models:
   - **Process Flow Diagram** (Figure 7): This model visualises a schematic representation of the sequence of steps in the process of delivering CPT systems in global capacity expansions. It helps identify potential risks at each step of the process. By mapping out the process, it becomes clear where potential bottlenecks

and risks may occur. Although this does not directly identify risks, it is a crucial step to later plot the CSFs and risks, providing insight into where these risks are located (Theisens, 2016).

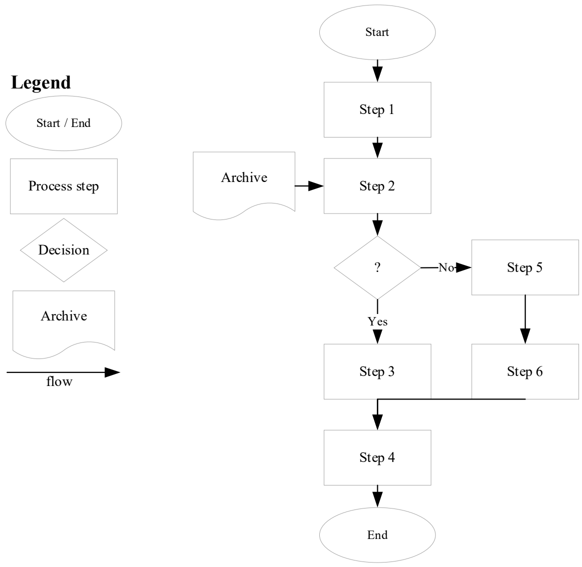

Figure 7: Schematic representation of a Process Flow Diagram (Theisens, 2016), illustrating the steps and sequence of the process.

- **Gantt Chart** (Theisens, 2016): This model is crucial for visualising the planning and coordination of the delivery and installation of CPT system groups across different Urenco sites, helping to prevent project disruptions. It provides an overview of the period of activities before and during the delivery and installation.

3. Logic/Need: Understanding the process and information flows is crucial for later plotting CSFs and risks and developing improvements. By setting up the process model, all the steps involved can be visualised, identifying who is involved, and understanding how information flows. This process model serves as the foundation for the entire research, allowing for later plotting of CSFs and risks for better visualization. In addition, understanding the strategic timelines and coordination of different projects is essential to ensure the timely delivery and installation of CPT systems. The literature provides a systematic approach to achieve this, supported by the techniques and models used.

2.2.2. Measure – Risk Identification & Risk Assessment

1. Literature Review:
   - (Jüttner et al., 2003): This study proposes that identifying and evaluating the various sources of risk within the supply chain is essential. This includes both internal sources, such as operational errors, and external sources, such as natural disasters or political instability. This is relevant for identifying CSFs to narrow down the scope and focus on what is critical for timely delivery.
   - (Denolf et al., 2015): This study builds on the MIT90 framework and helps understand the interactions in IT-driven organisational change. This is relevant for identifying CSFs by providing a structured approach to manage these interactions and ensuring all critical elements are considered.

- (Gaudenzi & Borghesi, 2006): This study emphasises the importance of a systematic approach to identify all possible risks. This is relevant for identifying CSFs, as it provides a comprehensive method to understand and assess risks.
- (Theisens, 2016): This study designs specific techniques and models that seamlessly fit into each step of the DMAIC methodology, from defining problems to implementing improvements. This ensures a consistent and effective approach throughout the entire research project.

2. Techniques & Models:
    - **Grounded Theory** (McLeod, 2024): is a research method that develops theories based on systematically collecting and analysing data. Instead of starting with existing assumptions or theories, the theory emerges from the data. This approach relies on stakeholder input to identify CSFs, ensuring a comprehensive understanding by closely listening to participants' experiences and perspectives. In this research, Grounded Theory is used to identify CSFs through iterative data collection and analysis, identifying themes and patterns until no new insights are gained. This ensures that the CSFs are derived directly from the data, providing a thorough understanding of the critical factors for the timely delivery and installation of CPT systems.
    - **Bottom-Up Affinity Diagramming** (Theisens, 2016): This technique (Figure 8) clusters various topics based on their natural relationship, helping to identify CSFs. This allows to sort large amounts of information and identify the CSF clusters critical to the timely delivery and installation of CPT systems.

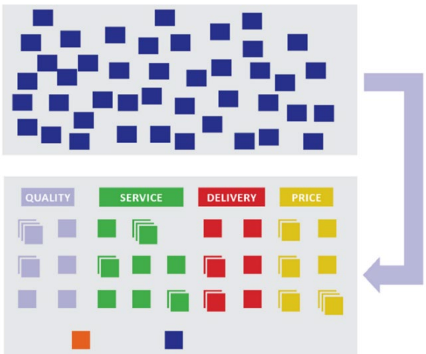

Figure 8: Example of Affinity Diagramming (Theisens, 2016)

- **MIT90 Framework** (Denolf et al., 2015): This framework (Figure 9) helps understand the interactions in IT-enabled organisational change. In this research case, it represents the entirety of the CSF clusters

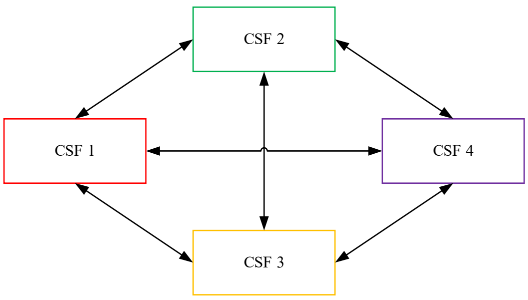

Figure 9: Adopted MIT90 Framework to understand interrelationship (Denolf et al., 2015)

and their interrelationships. Structuring and understanding these relationships helps identify bottlenecks and areas for improvement. The MIT90 framework provides a structured approach to manage these interactions, ensuring that all critical elements are considered and addressed.

- **CSF mapping to process**: Mapping the CSFs to the Process Flow Diagram (Figure 10) shows where the CSFs are in the process and why they are critical. This allows more effective identification of ways to proactively strengthen these CSFs.

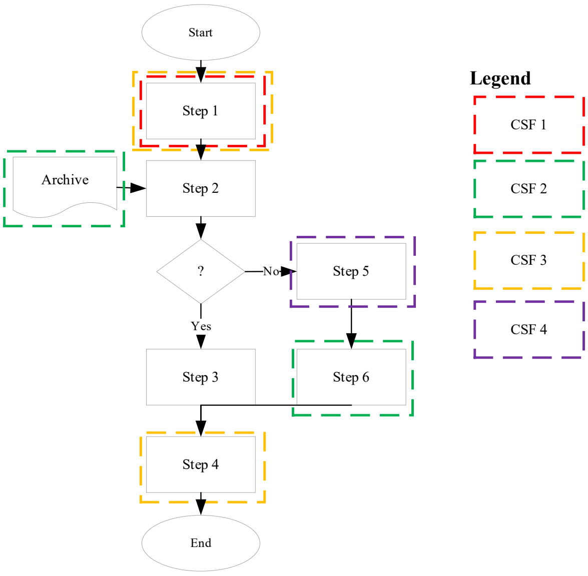

Figure 10: Example of Critical Success Factor Mapping to the Process Flow Diagram

- **Impact Calculation**: This technique quantifies the impact of CSFs in terms of delays. Understanding the impact of CSFs helps to prioritise which risks need the most attention by assigning a numerical value to the likelihood and impact of each risk. This allows for a more structured and systematic approach to risk management later in the research.

3. Logic/Need: Identifying CSFs is crucial to narrow down the scope and focus on what is critical for timely delivery. By identifying and mapping CSFs, this research can pinpoint the critical areas in the process that need attention. This helps to proactively address potential issues and ensure the timely delivery and installation of CPT systems. The literature provides methods to achieve this, supported by the techniques and models used. By applying these methods, this research can effectively identify and assess CSFs, ensuring a comprehensive risk management approach.

2.2.3. Analyse – Risk Identification & Risk Assessment

1. Literature Review:
   - (Farhan et al., 2018): This study argues that the failure or non-existence of a critical element could represent a potential risk. This is relevant for identifying risks within the CSFs in the context of CPT system delivery and installation.

- (Aven, 2010): This study provides a method for quantifying the likelihood of risks occurring. This is essential for developing a systematic approach to risk assessment in the supply chain.
- (Jüttner et al., 2003): This study proposes the basic risk analysis steps, which are crucial for conducting a comprehensive risk assessment:
  - Assessing the risk sources for the supply chain: Identifying and evaluating the various sources of risk within the supply chain, including internal sources (e.g., operational errors) and external sources (e.g., natural disasters, political instability).
  - Defining the supply chain adverse consequences: Identifying the potential negative impacts that risks can have on the supply chain, such as delivery delays, financial losses, and reputational damage.
  - Identifying the risk drivers: Identifying the factors that cause or exacerbate risks, including specific events, circumstances, or trends that increase the likelihood or impact of risks.
  - Mitigating risks for the supply chain: Developing and implementing strategies and measures to reduce or eliminate identified risks, including preventive measures (e.g., supplier diversification) and reactive measures (e.g., contingency plans).

2. Techniques & Models:
- **Reverse Risk Analysis:** Inspired by (Farhan et al., 2018), this technique identifies risks within the CSFs by formulating the opposite of the identified CSFs. This helps identify potential risks and clarifies which CSFs are critical for success and what potential issues may arise if CSFs are not properly managed. This technique is crucial for proactively identifying and addressing risks in the CPT system delivery process.
- **Risk Score Calculation**: Based on (Aven, 2010), this technique quantifies the likelihood of risks occurring. The risk score is calculated using the formula: "$Risk = Probability\ (likelihood) * Impact\ (consequence)$". This helps prioritise risks based on their impact and likelihood. This helps prioritise risks based on their impact and likelihood, ensuring that the most significant risks are addressed first.

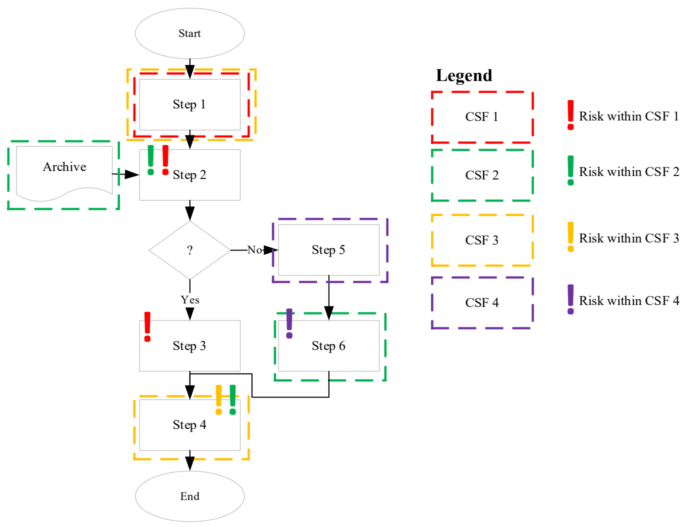

Figure 11: Example of risk mapping to the Process Flow Diagram

- **Risk mapping to process**: mapping both the CSFs and the associated risks to the Process Flow Diagram (Figure 11) locates the CSFs, identifies where they may lead to risks, and illustrates the distribution of these risks throughout the process. This allows for proactive measures to be taken to control or reduce the impact of risks, ensuring a more resilient and efficient delivery process for CPT systems.

3. **Risk** Logic/Need: Assessing risks is crucial to determine which risks have the greatest impact and where they occur in the process. The literature provides methods to achieve this, supported by the techniques and models used. By applying these methods, this research can effectively identify and assess risks, ensuring a comprehensive risk management approach. This is essential for maintaining the stability and reliability of the supply chain for CPT systems, ultimately contributing to the success of the capacity expansion projects.

2.2.4. Improve & Control – Risk Mitigation

1. Literature Review:
   - (Jüttner et al., 2003): This study discusses various risk mitigation strategies such as avoidance, control, cooperation, and flexibility. These strategies are crucial for developing effective solutions to mitigate risks and ensure the continuity of the supply chain. In the context of this research on the delivery and installation of CPT systems, these strategies are applied as follows:
     - Avoidance: Avoiding risks by not operating in high-risk markets or product areas. This may involve Urenco dropping specific suppliers or markets if the supply is deemed unreliable, which is essential for minimizing disruptions in the delivery of CPT systems.
     - Control: Managing risks by taking proactive measures, such as building additional inventories or maintaining excess capacity in production and logistics. This helps reduce uncertainties and ensures the stability of the delivery and installation of CPT systems.
     - Cooperation: Collaborating with other organisations in the supply chain to reduce uncertainties. This includes joint agreements to improve visibility and understanding of the supply chain and sharing information about specific risk sources, which is crucial for coordination between different Urenco sites.
     - Flexibility: Increasing responsiveness without changing the predictability of factors. Examples include postponement and multiple sourcing, which allow for shorter delivery times and faster responses, important for quickly reacting to variability in the demand for CPT systems.

2. Techniques & Models:
   - **Business Case** (Rijksorganisatie voor Ontwikkeling, 2023): This technique assesses the feasibility and effectiveness of proposed solutions. A business case evaluates the potential benefits, costs, and net benefits, as well as the risks associated with implementing the solution. In this research, this technique will be used to evaluate the proposed risk mitigation measures and their impact on the delivery and installation of CPT systems.
   - **Scenario Analysis and Sensitivity Analysis** (Capital City: Training & Consulting, 2023): These techniques help ensure the effectiveness of solutions in different scenarios. Scenario analysis helps understand possible outcomes and provides a comprehensive analysis of the proposed measures. Sensitivity analysis assesses the robustness of the solution by examining how changes in key variables

affect the results. These techniques will be applied to ensure the resilience of the risk mitigation measures in this research.

- **Improvement mapping to process**: Based on insights during the Define, Measure, and Analyse phase, the researcher proposes solutions to reduce risk and integrates them into the process model (Figure 12).

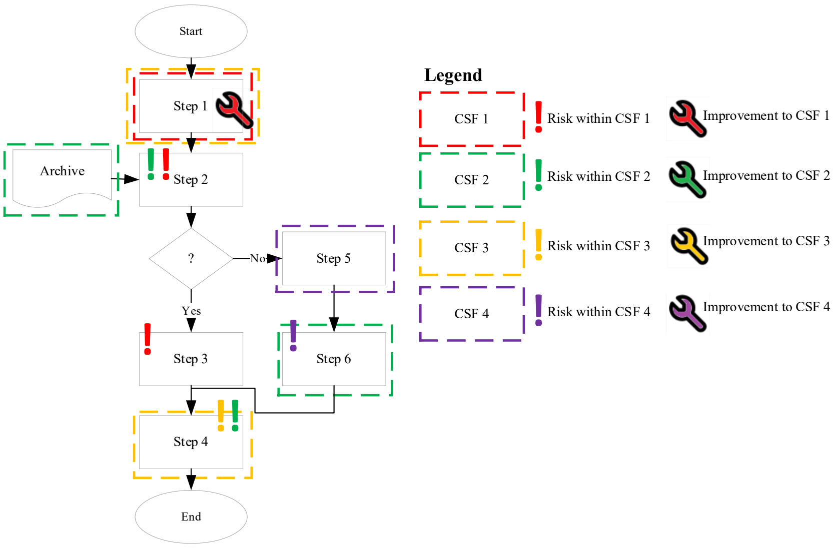

Figure 12: Example of proposed solution for CSF 1 to the Process Flow Diagram

This ensures that the proposed measures directly contribute to improving the delivery and installation of CPT systems.

3. Logic/Need: Developing solutions to mitigate risks is essential to maintain the continuity and efficiency of the process. The literature provides strategies to achieve this, supported by the techniques and models used. By applying these strategies, this research can develop effective risk mitigation measures that contribute to the stability and reliability of the supply chain for CPT systems.

Chapter conclusion

This chapter established a theoretical and literature framework to address the action problem. The relevant literature field of Supply Chain Risk Management (SCRM) is explored, to provide the necessary context and insight to develop effective risk mitigation strategies. The perspectives within SCRM - Risk Identification, Risk Assessment, and Risk Mitigation – are integrated into the DMAIC methodology. By linking each DMAIC phase to these perspectives, a structured and systematic approach to managing risk within the supply chain is created. Throughout the chapter, the relevant literature, techniques, and models are discussed for each DMAIC phase, highlighting their necessity and essence.

Chapter 3 focuses on the Define phase, which identifies and defines the problem in detail, setting the foundation for the subsequent phases.

3. Define: Process of CPT System Delivery in Global Capacity Expansions

Chapter introduction

This chapter identifies and defines the process of CPT system delivery in global capacity expansions, how information flows between the Commodity Team and the Project Expansion Team, and how they interact with each other. It defines CPT systems and clarifies their timing in different capacity expansion projects. This chapter addresses the following sub-research question:

1.What does the process of delivering and installing CPT systems in global capacity expansions entail?

The chapter is divided into the following sections:

- *Section 3.1:* ***Methodology*** *– Presents the methodology to address the sub-research question.*
- *Section 3.2:* ***Core Process Technology Systems*** *– Defines CPT systems.*
- *Section 3.3:* ***Timeline for CPT Systems****– Outlines the timeline of CPT systems required for global capacity expansions.*
- *Section 3.4:* ***Process Regarding CPT System Delivery in Global Capacity Expansions*** *– Illustrates the processes involved.*

3.1. Methodology

Table 2 already presented the sub-research questions, data collection methods, techniques & models, and deliverables for the DMAIC-methodology. Below is an excerpt focussing on the Define-phase, reiterating the relevant details.

Extracted from Table 2: Sub-research questions, methods, techniques & models, and deliverables, (Section 1.4.)

Sub-research questions	Data collection methods	Techniques & models	Deliverables
Define			
1.What does the process of delivering and installing CPT systems in global capacity expansions entail?	-Semi-structured interviews with key stakeholders. - Urenco's intranet	- Process Flow Diagram. -Gantt charts.	-Process of CPT system delivery in global capacity expansions.

3.1.1. Methodology

Semi-structured interviews with key stakeholders and Urenco's intranet are used to derive insights of the process regarding CPT system delivery in global capacity expansions. Urenco's intranet provides information on the definition and content of CPT systems required for global capacity expansions to enrich uranium. In addition, the ten-year timeline for CPT systems required in various global capacity expansions is obtained from the intranet.

Semi-structured interviews are conducted with one person from each key stakeholder group (Procurement, Asset Management, Design Authority, Research & Development, Project Management, and a CPT supplier). In total**, six people** are interviewed. The aim was to gain specific insights and confirm details of the process and its interactions.

Semi-structured interviews are chosen for their flexibility and depth. This method combines pre-established questions with the ability to explore relevant issues further, resulting in comprehensive and detailed information. This approach allows for the collection of both specific and unexpected insights, which are essential for the analysis of complex processes. The open-ended questions covered various aspects of the process, categorised and illustrated with an example in Table 6. The total of questions can be found in Appendix F.

Table 6: Categories of questions with examples and key points of agreement and disagreement from the interviews with key stakeholders

Question category	Example	Unanimously agreed	Unanimously disagree
Definitions	"What is the definition and time perspective of CPT systems in capacity expansions?"	A project has a clear start and end point.	
Process Steps	"What steps are involved in the process and in which sequence?"	Parallel activities make it difficult to follow a clear process.	The parallel way processes run.
Decision-Making	"What decisions are made?" and "What documents are crucial and how do these move through the process?"	Alignment with suppliers on CPT systems needed across Urenco is a continuous process and not project driven.	Information flow between teams.
Communication	"Who are involved and how do they interact during the process?"	Different stakeholders with different interests and multiple groups talking into suppliers add complexity.	Responsibilities for communication with suppliers.
Management	"What is required for capacity expansions and how are various capacity expansions managed?"	General requirements for capacity expansions.	

3.1.2. Findings

The interviews revealed several key challenges in the CPT system delivery process, particularly regarding a difference of opinion on who plays the dominant role in communication with suppliers. A critical finding is the importance of **transparent stakeholder communication** between the Commodity Team, the Project Expansion Team, and the suppliers (Chapter 4). This information flow is essential for successful capacity expansions. The data obtained can be found in Appendix G.

However, due to the involvement of three groups of stakeholders – the Commodity Team (four departments), the Project Expansion Team (eight departments) and multiple suppliers – there are **inconsistencies** in the process. These inconsistencies refer to differences or contradictions in how information is communicated and understood between teams, leading to **different interpretations** and an unclear understanding of the process. For example, inconsistencies can manifest as delays in decision-making, conflicting instructions to suppliers, or misunderstandings about project timelines and responsibilities.

Summary of Table 6

- Definitions: There is agreement that a project has a clear start and end point. However, no specific disagreement is mentioned in the table.
- Process Steps: There is agreement that parallel activities make it difficult to follow a clear process. There is disagreement on the way parallel processes run.
- Decision-Making: There is agreement that alignment with suppliers on CPT systems is a continuous process and not project driven. There is disagreement on the information flow between teams.
- Communication: There is agreement that different stakeholders with different interests and multiple groups talking to suppliers add complexity. There is disagreement on the responsibilities for communication with suppliers.
- Management: There is general agreement on the requirements for capacity expansions. No specific disagreement is mentioned in the table.

For example, the Project Expansion Team believes that they make the key decisions and dominate the discussions with suppliers:

- **Project Expansion Team perspective**: *"We are the ones who make the decisions and have the most interaction with suppliers. Our role is crucial in coordinating and managing the communication".*

On the other hand, the Commodity Team sees itself as the dominant party in this communication:

- **Commodity Team perspective**: *"Our team has the deepest knowledge of suppliers and their capacities. We are the ones who define and maintain the strategic relationship and the most important transactions".*

These different perspectives highlight the inconsistencies in the process. The Project Expansion Team belief that they are the primary decision-makers can lead to delays and confusion if the Commodity Team, who sees themselves as the main point of contact for suppliers, provides conflicting instructions. This misalignment can result in suppliers receiving mixed messages, causing delays and inefficiencies in the project timeline.

To further clarify, the researcher also gained insight into the perspective of a supplier long associated with Urenco:

- **Supplier perspective:** *"We primarily discuss long-term capacity and system needs across Urenco with the Commodity Team, as that is where our relationship starts. The Project Expansion Team contacts us mainly about specific engineering questions related to the expansion project".*

This supplier perspective underscores the inconsistencies in communication. While the Commodity Team focuses on long-term strategic relationships, the Project Expansion Team's interaction is more project specific. This division can lead to gaps in communication and understanding, further complicating the process.

3.1.3. Process Visualisation

Section 3.4. explains the identified inconsistencies by detailing the information flows and decisions between relevant stakeholders, as visualised in the Process Flow Diagram (Figure 16). Based on the insights of nine interviewees, this diagram clarifies responsibilities and interactions. It helps to resolve ambiguities or overlaps across stakeholders. The researcher created this visual representation based on their own interpretation and validated it through discussions with some of the stakeholders to ensure it reflects the process. Table 7 summarises the key points of agreement and disagreement from the key stakeholder interviews.

3.2. Core Process Technology Systems

A system can be defined as a collection of interrelated and interdependent components that together form a complex whole and function as a unit to fulfil a specific purpose (Intranet Urencogroup, n.d.). In the context of this research, it refers to the CPT systems that work together to perform the uranium enrichment process. The uranium enrichment process comprises five system groups (Table 7): uranium hexafluoride system (400), control & instrumentation system (500), mechanical utility system (600), electrical utility system (700), and site, building & landscape system (800). System group 400 directly engage with the cascade header pipework & centrifuge. The remaining four system groups serve to support its proper functioning in the uranium enrichment process.

Table 7: Overview of system groups in uranium enrichment process

System group nr. and name	System group description
400: Uranium hexafluoride system	systems directly connected to the cascade header pipework & centrifuges.
500: Control & instrumentation system	network of systems needed for complete overview, management, and monitoring.
600: Mechanical utility system	mechanical support systems for proper functioning of cascade header pipework & centrifuge.
700: Electrical utility system	electrical support systems for proper functioning of cascade header pipework & centrifuge.
800: Site, building & landscape system	facility support systems that serve as foundation for cascade header pipework & centrifuge.

The interaction between these system groups can be compared to the functioning of the human body, in which all organs must work properly for optimal function. System group 400 functions as the heart, essential for circulation. System group 500 acts as the brain, regulating operations. System group 600 represents blood circulation, supplying resources. System group 700 corresponds to the hearts' electrical system, coordinating and synchronising activities. Finally, system group 800 serves as the rib cage, providing protection. Figure 13 illustrates these analogies.

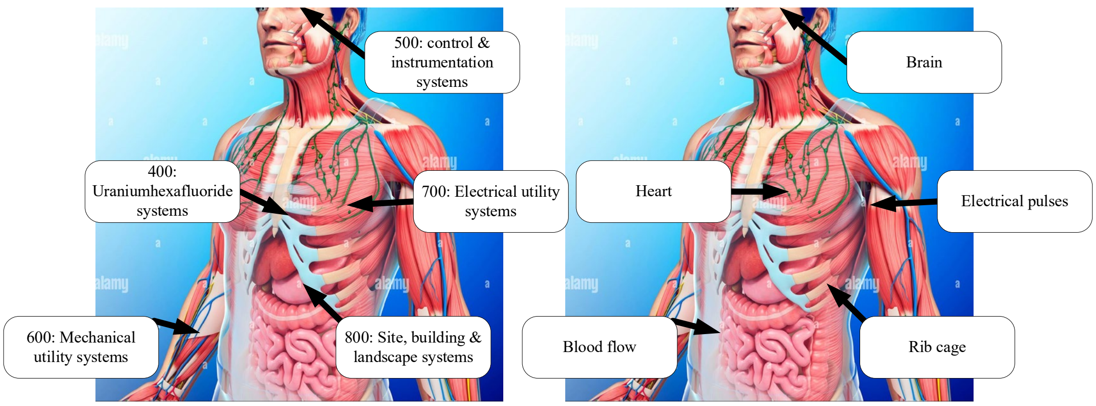

Figure 13: Analogies between Urenco system groups (left) and human organs (right)

The system groups (400 to 800) contain various systems such as [redacted] , [redacted] , [redacted] , [redacted] , [redacted] , and more. Each system has several subsystems. For example, the [redacted] , with the purpose to provide electrical power to the centrifuge, consists of six subsystems: [redacted] , [redacted] , [redacted] , [redacted] , [redacted] , and [redacted] Figure 14 illustrates an example of system classification with system groups, systems, and subsystems. The timely delivery and installation of CPT systems necessitates consideration of the entire interfaces as all groups (400 to 800) are interdependent.

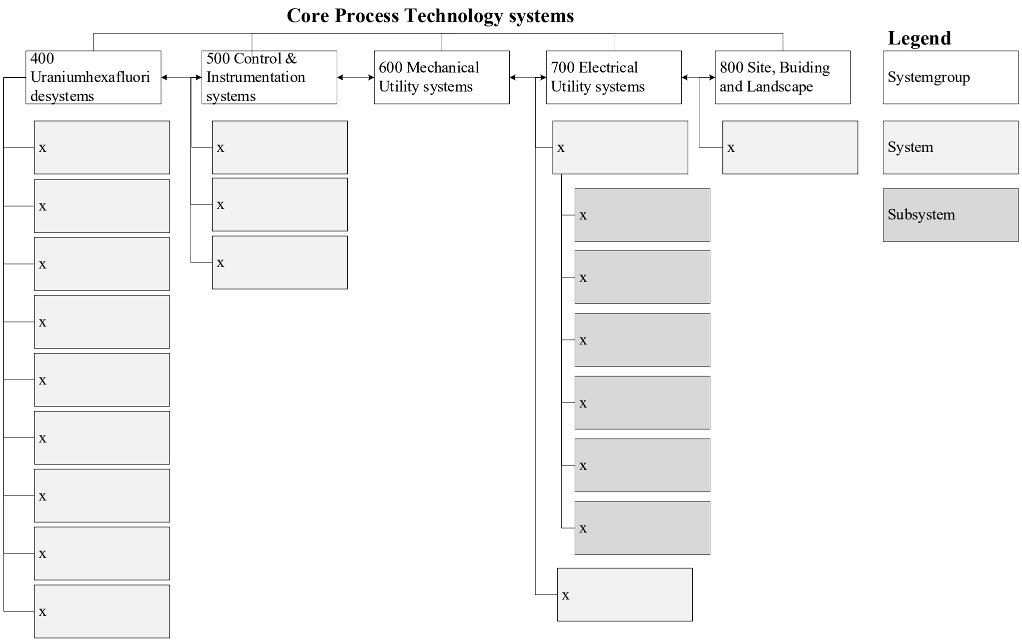

Figure 14: Example of a system classification with system groups, systems, and subsystems.
*Note: systems in system group 600 are excluded from this system classification because they include systems outside Core Process Technology

3.3. Timeline for CPT Systems in Global Capacity Expansions

Capacity expansions are planned in order of priority over the next ten years and are allocated to a specific Urenco site (Urenco Netherlands (UNL), Urenco United Kingdom (UUK), Urenco United States of America (UUSA), or Urenco Deutschland (UD)). Each capacity expansion plan is translated into a project plan with a deadline for project completion. According to the Project Expansion Team, the total duration of a capacity expansion project is generally **six years**. The deployment of the uranium enrichment process in a capacity expansion plan depends on the availability of CPT system groups, which consist of systems and subsystems that interface with the Cascade Header Pipework & Centrifuges, Section 3.2. There is no single point in time when all system groups are delivered and installed. Based on previous project schedules, **the delivery and installation of all CPT system groups should occur over a two-year period. This period must be timed to fall between three and one years before the project deadline. Avoiding late delivery of CPT system groups is essential to avoid disruption to the project.**

The Gantt chart (Figure 15) shows that CPT system groups are required at both overlapping and sequential times at different Urenco sites. For example, two capacity expansion plans (UD and UUSA) require CPT systems at the same time. In addition, the subsequent capacity expansion project at UNL may overlap with these two projects and require CPT systems shortly after the initial projects have started. This research therefore focuses on the activities that occur both before and during the delivery and installation of CPT systems. Specifically, the research covers:

- Three years of pre-delivery activities
- Two years of activities during delivery and installation.

In total, this research examines a **five-year period**, which is a subset of the overall project timeline. By focusing on this critical five-year window, the research aims to provide detailed insights into the processes associated with the delivery and installation of CPT systems.

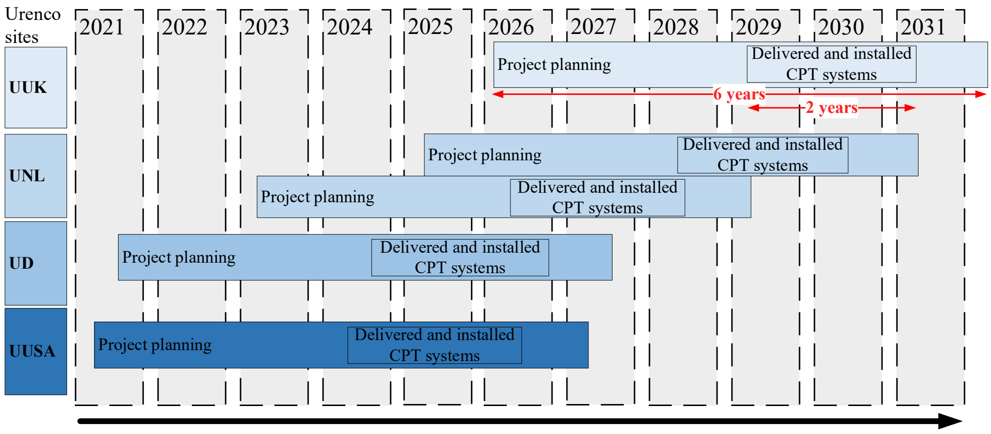

Figure 15: Schematic representation of 10-year project portfolio

3.4. Process of Delivering and Installing CPT Systems in Global Capacity Expansions

The process (Figure 16) includes two parallel processes, each with its own characteristics and interests, that are essential to Urenco's capacity expansions: the Commodity Process (green colour coding), and the Expansion Project Process (blue colour coding). **The Expansion Project Process is dependent on the Commodity Process for supplier information and capacity**, highlighting how the two processes are integrated and interdependent (Figure 16).

3.4.1. Commodity Process

The infinite Commodity Process aims to define strategies to secure supplier commitment for the required CPT systems over the 10-year demand outlook for future enriched uranium. The relevant Commodity Team is responsible for the various 'commodities', i.e., groups of systems, required for global capacity expansions. Suppliers are involved in the Commodity Process to obtain information about their systems, services, and capabilities in relation to Urenco's 10-year project portfolio. The frequency of the Commodity Process loop is determined by project demand, planning, number of suppliers involved, and the number of commodities involved. The process is continuous and adapts to changing requirements and circumstances.

3.4.2. Expansion Project Process

The Expansion Project Process is an illustration of a single project example applicable to any project in the 10-year project portfolio (Figure 15). This unique process covers the specific activities and decisions required to implement a single capacity expansion plan. The dedicated Project Expansion Team is responsible for a site-specific capacity expansion project. The supply and installation of CPT systems requested for this specific capacity expansion is part of the Expansion Project Process. Suppliers are involved in developing the detailed design specification of the required CPT systems and transport and deliver them to the appropriate Urenco site. Table 8 shows the different categories of times **directly** relevant to the supply and installation of CPT systems involving CPT suppliers and indicates where in the process these times occur.

Table 8: Overview of categories of times directly relevant to supply and installation of CPT systems

Process nr and step	Type of time	Description
7.Engineer technical details	Design time	Time taken by suppliers to develop detailed design specifications.
8.Produce systems	Production time	Time required for manufacturing and testing of CPT systems by suppliers.
9.Transport and deliver systems	Delivery time	Time required for transportation of CPT systems to the Urenco site, including any customs or regulatory delays.
10.Install systems	Installation time	Time required to install the systems on site, including adjustments or calibrations

3.4.3. Communication and Information Flow

In this research, the communication and information flow between the Commodity Team, the Project Expansion Team and the Suppliers is identified later as critical (Chapter 4). They are therefore highlighted in this section (Table 9). The Commodity Team provides input to the Project Expansion Team via four different information flows including the 10-year project portfolio, CPT developments, supplier engineering time, and supplier lead time. In addition, there are five information points between the Commodity Team and suppliers including the request for information, demand planning, production slots, supplier engineering time, and supplier lead time. Finally, there are six information points between the Project Expansion Team and suppliers including supplier engineering time, supplier lead time, design specification, scope of work, purchase order, and the detailed design specification. This complexity is further compounded by two factors (see Table 9 and Figure 16).

1. **Overlap of Responsibilities:** there is a significant overlap of responsibilities between the Commodity Team and the Project Expansion Team. For example, both teams are involved in managing supplier engineering and lead times.
2. **Supplier Interaction Focus:** the Commodity Team interacts with suppliers primarily to identify qualified suppliers and gather information about their capabilities. In contrast, the Project Expansion Team coordinates with suppliers on project-specific issues, such as detailed design specifications and project schedules.

Communication between the Commodity Team and the Project Expansion Team is currently informal. The teams operate independently and rely on each other for information, but there are no formal meetings with all relevant stakeholders. This leads to several communication issues:

- **Informal discussions**: communication is based on informal discussions between some members of each team. As a result, not all stakeholders are equally informed.
- **Email communication**: information is mainly shared via email, often without ensuring that it is clear to the recipients. This can lead to misunderstandings and incomplete information transfer.
- **Lack of frequency**: there is no set frequency for communication, which means that updates and important information may not be shared in a timely manner.

- **Unclear responsibilities**: responsibilities for communication are not clearly defined. It is not explicitly documented who should be involved in which steps, leading to confusion and inefficiency.
- **Dependency without coordination**: the teams are dependent on each other for information, but there is no formal coordinator to ensure that the information is accurate and complete.

Dealing with delay: In the event of a delay, projects are rescheduled, and priorities are revised to minimise the impact on the overall capacity expansion. This may involve postponing certain projects or allocating additional resources to address delays. Urenco aims to mitigate the negative effects of outages on capacity expansion. For example, if a supplier lacks sufficient production slots (decision after *process step IX)*, and scaling up is not an option, the Commodity Team must consider revising the forecast (*process step X.b)*. If feasible, the schedule is adjusted (*process step XI.a)* and communicated to suppliers. If it is not possible to adjust the schedule (*process step XI.b)*, the Commodity Team must return to supplier selection, conduct pre-investigation, and qualify and contract a new supplier before proceeding.

Table 9: Information flows in process with description. 'X' indicates which stakeholder is involved

Commodity Team	Project Expansion	Suppliers	**Document / information flow**	**Description**
			Commodity Process	
X	*X*		10-year project portfolio	overviews all capacity program expansions planned for next 10 years.
X			CPT designs	Contains site-generic designs of CPT systems.
X	*X*		CPT developments	outlines CPT system developments for next 10 years.
X		*X*	Request for information	gathers information from suppliers about their systems, services, and capabilities.
X			CPT suppliers	identifies the qualified suppliers for CPT systems.
X		*X*	Demand planning	forecasts future demand for CPT systems to align production and inventory.
X		*X*	Production slots	specifies the time periods for production in a manufacturing facility.
X	*X*	*X*	Supplier engineering time	records the time suppliers spend on design, development, and testing.
X	*X*	*X*	Supplier lead time	outlines the total time needed by a supplier to process and deliver an order.
			Expansion Project Process	
	X		Project scope	describes the goals, deliverables, and boundaries of a project.
	X		System breakdown	details a systems' components and subcomponents.
	X		Project planning	outlines the goals, tasks, timeline, and resources for a project.
	X	*X*	Design specification	provides the technical and functional requirements of a system.
	X	*X*	Scope of work	outlines the project tasks and system schedules.
	X	*X*	Purchase Order	confirms an order, including quantities, prices, and delivery- and installation terms.
	X	*X*	Detailed design specification	details a comprehensive description of a technical systems' design.

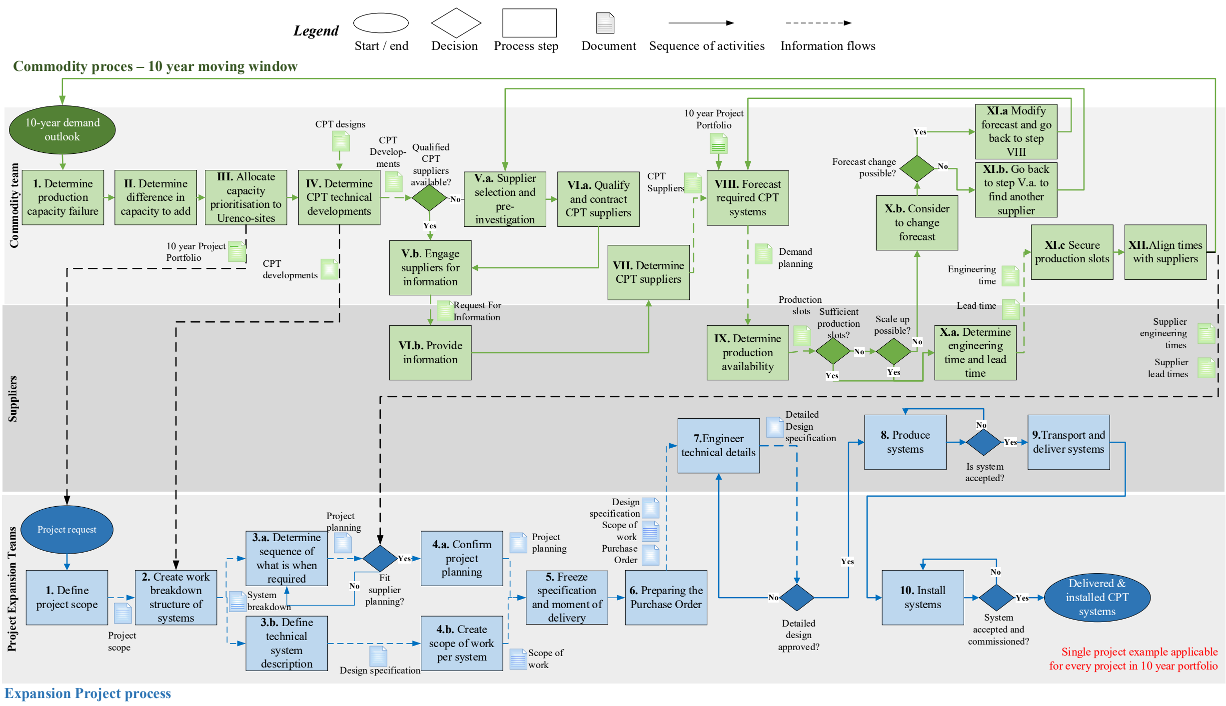

Figure 16: Process model of CPT system-delivery in global capacity expansions

Chapter conclusion

This chapter included the processes of delivering and installing CPT systems in global capacity expansions. The Commodity Process and the Expansion Project Process run in parallel to ensure efficient delivery. The infinite Commodity Process secures supplier commitment for CPT systems over a 10-year period, managed by the Commodity Team. The Expansion Project Process details the activities and decisions for single capacity expansion projects, executed by the Project Expansion Team. Suppliers play a crucial role in both processes, providing system information and securing production slots in the Commodity Process, and developing detailed designs and delivering CPT systems in the Expansion Project Process. Various documents flow through these processes. It is therefore important that all stakeholders involved have a clear and shared understanding.

The process model illustrated in Figure 16 is quite complex. Therefore, Chapter 4 (Measure phase) delves deeper into identifying what makes this process critical and identifies and maps the Critical Success Factors (CSFs) essential for timely delivery and installation of CPT systems.

4. Measure: Critical Success Factors

Chapter introduction

This chapter identifies the Critical Success Factors (CSFs) in the processes involved in delivering CPT systems for global capacity expansion. It quantifies the impact associated with each CSF, highlighting the additional time and resources required if these factors are not properly managed. It also analyses the links between stakeholders and the CSFs they identify, grouping these factors into clusters. This chapter addresses the following sub-research questions:

2.a. What are the Critical Success Factors to achieve a timely delivery and installation of CPT systems in global capacity expansions?
2.b. Where do these Critical Success Factors fit within the process?

The chapter is divided into the following sections:

- *Section 4.1:* ***Methodology*** *– Presents the methodology to address the sub-research question.*
- *Section 4.2:* ***Definition of Critical Success Factors*** *– Defines CSFs within this research's context.*
- *Section 4.3:* ***Critical Success Factors Identified****– Identifies CSFs, analyses stakeholder relationships, and groups CSFs into clusters.*
- *Section 4.4:* ***Clustering Critical Success Factors*** *– Clusters the identified CSFs.*
- *Section 4.5:* ***Critical Nature of Critical Success Factors*** *– Emphasises the critical nature of CSFs through quantification.*
- *Section 4.6:* ***Critical Reflection on Critical Success Factors*** *– reflects on the identification and quantification of CSFs.*

4.1. Methodology

Table 2 already presented the sub-research questions, data collection methods, techniques & models, and deliverables for the DMAIC-methodology. Below is an excerpt focussing on the Measure-phase, reiterating the relevant details.

Extracted from Table 2: Sub-research questions, methods, techniques & models, and deliverables (Section 1.4)

Sub-research questions	Data collection methods	Techniques & models	Deliverables
		Measure	
2.a. What are the Critical Success Factors to achieve a timely delivery and installation of CPT system delivery in global capacity expansions? 2.b. Where do these Critical Success Factors fit within the process?	-Semi-structured interviews with key stakeholders.	-Bottom-Up affinity diagramming. - Grounded Theory. -Critical Success Factors framework. -Impact calculation -Critical Success factor mapping.	-Critical Success Factors. -Critical points in process.

4.1.1. Methodology

Data Collection: Semi-structured interviews are conducted to identify the CSFs that ensure the timely delivery and installation of CPT systems. Interviews are conducted with one person from each key stakeholder group (Procurement, Asset Management, Design Authority, Research & Development, Project Management, and a CPT supplier). In total**, six people** are interviewed.

A hybrid approach, incorporating elements of **Grounded Theory**, are applied to identify CSFs. This approach develops theories based on systematically collecting and analysing data (McLeod, 2024). Instead of starting with existing clusters, assumptions or theories, the researcher allows the theory to "emerge" from the data. This data-driven approach relies on stakeholder input to determine CSFs. The process involves iteratively collecting and analysing data, identifying themes and patterns until **theoretical saturation** is reached, meaning no new insights are gained from further data collection. This ensures a comprehensive understanding of the CSFs by closely listening to the experiences and perspectives of participants.

Broad and open-ended questions are asked to allow stakeholders to identify various CSFs without being influenced by predefined categories. For example:

- *"What factors do you consider crucial for achieving a timely delivery and installation of CPT systems?"*
- *"What key aspects should be focused on to achieve a timely delivery and installation of CPT systems?"*

This approach ensures unbiased and data-driven data collection, capturing a wide range of perspectives on what is crucial for the timely delivery and installation of CPT systems. The objective of the interview, the stakeholder population and the questions posed are presented in Appendix H.

Quantification of Impact: To quantify the impact of the identified CSFs on the timely delivery and installation of CPT systems, ranges are used to represent potential delays. These ranges are defined by a Lower Bound (LB) and an Upper Bound (UB). The LB represents the minimum expected impact, while the UB represents the maximal expected impact. This approach is used due to the inherent uncertainty and variability, as stakeholders are unable to provide exact delay times. By maintaining these ranges, the analysis can account for different potential outcomes and provide a more comprehensive risk assessment.

4.1.2. Findings and Analysis

During the semi-structured interviews, each stakeholder group provided valuable insights into the factors they considered critical to the timely delivery and installation of CPT systems. Table 10 summarises these key insights, highlighting the specific concerns and priorities of each stakeholder group. These insights form the basis for the identification of the CSFs presented in Table 11.

Reflection on insights and Process Model: The insights from Table 10 emphasise the importance of communication among the involved stakeholders. These insights align with the process model, as outlined in Chapter 3, as follows:

- **Procurement**: The emphasis on effective relationship management and early involvement of suppliers aligns with the Commodity Process, where suppliers are engaged early to provide information about their systems and capabilities.

- **Asset Management:** The need for proactive planning and clear demand information is reflected in the demand planning and production slots within the Commodity Process. This helps suppliers match their capabilities with project requirements, as highlighted by Asset Management.
- **R&D:** The necessity for clear and detailed project specifications is emphasised in the Expansion Project Process, where detailed design specifications and scope of work are developed.
- **DA:** Transparent communication about specifications between suppliers, the Commodity Team, and the Project Team is supported by the various information flows and communication points in both processes. This ensures that specifications remain consistent and accurate throughout the project lifecycle.
- **Project Management**: The importance of a well-defined project scope and clear specifications is reflected in the project planning and design specifications in the Expansion Project Process. The reliance on the Commodity Team for information and capacity underscores the need for clear and timely communication.
- **Suppliers:** The emphasis on early involvement and clear communication channels aligns with the information flows between the Commodity Team, Project Expansion Team, and suppliers in the process model. Early supplier involvement and transparent communication are crucial for successful collaboration.

Table 10: Key insights from interviews

	Key insights
Procurement	Procurement emphasised the importance of effective relationship management with suppliers. They believe that early involvement of suppliers and transparency in planning are critical for building strong relationships. This collaboration is critical throughout the project lifecycle. They also highlighted the need to have a pool of qualified suppliers to choose from and the importance of accurate forecasting and capacity reservation to avoid bottlenecks.
AM	Asset Management highlighted the need for proactive planning to ensure efficient resource utilisation. They emphasised the importance of providing suppliers with clear and generic demand information to match their capabilities with project requirements.
R&D	R&D focused on the need for clear and detailed project specifications. They pointed out that any ambiguity in the project scope or specifications can lead to significant delays and errors during execution. Clear communication of specifications between teams is essential to avoid these problems.
DA	DA highlighted the importance of transparent communication on specifications between suppliers, the commodity team, and the project team. They emphasised that specifications should be finalised, and "frozen" once orders are placed to ensure consistency and accuracy throughout the project lifecycle.
Project Management	Project Management underscored the criticality of having a well-defined project scope and clear specifications. They stressed the importance of clear prioritisation of projects by the commodity team and ensuring that capacity is reserved. They rely heavily on the groundwork laid by the commodity team and need transparent communication to manage their projects effectively. They emphasised that they are the ones who need to collaborate closely with suppliers during the engineering phase, as suppliers play a crucial intermediary role.
Supplier	Suppliers emphasised the need for early involvement in the project planning stages and the importance of having clear communication channels with all stakeholders. They highlighted that the more transparent Urenco is, the better they can respond and plan accordingly. Collaboration throughout the process is crucial to them. Suppliers also noted the importance of receiving general demand information to remain flexible for specific project needs and stressed that specifications should not be changed after being sent to avoid re-engineering delays.

Transition from individual stakeholder key insights to twelve CSFs: The transition from individual key insights (Table 10) to the identification of twelve CSFs (Table 11) involved two steps using a hybrid approach incorporating elements of Grounded Theory:

1. **Iterative analysis and Synthesis**: The data from the semi-structured interviews is analysed by identifying common terms and themes mentioned by multiple stakeholders. Instead of formal coding, the analysis focused on recurring terms and themes. For example:
    a. Terms such as 'early supplier involvement' and 'transparent communication' are frequently mentioned and identified as key factors. The key insights from each stakeholder group are reviewed to identify these common themes and concerns. Recurring themes and factors mentioned by several stakeholders are noted as potential CSFs. For example, the need for clear project specifications is highlighted by R&D, DA, and Project Management, leading to the identification of 'specification clarity' as a CSF.

2. **Validation and Theoretical Saturation:** The potential CSFs are validated through further analysis and discussion to ensure that they accurately reflected the CSFs identified by the stakeholders. Each stakeholder is visited separately to achieve consensus among all stakeholders. This process also involved refining the CSFs to ensure clarity and relevance. For example:
    a. ‘Transparent stakeholder communication' is identified as a CSF because it was consistently mentioned by all stakeholder groups.

    Theoretical saturation is reached when further data analysis does not yield new insights, indicating that the collected data is sufficient to develop a comprehensive theory. For instance:
    b. After multiple rounds of discussions and no new CSFs being identified, it is concluded that the data collection was comprehensive and complete.

To gain insight into the criticality of each CSF, the identified twelve CSFs are mapped onto the established process model. This mapping involves associating each CSF with specific stages and activities within the process, highlighting where each factor plays a critical role. This visualisation helps to identify the impact of each CSF on the overall process and assists in estimating potential delays.

4.2. Definition of Critical Success Factors

A CSF is defined according to (Wuni & Shen, 2020) as “a specific element, condition or variable that is essential to the success of an organisation or project”. Identifying CSFs helps to focus efforts on the most critical areas, thereby narrowing the scope to ensure success. The success of an organisation or project is often measured against predefined objectives (Wuni & Shen, 2020). In this research context, the predefined objective is the delivery and installation of CPT system groups three to one years before project deadline in global capacity expansions (refer to Gantt-chart in Figure 15).

CSFs are factors that are critical to ensure this delivery and installation of CPT system groups within a two-year period, specifically three to one years before the project deadline, to avoid late delivery that could disrupt the project.

4.3. Critical Success Factors Identified

Based on the insights gathered from the stakeholders (Table 10), twelve CSFs are identified as critical for the delivery and installation of CPT systems within a two-year period. Table 11 represents the CSFs, indicating with an 'X' which stakeholders identified each factor as critical. For a description of all identified CSFs, please refer to Appendix I.

Table 11: Critical Success Factors identified by key stakeholders

Note: The 'X' mark indicates which stakeholders identified each factor as critical. They are color-coded by cluster. Red for Supplier Relationship Management, Orange for Dialogue Specification and Scope, Green for Enterprise Planning, and Purple for Stakeholder Transparency

Critical Success Factors	Key Stakeholders					
	Procurement	Asset Management	R&D	DA	Project management	Supplier
1. Supplier collaboration	X				X	X
2. Project scope clarity			X	X	X	
3. Qualified suppliers	X				X	X
4. Proactive system forecasting	X	X			X	
5. Specification clarity			X	X	X	X
6. Project prioritisation					X	
7. Transparent stakeholder communication	X	X	X	X	X	X
8. Demand generality			X	X	X	X
9. Capacity reservation	X				X	
10. Engineering- and lead time alignment	X				X	X
11. Early supplier involvement	X					X
12. Specification frozen-based ordering			X	X	X	X

Key findings from the table are in line with the specific roles and responsibilities of the stakeholders, as described in Appendix C and Appendix D:

- **Procurement and Supplier:** Supplier collaboration, qualified suppliers, and early supplier involvement are critical for Procurement and the Supplier. This is because both stakeholders are directly involved in the supply chain. It makes sense they consider these factors important because collaboration, qualification, and supplier involvement directly affect their work.
- **Project Management and R&D:** Project scope clarity and specification clarity are important for Project Management and R&D. These roles focus on the technical details and specifications of projects. Lack of clarity in these can lead to delays and errors.
- **Asset Management and DA:** Proactive system forecasting is important for Asset Management, while demand generality is important for DA. These differences reflect their unique responsibilities. Asset Management focuses on forecasting system needs to ensure efficiency, while DA focuses on understanding and managing demand.

- **Procurement and Project Management:** Both stakeholders find factors such as Proactive system forecasting, Project prioritisation, Capacity reservation, and Engineering and lead time alignment critical. This is because both roles are involved in strategic planning and resource coordination, which is essential for managing resources and time efficiently.
- **Project Management:** Project Management finds almost all the CSFs important because their role touches on all aspects of an expansion project. They are responsible for the coordination and success of the expansion project, which means that they must pay attention to a wide range of factors. This includes everything from supplier relationships to specification management and stakeholder communication.

4.4. Clustering Critical Success Factors

Clustering the CSFs identified through bottom-up affinity diagramming helps to reduce the complexity by grouping them according to common themes and interrelationships. This makes it easier to identify key areas of concern (Theisens, 2016). Clustering is based on a combination of the following four factors:

1. **Identification of CSFs**: identification of the CSFs that considered critical by stakeholders, as shown in Table 12. For example: Both Procurement and Suppliers emphasised the importance of early supplier involvement and transparent communication, leading to the identification of 'supplier involvement' as a CSF.
2. **Analysis of roles and responsibilities:** the roles and responsibilities of each stakeholder group (as described in Appendix C and Appendix D) help to understand why certain factors are considered critical for certain stakeholders. For example: Project Management and R&D emphasised the importance of clear specifications due to their focus on technical details, leading to the identification of 'specification clarity' as a CSF.
3. **Grouping of related factors**: grouping the identified CSFs based on their logical interrelationships and the common themes using affinity diagrams. For example, factors such as 'early supplier involvement', 'qualified suppliers', and 'supplier collaboration' are grouped together under the 'Supplier Relationship Management (SRM)' cluster because they all relate to the effective management of supplier relationships.
4. **Formation of clusters**: definition of clusters to address specific aspects, ensuring a holistic approach. The CSFs are grouped into four high-level clusters. For example: The 'Supplier Relationship Management (SRM)' cluster focuses on managing interactions with suppliers, while the 'Enterprise Planning' cluster addresses strategic planning and resource co-ordination. These clusters are interrelated, as effective supplier management supports better planning and resource allocation. Similarly, 'Dialogue Specification and Scope' ensures clear communication of project specifications, which is essential for both supplier management and enterprise planning. Finally, 'Stakeholder Transparency' underpins all clusters by promoting open communication and alignment between all stakeholders, ensuring that everyone is on the same page and working towards common goals.

The four clusters are as follows:

Cluster 1: Supplier Relationship Management (SRM): This cluster focuses on interaction and collaboration with suppliers, which is crucial for the quality and timeliness of deliveries. By grouping factors such as supplier collaboration, qualified suppliers, and early supplier involvement, it becomes clear that a good relationship with suppliers is essential for the success of the project. Table 12 shows that both Procurement and Supplier consistently identified these factors as critical (marked in red), highlighting the importance of effective supplier management.

Cluster 2: Enterprise Planning: This cluster includes strategic planning and resource coordination, which is essential for managing resources and time efficiently. Factors such as proactive system forecasting, project prioritisation, capacity reservation, and engineering and lead time alignment ensure that the project is properly planned and executed. Table 12 indicates that Project Management and Procurement consider these factors critical (marked in green), highlighting their shared focus on strategic planning and resource coordination.

Cluster 3: Dialogue Specification and Scope: This cluster focuses on defining and communicating specifications and project scope. Clear specifications and scope are essential to avoid misunderstandings and errors. By grouping factors such as project scope clarity, specification clarity, demand generality, and specification frozen-based ordering, the importance of clear communication and specifications is emphasised. Table 12 shows that DA, R&D and Project Management are involved in these factors (marked in orange). This supports the logic of this cluster, which focuses on defining and communicating specifications and project scope.

Cluster 4: Stakeholder Transparency: This cluster emphasises the importance of transparent communication between all stakeholders. Transparent stakeholder communication is essential to ensure that everyone is on the same page and that there are no misunderstandings. Although this cluster contains only one CSF, it is fundamental because it affects all other clusters and processes. Table 12 shows that all stakeholders consider this factor to be critical (marked in purple). This highlights the need for effective communication to ensure the success of the project.

4.4.1. Rationale for Cluster Selection

The four clusters provide a holistic approach to CSFs by each addressing a specific aspect (Table 13). These clusters are chosen to cover all key areas, from supplier relations to strategic planning, specification management and communication. Moreover, the clusters are interrelated and mutually reinforcing. Figure 17 visualise their overall coherence required for the timely delivery and installation of CPT systems.

Furthermore, the importance of these four clusters is supported by scientific literature, indicating that the chosen clusters are based on proven best practices and theoretical frameworks:

- Supplier Relationship Management (SRM) (Hukkanen, 2023); (Jones, 2024) emphasises the importance of cooperation, trust, and mutual benefits in SRM.
- Enterprise Planning: (Ruuskanen et al., 2021) shows that proactive planning and capacity reservation are essential for efficiency.
- Dialogue Specification and Scope: (Robert et al., 2020) emphasises the importance of clear specifications and communication to reduce project risks.
- Stakeholder Transparency: (Oels, 2006) shows that transparent communication is crucial for alignment and avoiding misunderstandings.

Integration of risk management in clusters: (Elock Son, 2018) highlights the importance of risk management in the supply chain and the different strategies to mitigate risks. Although risk management is not explicitly mentioned by stakeholders, it is implicitly integrated into the existing clusters. Each cluster contributes to identifying, assessing, and mitigating risks by focussing on specific aspects, as detailed in Table 12.

Table 12: Focus area of each CSF cluster

Column ‘focus’ describes the focus area of each cluster. Column ‘essence’ explains why this focus area is important and what it is trying to achieve. Column ‘risk management’ shows how each cluster contributes to identifying, assessing, and mitigating risks in the supply chain.

CSF cluster	Focus	Essence	Risk management
Supplier Relationship Management (SRM)	Interaction and collaboration with suppliers.	Ensuring a reliable supply chain.	Reduces risks such as delivery delays and quality problems.
Enterprise Planning	Strategic planning and resource coordination.	Proactive system forecasting and capacity reservation.	Helps identify and mitigate risks such as resource shortages and scheduling conflicts.
Dialogue Specification and Scope	Defining and communicating of technical specifications and project scope.	Detailed and accurate specifications and scope to avoid technical misunderstandings and errors.	Avoids risks such as technical misunderstandings, specification errors, and project delays.
Stakeholder Transparency	Transparent and continue communication between all stakeholders during all processes.	Ensuring alignment, trust, and cooperation through open and frequent communication.	Ensures all stakeholders are aware of potential risks, promotes cooperation, and helps coordinate risk mitigation measures.

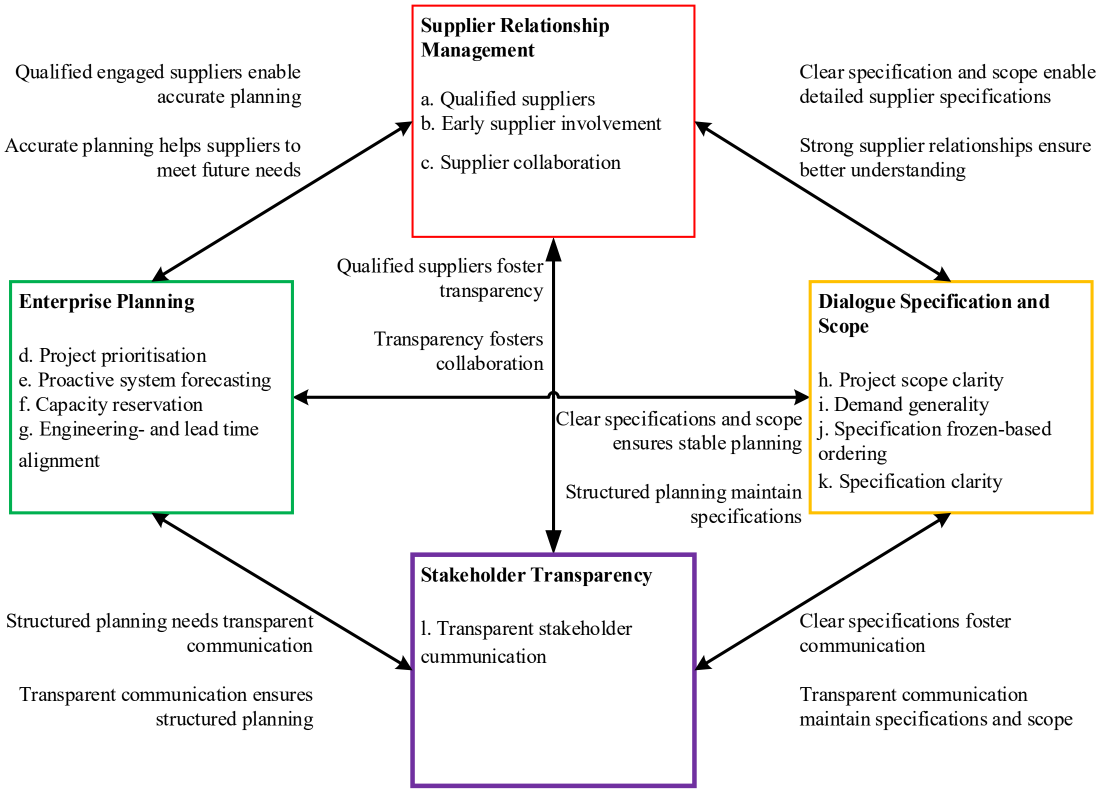

Figure 17: Critical Success Factor Framework with four clusters and a total of thirteen CSFs

4.5. Critical Nature of Critical Success Factors

To highlight the critical nature of each CSF, the researcher estimates its impact on the timely delivery and installation of CPT systems. The Expansion Project Process in Section 3.4., which includes **ten process steps**, is used to determine the brackets for these estimates. According to the Project Expansion Team, each process step takes approximately **six months** to complete. This estimate is based on the **average duration observed in previous projects** and validated by the **expertise of the Expansion Project Team**. Based on this assumption, the entire Expansion Project Process requires 60 months from project request to the delivery and installation of CPT systems, in line with the Gantt chart in Section 3.3. An additional year is required after delivery to complete the project. Therefore, **six months** is used as a bracket for quantifying impacts (Table 13). Given the similar complexity of the Expansion Project Process and the Commodity Process, the same classifications are used for consistency.

Table 13: Classification for CSF impact quantification

Short	0-3 months	a quarter of a process step
Medium	3-6 months	half to a full process step
Long	6-12 months	one to two process steps
Very Long	12–18 months	more than two process steps

Table 14 quantifies the impact quantification of delays caused by CSFs in different processes. Each column represents:

- Column 1: The CSF
- Column 2: In which process the CSF is critical.
- Column 3: To which process step, decision, or document the CSF is related.
- Column 4: The current Lower Bound (LB) delay time if the CSF is not properly managed.
- Column 5: The current Upper Bound (UB) delay time if the CSF is not properly managed.
- Column 6: The process step, decision, or document that is delayed if the CSF is not properly managed.
- Column 7: The additional process steps required if a decision is delayed or if the decision results 'no'
- Column 8: The current Lower Bound (LB) delay time for these additional process steps.
- Column 9: The current Upper Bound (UB) delay time for these additional process steps.

The estimates in columns 4, 5, 8, and 9 are based on a combination of logical assumptions derived from the process model (Figure 16) discussed in Chapter 3, and the criticality assessments of key stakeholders as shown in Table 14. Specifically, the following three points are considered to estimate the impact:

1. **Stakeholder Criticality Assessments**: The stakeholder assessments, as shown in Table 12, indicate which CSFs are considered critical. For example, transparent stakeholder communication is considered critical by all stakeholders, highlighting its high impact. This criticality is reflected in the estimated delay times, as higher criticality often correlates with higher delay potential. However, there are important exceptions:
    a. Specification Clarity: Although considered critical by four stakeholders, it is estimated to cause a delay of only 0-3 months. This is because, although it is critical, it deals with more tactical to operational issues within the Expansion Project Process.

b. Demand Generality: Also considered critical by four stakeholders and part of the Commodity Process, it is estimated to cause a delay of 0-3 months. The impact manifests in specific projects where suppliers may have to adjust their engineering schedules due to the lack of generality in the demand information provided by the Commodity Process.

2. **Assumptions Based on Process Interdependencies**: The interdependencies between the Commodity Process and the Expansion Project Process, as shown in Figure 16, are used to understand how delays in one process could lead to additional work or delays in the other. For example:
    a. Capacity Reservation: It is critical that capacity is reserved in the Commodity Process so that the Expansion Project Process can use it later. If capacity is not reserved, the Expansion Project Process must wait until the supplier has capacity available, or the Commodity Process must find another supplier who can provide capacity in a timely manner. This can cause significant delays in the project timeline.

3. **Strategic vs. Tactical/Operational Impact**: The impact of CSFs in the Commodity Process is relatively greater, as it deals with strategic issues that affect long-term supplier commitment and the overall project portfolio. In contrast, the impact of CSFs in the Expansion Project Process is lower, as it deals with specific projects and more tactical or operational issues. However, there are exceptions:
    a. Project Scope Clarity: Although part of the Expansion Project Process, it has a significant impact as it forms the basis for the entire project. An unclear project scope can delay the overall project schedule by 6-12 months.
    b. Proactive System Forecasting: Although critical in the Commodity Process, it has an estimated impact of only 0-3 months. This is because a reactive system forecast provides less predictability and planning time, making it more difficult for suppliers to efficiently allocate resources and plan production. This complexity can lead to initial delays but is generally manageable within a short timeframe.

By combining these assumptions with the findings from the stakeholder criticality assessments, Table 14 provides a reasoned approximation of the potential delays associated with each CSF. Sections 4.5.1. to 4.5.4. provide a detailed explanation of the impact of each CSF on the process model, including a rationale for how and why these factors influence the process.

Table 14: Impact quantification of delays caused by CSFs in different processes

Note*: the delay time for CSF l 'transparent stakeholder communication' is the cumulative sum of delays across several documents due to lack of transparency.

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
CSF	**Critical in proces**	**Critical to**	**Current delay time Lower Bound (LB)**	**Current delay time Upper Bound (UB)**	**Process being delayed**	**Extra steps ('no-line')**	**Current delay time extra steps Lower Bound (LB)**	**Current delay time extra steps Upper Bound (UB)**
a. Qualified suppliers	Commodity	*Decision 'qualified suppliers available?'*	-		Process step V.b	Process step V.a and Process step VI.a	6 months	12 months
b. Early supplier involvement	Commodity	Process step VI.b	-		*Decision 'scale up possible?'*	Process step X.b and XI.b	6 months	12 months
c. Supplier collaboration	Expansion Project	Process step 7	-		*Decision 'detailed design approved?'*	Process step 7	0 months	3 months
d. Project prioritisation	Commodity	Process step III	12 months	18 months	Process step 1	-	-	
e. Proactive system forecasting	Commodity	Process step VIII	0 months	3 months	Process step IX	-	-	
f. Engineering- and lead time alignment	Expansion Project	*Decision 'fit supplier planning?'*	-		Process step 4.a	Process step 3.a	0 months	3 months
g. Capacity reservation	Commodity	Process step XI.c	6 months	12 months	Process step 7, 8, 9		-	
h. Project scope clarity	Expansion Project	Process step 1	6 months	12 months	Process step 2	-	-	
i. Demand generality	Commodity	Demand planning	0 months	3 months	Process step 4.a	-	-	
j. Specification frozen-based ordering	Expansion Project	Process step 5	0 months	3 months	Process step 7	-	-	
k. Specification clarity	Expansion Project	Design specification	0 months	3 months	Process step 7	-	-	
l. Transparent stakeholder communication	Both	Several documents	12 months*	18 Months*	Several process steps [1]	-	-	

4.5.1. CSFs in Supplier Relationship Management

- CSF a (qualified suppliers) is critical to decision making in the Commodity Process. Due to the **required additional** ***process steps V.a and VI.a,*** it can cause a delay of **6-12 months** if no qualified CPT suppliers are available and new suppliers need to be acquired. The Commodity Team need to consider supplier selection, supplier pre-investigation, qualification and contracting to engage and request information in *process step V.b*.
- CSF b (early supplier involvement) is critical for identifying supplier production availability in *process step IX* when forecasting the required CPT systems based on the 10-year Project Portfolio. If suppliers are not involved early enough, they may not be able to confirm their production availability in the decision after *process step IX.* Due to the **required additional** ***process steps X.b and XI.b*** to verify their capacity, this may result in a delay of **6-12 months**.
- CSF c (supplier collaboration) is critical for developing the technical details of CPT systems in *process step 7*. If there is a lack of supplier collaboration on designs, resulting in unapproved designs, an ***additional process***

step 7 is required. This can result in a delay of **0-3 months** to re-engineer the technical details of CPT systems due to design errors.

4.5.2. CSF in Enterprise Planning

- CSF d (project prioritisation) is critical in *process step III* to correctly prioritise different capacity expansion plans. Incorrect prioritisation at this stage affects *process step 1*, where the project scope is determined. This can disrupt the entire project planning and lead to delays of **12 – 18 months**, as the scope forms the basis for all subsequent planning and execution activities.
- CSF e (proactive system forecasting) is critical in *process step VIII* to enable the supplier to determine its production availability in *process step IX*. A reactive system forecast can lead to an initial delay of **0-3 months** due to the increased complexity for the supplier in determining its production availability. This complexity arises because a reactive forecast provides less predictability and planning time, making it more difficult for suppliers to efficiently allocate resources and plan production.
- CSF f (engineering- and lead time alignment) is critical in determining whether the supplier's planning and the project planning are aligned in the Expansion Project Process. If the two are not aligned, the **required additional *process step 3.a*** can cause a delay of **0-3 months** to *process step 4.a*. The Project Expansion Team should re-evaluate and align the sequence and timing of the required systems with the supplier planning.
- CSF g (capacity reservation) is critical in *process step XI.c* to secure supplier production slots for *process steps 7, 8 and 9* in the Expansion Project Process. If the Commodity Team has not secured production slots, this can cause a delay of **6-12 months** for these process steps, as the process must wait until the supplier has available resources.

4.5.3. CSF in Dialogue Specification and Scope

- CSF h (project scope clarity) is critical to *process step 1*, as the scope forms the basis for all subsequent planning and execution activities. An unclear project scope affects *process step 2* and subsequent process steps, potentially delaying the overall project timeline by **6-12 months**.
- CSF i (demand generality) is critical to the *demand planning*, as information flow to the supplier after *process step VIII*. By providing general demand information, suppliers can determine their production availability in *process step IX*. This flexibility helps to avoid delays of **0-3 months** in *process step 4.a* due to incorrect supplier engineering- and lead times.
- CSF j (specification frozen-based ordering) is critical in *process step 5* to finalise and agree on specifications before orders are placed, ensuring thorough design approval. Specification disagreements can cause a delay of **0-3 months** in *process step 7* due to the need for re-engineering.
- CSF k (specification clarity) is critical in the *design specification*, as information flow to the supplier after *process step 6*. Clear specifications allow suppliers to accurately design technical details in *process step 7*. Unclear specifications can cause a delay of **0-3 months** due to the need for re-engineering.

4.5.4. CSF in Stakeholder Transparency

- CSF l (transparent stakeholder communication) is critical for several documents. Table 9 in Section 3.4. provides an insight into the information flows between the Commodity Team, the Project Expansion Team, and suppliers. Given the involvement and interdependence of these three stakeholder groups, transparent communication about documents is critical for effective project flow and alignment. If stakeholders do not communicate transparently about the information, this can lead to significant misunderstandings and delays of **12 – 18 months**. Coordinating and aligning information between three groups of stakeholders can be time consuming. Lack of transparency can result in multiple rounds of revisions and approvals, further extending the timeline.

In summary, Table 14 and Figure 18 illustrate the following:

- All four CSF clusters are critical to both the Commodity Process and the Expansion Project Process. For example: CSF a and b within the Supplier Relationship Management CSF cluster are critical in the Commodity Process, while CSF c (within the same cluster) is critical in the Expansion Project Process.
- CSFs that are critical in the Commodity Process affect both the Commodity Process and the Expansion Project Process. For example, CSF d is critical to process step III (Commodity Process) and affect process step 1 (Expansion Project Process), and CSF e is critical to process step VIII and affects process step IX, both in the Commodity Process.
- CSFs that are critical in the Expansion Project Process primarily affect steps within that process. For example, CSF h is critical to process step 1 and affects process step 2.
- CSFs d (project prioritisation) and l (transparent stakeholder communication) often cause long delays (12-18 months). These delays are logical as these strategic process steps are fundamental and affect the whole project timeline. Incorrect prioritisation or poor communication can result in executing incorrect projects or significant rework, causing substantial delays.

4.6. Critical Reflection on Critical Success Factors

Analysis of the CSFs and their impact on the timely delivery and installation of CPT systems reveals four key insights:

1. **Differences in Criticality Between Clusters**: The clusters 'Supplier Relationship Management' (red) and 'Enterprise Planning' (green) are relatively less frequently mentioned as critical by stakeholders (Table 11). The lower frequency of mentions may reflect the specific roles and responsibilities of these stakeholders, who may not see these factors as universally critical. For example, Supplier Relationship Management primarily involves Procurement and Suppliers, who are directly involved in the supply chain. Similarly, Enterprise Planning involves Procurement and Project Management, with a focus on strategic planning and coordination of resources.
2. **Impact of CSFs in Less Frequently Mentioned Clusters:** Although less frequently mentioned, the CSFs within these clusters can still have a significant impact. For example, project prioritisation within Enterprise Planning has one of the highest impacts (12-18 months). This suggests that although fewer stakeholders may identify these factors as critical, their impact on the project timelines can be significant if they are not properly managed. This is because project prioritisation is critical in the Commodity Process, which deals with strategic issues that affect long-term supplier commitment and the overall project portfolio.
3. **Complexity and Interdependencies:** The results highlight the complexity of managing CSFs and the interdependencies between different processes. Delays in one process can have a significant impact on other processes. For example, capacity reservation in the Commodity Process is critical to the Expansion Project

Process. If capacity is not reserved, the Expansion Project Process must wait for supplier availability or find an alternative supplier, resulting in delays of 6-12 months.

4. **Importance of Transparent Communication:** Transparent stakeholder communication is consistently identified as critical by all stakeholders, underlining its importance. This CSF is critical to both the Commodity Process and the Expansion Project Process and requires interaction from all stakeholder groups. Effective communication is essential to ensure alignment and to avoid misunderstandings that can lead to significant delays.

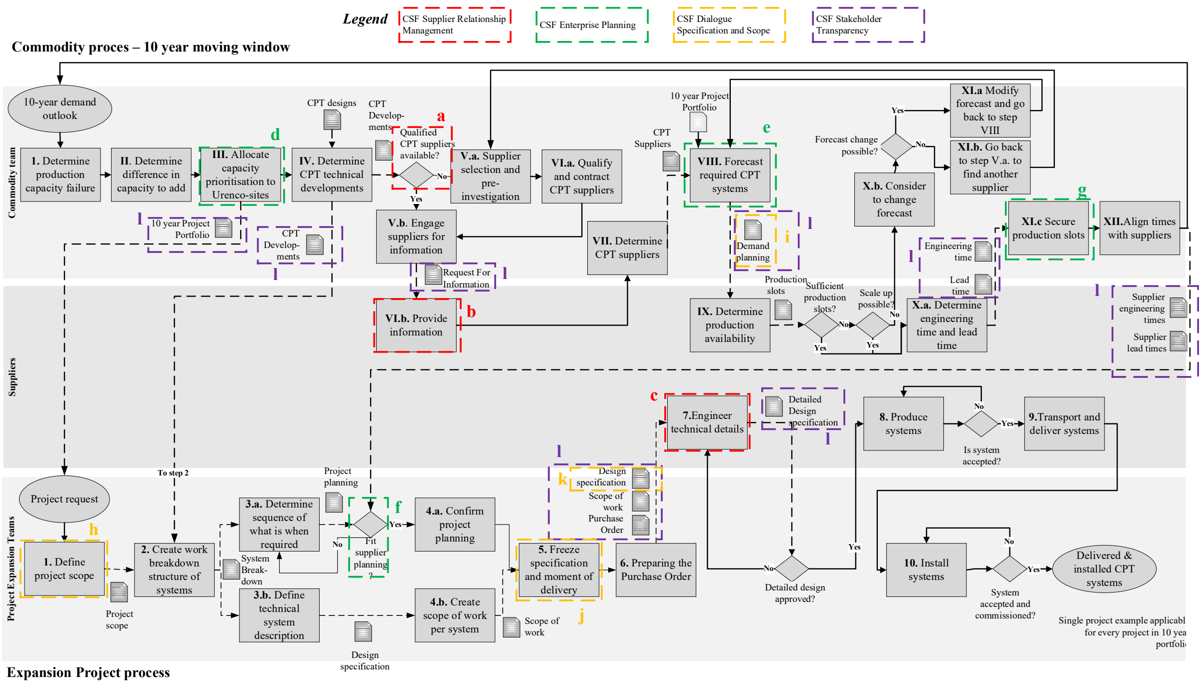

Figure 18: Critical Success Factors mapped to process

Chapter conclusion

This chapter identified and quantified CSFs that are essential for the timely delivery and installation of CPT system groups within a two-year period, specifically three to one years before the project deadline. The CSFs are grouped into four clusters: Supplier Relationship Management, Enterprise Planning, Dialogue Specification and Scope, and Stakeholder Transparency. These clusters are identified based on the identification of what stakeholders consider critical, analysis of their roles and responsibilities, and grouping of related factors based on their logical interrelationships and common themes. Each cluster addresses a specific aspect, ensuring a holistic approach. All four CSF clusters are critical to both the Commodity Process and the Expansion Project Process. Project prioritisation (CSF d) and transparent stakeholder communication (CSF l) are particularly critical, often cause significant delays (12-18 months) if not properly managed. Incorrect prioritisation or poor communication can lead to the execution of the wrong projects or significant rework, resulting in significant delays.

Chapter 5 analyses the risks associated within the identified CSFs through a reverse risk analysis. It also evaluates the probability and calculates the risk scores to work towards a focus risk for improvement.

5. Analyse: Risks Associated with Critical Success Factors

Chapter introduction

This chapter analyses the risks within the identified CSFs through a reverse risk analysis. It transforms the CSFs by identifying their opposites and formulating relevant risks that represent the potential negative consequences if the CSFs are not properly managed. It also includes a probability risk assessment and a risk score calculation to work towards a focus risk for improvement. This chapter addresses the following research question:

3.What are the supply chain-related risks associated with the Critical Success Factors?

The chapter is divided into the following sections:

- *Section 5.1: **Methodology** – Presents the methodology to address the sub-research question.*
- *Section 5.2: **Reverse Risk Analysis** – Outlines the reverse risk analysis.*
- *Section 5.3: **Risk Probability Assessment** – focuses on evaluating the likelihood of each risk occurring.*
- *Section 5.4: **Risk Focus** – Address and emphasise the focus risk for improvement.*

5.1.Methodology

Table 2 already presented the sub-research questions, data collection methods, techniques & models, and deliverables for the DMAIC-methodology. Below is an excerpt focussing on the Analyse-phase, reiterating the relevant details.

Extracted from Table 2: Sub-research questions, methods, techniques & models, and deliverables, Section 1.4.

Sub-research questions	**Data collection methods**	**Techniques & models**	**Deliverables**
Analyse			
3. What are the supply chain-related risks associated with the Critical Success Factors?	-Semi-structured interviews with key stakeholders.	-Reverse risk analysis. -Risk mapping. -Risk score calculation	-Supply chain-related risks for CPT systems within critical points. -Risks in process.

5.1.1. Methodology

Chapter 4 identified twelve CSFs and Section 4.5. conducted a detailed analysis to determine where and why each CSF is critical in the process, and what the implications are (refer to Table 15 for these analyses). Inspired by the work of (Farhan et al., 2018), who argued that the failure or non-existence of a critical element could be a potential risk, the reverse of these CSFs is formulated and used as the basis for the **semi-structured interviews** with **six key stakeholders** (Procurement, Asset Management, Design Authority, Research & Development, Project Management, and a CPT supplier). During these interviews, broad and open-ended questions are asked to identify specific risks that could hinder the timely delivery and installation of CPT systems in global capacity expansions. For example: *"How do you recognise this as a risk in the process"?* All initial questions are asked during these interviews. If new questions arise, follow-up questions are asked to gain additional insight. The objective of the interview, the stakeholder population and the questions asked are presented in Appendix J. Reversed CSFs are assigned to stakeholders based on their expertise and responsibilities. For example, reversed CSFs related to supplier involvement is discussed with Procurement and the Supplier, while reversed CSFs related to project prioritisation is discussed with Project Management. Table 15 shows the key insights of risk identification for each reversed CSF.

Table 15: Key insights risk identification

CSF	Swapped CSF	Stakeholder(s)	Paraphrase of stakeholder statement
a.Qualified suppliers	Unqualified suppliers	Procurement, Supplier	The lack of qualified suppliers can lead to significant issues in the qualification process, resulting in errors that affect the quality and reliability of delivered products, ultimately delaying the project timeline.
b.Early supplier involvement	Late supplier involvement	Project Management, Supplier	If suppliers are not involved early enough in the project, they may not be able to adjust their production capacity in time to meet project requirements, leading to delivery delays and issues meeting project deadlines.
c.Supplier collaboration	Lack of supplier collaboration	Procurement, Supplier	A lack of collaboration with suppliers can result in designs that are not approved because suppliers may not fully understand the project requirements, leading to misunderstandings and additional revisions.
d.Project prioritisation	Lack of emphasis	Project Management	Without clear prioritisation of projects, there is a risk that resources and attention are not allocated effectively, leading to delays and inefficiencies in project execution.
e.Proactive system forecasting	Reactive system forecasting	Procurement, Asset Management, Project Management	Reactive system forecasting can lead to a lack of alignment between project planning and supplier planning, resulting in unexpected bottlenecks and delays in the production process.
f.Engineering- and lead time alignment	Disorientation	Procurement, Supplier	Disorientation in planning can lead to a lack of alignment between project and supplier planning, ensuring that the required systems are not available on time, hindering project progress.
g.Capacity reservation	Capacity limitation	Procurement, Project Management	If capacity is not reserved in a timely manner, suppliers may not have the required resources available when needed, resulting in significant delays in the delivery of crucial components.
h.Project scope clarity	Unclear project scope	Project Management, R&D	Unclear project scope can lead to confusion and a lack of focus, resulting in inefficiencies and delays as teams do not know exactly what is expected of them.
i.Demand generality	Demand specificity	R&D, DA, Supplier	Specific demand information can lead to inaccurate engineering and lead times for suppliers, as they may not be able to effectively adapt their production processes to meet the specific project requirements.
j.Specification frozen based ordering	Dynamic specification	R&D, DA, Supplier	Dynamic specifications can lead to the re-engineering of detailed designs, as changes to specifications during the project require additional work and revisions, delaying the project timeline.
k.Specification clarity	Specification unclarity	R&D, DA, Project Management, Supplier	Unclear specifications can lead to redesign of detailed designs, as suppliers may not fully understand what is expected of them, leading to errors and additional revisions.
l.Transparent stakeholder communication	Non transparent communication	All stakeholders	A lack of transparent communication can lead to misalignment between different teams, resulting in misunderstandings, inefficiencies, and delays as key information is not shared effectively.

5.1.2. Findings

The reversed CSFs served as a starting point for discussions with stakeholders. The insights from Table 15 are analysed and clustered according to their scope and relevance. By identifying common themes and concerns, the insights are grouped into ten specific risks. For example, the key insight about the reversed CSF 'late supplier involvement' from Project Management and Supplier is analysed and clustered into the risk 'Supplier is not able to realise forecast'. This risk reflects the concerns of both stakeholders about the impact of late supplier involvement on production capacity and delivery times.

Although there are twelve CSFs, ten unique risks are identified. This is because some CSFs lead to the same risks. For example, swapped CSFs e and f both lead to the risk of misalignment between project and supplier planning. In addition, swapped CSFs j and k both lead to the risk of re-engineering the detailed design. A possible explanation for the common risk may be:

- **Misalignment between project and supplier planning**: Both proactive system forecasting (CSF e) and engineering- and lead time alignment (CSF f) are critical to ensure that project timelines and supplier capabilities are aligned. Reactive forecasting and disorientation in planning can both lead to a lack of synchronisation, causing bottlenecks and delays.
- **Re-engineering detailed design:** Both specification frozen-based ordering (CSF j) and specification clarity (CSF k) are essential for maintaining clear and stable project specifications. Dynamic specifications and unclear requirements can lead to frequent changes and misunderstandings, necessitating re-engineering efforts.

The ten risks provide an explicit terminology for the identified consequences discussed in Chapter 4. For example, CSF **capacity reservation (g)** is converted by the researcher into the potential negative consequence of **capacity limitation.**

- An example of a respondent's perspective: **Project Management states**: *"the problem could be that the Commodity Team has not secured long term productions slots with suppliers for some reason. As a result, there is a* ***risk that the supplier will not have resources available*** *in process steps 7, 8, and 9 of the Expansion Project Process. This hinders the timely delivery and installation of CPT systems in the relevant capacity expansion project. We must 'wait' until the supplier has resources available or until the Commodity Team can secure production slots from another CPT supplier".*

Each expansion project involves specific designs for CPT systems that cannot be supplied from existing inventory. This means that suppliers must have the necessary resources available at the right time to meet the unique requirements of each project. If the supplier does not have the resources available in time, this could result in the Expansion Project Team not being able to utilise the necessary resources, thereby delaying the timely delivery and installation of CPT systems in the relevant capacity expansion project. This highlights the critical nature of capacity reservation and the potential risks associated with its failure.

5.1.3. Risk Analysis

To further analyse the identified risks, the researcher asked stakeholders to assess the likelihood of each risk occurring to determine its relevance for Urenco. By comparing the probability with the impact, the researcher calculated risk scores to identify the focus risk. In addition, each risk is mapped to the established process model, highlighting the specific points where these risks occur. These points are determined on the researcher's interpretations of stakeholder key insights. The visualisation highlights where each CSF is critical and where it manifests as a risk if not properly managed. This helps to understand how these factors impact the process and where intervention is required.

5.2.Reverse Risk Analysis

Figure 19 shows the reverse risk analysis, illustrating how the twelve CSFs are transformed into ten risks by first exchanging the CSFs and then formulating relevant risks, based on key stakeholder insights (Table 15). These risks represent the potential negative consequences if CSFs are not properly managed.

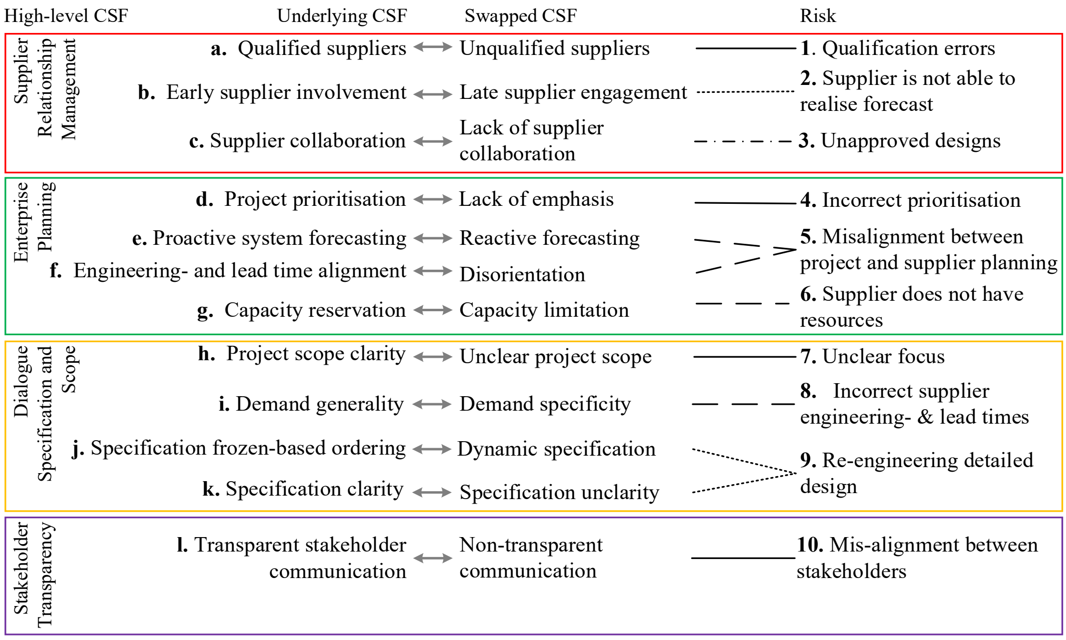

Figure 19: Reverse Risk Analysis

Although these risks are formulated based on stakeholder input, it is important to recognise that they represent only a partial insight. Risks are dynamic and can change according to circumstances and different project phases. A key characteristic of risk is its uncertainty, which makes it impossible to identify and manage all risks at any given time. According to (Krane et al., 2010), "*risk management is a continuous process that needs to be carried out throughout the entire project lifecycle*". This emphasises the need for an iterative and continuous approach to risk management.

5.3.Risk Probability Assessment

To determine whether the identified risks are risks at Urenco, stakeholders are asked to rate the likelihood of each risk occurring on a scale of 1 (very low) to 5 (very high). This assessment focuses on the general likelihood of each risk occurring, rather than the likelihood specific to the stakeholder's role. The qualitative categories for risk assessment are taken from the Expansion Project Team's risk management methodology, as shown in Table 16. Table 17 shows the stakeholder assessment of the probability of risk.

Table 16: Risk probability assessment categories

Risk category	Category description
1 – Very Low	Risk is very unlikely to occur, it almost never occurs.
2 – Low	Risk is unlikely to occur, it rarely occurs.
3 – Moderate	Risk may occur, there is a reasonable chance, but it is not guaranteed.
4 – High	Risk is likely to occur, it occurs regularly.
5 – Very High	Risk is very likely to occur and occurs frequently.

Table 17: Risk probabilities assessed by stakeholders

*Note: Percentages are calculated by dividing the average probability by 5 and multiplying by 100%

Risk	Procurement	Asset Management	R&D	DA	Project management	Supplier	Average Probability	%
1. Qualification errors	3	2	3	2	3	3	2.7	53.2%
2. Supplier is not able to realise forecast	3	2	2	2	4	4	2.8	56.6%
3. Unapproved designs	4	3	2	3	4	3	3.2	63.2%
4. Incorrect prioritisation	3	3	2	2	5	4	3.2	63.2%
5. Misalignment between project and supplier planning	4	2	2	2	4	4	3.0	60.0%
6. Supplier does not have resources	3	5	2	2	3	3	3.0	60.0%
7. Unclear focus	2	2	3	3	3	3	2.7	53.2%
8. Incorrect supplier engineering- and lead times	4	2	2	2	3	3	2.7	53.2%
9. Re-engineering detailed design	2	2	2	3	4	4	2.8	56.6%
10. Misalignment between stakeholders	5	4	3	3	5	4	4.0	80.0%

Key findings from the table:

- **Distinctive Patterns**: the probabilities of 2 and 3 are notably frequent. This may indicate a **neutral response bias**, where respondents tend to give neutral answers. A possible cause could be that respondents prefer to avoid extreme answers or are uncertain about the exact degree of a risk. The bias may give the impression that the risks are less pronounced than they really are (Sehwail, 2024). However, there are some probabilities of 4 and 5, indicating that certain risks are considered more serious.
- **Highest risk:** risk 10, misalignment between stakeholders, has the highest average risk probability of 4.0, corresponding to a likelihood of 80.0%. This risk is considered the most significant by respondents.

Building on these findings, Table 18 considers both the average risk probability and their potential lower and upper bound impacts (Section 4.5.) and calculates the risk scores for both bounds. This helps to rank risks and identify which risk receives the highest priority. Key findings from this table:

- **Highest Risk Scores:** risks 4 (probability 0,63, impact 12 to 18 months) and risk 10 (probability 0,80, impact 12 to 18 months) have relatively high probabilities and the highest impacts. These risks have the highest risk scores, ranging from 7,55 to 11,38 (risk 4) and from 9,60 to 14,40 (risk 10), marked in red in Table 18. These two have the greatest spread between LB and UB because broader impact intervals (such as 12-18 months) for higher impact lead to greater spread in risk scores.
- **Lowest Risk Scores:** although the average risk probabilities of risk 3 (0,63) and risk 8 (0,53) are relatively high, the consequences are less severe (0 to 3 months). These risks therefore have the lowest risk scores, ranging from 0 to 1,60 (risk 8) and 0 to 1,90 (risk 3) (marked in green in Table 18).

Table 18: Risk Score calculation

*Note: as risk 5 and risk 9 may arise from two critical points, and no statement can be made as to whether these delays are simultaneous or consecutive, the impact considers both cases, resulting in the range 0 to 6 months.

Risk	Average probability	Lower Bound (LB) Impact	Upper Bound (UB) Impact	Risk Score LB	Risk Score UB
1. Qualification errors	0.53	6 months	12 months	3.19	6.38
2. Suppliers is not able to realise forecast	0.57	6 months	12 months	3.40	6.79
3. Unapproved designs	0.63	0 months	3 months	0.00	1.90
4. Incorrect prioritisation	0.63	12 months	18 months	7.55	11.38
5. Misalignment between project and supplier planning	0.60	0 months	*6 months	0.00	3.60
6. Supplier does not have resources	0.60	6 months	12 months	3.60	7.20
7. Unclear focus	0.53	6 months	12 months	3.19	6.38
8. Incorrect supplier engineering- and lead times	0.53	0 months	3 months	0.00	1.60
9. Re-engineering detailed design	0.57	0 months	*6 months	0.00	1.70
10. Misalignment between stakeholders	0.80	12 months	18 months	9.60	14.40

5.4.Risk Focus

From the risks identified in Section 5.2., **risk 10**: **misalignment between stakeholders** due to poor management of the CSF transparent stakeholder communication deserves particular attention for the following three reasons:

1. Highest average probability 0,80 (Table 18), highest impact of 12-18 months, and thus the highest risks score of LB 9,60 and UB 14,40.
2. Observations during interviews in the research that indicate this is a risk:
   a. **Inconsistencies in the process leading to different interpretations and an unclear understanding** of the process due to the involvement of three stakeholder groups (Section 3.1.).
   b. **Overlap of responsibilities** between the Commodity Team and the Project Expansion Team (Section 3.4.).
   c. **Different focus in supplier interactions** between the Commodity Team and the Project Expansion Team (Section 3.4.).
   d. **Multiple stakeholders considering CSFs as critical**, which can lead to misalignment if not properly managed (Section 4.3.).
3. Fundamental impact on both the Commodity Process and the Expansion Project Process, given the involvement and interdependence required between three stakeholder groups (Table 9). Figure 20 shows the significant impact of the risk of misalignment (an exclamation mark and number 10 marked in purple) which is common to both processes and may occur after each flow of information between the Commodity Team, the Project Expansion Team, and the suppliers.

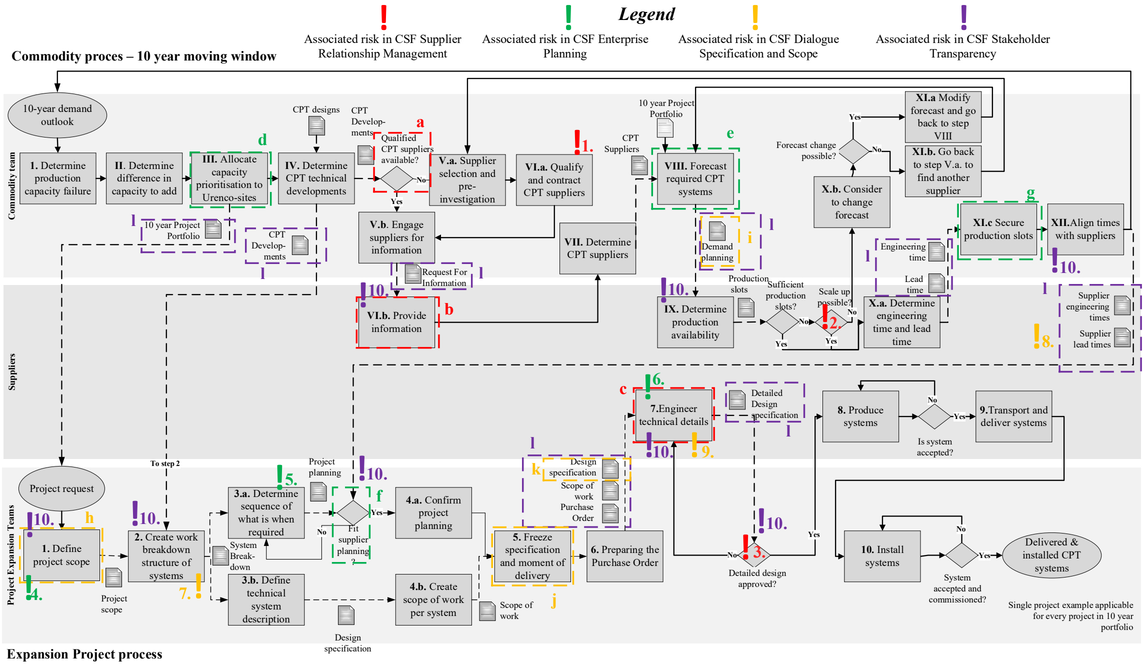

Figure 20: Risks associated with Critical Success Factors mapped to process

Further analysis of Figure 20: the process model not only highlights the critical risk of misalignment but also shows the other potential risk points (in numerical order, with an exclamation mark, marked in the CSF colour) across the processes. This helps to identify where CSFs are critical in the process and where the risk is most likely to occur. Notable observations are:

- Risks always manifest themselves **after** the critical point in the process.
- A CSF in the Commodity Process can lead to a risk in the Expansion Project Process as the Commodity Team provides information to the Project Expansion Team. For example, CSF d 'project prioritisation' is critical in the Commodity Process in *process step III*. The associated risk, risk 4, may emerges in *process step 1* of the Expansion Project Process.
- Risks 1 and 2 manifest particularly in the Commodity Process due to CSFs a and b if not properly managed.
- Risks 3 to 9 manifest themselves particularly in the Expansion Project Process as consequences of CSFs c to k, which are distributed across both processes. These risks are specific to the challenges within an expansion project, and therefore it is logical that they manifest themselves there.

Chapter conclusion

This chapter analysed risks associated with CSFs that could delay CPT system delivery and installation. Risk 10 (stakeholder misalignment) is critical to both the Commodity and Expansion Project Processes, occurring after information exchange between the Commodity Team, Project Expansion Team, and suppliers. Interviews revealed inconsistencies, overlapping responsibilities, and different focuses among stakeholders. This risk, with the highest average probability (0.80) and risk score (9.60 to 14.40), underscores the need for transparent communication.

Chapter 6 proposes improving communication and coordination between the Commodity and Project Expansion Teams to address this risk.

6. Improve & Control: Business Case

Chapter introduction

This chapter proposes a solution to improve the timely delivery and installation of CPT systems in global capacity expansions by addressing risk 10 (misalignment between the Commodity Team and the Project Expansion Team). The proposed approach includes cross-functional handover meetings and feedback mechanisms. This chapter details how this solution aims to reduce the risk, presents the expected impact on the risk scores, and analyses the financial benefits and costs through a comprehensive business case. In addition, a sensitivity analysis is conducted to assess the robustness of the proposed solution and its financial implications.
This chapter addresses the following research question:

4.What solutions can reduce and control the criticality of CPT system delivery in global capacity expansions?

The chapter is divided into the following sections:

- *Section 6.1: **Methodology** – Presents the methodology to address the sub-research question.*
- *Section 6.2: **Business Case** – Shows how the initiative addresses the problem, costs, and benefits.*

6.1. Methodology

Table 2 already presented the sub-research questions, data collection methods, techniques & models, and deliverables for the DMAIC-methodology. Below is an excerpt focussing on the Improve- & Control phase, reiterating the relevant details.

Extracted from Table 2: Sub-research questions, methods, techniques & models, and deliverables, Section 1.4

Sub-research questions	**Data collection methods**	**Techniques & models**	**Deliverables**
Improve & Control			
4.What solutions can reduce and control the criticality of CPT system delivery in global capacity expansions?	-Semi-structured interviews from Define-, Measure- and Analyse-phase with key stakeholders.	Process adjustment. -Business case -Scenario analysis -Sensitivity analysis	- Risk advice

Based on the observations and insights gathered during the Define, Measure, and Analyse phases with key stakeholders, the **researcher creates a unique design** for the improvement, detailing how the solution should be implemented. Throughout the improvement design process, relevant literature is consulted where possible to support and strengthen the assumptions and proposed solutions.

A business case is developed to ensure the feasibility and effectiveness of the proposed solution. This business case outlines the problem to be addressed, the goals and objectives, and potential alternatives. Given the necessity to make assumptions about costs and benefits, a sensitivity analysis is conducted to assess the robustness of the solution and the vulnerability of these assumptions. In addition, the improvement is incorporated into the process model to provide a comprehensive view of the proposed changes. Throughout this process, relevant literature is consulted to support and strengthen the assumptions and proposed solutions.

Quantification of impact and scenario analysis: As the new impact for each risk cannot be precisely estimated due to the inherent uncertainty and variability, the same impact ranges are maintained but translated into worst-case and best-case scenarios:

- **Worst-case scenario:** Upper Bound (UB) of impact
- **Best-case scenario:** Lower Bound (LB) of impact

This approach is used because stakeholders are not able to provide exact delay times, so ranges are used to represent potential delays. Maintaining these ranges allows the analysis to consider different potential outcomes and provide a more comprehensive risk assessment. The new risk scores are calculated by multiplying the expected new probability by the impact of the risk. This method allows potential outcomes to be assessed under different conditions, ensuring a robust analysis of the proposed improvements.

6.2. Business Case

This business case justifies investing in a proposed initiative by evaluating its risks, costs, and benefits. It includes the problem analysis, proposals, a detailed description of the initiative, assumptions, scenario analysis, and a thorough cost-benefit analysis. The aim is to show how the initiative addresses the problem and maximises benefits for Urenco (Rijksorganisatie voor Ontwikkeling, 2023).

6.2.1. Background

The purpose of this business case is to propose an improvement approach for the CPT system delivery process in global capacity expansions, aiming to **reduce misalignment between the Commodity Team and the Project Expansion Team**. The research perspective is Urenco, focussing on alignment between these two teams rather than between these teams and suppliers. This effort aims to help Urenco move closer to its target of increasing capacity by 2032, as outlined in Section 1.4. Although current data suggests that this target could be achieved by 2035, mitigating this risk may accelerate progress and help achieve the original target date, and prevent the target from being further delayed beyond 2035.

6.2.2. Proposals

The researcher considers three different proposals to address the misalignment between the Commodity Team and the Project Expansion Team. These alternatives are inspired by various literature sources and although there are many possible ideas, the following three are suggested as possible alternatives:

1. **Clear Role Definitions and Responsibilities**: Clearly defining the roles and responsibilities within teams. This involves a shared understanding of these roles and responsibilities, often using tools like a RACI-matrix (Responsible, Accountable, Consulted, Informed) to clarify responsibilities among stakeholders.
   - **Justification**: A study in (Gander et al., 2020) investigates the relationships between team roles, character strengths, and work-related outcomes. The results suggest that teams with more clearly defined roles report higher performance and quality of collaboration. This supports the idea that clear role definitions can improve team alignment and performance. In addition, the importance of clear role definitions is supported by the literature on Risk Mitigation, which emphasises the need for clear responsibilities to manage risks effectively (Jüttner et al., 2003).

2. **Cross-functional Handover Meetings**: Implementing regular cross-functional handover meetings between teams. These meetings provide a platform for representatives from both teams to discuss progress, challenges, expectations, and updates, ensuring alignment and effective communication. This requires stakeholder commitment to meet.
   - **Justification**: A systematic review by (Desmedt et al., 2021) discusses the effectiveness of clinical handovers and emphasises the importance of structured communication during handover meetings. This supports the proposal that regular cross-functional handover meetings can improve communication and alignment between teams. This is further supported by the literature on Risk Identification and Risk Assessment, which highlights the importance of structured communication to identify and assess risks effectively (Gaudenzi & Borghesi, 2006).
3. **Feedback mechanisms**: Establishing feedback mechanisms between the teams. This involves creating a process for continuous feedback to ensure ongoing alignment and address any issues promptly.
   - **Justification**: An article by (Hagemann et al., 2024) examines the effects of various feedback interventions on team coordination and performance. The study highlights the importance of collective orientation and feedback interventions for improving team processes and performance. This supports the proposal that feedback mechanisms can enhance team alignment and performance. The literature on Risk Mitigation also emphasises the importance of feedback mechanisms to continuously improve risk management strategies (Jüttner et al., 2003).

Although clearly defining roles and responsibilities of all engaged stakeholders (proposal 1) is important, interviews revealed that communication problems are often the cause of misalignment. As one interviewee noted: *"You can have such clarity in roles and responsibilities, but if people don't talk to each other, you still won't achieve alignment".* Therefore, this research will explore a specific initiative that focuses on improving communication between stakeholders, combining elements of proposals 2 and 3 in Section 6.2.3. This initiative will be examined to demonstrate its potential impact and feasibility, providing a concrete example of how misalignment can be addressed. **It is important to note that this initiative focuses specifically on the roles and responsibilities of the representatives in the cross-functional handover meetings, rather than defining the roles and responsibilities of all teams and stakeholders involved in the process.**

6.2.3. Description of Initiative and Desired Situation

The idea behind cross-functional handover meetings is that representatives from the Commodity Team and the Project Expansion Team regular meet to discuss progress, challenges, expectations, and updates, to reach stakeholder alignment and continue progress. With the addition of feedback mechanisms, representatives can verify whether there is alignment between the Commodity Team and the Project Expansion Team.

- Justification: The importance of structured communication and collaboration is emphasised in the literature on risk mitigation strategies (Jüttner et al., 2003). They discuss various strategies such as cooperation and flexibility, which are crucial for developing effective solutions to mitigate risks and ensure the continuity of the supply chain. The implementation of cross-functional handover meetings is in line with the cooperation strategy, as it involves collaboration between different teams to reduce uncertainty and improve visibility and understanding of the supply chain.

Figure 21 shows the three process steps and decisions, marked in green blue, indicating where the Commodity Process (green) and the Project Expansion Team (blue) should intersect via information flows. In addition, feedback loops are represented by bold black dotted lines. A decision is made whether there is alignment:

- **If there is alignment**, the Project Expansion Team can proceed with the subsequent process step.
- **If there is no alignment,** a feedback loop is initiated, sending the process back to the Commodity Process. This cycle repeats until alignment is achieved. The Commodity Process can make strategic adjustments based on feedback from various expansion projects. This ensures that the overall supplier management and capacity planning strategy is continuously improved and aligned with the needs of all expansion projects.

While the primary approach is to send the feedback loop back to the Commodity Process, there are exceptional situations where the Project Expansion Team may need to adapt. These situations are not depicted in the process model but may include the following scenario:

- **Project-specific constraints**: when unique project-specific requirements cannot be resolved through the Commodity Process. This includes urgent needs to proceed with a project without the time to go through the Commodity Process.

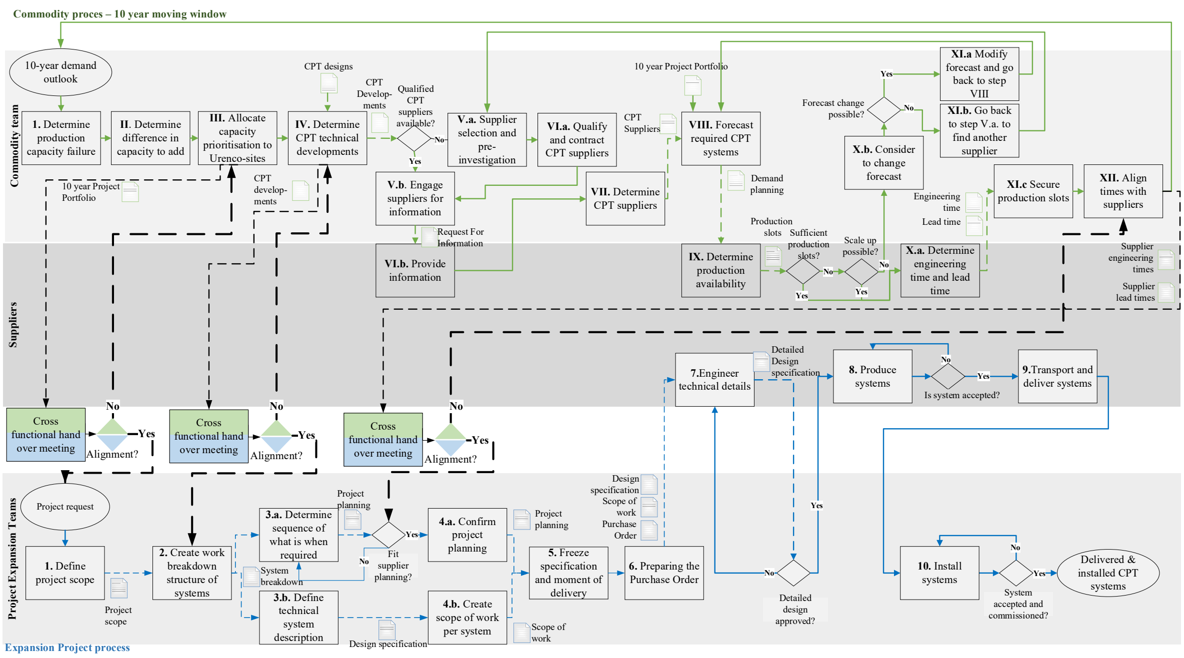

Figure 21: Advice for improvement, approached on process model

Each cross-functional handover meeting requires a different perspective: strategic, innovative, and operational. The main reason for distinguishing between these three levels are:

- **Strategic level**: the first meeting focuses on long-term planning and strategic changes. It is essential to involve representatives who can ensure alignment with the overall business strategy and provide technical and design assurance. This level addresses the need for strategic alignment and comprehensive understanding of both technical and business implications.
- **Innovative level**: the second meeting emphasises discussing the latest developments and innovations. Representatives involved at this level are crucial for driving technological advancements and integrating new

solutions into the project. This level is necessary to keep the project at the forefront of innovation, leveraging new technologies and methodologies.

- **Operational level**: the final meeting addresses the practical aspects of project execution, such as procurement, construction, and quality control. It is important to have representatives who can manage day-to-day operations and ensure compliance with policies and standards. This level focuses on the smooth execution of the project, meeting deadlines, maintaining quality, and managing resources effectively.

Justification: The literature on risk mitigation strategies emphasises the importance of flexibility and control. By distinguishing between strategic, innovative, and operational levels, the proposed solution ensures that different aspects of the project are adequately addressed. This is consistent with the flexibility strategy discussed by (Jüttner et al., 2003), which emphasises the need for responsiveness and adaptability in managing supply chain risks.

Table 19 provides the details of these meetings, including the levels, corresponding process steps, the information transfer, and representatives. Table 20 shows the responsibilities per representative per level. The focus is specifically on the **roles and responsibilities of representatives in the cross-functional handover meetings**, rather than defining the roles and responsibilities of all teams and stakeholders involved. The representatives and their roles are determined by examining the current roles and responsibilities (Appendix C & D).

In addition, cross-functional handover meetings at each level should have a **meeting facilitator** and a **note-taker** to maintain structure, productivity, and thorough documentation:

- **Meeting facilitator:** the meeting facilitator guides the meeting according to the agenda, ensuring that everyone can contribute, managing the flow, keeping discussions on track, and addressing issues. Their presence is critical to maintaining order and achieving objectives. **Representatives from the Commodity Team act as meeting facilitators at all levels to provide the Project Expansion Team with sufficient information to ensure that the process continues.**
- **Note-Taker:** the note-taker's role is to document the proceeding of the meeting, including key points, action items, and decisions. They provide a clear summary of discussions and agreements. Their role is essential for thorough documentation and tracking of follow-up actions. Like the Facilitator, the goal is to inform and align the **Project Expansion Team. Therefore, it is recommended that a junior member of the Commodity Team fills this role, coordinated among team members prior to the meeting**

Table 19: Meeting details

Level	Between process steps	Information transfer	Representatives	
			Commodity Team	Project Expansion Team
Strategic	III and 1	10-year Project Portfolio	Design Authority, Asset Management	Project Management, Design Authority
Innovative	IV and 2	CPT developments	Design Authority, Research & Development, CPT Procurement	Project Management, Design, Engineering
Operational	XII and decision before 4.a	supplier engineering- and lead times	CPT Procurement, Design Authority	Project Management, Procurement & Contracting, Construction, Quality

Table 20: Responsibilities per representative per level

Level	Commodity Team	Responsibility	Project Expansion Team	Responsibility
Strategic	Design Authority	Technical and design assurance.	Project Management	Overall project delivery and reporting.
	Asset Management	Alignment of Urenco's business strategy with asset management plans. And **meeting facilitator.**	Design Authority	Technical and design assurance within project team
Innovative	Design Authority	Technical and design assurance.	Project Management	Overall project delivery and reporting
	Research & Development	Identification, development, and implementation of new technologies.	Design	Technical and design assurance and design approval
	CPT Procurement	**Meeting facilitator.**	Engineering	Production and development of technical aspects
Operational	CPT Procurement	Compliance with procurement policies and supplier relationships. And **meeting facilitator.**	Project Management	Overall project delivery and reporting
	Design Authority	Technical and design assurance.	Procurement & Contracting	Supplier selection and contract management
			Construction	Supervision and directing the execution of construction phase
			Quality	Verifying product and service quality
Note-taker		Documenting, action items, decision made.		

Table 21 lists the key open- and closed questions to address during the cross-functional handover meeting to maintain focus. Using both open and closed questions is beneficial because they serve different purposes. Open questions encourage dialogue, critical thinking, and engagement, while closed questions provide clarity, facilitate decision-making, and obtain specific information (Parker, n.d.).

Table 21: Key open- and closed questions

Level	Key open questions	Key closed questions
Strategic	"What is the current status of the 10-year project portfolio?" and "Are there any strategic changes we need to consider?"	"Is the project scope clear?" and "Is there approval for the proposed strategic changes?"
Innovative	"What are the latest developments in CPT technology?" and "How do these developments impact the project timeline?"	"Have the new technologies been tested and validated?" and "Are there any approvals needed for implementation of these innovations?"
Operational	"What are the current challenges regarding supplier engineering and lead times?" and "Are there any operational issues that need to be addressed?"	"Have all supplier contracts been signed and approved?" and "Have the quality checks been completed and approved?"

Additional points relevant regarding the cross-functional handover meetings:

- **Representation**: each department should have **one representative** to ensure balanced input. The meeting facilitator is one of these representatives, and the note-taker is an additional attendee. The number of attendees during each level of the meeting is:
  - Strategic: 5 attendees
  - Innovative: 7 attendees
  - Operational: 7 attendees

- **Meeting duration:** to provide an overview of the time required for cross-functional handover meetings at three different levels, it is important to break down the time into three distinct phases: preparation, the meeting itself, and the follow-up. This approach ensures an understanding of the total time commitment and highlights the importance of each phase in achieving effective and productive meetings:
  1. **Preparation:** adequate preparation involves reviewing the agenda, gathering necessary data and materials, and coordinating with team members to ensure everyone is aligned on the discussion points.
  2. **Meeting:** the actual meeting is where discussion take place on key questions, decisions are made, and action items are assigned. Each participant should have the opportunity to contribute, discussions stay on track, and any issues that arise are addressed promptly.
  3. **Follow-Up:** after the meeting, it is essential to review and finalise meeting notes, distribute them to all participants, and track action items to ensure follow-up on decisions made. The outcomes of the meeting are documented and there is accountability for completing assigned tasks.

Table 22 shows the duration for each phase and for each level of the meeting. These are based on common practices for effective meeting management and on the researcher's interpretation, which emphasise thorough preparation, structured meetings, and follow-op to ensure all objectives are met (Statusnet, n.d.). The duration of meetings varies by level due to the nature and complexity of the topics discussed (Table 22):

- **Strategic meetings:** these meetings address topics that impact long-term and broader business objectives. They require extensive preparation, in-depth discussions, and careful follow-up to ensure that strategic initiatives are correctly implemented.
- **Innovative meetings:** focus on the latest developments and their impact on projects. They require a moderate amount of preparation and discussion to integrate new technologies and innovations into the project timeline.
- **Operational meetings:** these meetings are more focused on daily activities and resolving immediate issues. The questions are more specific and technical, which generally requires less time and preparation.

Table 22: Breakdown of meeting duration

Level	**Preparation duration**	**Meeting duration**	**Follow-Up duration**	*Total*
Strategic	60 minutes	120 minutes	60 minutes	*4 hours*
Innovative	45 minutes	90 minutes	45 minutes	*3 hours*
Operational	30 minutes	60 minutes	30 minutes	*2 hours*
Total				*9 hours*

- **Frequency of meetings:** the proposed frequency of meetings is as follows:
    - At the start of an Expansion Project Process before *process step 1*
    - Six months later before *process step 2*
    - Twelve months later after *process step 3.a*, thus before *process step 4.a*

In line with the earlier used assumption that a process step takes approximately six months, these meetings should take place in the **first 21 months** of an expansion project. 21 months is the average lead time between *project request* and the decision before *process step 4*.

- **Feedback mechanisms:**

Using structured feedback mechanisms is essential for effective project management and team alignment. According to a study by (Hartmann et al., 2021), clear documentation and feedback processes significantly improve project outcome and team collaboration. Inspired by these findings, the researcher has designed the following feedback mechanisms:

- Decision documentation: after each meeting, summarise the key points discussed (Table 22) and the decisions made. This summary should be shared with both teams to ensure transparency and alignment.
- Positive feedback: if the decision is to proceed ('yes'), document the reasons for alignment and the key points discussed.
- Corrective feedback: if the decision is to not proceed ('no'), clearly outline the misalignment issues and the steps needed to resolve them. Include a detailed action plan with assigned responsibilities to address the issues.

6.2.4. Assumptions

Cross-functional handover meetings and feedback mechanisms are initially designed to address **risk 10: misalignment between stakeholders.** However, the researcher expects that it also may impact the risks included in Table 23 with the reason for reduction included. Figure 22 marked these risks in orange.

Table 23: impacted risks through cross-functional handover meetings

Risk nr	Risk name	Reason for reduction
4	Incorrect prioritisation	Aligning priorities based on strategic importance during cross-functional handover meetings ensures that the most critical projects receive the necessary focus and resources. This reduces the risk of incorrect prioritisation.
5	Misalignment between project and supplier planning	Aligning supplier timelines during cross-functional handover meetings addresses discrepancies early, reducing misalignment.
7	Unclear focus	Aligning the efforts of the Commodity Team and the Project Expansion Team towards common objectives reduces different and unclear focusses.
8	Incorrect supplier engineering- and lead times	Aligning supplier timelines ensures that engineering and lead times are accurate and reliable.
10	Misalignment between stakeholders	Improving communication among the Commodity Team and the Project Expansion Team reduces miscommunication and ensures that everyone is working towards the same goals.

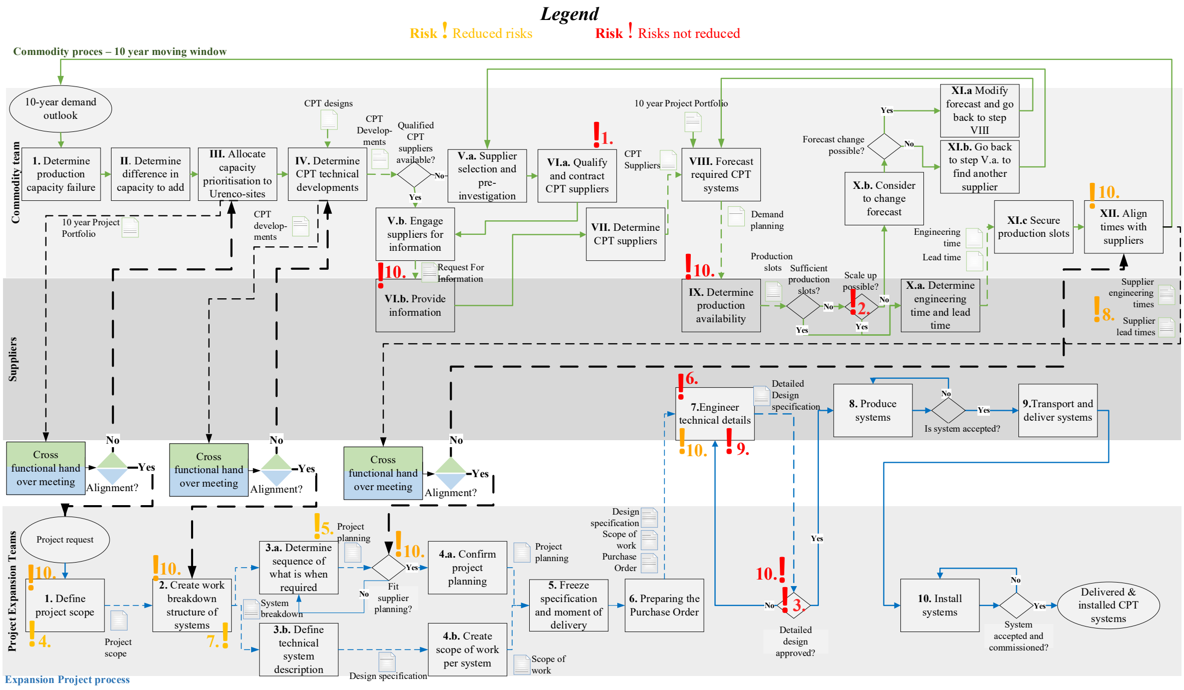

Figure 22: Risks reduced (orange) and not reduced (red) through improvement approach

Risk 10 initially occurs a total of eight times throughout the process. **Five of these eight instances are expected to reduce** (marked in orange in Figure 22), either direct or accumulated:

1. **Direct reduction** (three instances): as they involve alignment between the Commodity Team and the Project Expansion Team:
    - *Process step 1* (Expansion Project Process)
    - *Process step 2* (Expansion Project Process)
    - Decision 'fit supplier planning' before *Process step 4.a* (Expansion Project Process)
2. **Accumulated reduction** (two instances): via mitigation of the three instances mentioned above:
    - *Process step XII* (Commodity Process)
    - *Process step 7* (Expansion Project Process)

Not reducible by proposed solution (three out of eight instances), marked in red in Figure 22:

1. **Involvement of Commodity Team and the Supplier** (two instances)
    - *Process step VI.b* (Commodity Process)
    - *Process step IX* (Commodity Process)
2. **Involvement of Project Expansion Team and the Supplier** (one instance):
    - Decision 'detailed design approved?' after *Process step 7* (Expansion Project Process)

(Schaubroeck et al., 2016) shows that implementing cross-functional collaboration improves "first-time-right" delivery from 65% to 80%, indicating a 23% improvement. This suggest that cross-functional handover meetings reduce errors and increase efficiency. Therefore, it is assumed that the probability of certain risks can be reduced by **23%** through these meetings, as fewer errors and higher efficiency directly contribute to lower risk probabilities.

6.2.5. Project Framework

The 23% reduction is applied to the five identified risks that are expected to reduce. Since the new impact for each risk cannot be estimated with precision due to inherent uncertainty and variability in the project environment, the same impact ranges are maintained but translated into worst case and best-case scenarios.

- **Worst-case scenario**: Upper Bound (UB) of impact
- **Best-case scenario**: Lower Bound (LB) of impact

This approach ensures that the analysis can consider different potential outcomes and provide a more comprehensive risk assessment. The new risk scores are calculated by multiplying the expected new probability by the impact of the risk (Table 24). This method allows potential outcomes to be assessed under different conditions, ensuring a robust analysis of the proposed improvements. Key observations from the table:

- **Risk 4**: shows the largest decrease in both worst case and best-case scenarios, with deltas of -1.67 and -2.56 respectively. This indicates that cross-functional handover meetings can be substantially mitigate this risk, demonstrating the effectiveness of improved collaboration and communication.
- **Risk 10**: Also shows a notable reduction in risk scores, with deltas of -1.32 and -1.98. This underscores the direct impact of the proposed solution on reducing misalignment between stakeholders.

Table 24: Expected risk reduction

*Note: new probability for risk 10 is calculated by applying the 23% reduction to the 5 out of 8 instances being addressed, resulting in a weighted average of 68.5%

Risk	Expected probability (23% reduction)	Best Case Impact	Worst Case Impact	New Risk score Best Case	New Risk score Worst Case	Delta probability reduction	Delta risk score Best Case	Delta risk score Worst Case
1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-
4	0.49	12 months	18 months	5.88	8.82	-0.14	-1.67	-2.56
5	0.47	0 months	6 months	0.00	2.82	-0.13	0.00	0.78
6	-	-	-	-	-	-	-	-
7	0.41	6 months	12 months	2.46	4.92	-0.12	-0.73	-1.46
8	0.41	0 months	3 months	0.00	1.23	-0.12	0.00	0.37
9	-	-	-	-	-	-	-	-
10	*0.69	12 months	18 months	8.28	12.42	-0.11	-1.32	-1.98

The expected overall impact of these reductions is reflected in the total risk scores before and after the implementation of cross-functional handover meetings for both worst case and best-case scenarios (Table 25). This provides an overview of the expected overall risk reduction achieved by the proposed improvement. The total of risk scores is calculated by summing the individual risk scores (Understanding and Implementing Risk Summing as a Practical Element of Risk Management, 2011). The table shows that implementing cross-functional handover meetings leads to a significant reduction in total risk scores:

- **Worst case scenario**: total risk score decreases from 61.33 to 54.18, a reduction of **7.15**.
- **Best case scenario**: total risk score decreases from 30.53 to 26.81, a reduction of **3.72.**

The relative impact of these absolute changes is **-11.65%** (worst case scenario) and **-12.18%** (best case scenario) and. The proximity of these percentages indicates a consistent impact of the cross-functional handover meetings on risk reduction, regardless of the scenario. This consistency suggests that the proposed solution is robust and reliable, providing significant risk reduction under different conditions. In addition, the significant absolute reductions in risk score **(3.72 and 7.15**) further demonstrate the effectiveness of the proposed solution.

Table 25: Expected risk score comparison before and after improvement

Note: the new risk scores that change are in bold

Risk	Initial risk score Best Case	Initial risk score Worst Case	New risk score Best Case	New risk score Worst Case
1	3.19	6.38	3.19	6.38
2	3.40	6.79	3.40	6.79
3	0.00	1.90	0.00	1.90
4	7.55	11.38	**5.88**	**8.82**
5	0.00	3.60	**0.00**	**2.82**
6	3.60	7.20	3.60	7.20
7	3.19	6.38	**2.46**	**4.92**
8	0.00	1.60	**0.00**	**1.23**
9	0.00	1.70	0.00	1.70
10	9.60	14.40	**8.28**	**12.42**
Total	*30.53*	*61.33*	*26.81*	*54.18*
Delta best case scenario			*-3.72*	
Delta worst case scenario				*-7.15*

6.2.6. Benefits and Cost Consideration

The cost analysis (Table 26) and benefit analysis (Table 27) is performed on both the worst-case and best-case scenarios. This approach ensures that both the conservative and the optimistic estimates are considered, providing a balanced view of the potential financial impact.

Assumption in cost- and benefit analysis:

- For this benefits and cost analysis, it is assumed that the cycle in the process model (Figure 21) completes once without additional alignment meetings. This keeps the analysis manageable and focused. Misalignments and extra meetings are considered out of scope. This allows for a clear evaluation of the primary costs and benefits.

Assumptions in cost consideration (Table 26**):**

- Salary for Senior Project Manager: average annual salary: €92.805 (based on (Payscale, 2023); (Levels.fyi, 2024)).
- Working hours per year: working hours per year: 1920 hours (40 hours/week, 48 weeks/year)
- Average hourly rate: €48,34/hour.
- Hourly rates assumed: other representatives (Procurement, Design, etc.): €48,34/hour.
- Note-taker: for simplification, the same hourly rate is assumed: €48,34/hour.

The total costs for implementing cross-functional handover meetings are €2658,70 (Table 26)

Table 26: Costs per level of cross-functional handover meeting

Note: the costs per level are calculated by multiplying the number of stakeholders by the total hours and the hourly rate of €48,34/hour.

Level	Number of stakeholders	Preparation duration (hours)	Meeting duration (hours)	Follow-Up duration (hours)	Total hours	Costs per level (EUR)
Strategic	5 representatives	1.00	2.00	1.00	4.00	€966,80
Innovative	7 representatives	0.75	1.50	0.75	3.00	€1015,14
Operational	7 representatives	0.50	1.00	0.50	2.00	€676,76
Total	-				9.00	**€2658,70**

Assumptions in benefit consideration (Table 27**):**

- The Project Expansion Team assesses the total remaining project costs and associated risks throughout a project's duration. At the beginning of a project, risks are identified and their potential impact on the project costs is estimated. By identifying and quantifying these risks early, it is possible to estimate the potential cost savings from mitigating these risks. The Project Expansion team's methodology to quantify these cost savings is that each percentage of risk reduction at the beginning of a project yields an average benefit of €1123. This average is used to calculate the benefit.

Table 27 shows that the financial risk ranges between €13.082.95 (worst-case scenario) and €13.678.14 (best-case scenario).

Table 27: Benefits per scenario

Note: the financial risk is calculated by multiplying the percentage change with €1123.

Scenario	Absolute change	Percentage change	Financial risk (EUR)
Worst-case	-7.15	-11.65%	€13.082.95
Best-case	-3.72	-12.18%	€13.678.14

Table 28 shows the total costs, benefits, and net benefits for both the worst-case and best-case scenarios. This provides the financial impact of risk reduction, which ranges between €10.424.25 (worst-case scenario) and €11.019.44 (best-case scenario).

Table 28: Net Benefits

Scenario	Total costs (EUR)	Total benefits (EUR)	Net benefits (EUR)
Worst-case	€2658.70	€13.082.95	€10.424.25
Best-case	€2658.70	€13.678.14	€11.019.44

6.2.7. Sensitivity Analysis

Conducting a sensitivity analysis assesses the robustness and reliability of the improvement approach. By varying the parameters within a certain range, it provides an understanding of how changes in these parameters affect the results. This helps to prepare for different **scenarios and** make informed decisions (Capital City: Training & Consulting, 2023).

First, the critical parameters that could affect the results are identified and included in the sensitivity analysis (Table 29). A fixed percentage of ± 10% is used with **Scenario 1 as -10%** and **Scenario 2 as +10%,** to explore the range of possible outcomes. This common practice in sensitivity analysis allows the impact of variations to be assessed without making the analysis overly complex (Capital City: Training & Consulting, 2023). This helps to assess the robustness of the research in several ways:

- **Sensitivity**: it allows to determine how sensitive the research is to changes in input parameters.
- **Critical Factors**: it helps to identify which input parameters have the greatest impact on the results.
- **Validation of assumptions**: it helps to confirm that the assumptions are realistic and reliable.

By varying the parameters in the cost analysis (number of representatives, duration of meeting, and hourly rates), the parameters in the benefit analysis remain constant. This approach ensures a clear comparison of the impact of cost changes without other variables influencing the results. The same method is used for the benefit analysis parameters.

Table 29: Critical parameters in business case

Category	Assumption	
Cost analysis	Number of required representatives per level of meeting.	Strategic: 5 attendees Innovative: 7 attendees Operational: 5 attendees
	Duration of meeting	Strategic: 4 hours Innovative: 3 hours Operational: 2 hours
	Hourly rates of representatives	€48.34/hour.
Benefit analysis	Percentual risk probability reduction through cross-functional handover meetings.	23%
	Financial benefit for each percentual risk reduction	€1123

The sensitivity analysis for the five key parameters is presented in Table 30 to Table 34. Appendix K includes the detailed calculations for the sensitivity analysis. Key findings are:

- Parameter of Percentual risk probability reduction:
  - **Largest potential increase:** this parameter can lead to an increase in net benefits of up to +€1987,71, which is the largest potential increase of all parameters.
  - **Widest range:** the variability in net benefits due to risk reduction percentages is the largest, ranging from - €1098,19 to + €1987,71. This indicates that changes in this parameter can have a large impact on the results.

- **Critical parameter:** the significant impact of small changes in this parameter highlights its importance for the robustness of the analysis.

- Parameter of Number of representatives and Duration of meeting:
  - **Smallest potential change:** the changes in the net benefits due to the number of representatives and the duration of the meeting show the smallest potential drawbacks, around - €600,40. This suggests that these parameters are less critical to the robustness of the analysis.

Overall, the analysis shows that the assumptions are sensitive to changes in certain parameters, in particular the percentual risk probability. The significant variability in the results indicates potential vulnerabilities in these assumptions and highlights the need for careful consideration and possible adjustment of these assumptions to ensure the robustness of the analysis.

Table 30: Sensitivity analysis: Number of representatives per level of meeting
Note: the numbers in scenario 1 are rounded down and in scenario 2 are rounded up, as half a person is not possible.

	Number of representatives							
	Scenario	Strategic	Innovative	Operational	Costs	Benefit	Net benefit	**Delta**
Worst-case	Baseline	5 persons	7 persons	7 persons	€2658.70	€13.082,95	€10.424,25	-
	Scenario 1	4 persons	6 persons	6 persons	€2224,64	€12.048,49	€9823,85	- €600,40
	Scenario 2	6 persons	8 persons	8 persons	€3093,76	€14.902,21	€11808,45	+ €1384,20
Best-case	Baseline	5 persons	7 persons	7 persons	€2658,70	€13.678,14	€11.019,44	-
	Scenario 1	4 persons	6 persons	6 persons	€2224,64	€12.579,95	€10.355,31	- €664,13
	Scenario 2	6 persons	8 persons	8 persons	€3093,76	€15.665,85	€12.572,09	+ €1552,65

Table 31: Sensitivity analysis: Duration of meeting

	Duration of meeting							
	Scenario	Strategic	Innovative	Operational	Costs	Benefit	Net benefit	**Delta**
Worst-case	Baseline	4 hours	3 hours	2 hours	€2658.70	€13.082,95	€10.424,25	-
	Scenario 1	3,6 hours	2,7 hours	1,8 hours	€2392,46	€12.048,49	€9823,85	- €600,40
	Scenario 2	4,4 hours	3,3 hours	2,2 hours	€2924,58	€14.902,21	€11977,63	+ €1553,38
Best-case	Baseline	4 hours	3 hours	2 hours	€2658,70	€13.678,14	€11.019,44	-
	Scenario 1	3,6 hours	2,7 hours	1,8 hours	€2392,46	€12.579,95	€10.355,31	- €664,13
	Scenario 2	4,4 hours	3,3 hours	2,2 hours	€2924,58	€15.665,85	€12.741,27	+ €1721,83

Table 32: Sensitivity analysis: Percentual risk probability reduction

	Scenario	**Risk reduction**	**Costs**	**Benefit**	**Net benefit**	**Delta**
Worst-case	Baseline	23%	€2658.70	€13.082,95	€10.424,25	-
	Scenario 1	20.7%	€2658,70	€12.048,49	€9389,79	- €1034,46
	Scenario 2	25.3%	€2658,70	€14.902,21	€12.243,51	+€1819,26
Best-case	Baseline	23%	€2658,70	€13.678,14	€11.019,44	-
	Scenario 1	20.7%	€2658,70	€12.579,95	€9921,25	- €1098,19
	Scenario 2	25.3%	€2658,70	€15.665,85	€13.007,15	+ €1987,71

Table 33: Sensitivity analysis: Hourly rates of representatives

	Scenario	Hourly rate	Costs	Benefit	Net benefit	Delta
Worst-case	Baseline	€48,34/hour.	€2658.70	€13.082,95	€10.424,25	-
	Scenario 1	€43,51/hour	€2393,05	€12.048,49	€9655,44	- €768,81
	Scenario 2	€53,17/hour	€2987,35	€14.902,21	€11914,86	+ €1490,61
Best-case	Baseline	€48,34/hour.	€2658,70	€13.678,14	€11.019,44	-
	Scenario 1	€43,51/hour	€2393,05	€12.579,95	€10.186,90	- €832,54
	Scenario 2	€53,17/hour	€2987,35	€15.665,85	€12.678,50	+ €1659,06

Table 34: Sensitivity analysis: Financial Benefit for each percentual risk reduction

	Scenario	Financial benefit	Costs	Benefit	Net benefit	Delta
Worst-case	Baseline	€1123	€2658.70	€13.082,95	€10.424,25	-
	Scenario 1	€1010,70	€2658,70	€11.774,66	€9115,96	- €1308,29
	Scenario 2	€1235,30	€2658,70	€14.391,24	€11.732,54	+ €1308,29
Best-case	Baseline	€1123	€2658,70	€13.678,14	€11.019,44	-
	Scenario 1	€1010,70	€2658,70	€12.310,33	€9651,63	- €1367,81
	Scenario 2	€1235,30	€2658,70	€15.045,96	€12.387,26	+ €1367,81

6.2.8. Conclusion

Based on the assumptions and calculations, it can be concluded that the implementation of cross-functional handover meetings can yield significant benefits. In the best-case scenario, a risk reduction of 12,18% results in €13.678,14 in benefits. The worst-case scenario yields a 11,65% risk reduction, resulting in €13.082,95 in benefits. The total costs of the implementation for the various levels amount to €2658,70. In the worst-case scenario, this results in a net benefit of €10.424,25, while in the best-case scenario, the net benefit is €11.019,44. Thus, the potential risk reduction and associated financial benefits justify the investment. Importantly, both scenarios demonstrate positive outcomes, ensuring that the implementation of these meetings is beneficial regardless of the scenarios.

The sensitivity analysis further supports these findings by highlighting the critical impact of the percentual risk probability reduction. This parameter shows the largest potential increase in net benefits (up to +€1987,71) and the widest range of variability (from -€1098,19 to +€1987,71). This indicates that optimising risk reduction strategies is crucial for maximising net benefits. Conversely, the parameters of the numbers of representatives and the duration of the meeting show the smallest potential drawbacks, around -€600,40, suggesting that changes in these areas have limited negative impact on the financial results.

By focussing on optimising risk reduction strategies, the implementation of cross-functional handover meetings not only maximises the financial benefits but also enhances the likelihood of timely delivery and installation of CPT systems. The risk reduction of 12,18% (best case scenario) and 11,65% (worst-case scenario) reduces the probability of delays and unforeseen issues, thereby increasing the likelihood of achieving delivery and installation within the two-year period, specifically three to one years ahead of the project deadline. This improvement will help Urenco move closer to its target of increasing capacity by 2032.

Consequences if Urenco does not implement this solution:

- **Unchanged risk scores**: without these meetings, the likelihood of risks does not decrease as risks may go unnoticed and unaddressed. This means that the likelihood of delivering and installing CPT systems within the two-year period may remain unchanged, potentially leading to delays.
- **Higher overall risk exposure:** the absence of these meetings could result in higher overall risk exposure. Unidentified risks may escalate, causing unforeseen problems that could disrupt the project schedule and increase costs.
- **Impact on capacity targets:** failure to reduce risks and ensure timely delivery and installation of CPT systems could hinder Urenco's ability to meet its target of increasing capacity by 2032. Delays and inefficiencies could have a long-term impact on Urenco's strategic objectives.

Chapter conclusion

This chapter proposed a solution to improve the timely delivery and installation of CPT systems by addressing the misalignment between the Commodity Team and the Project Expansion Team. The approach includes cross-functional handover meetings and feedback mechanisms to ensure regular communication and alignment at strategic, innovative, and operational levels. The solution reduced Risk 10 (misalignment between stakeholders), reducing the overall risk score from 61,33 to 54,18 (worst-case scenario) and from 30,53 to 26,81 (best-case scenario). In financial terms, the best-case scenario yields a net benefit of €11.019,44, and the worst-case scenario yields a net benefit of €10.424,25 after accounting for implementation costs of €2.658,70. The sensitivity analysis highlights the importance of optimising risk reduction strategies to maximise net benefits. This improvement reduces the probability of delays and increases the likelihood of meeting the delivery and installation within the two-year period of projects, helping Urenco move closer to achieve its capacity target.

Chapter 7 analyses the overall research findings, focusing on their interpretation and broader implications. It discusses the contributions to theory and practice, addresses the limitations of the research, and provides recommendations for future research.

7. Discussion

Chapter introduction

This chapter analyses the research findings, focusing on the interpretation of the results. It discusses contributions to theory and practice, includes an extensive discussion on the limitations of the research to ensure a comprehensive understanding of the research context limitations of the research. In addition, it entails challenges and problem-solving, and provides recommendations for further research.

The chapter is divided into the following sections:

- *Section 7.1: **Interpretation of Results** – Interprets the results. .*
- *Section 7.2: **Contribution to Theory** – Describes the theoretical contribution.*
- *Section 7.3: **Contribution to Practice** – Describes the practical application.*
- *Section 7.4: **Reflection of Methodology** – Reflects on the use of the DMAIC methodology.*
- *Section 7.5: **Limitations of the Results** – Discusses the subjectivity, assumptions, and limitations.*
- *Section 7.6: **Enhancing Validity and Reliability** – Suggest measures to improve validity and reliability.*
- *Section 7.7: **Recommendations for Future Research** – Recommends areas for future research.*
- *Section 7.8: **Challenges and Problem-solving** – Describes the challenges and problem-solving strategies.*

7.1. Interpretation of Results

The results align with expectations and literature, with four CSF clusters: Supplier Relationship Management, Enterprise Planning, Dialogue Specification and Scope, and Stakeholder Transparency. These clusters are based on best practices and theoretical frameworks emphasising collaboration, proactive planning, clear specifications, and transparent communication. Although stakeholders didn't explicitly mention risk management, it is integrated into these clusters, contributing to risk identification, assessment, and mitigation. The CSFs are influenced by stakeholder roles and project management dynamics at Urenco. Good supplier relationships ensure timely, quality deliveries. Strategic planning and resource coordination are crucial for efficient project delivery. Clear specifications and project scope prevent misunderstandings and errors. Transparent communication ensures alignment and improves collaboration.

7.1.2. Nature of Risks Identified

The risks identified in this research are not actual problems but potential issues that could cause problems in the future. This research focuses on preventing potential problems by identifying and managing these risks. By reducing the likelihood of these risks occurring, the aim is to minimise their potential impact on the timely delivery and installation of CPT systems in global capacity expansions.

7.2. Contribution to Theory

This research introduces a risk identification approach using CSFs, inspired by (Farhan et al., 2018). It identifies CSFs based on stakeholder input and then pinpoints specific risks. By focusing on CSFs, the research narrows the scope to the most critical elements, ensuring highly relevant risks. This method enhances risk management accuracy by concentrating on the most significant risks, making efforts more effective and efficient in addressing impactful risks that could affect project success.

7.3. Contribution to Practice

This research enhances risk management by applying it to both strategic Commodity and tactical-operational Expansion Project Processes. A detailed process model compares these processes and their interactions, highlighting how strategic decisions impact tactical tasks. This model serves as a practical tool to visualise and understand the links between strategic and operational activities. Specific risks are identified at different stages, showing how risks in the Commodity Process can affect the Expansion Project Process. By understanding these risks, the research offers a comprehensive approach to reduce stakeholder misalignment and improve transparency. This alignment helps lower the probability of risks, supporting timely delivery and installation of CPT systems in global capacity expansions.

7.4. Reflection of Methodology

The DMAIC methodology was chosen for its systematic approach, dividing the research into five phases: Define, Measure, Analyse, Improve, and Control. This structure aided clarity and organisation. However, DMAIC is typically used for operational processes, raising questions about its suitability for this strategic/tactical research. While DMAIC was effective, exploring other methodologies might have been beneficial. A notable challenge was the Define phase, which is usually straightforward in operational contexts but complex here due to the need to align broader, abstract elements with strategic objectives. This complexity suggests that a different methodology might have been more appropriate for strategic risk analysis. Despite this, DMAIC ensured a systematic and structured research process.

7.5. Limitations of the Results

7.5.1. Subjectivity and Participant Bias

The research's reliance on interviews due to limited data introduces uncertainty and subjectivity, making it sensitive to participant bias. Stakeholder input was crucial for understanding the process model, identifying CSFs, and estimating risk likelihood. This input, supported by relevant literature, formed the basis for calculations and analysis. However, this reliance introduces unavoidable subjectivity, influencing the findings and potentially affecting the research's overall reliability.

7.5.2. Assumptions in Impact Estimation

In the Measure phase, CSFs were identified, and their quantitative impact was estimated based on logical assumptions. These assumptions were necessary as stakeholders couldn't specify the exact impact of each CSF. The researcher made informed estimates through discussions and process model interpretations, quantifying the impact in terms of potential delays (in months) if not managed properly. Assumptions included stakeholder criticality, process interdependencies, and strategic vs. tactical impacts. While necessary, these assumptions are simplifications. Different assumptions could yield different results, potentially highlighting other significant risks and influencing risk management focus and solutions.

7.5.3. Subjectivity in Likelihood Assessments

In the Analyse phase, stakeholders rated the likelihood of each identified risk on a scale of 1 (very low) to 5 (very high), focusing on general likelihood rather than role-specific likelihood. These qualitative assessments, based on the Expansion Project Team’s methodology, are inherently subjective and influenced by individual perspectives and biases. Frequent ratings of 2 or 3 may indicate a neutral response bias, suggesting risks are less pronounced than they are. High percentages in Table 18's right-hand column may appear arbitrary and problematic if seen as precise probabilities, indicating a volatile situation that may not reflect the actual risk environment. Different stakeholders or timescales could yield different ratings, highlighting other significant risks. To address these uncertainties, a sensitivity analysis on stakeholder ratings would have been beneficial, allowing a thorough assessment of variability and ensuring better decision-making. Future research should incorporate the standard deviation of responses for more realistic likelihood estimates.

7.5.4. Sensitivity Analysis

To address the uncertainties, a sensitivity analysis was carried out to assess the robustness of the proposed solution. However, this analysis focused on the cost-benefit variables of the solution rather than the impact and likelihood estimates. Future research should consider conducting a sensitivity analysis specifically for the impact and likelihood estimates to better understand the variability and reliability of these estimates. This would have allowed a more thorough assessment of the potential variability in these estimates and helped to ensure that the right decisions were made at this early stage of the research.

7.5.5. Evaluation of Proposed Solution

The proposed improvement involves cross-functional handover meetings and feedback mechanisms between the Commodity Team and the Project Expansion Team to ensure regular communication and alignment. These meetings are structured on three levels: strategic, innovative, and operational, with a facilitator and a note-taker. The advantages of this solution include improved communication and alignment, which reduces stakeholder misalignment and enhances coordination and project outcomes. It also results in a reduced overall risk score, from 61.33 to 54.18 in the worst-case scenario and from 30.53 to 26.81 in the best-case scenario. Financially, the solution provides a net benefit of €11,019.44 in the best-case scenario and €10,424.25 in the worst-case scenario after considering implementation costs.

However, there are some limitations and uncertainties. While the risk of misalignment is reduced, it is not eliminated, necessitating continuous monitoring and adjustment. The effectiveness of the solution depends heavily on active stakeholder participation, and limited participation may reduce its benefits. The assumptions and estimates used are based on stakeholder assessments, and inaccuracies could affect the solution's effectiveness. Additionally, the introduction of more meetings and feedback mechanisms may increase administrative overhead, potentially offsetting some financial benefits. Sensitivity analysis shows that optimizing risk mitigation strategies can increase net benefits up to €1,987.71. Changes in the number of representatives and meeting duration have minimal negative financial impact (-€600.40), indicating that the solution is relatively robust but still sensitive to implementation details.

7.6. Enhancing Validity and Reliability

To enhance the validity and reliability of the research, several measures can be considered. First, triangulating data by using multiple sources, such as surveys and performance metrics, can help validate findings and reduce reliance on subjective inputs. Additionally, conducting longitudinal studies to monitor the proposed solution over time allows for tracking its effectiveness and making necessary adjustments based on real-world performance.

Implementing pilot testing on a smaller scale before full deployment can identify potential issues and refine the approach. Developing and using standardized risk assessment tools ensures consistency and reduces subjectivity in evaluations. Finally, establishing a process for regular review and adjustment of risk management strategies, based on ongoing feedback and changing conditions, helps maintain their relevance and effectiveness. This process could include periodic reviews and updates of risk assessment criteria.

7.7. Recommendations for Future Research

To improve future research robustness, it should aim to collect more accurate and comprehensive data to reduce reliance on subjective inputs and increase reliability, especially regarding risk likelihood. When subjective inputs are necessary, conduct early sensitivity analysis to assess variability and minimise bias. In addition, invest more time in selecting a methodology tailored to the research's strategic or tactical level for better alignment with objectives and insights. Future research could explore different communication strategies and tools to reduce stakeholder misalignment and improve project outcomes. Developing quantitative risk assessment models that combine qualitative and quantitative data can provide comprehensive assessments using statistical methods for accurate predictions. Comparing risk management practices across industries can identify best practices and areas for improvement. Exploring project management software and communication platforms can enhance coordination and decision-making. By addressing these areas, future research can build on this study's findings and contribute to a more robust understanding of risk management in strategic and tactical contexts.

7.8. Challenges and Problem-Solving

During the research, challenges arose from differing approaches of the company and university supervisors. The company supervisor focused on a strategic overview, while the university supervisor emphasised process modelling and measurability. Reconciling these approaches was difficult, especially in building the process model during the Define phase, which was complex and time-consuming. To address these challenges, a joint meeting was held to align expectations, and a second professor helped refine the focus. By managing discussions and integrating perspectives, the researcher combined strategic and process-oriented approaches. This experience highlighted the importance of problem-solving skills and flexibility, ensuring the project's success and providing valuable lessons for future research.

Chapter conclusion

This chapter analysed the research findings, showing alignment with existing literature and best practices. It introduced a novel method for risk identification using CSFs, contributing to both theory and practice. The study acknowledged limitations such as subjectivity in stakeholder input and assumptions in impact estimation, highlighting the need for continuous validation. The use of the DMAIC methodology was critically assessed, noting its strengths, and questioning its fit for strategic analysis. Recommendations for future research were provided, emphasising the importance of accurate data collection, and exploring alternative methodologies. The insights gained are valuable for both academic and practical applications.

The insights gained from this discussion provide a foundation for Chapter 8, which synthesises these findings into a comprehensive conclusion and recommendation that answers the main research question.

8. Conclusion

Chapter introduction

Chapters 3 to 7 have provided answers to various sub-research questions. This chapter combines these answers to answer the main research question and thus to write the conclusion of this research.

8.1. Answers to Sub-research Questions

The main research question in this research is as follows: ***"How can Urenco manage supply chain-related risks to ensure the timely delivery and installation of Core Process Technology systems in global capacity expansions?"*** *To answer this main research question, answers to the following sub-research questions are combined:*

1.What Does the Process of Delivering and Installing CPT Systems in Global Capacity Expansions Entail?

The process involves parallel running of the Commodity Process and the Expansion Project Process. The Commodity Process secures long-term supplier commitment, while the Expansion Project Process details project-specific activities and decisions. These processes are interdependent, highlighting the need for improved communication and alignment.

2.a. What are the Critical Success Factors to Achieve the Timely Delivery and Installation of CPT Systems in Global Capacity Expansions?

Critical Success Factors to ensure a timely delivery and installation of CPT systems in global capacity expansions are grouped into four clusters: 1: Supplier Relationship Management with CSFs that all relate to the interaction and collaboration between Urenco and its suppliers. 2: Enterprise Planning with the CSFs that all focus on strategic planning and resource coordination. 3: Dialogue Specification and Scope with the CSFs that relates to the definition and communication of specifications and project scope. 4: Stakeholder Transparency with the CSF transparent stakeholder communication, which emphasises the importance of clear communication between stakeholders. CSF Project prioritisation (within cluster 2) and CSF transparent stakeholder communication (within cluster 4) are particularly critical, often causing delays of 12-18 months if not properly managed.

2.b. Where Do These Critical Success Factors Fit within the Process?

All four CSF clusters are critical to both the Commodity Process and the Expansion Project Process. CSFs that are critical in the Commodity Process affect both the Commodity Process and the Expansion Project Process. CSFs that are critical in the Expansion Project Process primarily affect steps within that process. Effective communication processes are essential in both processes to ensure alignment and prevent misunderstandings.

3.What are the Supply Chain-Related Risks Associated with the Critical Success Factors?

Ten potential risks are identified that could hinder the timely delivery and installation of CPT systems. Among these, stakeholder misalignment is particularly significant. This risk is common to both the Commodity Process and the Expansion Project Process, occurring after each flow of information between the Commodity Team, the Project Expansion Team, and the suppliers. It deserves particular attention for several reasons. First, it has the highest average probability 0,80 and the highest impact of 12-18 months, resulting in the highest risks score of LB 9,60 and UB 14,40. Second, it fundamentally impacts both processes, due to the required involvement and interdependency between these stakeholder groups. Finally, interviews revealed inconsistencies in the process, overlapping responsibilities, different focuses in supplier interactions, and multiple stakeholders considering CSFs as critical.

4.What Solutions can Reduce and Control the Criticality of CPT System Delivery in Global Capacity Expansions?

The proposed improvement involves cross-functional handover meetings and feedback mechanisms between the Commodity Team and the Project Expansion Team to ensure regular communication and alignment. These meetings, structured on strategic, innovative, and operational levels, include a facilitator and note-taker for thorough documentation. Initially aimed at reducing Risk 10 (stakeholder misalignment), this solution reduced the overall risk score from 61.33 to 54.18 (worst-case) and from 30.53 to 26.81 (best-case). In the best-case scenario, the solution has a relative impact of 12.18%, resulting in financial benefits of €13.678,14 and a net benefit of €11.019,44 after accounting for implementation costs of €2.658,70. In the worst-case scenario, the relative impact is 11.65%, resulting in financial benefits of €13.082,95 and a net benefit of €10.424,25 after implementation costs. Sensitivity analysis shows that optimizing risk reduction strategies can increase net benefits up to €1.987,71. Changes in the number of representatives and meeting duration have minimal negative financial impact (-€600,40). This improvement reduces the likelihood of delays and unforeseen issues, increasing the chances of meeting project delivery and installation timelines, helping Urenco move closer to its capacity target.

8.2. Answer to Main Research Question

All the above answers together answer the main research question:

Urenco can manage supply chain-related risks and achieve timely delivery and installation of CPT systems in global capacity expansions **by implementing cross-functional handover meetings and feedback mechanisms** between the Commodity Team and the Project Expansion Team. These meetings ensure regular communication and alignment, discussing progress, challenges, expectations, and updates. Structured at **strategic**, **innovative**, and **operational** levels, each meeting includes a facilitator and a note-taker for thorough documentation. Key meetings occur at the start, six months later, and twelve months into the project. The solution reduced the overall risk score from **61,33 to 54,18** (worst-case) and from **30,53 to 26,81** (best-case). Financially, it yields **net benefits of €11.019,44** (best-case) and **€10.424,25** (worst-case), after implementation costs of €2.658,70. Sensitivity analysis shows potential net benefits increasing up to €1.987,71. This improvement reduces delays, **increasing the likelihood of meeting the two-year delivery and installation period,** supporting Urenco’s capacity target by 2032.

Chapter conclusion

This chapter concludes that Urenco can manage supply chain-related risks for CPT systems and achieve timely delivery and installation of CPT systems in global capacity expansions by implementing cross-functional handover meetings and feedback mechanisms. These meetings ensure regular communication and alignment at strategic, innovative, and operational levels, reducing the overall risk score and yielding significant financial benefits. This approach minimises delays and unforeseen issues, increasing the likelihood of meeting project timelines and supporting Urenco's capacity expansion goals for 2032.

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10. Appendices

A. Overall Management System Urenco

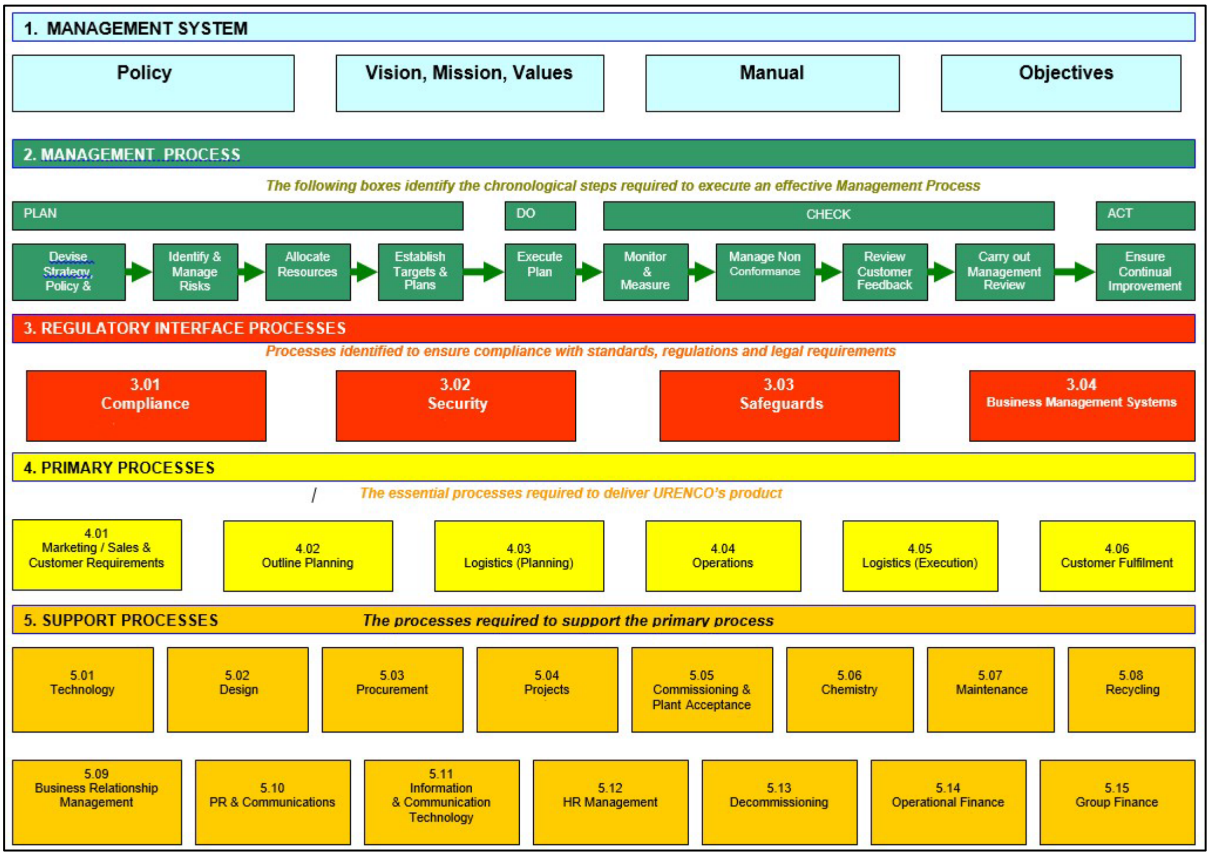

Figure A23: Overall Management System Urenco

B. Organisation Chart Urenco

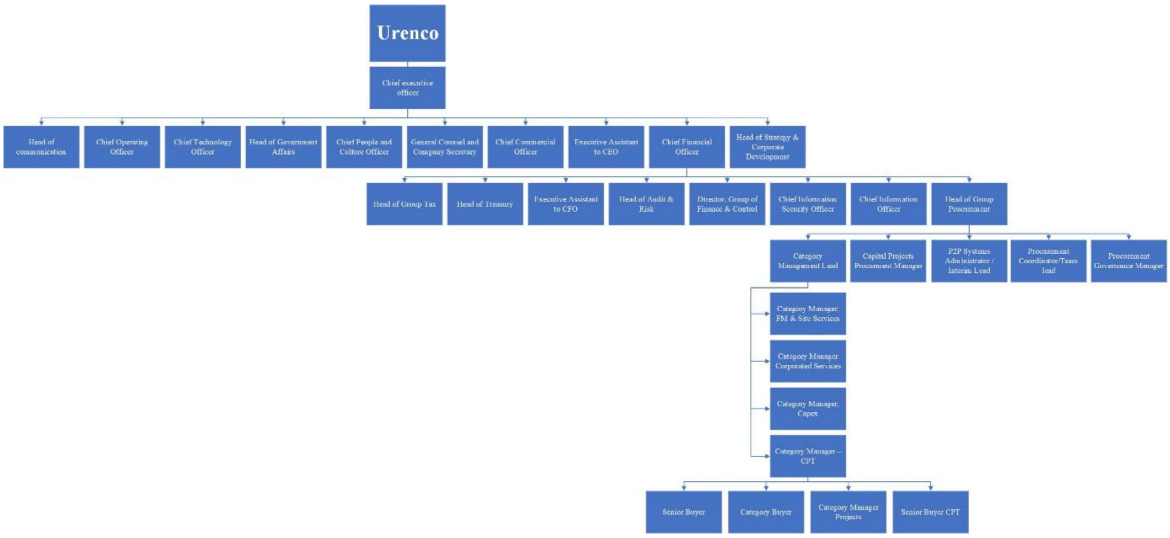

Figure B24: Organisation chart Urenco

Figure B25: Specific organisation chart Urenco

C. Function Descriptions in Project Expansion Team

Project Management: Accountable for the delivery of the project and is held to account by the project board. The Project Manager manages the delivery of scope, time, cost, and quality within agreed project tolerances and prepares and executes the Project Initiation Document (PID), project strategy, scope of work (SoW) and all expenditure proposals. This includes:

- Setting the project baseline for scope, cost, schedule, and risk
- Agreeing the Categorisation for the project
- Accurately recording project progress against the agreed and sanctioned project baseline
- Ensuring compliance with Export Control requirements
- Owning and updating the project risk register
- Monitoring and controlling project costs
- Owning and updating the project schedule
- Managing delivery of the relevant design documentation for review and client acceptance in line with the Design Management Procedures where appropriate
- Implementing the procurement, construction, and commissioning activities
- HS&E compliance and adherence to Urenco procedures and obligations
- Providing accurate Project Highlight Reports to the project board
- Monitoring that all project participants comply with site rules and regulations.
- Preparing handover documentation including Quality Assurance (QA) files and Operations and Maintenance (O&M) Manuals

Procurement & Contracting: Responsible for appropriate supplier selection / bidding processes and supplier contract pricing validation for the project. Responsible for the management of all supplier communications, during pre-contract negotiations.

Design: The Design Authority is responsible for ensuring the consequences of any design decisions are understood. The Design Authority is the intelligent customer that provides technical/design assurance on the project. This includes:

- Being accountable for the integrity of the design, including design interfaces, and the compliance with site licenses and local standards and legislations
- Consultation with Urenco Group Design Authority for issues regarding standard, qualified Urenco design
- Approving and releasing design deliverables, scope, and schedule changes (for escalation and consideration of the project board)

Acceptance & Commissioning: Providing any relevant acceptance and commissioning criteria to be included in the overall Project Schedule. Approving the Acceptance Plan and the Commissioning Plan if produced. Accepting the installation/equipment once all commissioning is complete. Responsible for developing an Acceptance Test Plan (ATP) as detailed.

Construction: Ensure constructability is an integral part of the design process. Supervise and direct the delivery of the construction phase of a project from conception through to completion. Oversees onsite and offsite construction and liaises between the project manager and the site works.

Engineering: Responsible for the production and development of technical aspects as defined by the Project Engineering Manager or Project Manager. Liaison between the Project Engineering Manager or Project Manager and technical disciplines (including User responsible elements).

Quality: Responsible for verification that the products or services delivered by the project are fit for purpose and capable of delivering the benefits specified by the project board.

Health Safety Environment: Responsible for the encouragement, regulation and enforcement of workplace health, safety, environmental concerns, welfare, and occupational risk on the project.

D. Function Descriptions in Commodity Team

Design Authority provides technical and design assurance, ensuring the implications of design decisions are understood and maintaining the integrity of the design and its interfaces. It handles issues related to Urenco's standard design, approves, and releases design deliverables, and manages scope and schedule changes.

Asset Management aligns Urenco's business strategy with asset management plans, translating strategic needs into asset requirements and investment decisions to fulfil commitment to a sustainable future. It involves planning and ensuring programme assurance across the asset lifecycle for all tangible assets (excluding mobile assets, R&D assets, business development related assets) and plant-IT assets (excluding office IT). This also includes core enrichment assets as defined in Urenco Group engineering standards.

Research & Development plays a critical role in driving innovation and technological advancement within Urenco. The R&D team is responsible for identifying, developing, and implementing new technologies and processes that contribute to the company's strategic objectives. This includes conducting fundamental and applied research, developing prototypes, and testing new concepts to enhance the efficiency, safety, and sustainability of Urenco's operations. R&D collaborates closely with other departments to ensure the seamless integration of new technologies into existing systems and processes. In addition, R&D manages Urenco's intellectual property and ensures compliance with relevant laws and regulations.

CPT *Procurement* ensures that Urenco's external third-party expenditures align with delivering value for money, being a responsible buyer, and maintaining the safe, efficient, and secure operations of assets. It supports transparent, equitable, and legally compliant supplier relationships, overseeing procurement activities across the Urenco group. This includes all activities related to the lifecycle of goods or services, with adherence to the procurement policy begin responsibility at both individual and corporate levels.

E. Comparison of Project Schedules

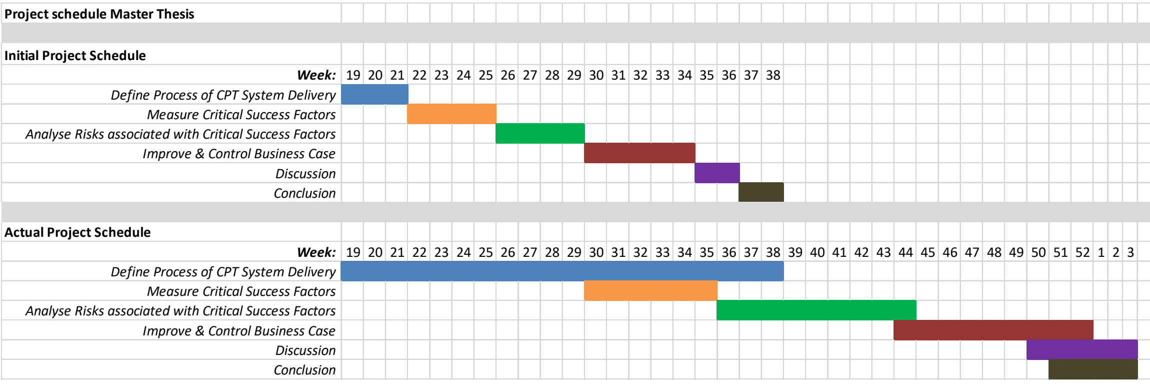

Figure E26: Comparison between Initial Project Schedule and Actual Project Schedule

F. Interview DEFINE– Identification of the Process

Goal: To gain insight into the process regarding CPT system delivery in capacity expansions globally.

Type of interview: Semi-structured interview

Stakeholder population: Participants of the Commodity Team and the Project Expansion Team, 6 key stakeholder groups:

1. Research & Development
2. Design Authority
3. CPT Procurement
4. Project Management
5. Asset Management
6. Supplier

Questions posed:

- What are CPT systems? And what is its time perspective in capacity expansion?
- What steps are involved in the delivery and installation of CPT systems in capacity expansions globally?
- How do the Commodity Process and the Project Expansion Process run?

- What decisions are made in and between these steps?
- What documents or inputs/outputs are crucial?
- How do these documents or inputs/outputs move through the process and who has the responsibility for communication with suppliers?
- Who are involved in these steps and decisions?
- How do different Teams interact during the process?
- What is the information flow between the different stakeholders?

- How are various capacity expansions managed?
- What is required to start a capacity expansion?
- Who manage the entirety of capacity expansions?
- How is one capacity expansion managed?
- How are multiple capacity expansions managed?
- Where in the process are CPT systems delivered and installed?
- What is required to deliver CPT items?

G. Obtained Data DEFINE – Identification of the Process

For each team, only the questions on which the researcher observed disagreement are worked out in detail.

What are CPT systems? And what is its time perspective in capacity expansion?

- Entirety of (sub)components
- Several system groups: 400 to 800
- Several systems and subsystems
- Required in enrichment facilities, in expansion projects around 2 years before project deadline.

What steps are involved in the delivery and installation of CPT systems in capacity expansions globally?

- Determine capacity failure and required capacity addition.
- Determine CPT technology.
- Determine CPT suppliers.
- Determine ranking of capacity expansion plans
- Determine forecast of CPT systems
- Determine production availability.
- Determine engineering- and lead times.
- Secure production slots
- Align production slots and supplier times.

How do the Commodity Process and the Project Expansion Process run?

Table G35: Stakeholder answers to question: How do the Commodity Process and the Project Expansion Process run?

Stakeholders Commodity Team	**Stakeholders Project Expansion Team**	**Stakeholder Supplier**
Research & Development Design Authority CPT Procurement Asset Management	Project Management	Supplier
The Commodity Team views the Commodity Process as the backbone of the entire operation, running continuously and providing a stable foundation for the Project Expansion Process. They argue that the Project Expansion Process should align with the Commodity Process timelines and milestones. They believe that their process is more	The Project Expansion Team believes that the Commodity Process and the Project Expansion Process run in parallel but with distinct phases of interaction. They see the Project Expansion Process as the primary driver, with the Commodity Process providing support at key milestones. They emphasise that their process is more dynamic and responsive to	From the supplier's perspective, the Commodity Process and the Project Expansion Process run in parallel but often lack clear points of interaction. They find it challenging to synchronise their efforts with both processes due to the lack of clear communication and alignment. They believe that better integration and coordination between the two processes are

strategic and long-term, while the Project Expansion Process is more tactical and project specific. They also recognise that the Commodity Process is ongoing, operating on a moving window of 10 years, whereas the Project Expansion Process is finite with defined beginning and end points, typically lasting approximately 6 years per project but depending on the project. They acknowledge that the parallel activities make it difficult to follow a clear process.	project-specific needs, while the Commodity Process is more static and focused on long-term planning. They acknowledge that the Commodity Process is continuous and has no end, operating on a moving window of 10 years, while the Project Expansion Process has a clear start and end point, typically lasting approximately 6 years per project but depending on the project. They are aware that the parallel activities make it difficult to follow a clear process.	needed to ensure smooth operations and timely deliveries. Suppliers understand that the Commodity Process is continuous and never-ending, operating on a moving window of 10 years, while the Project Expansion Process has distinct start and end points, typically lasting approximately 6 years per project but depending on the project. They also recognise that the parallel activities make it difficult to follow a clear process.

What decisions are made in and between these steps?

- Decision of production availability
- Decision of changing forecast
- Decision of planning alignment
- Decision of approved detailed design specification
- Decision of system acceptance

What documents or inputs/outputs are crucial?

- Project portfolio
- Designs
- Developments
- Request for information
- Lead time and engineering times
- Production slots
- Demand planning
- Supplier base
- Project planning
- Scope of work
- System breakdown
- Project scope
- Purchase order
- (detailed) Design specification

How do these documents or inputs/outputs move through the process and who has responsibility for communication with suppliers?

Table G36: Stakeholder answers to question: How do these documents or inputs/outputs move through the process and who has responsibility for communication with suppliers?

Stakeholders Commodity Team	**Stakeholders Project Expansion Team**	**Stakeholder Supplier**
Research & Development Design Authority CPT Procurement Asset Management	Project Management	Supplier
The Commodity Team views themselves as the key players in managing the strategic flow of documents and inputs/outputs. They argue that their deep knowledge of suppliers and their capacities positions them to define and maintain the strategic relationships and handle the most critical transactions. They believe that they are responsible for ensuring that long-term capacity and system needs are communicated and documented accurately. The Commodity Team sends documents to both suppliers and the Project Expansion Team, and they receive inputs from suppliers and internal planning teams. Different stakeholders with different interests and multiple groups talking to suppliers add complexity. *"Our team has the deepest knowledge of suppliers and their capacities. We are the ones who define and maintain the strategic relationship and the most important transactions."*	The Project Expansion Team believes that they play a central role in managing the flow of documents and inputs/outputs throughout the process. They see themselves as the primary decision-makers and coordinators, ensuring that all necessary information is communicated effectively to suppliers and other stakeholders. They emphasise their responsibility in overseeing the documentation related to engineering and project-specific requirements. The Project Expansion Team sends documents primarily to suppliers and receives inputs from the Commodity Team and other internal stakeholders. Different stakeholders with different interests and multiple groups talking to suppliers add complexity. For example, while the Project Expansion Team might focus on immediate project needs, the Commodity Team might prioritise long-term strategic goals, leading to potential conflicts and confusion. "*We are the ones who make the decisions and have the most interaction with suppliers. Our role is crucial in coordinating and managing the communication".*	From the supplier's perspective, the flow of documents and inputs/outputs primarily involves long-term capacity and system needs discussions with the Commodity Team. They see the Commodity Team as their main point of contact for strategic planning and relationship management. The Project Expansion Team, on the other hand, interacts with them mainly for specific engineering questions and project-specific documentation. Suppliers send documents to both the Commodity Team and the Project Expansion Team, and they receive inputs primarily from the Commodity Team. *"We primarily discuss long-term capacity and system needs across Urenco with the Commodity Team, as that is where our relationship starts. The Project Expansion Team contacts us mainly about specific engineering questions related to the expansion project."*

What is the information flow between the different stakeholders?

Table G37: Stakeholder answers to question: What is the information flow between the different stakeholders?

Stakeholders Commodity Team	**Stakeholders Project Expansion Team**	**Stakeholder Supplier**
Research & Development Design Authority CPT Procurement Asset Management	Project Management	Supplier
The Commodity Team views themselves as the key players in managing documents such as the 10-year project portfolio, CPT designs, CPT developments, and supplier base information. They argue that their deep knowledge of suppliers and their capacities positions them to define and maintain the strategic relationships and handle the most critical transactions. They believe that they should also manage documents like the project scope and detailed design specifications, which they see as essential for maintaining strategic alignment. There is clear alignment on the required CPT systems for various expansions. This alignment is a continuous process and is managed by the Commodity Team, not within individual projects. This is unanimously agreed upon by all stakeholders.	The Project Expansion Team believes that documents such as the project scope, system breakdown, project planning, and detailed design specifications are primarily managed by them and shared with suppliers. They see themselves as the primary decision-makers and coordinators, ensuring that all necessary information is communicated effectively to suppliers and other stakeholders. They believe that they should also handle documents like the 10-year project portfolio and CPT developments, which they feel are crucial for their planning. They are also aware that the required CPT systems for various expansions are not driven by individual projects but are managed by the Commodity Team. This is a continuous process.	From the supplier's perspective, documents such as request for information, demand planning, production slots, and supplier lead times are primarily managed through their interactions with the Commodity Team. They see the Commodity Team as their main point of contact for strategic planning and relationship management. However, they also believe that the Project Expansion Team should be more involved in managing documents like the detailed design specifications and project planning to ensure that engineering requirements are met.

What is the time perspective of the process?

- Commodity Process: moving window of 10 years.
- Project process: approximately 6 years per project but depends on project.

How are various capacity expansions managed?

- Via helicopter view of Commodity Team

What is required to start a capacity expansion?

- Information from Commodity Team: project portfolio, cpt development, project Team

Who manage the entirety of capacity expansions?

- Commodity Team

How is one capacity expansion managed?

- Via Expansion Project Process, Project Expansion Team is responsible.

Where in the process are CPT systems delivered and installed?

- At the end of the project process, after approval and production of detailed design specification

H. Interview MEASURE – Identification of the Critical Success Factors

Goal: To identify CSFs that ensure the timely delivery and installation of CPT systems in capacity expansions globally.

Type of interview: Semi-structured interview

Stakeholder population: Participants of the Commodity Team and the Project Expansion Team, 6 key stakeholder groups:

1. Research & Development
2. Design Authority
3. CPT Procurement
4. Project Management
5. Asset Management
6. Supplier

Questions posed:

- What factors do you consider crucial for achieving a timely delivery and installation of CPT systems?
- What elements are essential in the process to ensure the timely delivery and installation of CPT systems?
- What key aspects should be focused on to achieve a timely delivery and installation of CPT systems?
- What do you believe are the most important considerations for the timely delivery and installation of CPT systems?
- What challenges do you foresee in achieving a timely delivery and installation of CPT systems?

I. Obtained Data MEASURE – Identification of the Critical Success Factors

Data (critical success factors) obtained from stakeholder interviews:

1. Supplier collaboration: Working closely with suppliers to leverage supplier expertise and ensures effective design and timely delivery of CPT systems.

2. Project scope clarity: Clarity in the overall scope of an expansion plan with the expected deliverables, including objectives, phases, tasks, resources, and stakeholder needs.

3. Qualified suppliers: Qualify suppliers to ensure that they meet Urenco's quality standards.

4. Proactive system planning: Anticipating proactive system planning. This allows for adjustment to be made ahead of time to keep track.

5. Project prioritisation: Determining the order of importance of different projects. This helps allocate resources and attention to the most critical areas first.

6. Transparent supplier communication: Sharing clear and honest information about forecasts, plans, and expectations with suppliers. This transparency helps in aligning goals and preventing misunderstandings.

7. Capacity reservation: Securing necessary capacity and resources at suppliers in advance to meet project demands. This involves coordinating with both internal Teams and external suppliers to ensure availability.

8. Engineering and lead time alignment: Ensuring that plannings are placed in sync with project timelines. This helps avoid delays and ensures that all necessary items are available when needed.

9. Specification clarity: clarity in specification to prevent misunderstandings and rework.

10. Demand generality: It provides clarity by allowing room for adjustments and changes. This can be useful in the long term when the exact requirements are not yet fully known. Suppliers can prepare for a wide range of potential needs without committing to exact numbers or specifics early on.

11. Early supplier involvement: Engaging suppliers early to address resource availability.

12. Specification frozen-based ordering: Finalising and agreeing upon specifications before placing orders. This practice minimises delays and errors by ensuring that the design phase is thoroughly reviewed and approved.

J. Interview ANALYSE - Transforming Critical Success Factors into Potential Risks

Goal: Identification and validation of potential risks to the CSFs in question. The focus was on assessing whether these risks represent a threat to the CSFs and the timely delivery of CPT systems.

Input for interview: Underlying key Critical Success Factor points swapped into risks through researcher.

Type of interview: Semi-structured interview

Stakeholder population: Participants of the Commodity Team and the Project Expansion Team, , 6 key stakeholder groups:

1. Research & Development
2. Design Authority
3. CPT Procurement
4. Project Management
5. Asset Management
6. Supplier

Questions posed:

- What are the challenges or obstacles in realising this CSF?
- Do you see any other risks arising from this item that are not yet listed?
- How is this risk different from other risks we have discussed for this CSF?
- How do you recognise these risks in the process?

K. Sensitivity Analysis Business Case

Sensitivity analysis: Cost analysis: Number of required representatives per level of meeting

Table K38: Number of required representatives per level of meeting

		Number of representatives					
	Scenario	Strategic	Innovative	Operational	Costs	Benefit	Net benefit
Worst-case	Baseline	5 representatives	7 representatives	7 representatives	€2658.70	€13.082,95	€10.424,25
	Scenario 1	4 representatives	6 representatives	6 representatives	**€2224,64**	€12.048,49	€9823,85
	Scenario 2	6 representatives	8 representatives	8 representatives	**€3093,76**	€14.902,21	€11808,45
Best-case	Baseline	5 representatives	7 representatives	7 representatives	€2658,70	€13.678,14	€11.019,44
	Scenario 1	4 representatives	6 representatives	6 representatives	**€2224,64**	€12.579,95	€10.355,31
	Scenario 2	6 representatives	8 representatives	8 representatives	**€3093,76**	€15.665,85	€12.572,09

Level	**Number of stakeholders (scenario 1)**	**Preparation duration (hours)**	**Meeting duration (hours)**	**Follow-Up duration (hours)**	**Total hours**	**Costs per level (EUR)**
Strategic	4 representatives	1.00	2.00	1.00	4.00	€774,44
Innovative	6 representatives	0.75	1.50	0.75	3.00	€870.12
Operational	6 representatives	0.50	1.00	0.50	2.00	€580,08
Total	-				9.00	**€2224,64**

Level	**Number of stakeholders (scenario 2)**	**Preparation duration (hours)**	**Meeting duration (hours)**	**Follow-Up duration (hours)**	**Total hours**	**Costs per level (EUR)**
Strategic	6 representatives	1.00	2.00	1.00	4.00	€1160,16
Innovative	8 representatives	0.75	1.50	0.75	3.00	€1160,16
Operational	8 representatives	0.50	1.00	0.50	2.00	€773,44
Total	-				9.00	**€3093,76**

Sensitivity analysis: Cost analysis: Duration of meeting

Table K39: duration of meeting

		Duration of meeting					
	Scenario	Strategic	Innovative	Operational	Costs	Benefit	Net benefit
Worst-case	Baseline	4 hours	3 hours	2 hours	€2658.70	€13.082,95	€10.424,25
	Scenario 1	3,6 hours	2,7 hours	1,8 hours	**€2392,46**	€12.048,49	€9823,85
	Scenario 2	4,4 hours	3,3 hours	2,2 hours	**€2924,58**	€14.902,21	€11977,63
Best-case	Baseline	4 hours	3 hours	2 hours	€2658,70	€13.678,14	€11.019,44
	Scenario 1	3,6 hours	2,7 hours	1,8 hours	**€2392,46**	€12.579,95	€10.355,31
	Scenario 2	4,4 hours	3,3 hours	2,2 hours	**€2924,58**	€15.665,85	€12.741,27

Level	**Number of stakeholders**	**Preparation duration (hours)**	**Meeting duration (hours)**	**Follow-Up duration (hours)**	**Total hours (scenario 1)**	**Costs per level (EUR)**
Strategic	5 representatives	1.00	2.00	1.00	3,6	€870,12
Innovative	7 representatives	0.75	1.50	0.75	2,7	€913,26
Operational	7 representatives	0.50	1.00	0.50	1,8	€609,08
Total	-				8,1	**€2392,46**

Level	**Number of stakeholders**	**Preparation duration (hours)**	**Meeting duration (hours)**	**Follow-Up duration (hours)**	**Total hours (scenario 2)**	**Costs per level (EUR)**
Strategic	5 representatives	1.00	2.00	1.00	4,4	€1063,48
Innovative	7 representatives	0.75	1.50	0.75	3,3	€1116,66
Operational	7 representatives	0.50	1.00	0.50	2,2	€744,43
Total	-				9,9	**€2924,58**

Sensitivity analysis: Cost analysis: Hourly rates of representatives

Table K40: hourly rates of representatives

	Scenario	Hourly rate	Costs	Benefit	Net benefit
Worst-case	Baseline	€48,34/hour	€2658.70	€13.082,95	€10.424,25
	Scenario 1	€43,51/hour	**€2393,05**	€12.048,49	€9655,44
	Scenario 2	€53,17/hour	**€2987,35**	€14.902,21	€11914,86
Best-case	Baseline	€48,34/hour	€2658,70	€13.678,14	€11.019,44
	Scenario 1	€43,51/hour	**€2393,05**	€12.579,95	€10.186,90
	Scenario 2	€53,17/hour	**€2987,35**	€15.665,85	€12.678,50

Level	Number of stakeholders	Preparation duration (hours)	Meeting duration (hours)	Follow-Up duration (hours)	Total hours	Costs per level (EUR) (scenario 1)
Strategic	5 representatives	1.00	2.00	1.00	4.00	€870,20
Innovative	7 representatives	0.75	1.50	0.75	3.00	€913,71
Operational	7 representatives	0.50	1.00	0.50	2.00	€609,14
Total	-				9.00	**€2393,05**

Level	Number of stakeholders	Preparation duration (hours)	Meeting duration (hours)	Follow-Up duration (hours)	Total hours	Costs per level (EUR) (scenario 2)
Strategic	5 representatives	1.00	2.00	1.00	4.00	€1063,40
Innovative	7 representatives	0.75	1.50	0.75	3.00	€1179,57
Operational	7 representatives	0.50	1.00	0.50	2.00	€744,38
Total	-				9.00	**€2987,35**

Sensitivity analysis: Benefit analysis: Percentual risk probability reduction

Table K41: percentual risk probability reduction

	Scenario	Risk reduction	Costs	Benefit	Net benefit
Worst-case	Baseline	23%	€2658.70	€13.082,95	€10.424,25
	Scenario 1	20.7%	€2658,70	€12.048,49	€9389,79
	Scenario 2	25.3%	€2658,70	€14.902,21	€12.243,51
Best-case	Baseline	23%	€2658,70	€13.678,14	€11.019,44
	Scenario 1	20.7%	€2658,70	€12.579,95	€9921,25
	Scenario 2	25.3%	€2658,70	€15.665,85	€13.007,15

Risk	Expected probability (20.7% reduction)	Best Case Impact	Worst Case Impact	New Risk score Best Case	New Risk score Worst Case	Delta probability reduction	Delta risk score Best Case	Delta risk score Worst Case
1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-
4	0.50	12 months	18 months	6.00	9.00	-0.13	-1.55	-2.38
5	0.48	0 months	6 months	0.00	2.88	-0.12	0.00	0.72
6	-	-	-	-	-	-	-	-
7	0.42	6 months	12 months	2.52	5.04	-0.11	-0.67	-1.34
8	0.42	0 months	3 months	0.00	1.26	-0.11	0.00	0.34
9	-	-	-	-	-	-	-	-
10	*0.70	12 months	18 months	8.40	12.60	-0.09	-1.2	-1.80

Risk	Initial risk score Best Case	Initial risk score Worst Case	New risk score Best Case	New risk score Worst Case
1	3.19	6.38	3.19	6.38
2	3.40	6.79	3.40	6.79
3	0.00	1.90	0.00	1.90
4	7.55	11.38	**6.00**	**9.00**
5	0.00	3.60	**0.00**	**2.88**
6	3.60	7.20	3.60	7.20
7	3.19	6.38	**2.52**	**5.04**
8	0.00	1.60	**0.00**	**1.26**
9	0.00	1.70	0.00	1.70
10	9.60	14.40	**8.40**	**12.60**
Total	*30.53*	*61.33*	*27.11*	*54.75*
Delta best case scenario			*-3.42*	
Delta worst case scenario				*-6.58*

Scenario	Absolute change	Percentage change	Financial risk (EUR)
Worst-case	-6.58	10.73%	€12.048,49
Best-case	-3.42	11.20%	€12.579,95

Scenario	Total costs (EUR)	Total benefits (EUR)	Net benefits (EUR)
Worst-case	€2658,70	€12.048,49	€9389,79
Best-case	€2658,70	€12.579,95	€9921,25

Sensitivity analysis: Benefit analysis: Financial benefit for each percentual risk reduction

Table K42: financial benefit for each percentual risk reduction

	Scenario	Risk reduction	Costs	Benefit	Net benefit
Worst-case	Baseline	23%	€2658.70	€13.082,95	€10.424,25
	Scenario 1	20.7%	€2658,70	€12.048,49	€9389,79
	Scenario 2	25.3%	€2658,70	€14.902,21	€12.243,51
Best-case	Baseline	23%	€2658,70	€13.678,14	€11.019,44
	Scenario 1	20.7%	€2658,70	€12.579,95	€9921,25
	Scenario 2	25.3%	€2658,70	€15.665,85	€13.007,15

Risk	Expected probability (20.7% reduction)	Best Case Impact	Worst Case Impact	New Risk score Best Case	New Risk score Worst Case	Delta probability reduction	Delta risk score Best Case	Delta risk score Worst Case
1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-
4	0.50	12 months	18 months	6.00	9.00	-0.13	-1.55	-2.38
5	0.48	0 months	6 months	0.00	2.88	-0.12	0.00	0.72
6	-	-	-	-	-	-	-	-
7	0.42	6 months	12 months	2.52	5.04	-0.11	-0.67	-1.34
8	0.42	0 months	3 months	0.00	1.26	-0.11	0.00	0.34
9	-	-	-	-	-	-	-	-
10	*0.70	12 months	18 months	8.40	12.60	-0.09	-1.2	-1.80

Risk	Initial risk score Best Case	Initial risk score Worst Case	New risk score Best Case	New risk score Worst Case
1	3.19	6.38	3.19	6.38
2	3.40	6.79	3.40	6.79
3	0.00	1.90	0.00	1.90
4	7.55	11.38	**6.00**	**9.00**
5	0.00	3.60	**0.00**	**2.88**
6	3.60	7.20	3.60	7.20
7	3.19	6.38	**2.52**	**5.04**
8	0.00	1.60	**0.00**	**1.26**
9	0.00	1.70	0.00	1.70
10	9.60	14.40	**8.40**	**12.60**
Total	*30.53*	*61.33*	*27.11*	*54.75*
Delta best case scenario			*-3.42*	
Delta worst case scenario				*-6.58*

Scenario	Absolute change	Percentage change	Financial risk (EUR)
Worst-case	-6.58	10.73%	€12.048,49
Best-case	-3.42	11.20%	€12.579,95

Scenario	Total costs (EUR)	Total benefits (EUR)	Net benefits (EUR)
Worst-case	€2658,70	€12.048,49	€9389,79
Best-case	€2658,70	€12.579,95	€9921,25