Informed Decision-Making in the Transition to ERTMS in the Dutch Railway Sector

T.H. van Dijk

MSc Thesis
Construction Management & Engineering
Faculty of Engineering Technology

Colophon

Title	*Informed Decision-Making in the transition to ERTMS in the Dutch Railway Sector*
Version	*1.0 – Final version*
Location	*Utrecht*
Date	*May 27, 2024*

Author	*Ing. T.H. van Dijk (Thomas)*
Student number	*s2866552*
Institution	*University of Twente (UT)*
Faculty	*Engineering Technology (ET)*
Department	*Construction Management and Engineering*
Email	
Supervisor UT	*Dr. ir. R.S. de Graaf (Robin)* *University of Twente* *Faculty of Engineering Technology*
Supervisor UT	*Dr. ir. M. van Buiten (Marc)* *University of Twente* *Faculty of Engineering Technology*
Supervisor ProRail	*Mr. T.T.A. Oudenhoven (Tom)* *ProRail* *Programme Directorate ERTMS*

The company logos were obtained from http://www.ertms.nl and http://www.utwente.nl

Acknowledgements

Summary

The European Rail Traffic Management System (ERTMS) is the new European standard for train safety and enhances interoperability on the railway in Europe. To implement ERTMS in the Netherlands, adjustments are needed in the infrastructure and trains, and working methods must be adapted. The implementation of ERTMS in the Netherlands affects several rail sector parties, such as ProRail and NS. ProRail is the rail infrastructure owner and NS is the main passenger carrier in the Netherlands. The Programme Directorate ERTMS is responsible for directing and coordinating this ERTMS implementation programme in the Netherlands. To make this programme a success, it is essential that the three ERTMS components – infrastructure, train, and personnel – collaborate seamlessly.

Within the ERTMS programme, these components are affected by various ongoing projects and require decisions to be made. For example, on which location the ERTMS system is to be tested and what the technical design must look like. In addition, proposals are made for new projects that can contribute to the programme's goals, such as the project of the MerwedeLingelijn. This project is about converting the infrastructure of this railway line to ERTMS. It does not fall in the current scope of the programme. However, it is an example of a project the Programme Directorate faces. Such projects require careful analysis and informed decision-making because they impact the further progress of the overarching programme. Therefore, informed decision-making is crucial. Due to the unique nature of the projects, it is challenging to gather and analyse all crucial information, and adequately provide stakeholders with essential information before making a decision.

To answer the main research question of this thesis – *How is information dealt with in decision-making within the Programme Directorate ERTMS regarding ERTMS implementation projects in the Netherlands, and what recommendations can be drawn from the comparison between theory and the current decision-making process to enhance the success of the programme?* – this research is structured into four phases.

The first phase involves conducting literature research on characteristics of complex decision-making within public organisations. An underlying principle is that decision-making should strive for rationality, so that the benefits of a project are maximised based on the available information. Additionally, various information aspects (e.g. sources, timeliness, and accessibility of information) are specified that should be considered in public sector decision-making processes. These aspects are subdivided into why, what, who, when, where, and how questions. Based on the literature research, a theoretical framework is established in which these aspects are presented.

The second phase focuses on identifying the current decision-making practise within the Programme Directorate, with a focus on information. This is done based on an analysis of three sample projects where the decision-making process has been completed. The analysis looks at how information is handled in the projects based on the aspects as identified in the literature review. The case studies each involve one of the three ERTMS components. The first analysed decision-making process concerns the project about the test track section Hanzelijn, which is about the infrastructure component of ERTMS. The second project concerns the project about the European Instructions in Experience Driving, which is about the personnel component of ERTMS. The third project concerns the STM ATB-EG, which is about the train component of ERTMS.

For each project, the context and storyline with key events are first presented, followed by the analysis, which is structured similarly to the literature research. The storyline and analysis of the projects are based on internal documents and conducted interviews. Subsequently, the theoretical pattern is compared with the empirical pattern. Using the pattern matching method, it is determined whether the comparison between theory and practice result in a match, mismatch, or partial match. For each case, reflections are made on the differences and similarities between theory and practice, and it appears that the shortcomings from practice can be traced back to the information aspects in the theoretical

framework. This way, it becomes clear how information is managed in the decision-making of projects within the ERTMS programme.

The third phase focuses on trends resulting from the comparison between the theoretical pattern and empirical pattern. To identify these trends, an overview of the pattern matching results of the three projects is made and analysed across the projects to see how the aspects scored. It turns out that there are positive trends in how information is managed within the projects. The positive trends are regarding the following aspects: the decision-making rationale is known for all involved parties, internal and external information sources are both consulted, the information is accessible for all parties involved, and external information is sufficiently controlled. Furthermore, there is one aspect where performance is consistently partially below par: the quality of information. Furthermore, there are no negative trends; it varies per project and its unique characteristics how the information aspects score. Based on the analyses, recommendations are formulated for the Programme Directorate.

In the fourth phase, the implications of decision-making are described. The recommendations are further specified into seven concrete action points:

1. Rationality: Identify conflicting interests and deal with them in the analysis phase.
2. Stakeholders: Manage the stakeholders appropriately based on their interest and influence.
3. Support: Update the involved parties regularly about the programmes process.
4. Information quality: Consider prior to the decision on how things should be effectuated.
5. Timeliness: Ensure a clear timeline of the effectuation process.
6. Streamline/ decision authority: Work towards the appropriate decision-authorised body.
7. Information types: Assess whether applicable information types are sufficiently considered.

In addition to these recommendations, an information checklist has been developed to help the Programme Directorate assess to what extent various aspects have been considered in different phases of a decision-making process, or whether improvements can still be made. This checklist is practically applied to the MerwedeLingelijn project, which involves converting the infrastructure to ERTMS. This project is not within the scope of the current ERTMS programme. The application of the checklist to this project reveals that the rationale of this project is not entirely aligned with the programme goals. Furthermore, it is difficult to convert the MerwedeLingelijn together with the adjacent track sections due to the long preparation time for such projects. Additionally, this project does not add value in terms of learning. Therefore, it is advised not to further consider the conversion of the MerwedeLingelijn currently. The checklist can be used in future decision-making processes within the ERTMS programme by asking specific questions. If a question is answered with ‘no’, there may be a risk. By using this checklist, it is possible to look more specifically at which information aspects need attention, which can lead to better informed decision-making.

Samenvatting

Het European Rail Traffic Management System (ERTMS) is de nieuwe Europese standaard voor treinbeveiliging en verbetert de interoperabiliteit op het spoor in Europa. Om ERTMS in Nederland te implementeren, zijn aanpassingen nodig in de infrastructuur, de treinen en er moeten werkmethoden worden aangepast. De implementatie van ERTMS in Nederland heeft invloed op verschillende partijen in de spoorwegsector, zoals ProRail en de NS. ProRail is de eigenaar van de spoorinfrastructuur en de NS is de grootste passagiersvervoerder in Nederland. De Programmadirectie ERTMS is verantwoordelijk voor het regisseren en coördineren van dit implementatieprogramma in Nederland. Om dit programma succesvol te maken, is het essentieel dat de drie ERTMS-componenten – infrastructuur, trein en personeel – naadloos samenwerken.

Binnen het ERTMS-programma worden deze componenten beïnvloed door verschillende lopende projecten en zijn er besluiten nodig. Bijvoorbeeld over de locatie waar het ERTMS-systeem getest moet worden en hoe het technische ontwerp eruit moet zien. Bovendien worden er voorstellen gedaan voor nieuwe projecten die kunnen bijdragen aan de doelen van het programma, zoals het project van de MerwedeLingelijn. Dit project houdt in dat de infrastructuur van deze spoorlijn wordt omgebouwd naar ERTMS. Het valt niet binnen de huidige scope van het programma, maar het dient als voorbeeld van een project waarmee de Programmadirectie te maken krijgt. Dergelijke projecten vereisen een zorgvuldige analyse en gegronde besluitvorming omdat ze invloed hebben op de verdere voortgang van het overkoepelende programma. Daarom is geïnformeerde besluitvorming cruciaal. Vanwege de unieke aard van de projecten is het echter uitdagend om alle cruciale informatie te verzamelen en analyseren, en stakeholders adequaat van essentiële informatie te voorzien voordat er een besluit wordt genomen.

Om de hoofdvraag van deze thesis – *Hoe wordt informatie behandeld in besluitvorming binnen de Programmadirectie ERTMS met betrekking tot ERTMS-implementatieprojecten in Nederland, en welke aanbevelingen kunnen worden afgeleid uit de vergelijking tussen theorie en het huidige besluitvormingsproces om het succes van het programma te vergroten?* – te beantwoorden, is dit onderzoek gestructureerd in vier fasen.

De eerste fase omvat literatuuronderzoek naar de kenmerken van complexe besluitvorming binnen publieke organisaties. Een onderliggend principe is dat besluitvorming moet streven naar rationaliteit, zodat de voordelen van een project worden gemaximaliseerd op basis van de beschikbare informatie. Bovendien worden verschillende informatieaspecten gespecificeerd (zoals bronnen, actualiteit en toegankelijkheid van informatie) die moeten worden overwogen in besluitvormingsprocessen binnen de publieke sector. Deze aspecten zijn onderverdeeld in waarom, wat, wie, wanneer, waar en hoe vragen. Op basis van het literatuuronderzoek wordt een theoretisch kader opgesteld waarin deze aspecten worden weergegeven.

De tweede fase richt zich op het identificeren van het huidige besluitvormingsproces binnen de Programmadirectie, met een focus op informatie. Dit wordt gedaan op basis van een analyse van drie voorbeeldprojecten waarvan het besluitvormingsproces is afgerond. In de analyse wordt gekeken hoe er in de projecten omgegaan wordt met informatie op basis van de aspecten zoals ze zijn geïdentificeerd in het literatuuronderzoek. De casestudies omvatten elk een van de drie ERTMS-componenten. Het eerste geanalyseerde besluitvormingsproces betreft het project over het Proefbaanvak Hanzelijn, dat betrekking heeft op de infrastructuurcomponent van ERTMS. Het tweede project betreft het project over de European Instructions in Ervaringsrijden, dat betrekking heeft op de personeelscomponent van ERTMS. Het derde project betreft de STM ATB-EG, dat betrekking heeft op de treincomponent van ERTMS.

Voor elk project worden eerst de context en de tijdlijn met belangrijkste gebeurtenissen gepresenteerd, gevolgd door de analyse, die vergelijkbaar is gestructureerd als het literatuuronderzoek. De verhaallijn en analyse van de projecten zijn gebaseerd op interne documenten en gehouden interviews. Vervolgens

wordt het theoretische patroon vergeleken met het empirische patroon. Met behulp van de ‘pattern matching’ methode wordt bepaald of de vergelijking tussen theorie en praktijk resulteert in een match, mismatch of gedeeltelijke match. In elk project wordt er gereflecteerd op de verschillen en overeenkomsten tussen theorie en praktijk, waarbij blijkt dat de tekortkomingen in de praktijk te herleiden zijn naar de informatieaspecten in het theoretische kader. Op deze manier wordt duidelijk hoe informatie wordt beheerd in de besluitvorming van projecten binnen het ERTMS-programma.

De derde fase richt zich op trends die voortvloeien uit de vergelijking tussen het theoretische patroon en het empirische patroon. Om deze trends te identificeren, wordt een overzicht gemaakt van de ‘pattern matching’ resultaten van de drie projecten en wordt er geanalyseerd hoe de aspecten in de projecten hebben gescoord. Het blijkt dat er positieve trends zijn in hoe informatie wordt beheerd binnen de projecten. De positieve trends hebben betrekking op de volgende aspecten: de rationale is bekend bij alle betrokken partijen, zowel interne als externe informatiebronnen worden geraadpleegd, de informatie is toegankelijk voor alle betrokken partijen en externe informatie wordt voldoende gecontroleerd. Daarnaast is er één aspect waar de prestaties consequent gedeeltelijk ondermaats zijn: de kwaliteit van informatie. Verder zijn er geen negatieve trends; het varieert per project en de unieke kenmerken daarvan hoe de informatieaspecten scoren. Op basis van de analyses worden aanbevelingen geformuleerd voor de Programmadirectie.

In de vierde fase worden de implicaties van de besluitvorming beschreven. De aanbevelingen worden verder gespecificeerd in zeven concrete actiepunten:

1. Rationaliteit: identificeer tegenstrijdige belangen en houd hier rekening mee in de analysefase.
2. Stakeholders: beheer de stakeholders op de juiste manier op basis van hun belang en invloed.
3. Steun: informeer de betrokken partijen regelmatig over het proces van het programma.
4. Kwaliteit van informatie: overweeg voorafgaand aan het besluit hoe zaken moeten worden geeffectueerd.
5. Tijdigheid: zorg voor een duidelijke tijdlijn van het effectueringsproces.
6. Stroomlijnen/ besluitbevoegdheid: werk toe naar het juiste besluitvormingsorgaan.
7. Informatie typen: beoordeel of er voldoende rekening wordt gehouden met de van toepassing zijnde informatie typen.

Naast deze aanbevelingen is een informatiechecklist ontwikkeld om de Programmadirectie te helpen beoordelen in hoeverre verschillende aspecten zijn overwogen in verschillende fasen van het besluitvormingsproces, of dat er nog verbeteringen mogelijk zijn. Deze checklist wordt praktisch toegepast op het project MerwedeLingelijn, dat de ombouw van de infrastructuur naar ERTMS betreft. Dit project valt niet binnen de huidige scope van het ERTMS-programma. Het gebruik van de checklist voor dit project onthult dat de rationale van dit project niet volledig in lijn is met de programmadoelstellingen. Bovendien blijkt het lastig te zijn om de MerwedeLingelijn samen met de aangrenzende trajecten om te zetten vanwege de lange voorbereidingstijd voor dergelijke projecten. Daarnaast voegt dit project geen waarde toe wat betreft leren. Daarom wordt momenteel geadviseerd om de transitie van de MerwedeLingelijn naar ERTMS nu niet verder te overwegen. De checklist kan worden gebruikt in toekomstige besluitvormingsprocessen binnen het ERTMS-programma door specifieke vragen te stellen. Als een vraag met 'nee' wordt beantwoord, kan er een risico optreden. Door deze checklist te gebruiken, is het mogelijk om specifieker te kijken naar welke informatieaspecten aandacht nodig hebben, wat kan leiden tot beter gefundeerde besluitvorming.

Table of Contents

List of Figures

List of Tables

Abbreviations & Terminology

Abbreviation	Explanation
ATB(-EG)	Existing Dutch train protection system (first generation)
ATB(-NG)	Existing Dutch train protection system (new generation)
ATP	Automatic Train Protection, a generic term for train protection systems that continually check the train's speed and, if necessary, stop the train.
Betuweroute	Freight corridor from the harbour of Rotterdam to the German border
B2	Baseline 2, release version of ERTMS software (Appendix A)
B3	Baseline 3, release version of ERTMS software (Appendix A)
CSS	Central Safety System, ERTMS safety system
DG Move	Directorate-General for Mobility and Transport
Dual Signalling	Track section with two signalling systems (ATB + ETCS)
EC	European Commission; part of the executive body of the European Union
EKB	Rail section (Emplacement) Kijfhoek – Belgian Border
ERA	European Rail Agency; agency that sets mandatory requirements for European railways and manufacturers
ERTMS	European Rail Traffic Management System (ERTMS=ETCS+GSM-R)
ETCS	European Train Control System, new signalling, and control system
ETCS L2(B2/B3) only	ETCS Level 2 with baseline 2 or 3, only, (thus no Dual Signalling)
EVC	European Vital Computer, ETCS computer in the train
European Instructions, EIs	European Instructions, operational instructions for train drivers
Experience Driving	Project to give NS train drivers experience of driving under ERTMS
Freight carriers	Private parties transporting goods by rail
GSM-R	Rail communication system that provides connection between ETCS trains and ETCS infrastructure
Hanzelijn	Rail connection between Lelystad and Zwolle
IEMeV	Implementatie ERTMS Materieeleigenaren en Vervoerders
IenW	Ministry of Infrastructure and Water Management
MerwedeLingelijn, MLL	Rail connection between Dordrecht and Geldermalsen
Northern lines	Noordelijke lijnen, regional railway lines in the provinces of Friesland and Groningen
NS	Nederlandse Spoorwegen, transport concessionaire of the main rail network
NS'54	Current signalling system in the Netherlands
PD	Programme Directorate (ERTMS), coordinating body of ERTMS implementation in the Netherlands
Programme decision	Decision by the Cabinet to implement the ERTMS programme plan
ProRail	Managing body of the Dutch rail infrastructure
ProRail IEP	ProRail department Implementation ERTMS ProRail
ProRail LJV	ProRail department Leefomgeving juridische zaken en vastgoed
ProRail VL	ProRail department Verkeersleiding (traffic management)
Regional carriers	Passenger carriers operating under regional rail concessions
STM (ATB)	Specific Transition Module, device that enables ETCS trains to interact with ATB infrastructure
TEN-T	Trans-European Transport Network, transport network through Europe
Zeeuwse lijn	Rail connection between Vlissingen and Roosendaal

1. Introduction

Railway systems play a crucial role in transportation infrastructure, facilitating the movement of people and goods efficiently and safely. With significant expected growth in the near future of rail passengers, track capacity must be increased (ERTMS, 2020; NS, 2023; Treinreiziger, 2018). To enhance the performance of railways across Europe, a directive was established in the 1990s with the aim of increasing the interoperability of the European rail system (Unife, 2021b, 2021c). This is what created the European Rail Traffic Management System (ERTMS) (EUMonitor, 1994). The main goal of the ERTMS programme nowadays is to replace the various analogue national train command and control systems with a digital safety system to meet European obligations and to enable benefits in terms of safety, interoperability, capacity, speed and reliability (Bekius, 2019; Schuitemaker *et al.*, 2018).

In Europe, ERTMS is the standard for Automatic Train Protection (ATP) and command and control systems (EuropeanCommission, n.d.-a). ERTMS will replace 20 national signalling and control systems that are functioning in Europe today (Unife, 2021a). ERTMS consists of two systems: European Train Control System (ETCS) and Global System for Mobile Communication – Railways (GSM-R). ETCS is a standardised train control and signalling system that is used in Europe to monitor the train speed continuously and to keep it below the maximum values. It is applied in both the train and on the infrastructure. GSM-R is a communication system that is designed for railway operations that enables ETCS to communicate between train- and trackside (EuropeanCommission, n.d.-b). There are three main ERTMS components that must be considered for a smooth transition: infrastructure, train, and personnel.

In the Netherlands, ERTMS will replace the NS'54/ATB system. The NS'54 signalling system was developed in the 1950s. This system uses trackside signal posts that display distinct colours to inform train drivers of the state of the track ahead of them. Depending on the track occupancy, the signal turns green, yellow or red. This system requires the train driver to react appropriately to the signal. The ATB system is the Dutch variance of the ATP. It was developed in the 1960s and 1970s to provide additional safety measures. It automatically monitors speed and intervenes when a train exceeds permitted speed limits by stopping the train. This system works as an additional safety layer that monitors and corrects any error that could be made by the train driver (Coenraad, 2023). With a 70-year-old signalling system, the need for a new system increases.

In the Netherlands, ERTMS is being implemented in phases. The Programme Directorate was established to orchestrate and coordinate the transition to ERTMS in the Netherlands until 2030. Initially, this included converting seven railway sections, most of which are part of Trans-European Transport Network (TEN-T) corridors. Parts of such TEN-T corridors are the sections Kijfhoek – Belgian border and Utrecht – Meteren (ERTMS, 2021). Later, it was decided to implement ERTMS nationwide by 2050, this caused changes in the initial scope (e.g. tracks that needed to be replaced due to the reached life expectancy were also considered for the new rollout strategy). The ERTMS strategy in the Netherlands is based on the idea that trains are converted first in such a way that they can continue to operate on both 'new' and 'old' infrastructure. Secondly, personnel (e.g. train drivers and dispatchers) are being educated in phases and can gain operational experience on the first converted infrastructure sections. Lastly, the remaining infrastructure will be converted.

To ensure the success of the ERTMS implementation programme, the three components of ERTMS – infrastructure, train, and personnel – must align closely with each other. If any of these components are not functioning properly, it not only disrupts the entire ERTMS system but also jeopardises the ongoing implementation of ERTMS in the Netherlands. In Appendix A, more background information is provided regarding the ERTMS levels of application and the governance of the ERTMS programme.

1.1. Problem description

The MerwedeLingelijn (MLL) is a railway line between Dordrecht and Geldermalsen on which Qbuzz, a regional passenger carrier, operates. Qbuzz has raised the question of whether the MLL infrastructure could be equipped with ERTMS in the short term. This railway line is not currently within the scope of the ERTMS implementation programme. However, the two adjacent rail sections are planned to be converted to ERTMS: the section from Kijfhoek to the Belgian border in 2028 and from Utrecht to Meteren in 2031. Consequently, the infrastructure around Dordrecht station and Geldermalsen station must be converted, affecting the MLL (Figure 1).

Since these parts of the MLL will be equipped with ERTMS, Qbuzz trains must be equipped to be compatible with both ERTMS and the current ATB system. Qbuzz has invested in new trains equipped with an STM, allowing them to operate on ATB infrastructure as well. These new trains are longer and heavier than the current trains, requiring adjustments to be made to the infrastructure (e.g. platforms must be extended). The education of the personnel to be able to drive with ERTMS is also in progress.

Given that projects regarding the train and personnel components of ERTMS are already ongoing, that non-ERTMS related adjustments are also underway and that it is undesirable to have an ATB-isolated track between the ERTMS sections, it may be effective to consider this project at this time.

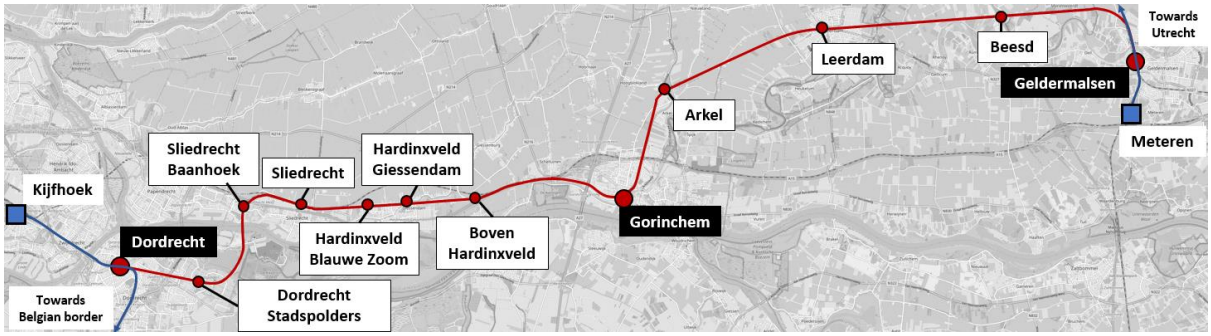

Figure 1. MerwedeLingelijn and interaction with sections of the TEN-T corridors

The ERTMS programme consists of dozens of projects that influences the progress of the programme. In addition, other projects, that are initially outside of the programme's scope, are proposed that might contribute to the ERTMS programme as well. The MerwedeLingelijn project is an example of a decision-making challenge that the Programme Directorate faces. Such projects require careful consideration before decisions are made, as there are limited resources available for the effective rollout of the ERTMS programme.

Information plays a crucial role in the consideration of these projects and eventual decision-making. An uninformed decision-making process could lead to poor decisions, resulting in significant delays to the programme. Incomplete or inaccurate information may be a factor in decision-making, and it is challenging to determine the informational aspects that should be considered before deciding. Additionally, issues may arise after a decision has been made, sometimes due to incomplete provision of information. The Programme Directorate struggles regularly with ensuring that all essential information is considered before a decision is made concerning ERTMS implementation in the Netherlands.

1.2. Research dimensions

1.2.1. Research objective

The objective of this thesis is to provide the Programme Directorate ERTMS with advice that facilitates well-informed decision-making by considering how information can be dealt with in the context of the ERTMS programme. This advice aims to enhance the success of the ERTMS programme in the

Netherlands. By ensuring that decision-making processes incorporate information appropriately, the likelihood of success in ERTMS-related projects within the programme is increased.

1.2.2. Research questions

To contribute to the research objective, the following main research question has been formulated:

> *How is information dealt with in decision-making within the Programme Directorate ERTMS regarding ERTMS implementation projects in the Netherlands, and what recommendations can be drawn from the comparison between theory and the current decision-making process to enhance the success of the programme?*

To provide an answer to the main research question, the following sub-questions have been formulated:

The first sub-question is *'What does the literature reveal about how complex decision-making is facilitated in public organisations and what role has information in this process?'* This question aims to review the academic literature on complex decision-making in public organisations. It seeks to provide context and identify informational aspects to consider in the decision-making process, and to arrive at a theoretical framework that helps to identify and compare the current practices of decision-making within the Programme Directorate.

The second sub-question is *'How does decision-making take place within the ERTMS programme concerning the three ERTMS components, and how is information dealt with?'* The goal of this question is to examine how decision-making regarding the ERTMS programme takes place, and to what extent information aspects are considered.

The third sub-question is *'What are the differences and similarities between the theoretical and empirical findings of information in the decision-making process, and what recommendations can be drawn from it for the Programme Directorate?'* The goal of this question is to compare the empirical findings with the theoretical findings, based on which recommendations can be made.

The fourth sub-question is *'What are the implications of this research for a real-world case such as the MerwedeLingelijn?'* This final question is intended to apply the findings to the MerwedeLingelijn project, ensuring the relevance and utility of the research outcomes in a real-world setting.

1.2.3. Research scope

The research scope for this study is structured to ensure feasibility within the allocated timeframe. It encompasses several key components:

Firstly, this study aims to provide context on complex decision-making in public organisations and examines the essential informational aspect relevant to decision-making processes. Secondly, it seeks to identify and analyse the decision-making practices within the ERTMS programme through three case studies. Thirdly, based on a comparison between the theoretical framework and empirical findings, the research proposes recommendations to enhance decision-making within the Programme Directorate ERTMS. Lastly, these recommendations are practically applied to a practical case study.

This research is conducted exclusively within the Programme Directorate ERTMS, the coordinating body of the ERTMS programme, which involves all rail sector parties (e.g. NS, freight carriers, regional carriers). This study does not extent its analysis to external sector parties or stakeholders. Additionally, the scope remains confined to the Dutch context of ERTMS implementation, limiting its generalisability to other countries. Moreover, the study does not delve into broader organisational or governmental decision-making contexts, nor does it explore alternative methodologies or decision-making frameworks, but it is limited to the information aspects of decision-making. Furthermore, this thesis adopts the bounded rationality decision-making theory, offering a specific perspective on decision-making. Other decision-making theories exist that may yield different insights and conclusions.

This thesis identifies various types of information that should be considered in the decision-making process. While these types of information are acknowledged, this research does not delve into them in depth but rather addresses them in a more overarching manner.

1.2.4. Relevance

The practical relevance of this thesis lies in its potential to directly impact decision-making processes regarding the ERTMS programme in the Netherlands. By providing recommendations based on the comparison between theoretical and empirical findings, this thesis aims to improve the efficiency and effectiveness of decision-making, leading to better outcomes.

The scientific relevance of this thesis lies in its contribution to the field of decision-making. A theoretical framework has been set-up based on existing literature which considers information aspects essential for decision-making processes. Through the comparison of this framework with empirical data and subsequent reflection, this thesis enhances the understanding of how information influences decision-making. This underscores the importance of thorough consideration of the information aspects before making decisions.

2. Methodology

2.1. Research strategy

The research strategy is presented in Figure 2 as a scheme. Below the figure, the methodology is further explained.

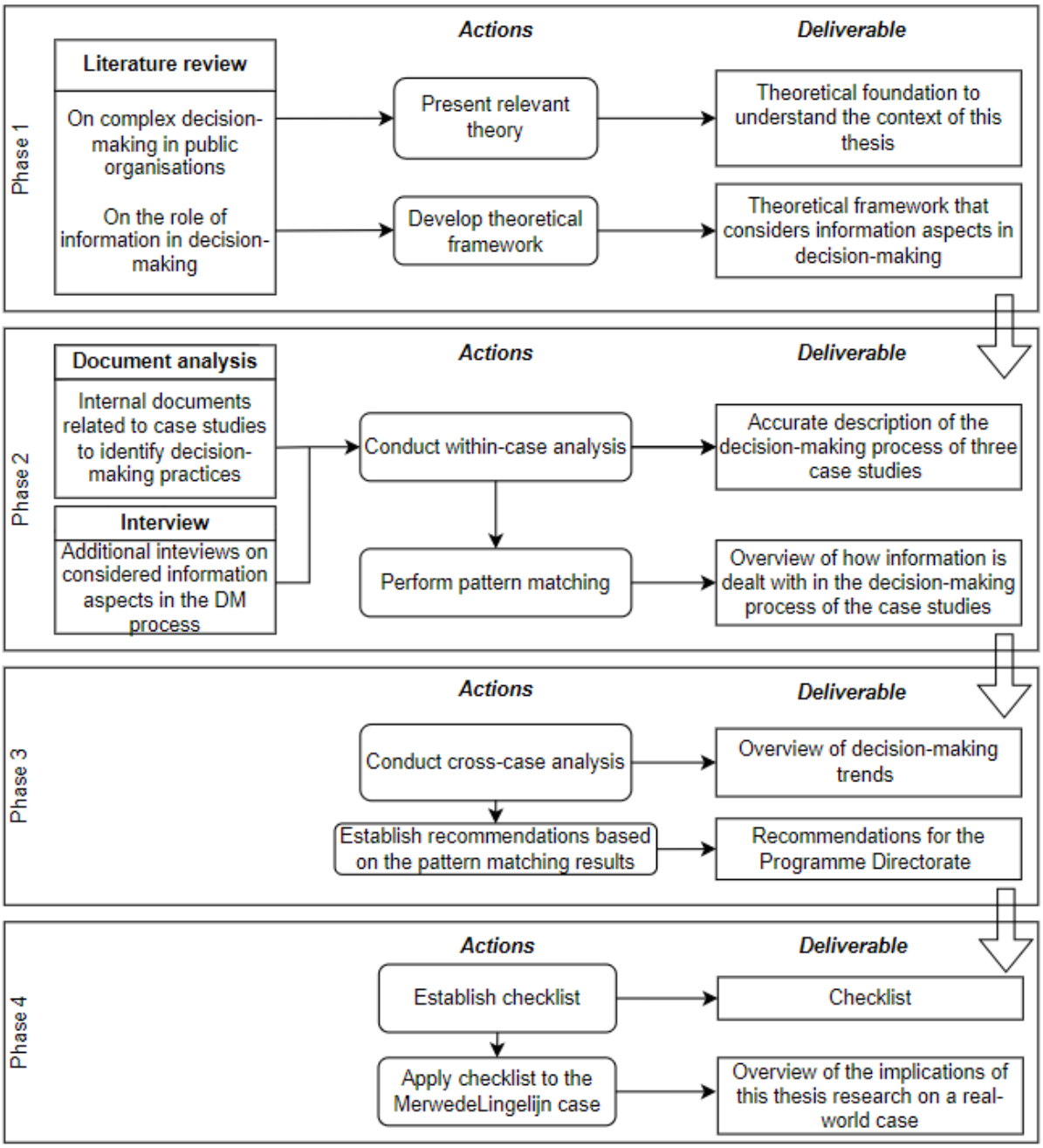

Figure 2. Research strategy

The proposed master thesis consists of different phases, corresponding to their sub-questions. The research methodology relies on qualitative data. To enhance the validity of the research, triangulation is used. Triangulation is defined as using multiple approaches to researching a question. This is beneficial since combining two or more approaches results in better-supported findings and outcomes (Heale & Forbes, 2013).

2.1.1. Phase 1: Literature review

To address the first sub-question – '*What does the literature reveal about how complex decision-making is facilitated in public organisations and what role has information in this process?'* – a literature review is conducted. Literature review is "described as a more or less systematic way of collecting and synthesising previous research" (Snyder, 2019, p. 333). The literature review focuses on several aspects which are relevant for complex decision-making in public organisations. First, key definitions are discussed. Then, the structure of organisations is addressed. After that, the role of information is addressed. Based on this, the theoretical framework is developed which forms the basis for the research. This is the deliverable for the first phase of this thesis research. This theoretical framework helps understand the role of information in decision-making processes within public organisations and helps to identify the current practices within the ERTMS programme.

2.1.2. Phase 2: Within-case analysis

To address the second sub-question – '*How does decision-making take place within the ERTMS programme concerning the three ERTMS components, and how is information dealt with?'* – document analysis is conducted, and additional interviews are held. Three case studies in which the decision-making process has been gone through, each touching upon a different ERTMS component; infrastructure, train, and personnel, are analysed. From these case studies, the empirical data is extracted.

First, document analysis was executed to get an in-depth view of the historical events and context related to the projects. Information aspects are considered as well for as much as possible. The documents that are examined are taskforce reports, decision memos, minutes of managerial meetings, and evaluation reports related to the decision and the decision-making process of each case project. The referenced internal documents are presented in Appendix B. In addition, interviews are held with the involved actors of each project. For each project, two interviews are held, adding up to a total of six interviews. The purpose of the interviews was to consider the informational aspects that are not dealt with in the document analysis and to complement on the document analysis. Two interviews for each case project are appropriate because the theoretical framework provides much guidance on the information aspects considered. The purpose of this sub-question is to understand the decision-making process within the programme, and the role of information in this process. The analysis is performed in such way that it can be compared to the theoretical framework. The deliverable of this phase is an overview of the findings of the three case-studies, compared to the theoretical framework using the pattern matching technique. Pattern matching is elaborated further in Chapter 2.3.

2.1.3. Phase 3: Cross-case analysis

To address the third sub-question – *'What are the differences and similarities between the theoretical and empirical findings of information in the decision-making process, and what recommendations can be drawn from it for the Programme Directorate?*' – the findings of sub-question 1 and 2 are analysed cross-case. This is done to identify trends among the patterns. Based on the trends, specific recommendations are established for the Programme Directorate to make more-informed decisions.

2.1.4. Phase 4: Implications for Decision-Making

To address the fourth sub-question – *'What are the implications of this research for a real-world case such as the MerwedeLingelijn?'* – the general implications for decision-making are presented. In addition to the recommendations, a checklist is established to determine whether all necessary informational aspects are covered in decision-making processes. The checklist is applied to the project of the MerwedeLingelijn, as described in the introduction. The purpose of this question is to reflect the implications of this research on this case study to provide a better picture of how the Programme Directorate can make more informed decisions. The checklist must be applicable to future decision-making processes within the ERTMS programme.

2.1.5. Final deliverable

By answering all sub-questions, the main research question - '*How is information dealt with in decision-making within the Programme Directorate ERTMS regarding ERTMS implementation projects in the Netherlands, and what recommendations can be drawn from the comparison between theory and the current decision-making process to enhance the success of the programme?'* - can be answered. To answer this main research question, this thesis document is established. In this document, all sub-questions are answered, as well as the main research question and the recommendations to the Programme Directorate are presented. This thesis document, including appendices is the final deliverable.

2.2. Data collection and data analysis

To achieve the research objective and to answer the main research question, empirical data must be collected. This data is obtained through document analysis and interviews. In the following chapters, a description of these data collection methods is given.

2.2.1. Document analysis

Document analysis is defined by G. A. Bowen (2009) as a "systematic procedure for reviewing or evaluating documents, both printed and electronic material" (p. 27). Morgan (2022) states that "any document containing text is a potential source for document analysis" (p. 64). It is a research method that is useful for case study research (G. A. Bowen, 2009). Therefore, document analysis is a suitable method for this research. The document analysis is executed through the READ approach. This method provides practical guidance on extracting the most information from documents and ensures that this work is thorough, careful, and accurate. This approach consists of four steps: 1) ready the materials, 2) extract data, 3) analyse data and 4) distil your findings (Dalglish *et al.*, 2020). Relating to each case project, relevant (electronic) documents are considered and placed structured in a local folder on the researcher's work laptop, sorted by date. This is done because there are multiple electronic documents that relate to a decision-making process but at a different time. As mentioned, the documents that are considered are taskforce reports, decision memo's, minutes of managerial meetings, and evaluation reports. Then the timeline with key events is distilled from the multiple documents. Informational aspects that can be used for matching with the theoretical findings are marked in the original document and an electronic sticky note is added. In this way, the comparison with the theoretical pattern can clearly be made. An overview of the documents consulted are added in Appendix B.

2.2.2. Interviews

An interview is defined as an interaction between two people, where one acts as an interviewer and another as an interviewee. In an interview questions are asked to obtain information about a topic of interest from the interviewee (Mashuri *et al.*, 2022). Interview styles range widely but primarily there are three types of interviews: (1) structured; (2) semi-structured; and (3) narrative. The main distinction among them lies in the level of control the interviewer has and the flexibility provided to the interviewee (Stuckey, 2013). For this thesis, all interviews that are executed have taken up to one hour and were executed in a semi-structured form. This interview method was chosen since it allows for new ideas and insights because the interviewer can deviate from the protocol slightly based on the response of the interviewee. Furthermore, the interviewee can provide responses freely (Hansen, 2021). Each interviewee was asked to sign a consent form prior to the interview. This consent form addresses the purpose of the research, recording, and transcription. A consent form template from the University of Twente (UT) is used for this. The signed consent forms are sent to the supervisors from the UT. The interviews were recorded through the standard sound-recorder app on iPhone. The interviews are held in Dutch because this is the native language within ProRail. The questions for the interview are established after phase 1, and after the document analysis of phase 2 of the thesis research because it is expected that the researcher then has more knowledge about the topic of decision-making and can formulate better and more accurate questions. An interview protocol is established. This is done to keep

a similar structure between the various interviews that are held, an interview protocol also ensures that no items are forgotten during the interview. The interview protocol includes the research title, an introduction in which the interviewee is welcomed and in which the purpose of the interview is explained. This is done in addition to the consent form. In the first part of the interview, the interviewer is asked to explain his/her professional background. The second part includes the core of the interview. In this part, in-depth questions are established based on the case study specifications. The concluding part consists of thanking the interviewee for participating in the interview. The interview protocols regarding the three case studies are added in Appendix C.

To process qualitative data from the interviews, the sound recordings is worked out verbatim. The interviews are conducted in a semi-structured way and the questions are based on the theoretical framework. In this way, a comparison with the theoretical pattern can be made.

2.3. Pattern matching

To process the qualitative data, the pattern matching strategy is used. Pattern matching is a desirable technique for qualitative analysis and case studies (Trochim, 1989). A pattern is defined as "any arrangement of objects or entities" (Trochim, 1989, p. 356). Pattern matching aims to link a theoretical pattern to an empirical pattern, thus the findings from the literature review is compared to the findings from the document analysis and interviews (Figure 3).

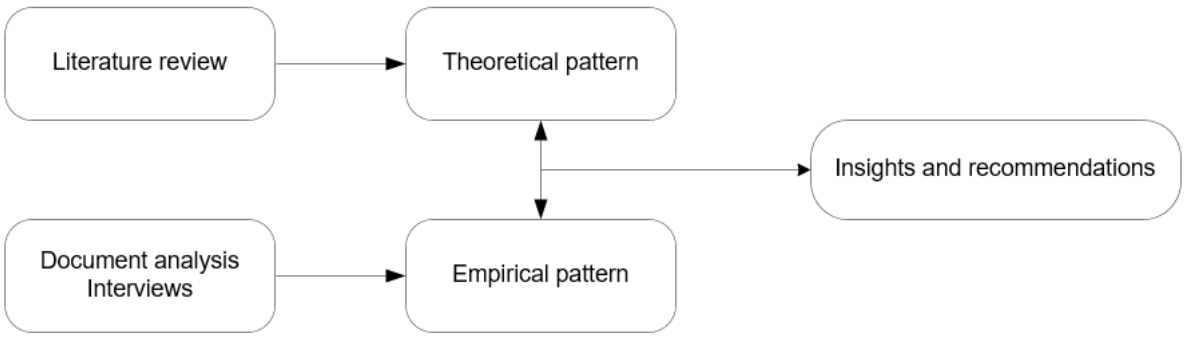

Figure 3. Pattern matching

The comparison of the theoretical and empirical pattern results in matches, partly matches or mismatches. The matches are determined on a scale of 3, a plus (+) indicates a complete match, a zero (0) means a partial match and a minus (-) indicates a mismatch (Cao *et al.*, 2004; Trochim, 1989). Based on these comparisons, and the explanations of these findings, potential areas of improvement can be found. Based on this, recommendations are drawn that help the Programme Directorate in making more informed decisions.

2.4. Case study selection

The empirical data is extracted based on three case studies, selected through purposive sampling. This is a technique used in research where cases are selected based on the researcher's judgement (Palinkas *et al.*, 2015). These cases are selected because these are typical decision-making projects encountered by the Programme Directorate in the implementation of ERTMS in the Netherlands. All case studies have completed their decision-making processes. Each case touches upon one component of ERTMS:

- Project A: Test track section Hanzelijn, covers the infrastructure component,
- Project B: European Instructions in Experience Driving, covers the personnel component.
- Project C: STM ATB-EG, covers the train component.

The description and analysis of these case studies are provided in Chapter 4.

3. Theoretical Framework

In this chapter, a literature review is performed. The fundamental concepts related to complex decision-making within public organisations are explained. The aim of this literature review is to get a thorough understanding of the research context and to establish a theoretical framework against which the empirical data is compared. Eventually, the first sub-research question of '*What does the literature reveal about how complex decision-making is facilitated in public organisations and what role has information in this process?'* is answered.

The structure of this literature review is as follows: Chapter 3.1 provides insight into the foundational concepts of complex decision-making within public organisations. Chapter 3.2 presents the fundamental informational aspects that should be considered in the decision-making process. In Chapter 3.3, the sub-question is answered, and the theoretical framework is established.

3.1. Complex decision-making in public organisations

Governmental organisations (also referred to as public organisations) often make complex decisions that for example decide the future of an area. Characteristics of public organisations are that they are government-owned and are funded through taxes, with a primary focus on providing goods and services for the benefit of society at large (Pratt *et al.*, 2007; Wess, 2021). The implementation of ERTMS in the Netherlands has an impact on the Dutch railway sector, and on European rail connections, therefore it is relevant to the public interest.

Decision-making in public organisations is a complex responsibility for public managers and requires strategic thinking (Al-Hashimi *et al.*, 2022; Yagnik & Chandra, 2019). Schoenmaker and Russo (2014) define decision-making as "the process whereby an individual, group or organisation reaches conclusions about what future actions to pursue given a set of objectives and limits on available resources" (p. 1).

The primary distinction between public-sector decision-making and private-sector decision-making lies in their respective motivations. Public sector decisions are guided by a wider social welfare agenda and must consider numerous constraints, for example, stakeholders' interests. On the other hand, private sector decision-making is primarily profit-driver and prioritises financial considerations (Button, 1979).

3.1.1. Stages of policy making

To understand the intricacies of public sector decision-making, it is essential to delve into the broader context of public policy. Public policy refers to the plans and actions established by the government to address specific problems, achieve goals, or improve society. The policy-making process is often conceptualised through a policy cycle, which consists of several stages. Despite criticisms (e.g. (Sabatier & Jenkins-smith, 1993)) suggesting that this representation oversimplifies the complexity of reality, the policy cycle remains a fundamental tool for understanding the dynamics of policymaking. Figure 4 illustrates the traditional policy cycle and provides a visual representation of its successive stages (Fischer & Miller, 2007; Parsons, 1995).

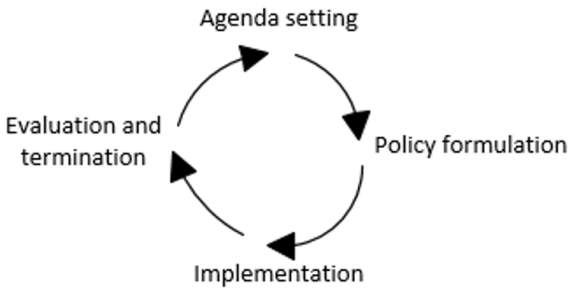

Figure 4. The policy cycle

1. Agenda Setting: problem recognition and issue selection

The first stage of the policy cycle is agenda-setting. This is the process of recognising and selecting policy issues for consideration and potential government action. It begins with the identification of a social problem that has been defined. The critical step is moving from the identified problem onto the political agenda, where it becomes a subject of attention for the government.

2. Policy formulation

During the second stage of the policy cycle, the focus is on transforming the problems into government programmes. This stage involves defining the objectives of the policy, considering different action alternatives, and making the formal decision to adopt the policy.

3. Implementation

In this stage, the policy is executed by the responsible organisations, which are often part of the public sector. An ideal process of policy implementation includes three core elements: 1) a specification of programme details. This addresses questions such as how and by whom the programme will be executed, and how the programme should be interpreted, 2) how resources are allocated and distributed, and who is in charge, 3) how smaller projects within the programme will be conducted.

4. Evaluation and termination

The final phase of the policy cycle is the evaluation and termination stage. In this stage, the intended outcomes and impacts of policies become the central focus. Evaluation is, however, not limited to the final stage of the policy cycle. A policy can either be terminated or redesigned based on a modified problem perception and agenda setting. Policy termination primarily takes place when a policy problem has been solved or the adopted policy measures have been recognised to be ineffective. However, this primary idea of policy termination seems difficult to enforce in practise. Large-scale budget cuts (related to subsidies) or changing governments could trigger policy termination.

3.1.2. Decision-making process

Within large governmental programmes, decisions regarding the allocation of resources and implementation of the sub-projects constantly take place. There are many approaches to decision-making processes (Harris, 2017; Parsons, 1995). According to Mustafa *et al.* (2021), "An approach signifies the actual techniques and methods which are applicable to find a specific task" (p. 1308). This thesis adopts the bounded rationality approach. The bounded rationality approach aims to reach maximum social profit objectively (Dye, 1984). However, because of human cognitive limitations and values, one can only reach bounded rationality while striving for full rationality (Lunenburg, 2010). In Figure 5, this is visually displayed.

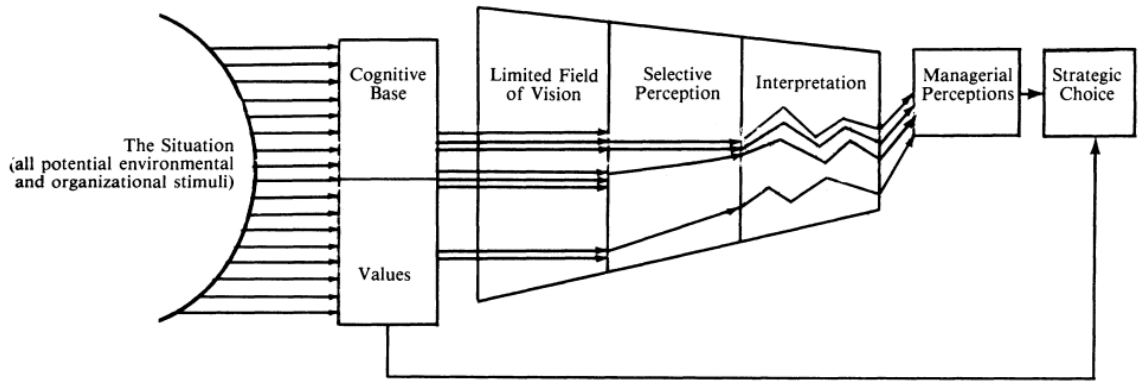

Figure 5. Decision-making under conditions of bounded rationality (Hambrick & Mason, 1984)

Citroen (2009, 2011) modelled the phases of the rational decision-making process (Figure 6). The phases of this process are delimited in time. The rounded boxes indicate the six phases in the decision process and the square boxes contain parameters that provide input for the indicated actions. Arrows indicate the main direction of interactions.

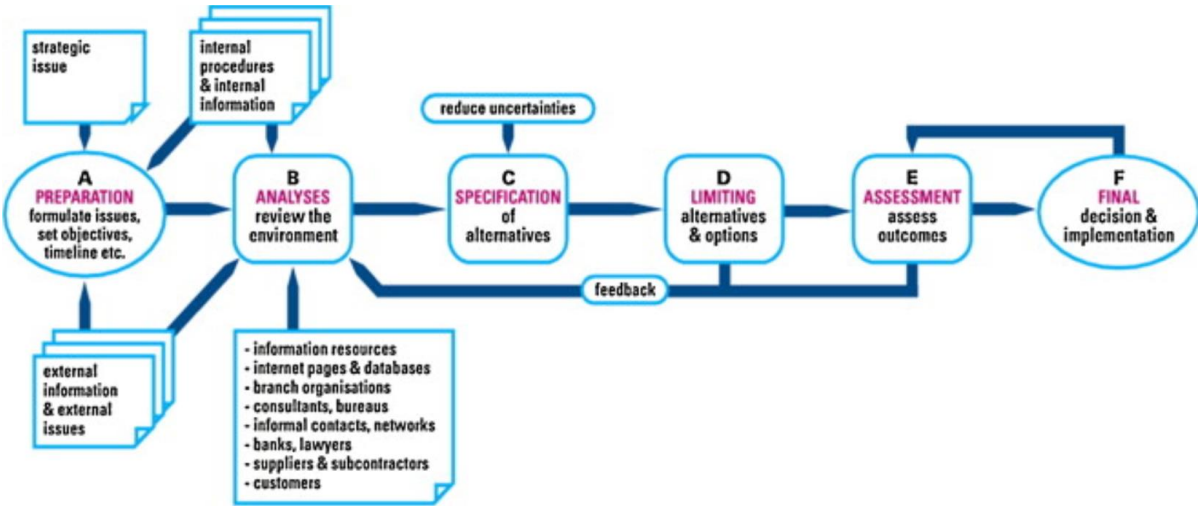

Figure 6. Model of the phases of a rational decision-making process (Citroen, 2011)

3.1.3. Organisation structure

Public organisations are structured in such a way that it effectively can achieve its goals. In general, three hierarchies can be distinguished in public organisations, and each hierarchy has a different concentration area of decision-making (Koliba *et al.*, 2022; Lunenburg, 2012; Henry Mintzberg, 1989; Wynen *et al.*, 2014). In Table 1, the hierarchies, type of decision and characteristics corresponding with the hierarchy levels are presented.

Table 1. Organisation structure and corresponding decisions

Hierarchy	Type of decisions	Characteristics
Top management	Strategic	• (Long term) policy decisions • Determine long-term strategy and scope
Middle line	Tactical	• Translate strategic long-term goals into specific objectives • Delegates work to operating core
Operating core	Operational	• Day-to-day decisions • Work out core activities • Enables an organisation to achieve outcomes

3.2. Information

Information plays a crucial role in decision-making processes. To determine the informational aspects to be considered in public sector decision-making, this literature review is conducted. In the field of engineering, not much research has been done on information aspects within (public) organisations, therefore other fields are also explored. In literature, why-, what-, who-, when-, where-, and how aspects of information could be distinguished (Kinneging *et al.*, 2021). Based on this structure, the theoretical framework is established.

Why

Rationale: The rationale of the decision should be known to all parties involved in the decision-making process. This is 'why' a decision needs to be taken. In the context of a programme which is in the implementation phase, the decision must contribute to the overarching programme's goals. In other words, information must be available to understand why a decision must be made (Parsons, 1995).

What

Information sources: In Figure 7 it is shown that both internal and external information sources are considered in a decision-making process. The impact of information on the decision-making process and its role in evaluating the available alternative solutions depends on the unique demands of each specific decision-making process. This means that in many cases the information must be generated and delivered in order to make a well-informed decision (Citroen, 2011). External sources may benefit decision-making by adding relevant knowledge (Zadelaar *et al.*, 2021)

Information sources that are used within decision-making processes can be categorised in four quadrants: formal, informal, internal, and external (Figure 7).

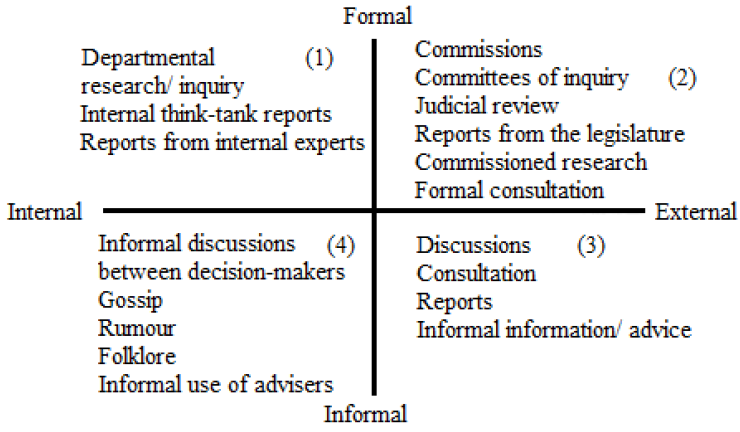

Figure 7. Sources of information in decision-making, adapted from (Parsons, 1995)

In quadrant one, decision-making will involve formal and internal sources of knowledge. This knowledge is, as explained, being generated within the governmental organisation. In quadrant two, knowledge is generated outside of the governmental organisation. Quadrant three displays the informal information which is generated outside of the governmental organisation and quadrant four shows the internal informal information. Governments rely on a mix of internal and external agencies to provide information, analysis and evaluation (Head, 2016). These sources of information for governmental agencies are mapped in terms of a hierarchy of inquiries and reports (Figure 8). 'All other advice and information' in the figure refer to different types of knowledge that inputs the government as feedback. This includes consultation, reports, and surveys in mostly an informal way. Official sources may be viewed as internal documents and unofficial sources refer to information that comes from non-governmental bodies. Eventually, the executive on is the receiving end of all types of inquiries and other advice (Parsons, 1995).

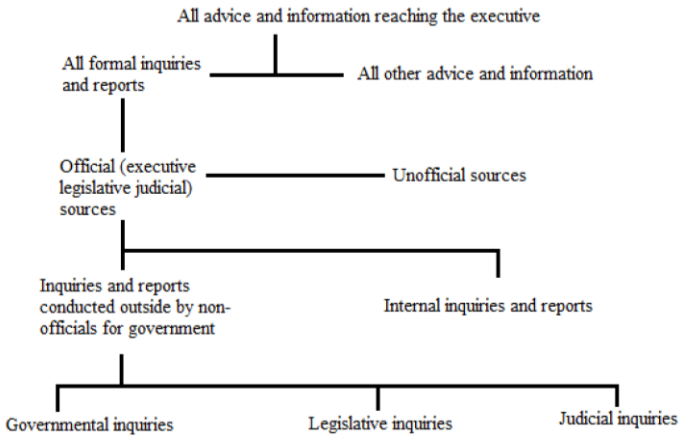

Figure 8. Framework of government information, adapted from (Peters & Barker, 1993)

Information types: S. Bowen and Zwi (2005) mention that the type of information can be categorised into five groups: research (i.e. analytic studies and qualitative studies), knowledge (i.e. published documents concerning technical details), ideas and interests (i.e. opinion and 'view'), politics (i.e. political risk, opportunity and crises) and economics. (i.e. cost effectiveness, opportunity cost and resource implications). When striving for rationality, it is important that the information is based on facts. In addition, more specific in relation to infrastructural projects, the type of evidence can be categorised into several types of informational aspects. Several studies have been performed to identify the success factors of rail projects. For a holistic view in decision-making in rail projects, the aspects summarised in Table 2 should be considered. Ignoring any of these factors may result in an incomplete understanding of the situation.

Table 2. Information types

Type of information	Explanation	Source
Environmental	Evaluating the project's impact on the built environment is crucial for sustainability.	(Fariq *et al.*, 2020; Gharehbaghi *et al.*, 2023; Zidane *et al.*, 2013)
Financial/ economical	Understanding the economic implication of the project is essential for assessing its viability.	(S. Bowen & Zwi, 2005; Citroen, 2011; Fariq *et al.*, 2020; Gharehbaghi *et al.*, 2023; Zidane *et al.*, 2013)
Logistical	Analysing the project's logistical impact limits disruption to the transportation system.	(Fariq *et al.*, 2020)
Social	Assessing the project's social impact helps understand its effects on communities.	(Fariq *et al.*, 2020; Gharehbaghi *et al.*, 2023; Zidane *et al.*, 2013)
Technical	Ensuring comprehensive knowledge of technical details is essential for successful project implementation, preventing costly delays and errors.	(S. Bowen & Zwi, 2005; Fariq *et al.*, 2020; Gharehbaghi *et al.*, 2023)
Judicial/ legal	Considering legal aspects ensures compliance with laws and regulations, reducing the risk of legal challenges during project execution.	(Citroen, 2011; Fariq *et al.*, 2020)
Political	Understanding political dynamics and developments aids in navigating regulatory processes	(S. Bowen & Zwi, 2005; Citroen, 2011; Fariq *et al.*, 2020; Zidane *et al.*, 2013)

As mentioned by Citroen (2011), the impact of information depends on the unique demand of each specific decision-making process. Regarding the three ERTMS components – infrastructure, train, and personnel – not all information types might apply equally. Furthermore, regarding the infrastructure component, there is a difference between new construction projects and upgrading the existing tracks. For each ERTMS component it is necessary to examine which aspects are applicable and which are not.

Information quality: Information quality plays a pivotal role in establishing the trustworthiness of the foundation for a decision-making process. Information quality dimensions that are often discussed are presented in Table 3. Availability and reliability are often mentioned dimensions as well (e.g. (Cai & Zhu, 2015; Chang *et al.*, 2022; Gürdür Broo & Schooling, 2021; Jylhä & Suvanto, 2015)), these dimensions can however be split into other dimensions; availability into timeliness and accessibility and reliability into accuracy, consistency and completeness (Cai & Zhu, 2015; Fang *et al.*, 2022). Timeliness is considered in this thesis under the when aspect and accessibility under the where aspect. The demanded quality of information can be improved through standardisation and process simplification (Kovac *et al.*, 1997; Lee *et al.*, 2002).

Table 3. Information quality dimensions

Information quality dimension	Definition	Indicator (Cai & Zhu, 2015)	Source
Accuracy	The information represents the truth and what actually happened.	-Information provided is accurate. -Information representation will not cause ambiguity.	(Borek *et al.*, 2013; Cabitza & Batini, 2016; Chang *et al.*, 2022; Citroen, 2011; Woodall *et al.*, 2013)
Completeness	All needed information is available.	-Whether the deficiency of a component will impact data accuracy.	(Borek *et al.*, 2013; Cabitza & Batini, 2016; Chang *et al.*, 2022; Zadeh *et al.*, 2017)
Consistency	All information with a consistent representation.	-During a certain time, data remain consistent and verifiable. -Data and the data from other data sources are consistent or verifiable.	(Chang *et al.*, 2022; Farnham *et al.*, 2009; Mena *et al.*, 2010; Woodall *et al.*, 2013; Zadeh *et al.*, 2017)
Relevance	Appropriate for the specified task.	-The data collected do not completely match, but they expound one aspect. -Information theme provides matches with users' retrieval theme.	(Chang *et al.*, 2022; Woodall *et al.*, 2013)
Usability	All information meets the user's requirements.	-Information comes from specialised organisation, field, or industry. -Expert regularly audit and check correctness of information contents.	(Cabitza & Batini, 2016; Chang *et al.*, 2022)

It can be argued that accuracy, and completeness are the most important dimensions of information quality. However, Fang *et al.* (2022) suggest that the other presented dimensions of information quality strengthen the overall information quality dimensions as well. All dimensions contribute to a more appropriate information quality level.

Who

Decision authority: "The flow of information involves three components – the source of information, the information transfer medium, and the receiver of the information" (Mahto & Davis, 2012, p. 2). Regarding the receiver of information, this person must be authorised to make the decision and must also be able to take responsibility over the decision. H. Mintzberg (1979) mentions in his book *The Structuring Of Organizations* that in decentralised organisations there are three questions that must be considered: 1) What decision powers should be delegated down the chain of authority? 2) How far down the chain should they be delegated? 3) How should their use be coordinated (or controlled)? These aspects must be agreed upon in advance of the projects and the division of authority must be known. The appropriate decision-making body should receive the information to be able to make the decision.

Stakeholders: Stakeholders should be dealt with appropriately. Stakeholders are groups or individuals who can affect an issue or who are affected by it (Schiller *et al.*, 2013). Some researchers state that ineffective stakeholder management is the primary concern of project failure (Aaltonen, 2011; Yang *et al.*, 2011). Organisations must deal with the needs of all relevant stakeholders to enhance the efficiency and effectiveness of projects. This is not possible when stakeholders are ignored (Khan *et al.*, 2021).

This can be done through a stakeholder analysis, based on their interest and power to the project they can be managed appropriately (Schiller *et al.*, 2013; Varvasovszky & Brugha, 2000).

Support: The internal flow of information must be open. This prevents that rumours arise and that motivation and trust within the organisation is reduced. Information is thus a critical aspect to ensure that team members are and stay committed to achieve the organisation's goals. Mahto and Davis (2012) underscore the importance of achieving consensus across various levels of hierarchy within an organisation (strategic apex, middle line, and operating core). A lack of consensus, particularly among lower-level members in the hierarchy, can be detrimental to the organisation. Increasing consensus between the various levels of hierarchy can be improved by increasing a sufficient vertical information flow within the organisation. For example, an intranet environment can be used to share successes of the company and it makes people more engaged and aligned (Citroen, 2011). S. Bowen and Zwi (2005) state that there should be commitment between internal and external parties for policy adoption. This means that within the organisation as well as with partners there must be a shared will to adopt changes. This applies both in the decision-making process leading up to the decision and in its implementation.

When

Timeliness: Simonsson *et al.* (2005) emphasise the importance of having timely information. With timeliness it is meant that the information should be available within a given time, or that information arrives on time (Borek *et al.*, 2013; Woodall *et al.*, 2013). This includes the ability to save time by filtering out unnecessary data, selecting optimal solutions based on crucial criteria, and identifying trade-offs among different parameters. As presented in Figure 6, it is shown that information is needed in the first two phases of the decision-making process. Top management requires information to formulate issues and set their strategic objectives. In the analysis phase, where the environment is reviewed, all different sources of information must be available (Citroen, 2011).

Where

Streamline: Effective information management is fundamental to the decision-making process. Caniëls and Bakens (2012) stress that inadequate information management will result in poor decision-making. On the other hand, decision-makers can become confused when dealing with an overwhelming amount of information, making it difficult for them to distinguish the relevant information. This highlights the importance of having the right volume of information to make the right decisions. However, Citroen (2011) found that information overload is not an issue for well-organised managers, when they are supported by staff (in the operating core) who filter the information and ensure that the managers only receive the necessary information for decision-making. On the contrary, it makes them feel more comfortable because they can make a more informed decision. The various parties involved in the operating core collect and generate information about their expertise in the field and eventually they send summaries of the analysis up in the hierarchy of the organisation. H. Mintzberg (1979) complements on this and teaches that down the hierarchy inside the organisation the tasks are more specified. The top management needs to set long-term strategic goals for the organisation. To reach such goals, commands and instructions are fed down the chain of authority, the more they flow down hierarchy levels, the more specified the commands and instructions are. The upward flow can be considered as a management information system that collects data about the executed work. In the stream upward the information is aggregated in each hierarchy level until it reaches decision authorised level.

Accessibility: Good accessibility of the information is essential in decision-making. With accessibility of information it is meant to conveniently access and retrieve existing information (Chang *et al.*, 2022). This includes the ability to share information with other parties (Cai & Zhu, 2015). With not having access, the information, and all efforts to generate or obtain the information can be considered worthless. Therefore the parties involved in the decision-making process must be able to access the

latest information at all times (Chang *et al.*, 2022; Gürdür Broo & Schooling, 2021; Jansen *et al.*, 2008; van der meer *et al.*, 2015; Varajão, 2022; Woodall *et al.*, 2013). A web interface or a software application can be used as an environment to store and retrieve information (Anumba *et al.*, 2008; Greeven & Williams, 2022). In such environments, a standard for the structure of how information is presented can improve the retrieval of the information and this speeds up the decision-making process as well (Farnham *et al.*, 2009; Mena *et al.*, 2010).

How

Control: While internal data sources, generated within the organisation, are inherently trusted, external sources of information, such as market data, may be viewed with greater scepticism, depending on the source of the information. To ensure that data from external sources are trusted, the flow of information that goes in the organisation is usually controlled by experienced staff. For example technical information specialists, legal people and strategy developers (Citroen, 2011; Zadelaar *et al.*, 2021).

Rationality: Parsons (1995) mentions that multiple researchers acknowledge that there is need for rationality in the decision-making process. The rational approach maintains that a decision is a result of a series of steps (As shown in Figure 6). It aims to maximise the social benefit of projects based on the available information (Constantin, 2013). However, in practise, the decision-making process is often influenced by subjective factors and involves clashes of values and beliefs. As presented in Figure 8, Subjective factors (unofficial sources, other advice) often occurs higher up in the organisation's hierarchy, thus less at the level of the operating core. These subjective sources are a danger to rationality of the decision-making process and can cause that maximum social benefit of the project is not reached.

3.3. Conclusions and theoretical framework

In this chapter, the first sub-question - '*What does the literature reveal about how complex decision-making is facilitated in public organisations and what role has information in this process?*'- is answered.

The literature highlights the complexity of public sector decision-making and presents various approaches and theories that attempt to reflect reality. Public sector decision-making aims to address societal issues and enhance societal welfare. In this regard, public policy theory provides a good picture of how this process proceeds. Within the implementation stage in the policy making process, decisions must take place regarding many projects which together ultimately lead to the outcome of the programme. This thesis adopts the bounded rationality theory, distinguishing phases within the decision-making process despite cognitive limitations (i.e. constraints on the human brain's capacity to process, store and retrieve information). This theory seeks to achieve high rationality by analysing different options objectively to determine the most effective use of taxpayer money. The Programme Directorate operates in such environment and is in the implementation stage at the time of writing this thesis.

Decision-making within public organisations involves different hierarchical levels. Figure 9 illustrates the organisational structure, phases of the rational decision-making process, and information flow. The decision-making process starts with setting objectives. This is done by top management because they are responsible for the organisation's long-term objectives. The middle line is responsible for translating the strategic objectives that are set by the top management into more practical objectives and to provide the operating core with more detailed instructions. In the operating core, the environment for a specific project is reviewed and specific internal and external information are obtained and generated. After that, the alternatives are explored by examining all possible solutions (within the bounded rationality terms), and the outcomes are objectively assessed. The operating core deliver the reports up to the middle line according to their specified instructions. Eventually, at this level decisions can be taken (depending on the authorisation) or the works from the operating core are merged and send up in the hierarchy to the top management in a more aggregated from with only containing the core information (e.g. executive

summaries), where ultimately the decision is taken. In the middle line or the top management, the advice, or decision, can be influenced by unofficial sources or other advice. This is usually performed in an informal manner and can be of influence of the rationality of the decision-making process.

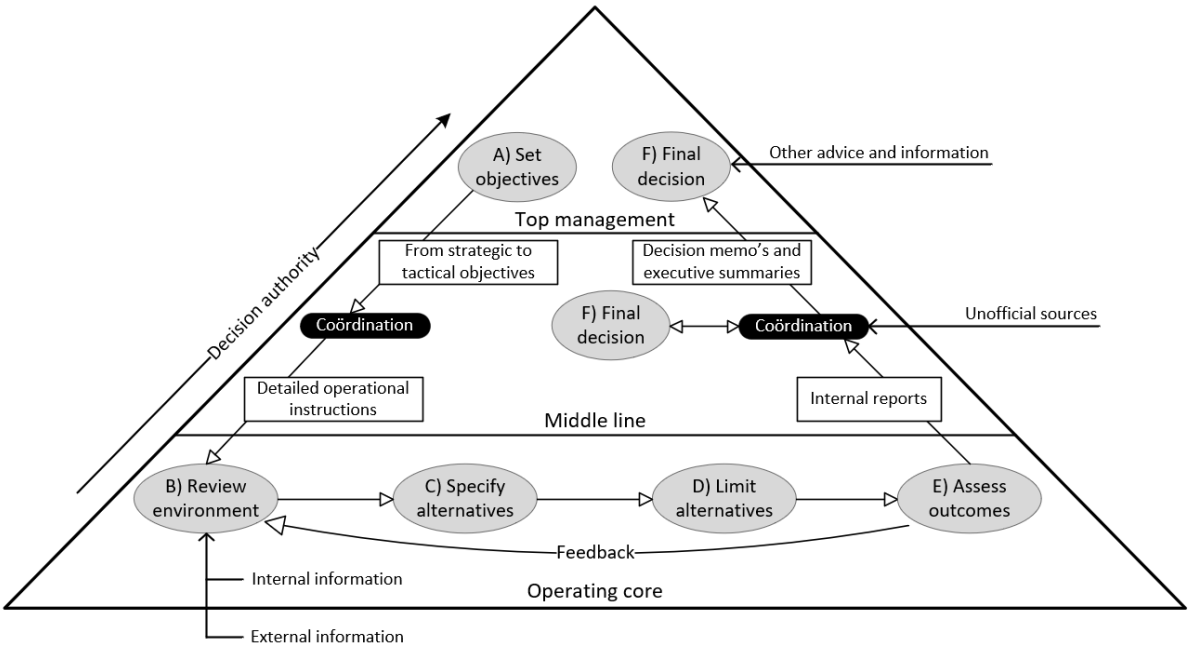

Figure 9. Decision-making process and information flow in public organisations

It is highlighted that information is crucial to make good and thorough decisions in the public sector. This broad concept encompasses various information aspects, each playing a crucial role in influencing decision-making processes. The information aspects considered in the literature review are summarised in the theoretical framework. This framework serves as the foundation for this thesis, providing a structured approach to understanding the complexities of decision-making processes within public organisations. This framework acts as a benchmark against which empirical data and results are evaluated, enabling the derivation of recommendations for the Programme Directorate. The theoretical framework is presented in Table 4.

Table 4. Theoretical framework

Theoretical framework	Aspect	Source
Why	*Rationale:* The rationale of the decision-making process should be known.	(Parsons, 1995)
What	*Information sources:* Governments should consider both internal and external information sources.	(Citroen, 2011; Head, 2016; Parsons, 1995; Peters & Barker, 1993; Zadelaar *et al.*, 2021)
	Information types: All relevant types of information should be considered.	*See Table 2.*
	Information quality: The information quality should be appropriate.	*See Table 3.*
Who	*Decision authority:* The appropriate decision-making body should receive the information.	(Mahto & Davis, 2012; H. Mintzberg, 1979)
	Stakeholders: The involved and affected parties should be considered and dealt with appropriately.	(Aaltonen, 2011; Khan *et al.*, 2021; Yang *et al.*, 2011)
	Support: There should be support for and participation in internal and external parties.	(S. Bowen & Zwi, 2005; Citroen, 2011; Mahto & Davis, 2012)
When	*Timeliness:* Internal and external information should be available in time.	(Borek *et al.*, 2013; Citroen, 2011; Simonsson *et al.*, 2005; Woodall *et al.*, 2013)
Where	*Streamline:* Information should be condensed when it goes up the hierarchical ladder of the organisation.	(Caniëls & Bakens, 2012; Citroen, 2011; H. Mintzberg, 1979)
	Accessibility: There should be accessible and efficient information systems to support work for all parties.	(Cai & Zhu, 2015; Chang *et al.*, 2022; Gürdür Broo & Schooling, 2021; Jansen *et al.*, 2008; van der meer *et al.*, 2015; Varajão, 2022; Woodall *et al.*, 2013)
How	*Control:* External information should be controlled by experienced staff.	(Citroen, 2011; Zadelaar *et al.*, 2021)
	Rationality: The information should be processed in a rational way.	(Citroen, 2011; Constantin, 2013; Parsons, 1995)

4. Current decision-making practise

This chapter offers a detailed analysis of three case studies within the ERTMS programme, examining their decision-making processes. The analysis is structured for comparison with the theoretical framework: first the story line of the project is given, followed by analysing information aspects to discern patterns. Next, it summarises and compares findings with the theoretical framework, provides reflections, and concludes with key insights. Finally, this chapter addresses the second sub-question.

4.1. Project A: Test track section Hanzelijn

The main goal of this project was to introduce a representative test track section in which the ERTMS functionality can be tested so that risk of disruption to the sections of track being transformed afterwards are limited. The decision that is analysed was the decision of the Steering Committee of March 10, 2022. In this meeting, multiple decisions were made. This analysis only focuses on the decision to conduct the test track section on the Hanzelijn (rail connection between Lelystad and Zwolle) with a technical design of ETCS L2B3only. The following chapter provides a story line of the key events that led up to the decision that is analysed.

4.1.1. Story line

The main trigger to introduce a test track section was following recommendations of a parliamentary inquiry on the Fyra high-speed train. The Fyra train service was introduced to function as high-speed connection between Amsterdam and Brussels. However, soon after introduction problems arose, including technical defects and breakdowns. About a year after introduction, this service was cancelled. A specific recommendation from this study was to conduct extensive testing and trial operation when introducing new train services.

The project of introducing a test track section started on July 13, 2018. In this meeting, several decisions were made: 1) there should be a test track section in the programme (main alternative was that there was no need), 2) the location should be the Hanzelijn (main alternative was Zeeuwse lijn), and 3) the technical design of the test track section on the Hanzelijn should be Dual Signalling (main alternative was L2B3only). These decisions were worked out in detail in advance. The Hanzelijn was already equipped with Dual Signalling (L2B2/NS'54). An important consideration to execute the test track section under Dual Signalling was that there was a fallback option, to resume operation under ATB in case the testing fails (Appendix B: DAPA1, 3, 4, 8, 10, 11).

On May 17, 2019, the Dutch Cabinet took the programme decision. In the programme decision, the scope for the realisation phase of the ERTMS programme was defined. If there are deviations from the scope, the decisions must be made by the Steering Committee, after this the State Secretary must ratify it. In the programme decision, it was determined that the test track section would take place on the Hanzelijn, under Dual Signalling (L2B3).

During 2019 and 2020, it was investigated by a taskforce to upgrade the Hanzelijn to Dual Signalling B3. However, by upgrading this section, it appeared that this would give the supplier of the current system a knowledge advantage for the procurement of the CSS system for the national deployment of ERTMS, this was a legal problem that needed to be solved. Furthermore, it was found that through this technical design, the benefits offered by ERTMS were "far to be utilised" (Appendix B: DAPA2). Therefore, this technical design was no longer an option.

During 2020 and 2021, an alternative technical design was discussed in the MT ERTMS in which there could be switched between ATB and ETCS L2B3only. This alternative was further investigated by a taskforce. Eventually, on March 4, 2021, the taskforce had advised against proceeding with this alternative in the MT ERTMS, since such unicate is complex and not representative. Therefore, it was proposed to execute the Hanzelijn with L2B3only technical design.

By introducing L2B3only on the Hanzelijn the fallback option disappeared. The fallback option was that the operation had to be able to continue under the ATB system. Therefore, NS set up boundary conditions, this was among others that it had to be possible to rebuild the infrastructure of the Hanzelijn to the ATB-system in 72 hours (Appendix B: DAPA5). By executing the test track section under L2B3only, no regular train traffic was possible for about 3-4 months.

Thus, the initial idea was to perform the test track section under Dual Signalling L2B3, which was not feasible. Then the switchable alternative was investigated, which was not representative. Both of these technical designs for the test track section would have minimal impact on the travellers. Since not all scenarios can be tested on the Hanzelijn, section Lage Zwaluwe – Roosendaal was added into the scope. In the meantime, the State Secretary had decided to add the northern lines into the programme scope. Since there is a different safety system on the northern lines (ATB-NG), and a different carrier is operating here, a test track section is also being introduced here. This decision changed the strategy of the test track section (i.e. how it can be performed in the most efficient way). A taskforce was assigned to work out test scenarios among the three locations that are now in the scope for the test track section. This taskforce consisted of three people representing NS, three representing ProRail, one representing IEMeV, and two representing the PD.

On April 8, 2021, it was decided in the MT ERTMS to continue research the test track section on the three locations: Harlingen haven- Leeuwarden (part of northern lines), Hanzelijn, and Roosendaal – Lage Zwaluwe. It was also decided to investigate the risks and their control, consequences to the planning, and costs. This work was finished before the MT ERTMS of December 16, 2021. In this MT ERTMS, the formal decisions were taken to examine the Hanzelijn under ETCS L2B3only, and to execute the roll-out. These decisions, after being taken in the MT ERTMS were put on the agenda of the Steering Committee (Appendix B: DAPA6).

On March 10, 2022, the Steering Committee decided to execute test track section on the locations Harlingen haven- Leeuwarden, Hanzelijn, and Roosendaal – Lage Zwaluwe following the advice given through the MT ERTMS (Appendix B: DAPA7, 8, 9, 10).

On September 27, 2023, the Steering Committee decided that an alternative location for the test track section Hanzelijn must be investigated. One of the reasons for this decision reconsideration was that the fallback option of this alternative, which was a rebuild that needed to be executed within 72 hours, was not feasible (Appendix B: DAPA11; Personal communications, February 20, 2024). An overview with the key events is presented in Table 5 .

Table 5. Main events related to Project A

Date	Who	Activity
July 13, 2018	Steering Committee	Advice to establish test track section (Dual Signalling)
May 17, 2019	Cabinet	Programme decision
2019/2020	Taskforce	Further research Dual Signalling L2B3
2020/2021	Taskforce	Start research switchable system L2B3only/ ATB
March 4, 2021	MT ERTMS	Advice to refrain from switchable systems, and start to investigate three locations for test track section
April 8, 2021	MT ERTMS	Decision to continue investigate three locations
May 20, 2021	State Secretary	Decision to add northern lines into programme scope
December 16, 2021	MT ERTMS	Decision to execute Hanzelijn under L2B3only
March 10, 2022	Steering Committee	Decision to execute Hanzelijn under L2B3only Roll out sequence: 1) Harlingen haven – Leeuwarden 2) Hanzelijn; Lelystad + Emplacement Lelystad 3) Lage Zwaluwe – Roosendaal (part of EKB).

4.1.2. Analysis

Why

Rationale: Regarding the decision taken by the Steering Committee of March 10, 2022, to distribute the test track sections to three locations, including the Hanzelijn, the rationale behind the decision was known by all involved parties. The underlying goal to do an extensive test and trial operation arose from the parliamentary inquiry of the Fyra train connection between the Netherlands and Belgium. A recommendation that arose from this was to always execute an extensive test and trail operation before implementing new changes on the railroad (Personal communications, February 20, 2024).

What

Information sources: Within the programme, collaboration and close coordination with the implementing organisations and other stakeholders is essential to make the projects a success. Concerning this project, the PD worked together in a taskforce with NS, ProRail IEP, representatives from the freight and regional carriers. The various parties all provided their information. For example, ProRail IEP examines and delivers technical options of the infrastructure and the costs, and NS provides information about scheduling and logistics. In the taskforce, the information was reviewed, and complete scenarios are further developed (Personal communications, February 20, 2024).

Information types: The type of information that has been considered in this decision-making process were technical information because several technical alternatives have been examined, logistical information had been considered and delivered by NS. Environmental aspects were not applicable to this project because the project consists exclusively of renewing the security system on existing infrastructure. This applies as well to financial information, with the programme decision, money was reserved to implement this project. In the further development of this project, finance was not decisive.

The issue in this decision-making process is that in the history, various decision-making processes have led to this situation. In the first decision, it was assumed that the Proefbaanvak would be conducted under Dual Signalling. The Hanzelijn was already equipped with Dual Signalling B2, therefore it only had to be upgraded to B3. In the study that led to this decision, all sections of track were already considered (it can be argued whether the track sections should have been split into smaller sections to create a more reliable picture of the possibilities. Because the Zeeuwse lijn was considered as a whole, the disadvantages are greater than if parts of the Zeeuwse lijn were considered). The Hanzelijn was in that study the most suitable track section and the Zeeuwse lijn scored second.

After that decision, the upgrade to Dual Signalling B3 was investigated. Later it turned out that this would give the current supplier a knowledge advantage for the procurement of the national central safety system. This was a risk that could not be taken from the legal perspective, this risk was underestimated. After this became clear, other technical interpretations were explored. However, at that moment it would have been better to reconsider the location of the test track section because other technical specification could be more suitable on different locations, for example the social disruption could be much lower. After the decision of March 10, 2022, to execute Proefbaanvak under L2only, the social impact was communicated. The province of Flevoland has conducted opposition to this decision, it seems that this stakeholder had to be better managed leading up to this decision to avoid this.

Summarising, it can be concluded that in the decision-making processes towards March 10, 2022, there are room for improvements regarding the social and political aspects. The financial, logistical, technical, and legal aspects seen to be considered sufficiently, and the environmental aspects have not played a determining role in this project, but neither did it seem necessary (Personal communications, February 12, 2024; February 20, 2024).

Information quality: The quality of the information was not adequate on all critical aspects. The report that had been established by the taskforce in advance of the decision of March 10, 2022, contained

background information and substantiation of the decisions and showed that many risks have been identified and managed. Furthermore, it showed that consequences to the planning, and costs were considered, and a detailed plan of the test strategy and duration was included. Thus, the information was complete. The information showed that the testing events on the Hanzelijn will take 82 days, and that during this testing no regular train traffic was possible. This would affect twenty-nine thousand travellers daily on the Hanzelijn from who 18.000 must be transferred by bus, which would cause them an additional travel time of at least 30 minutes and one or more extra transfers. 11.000 would detour via Amersfoort, which would lead to additional travel time as well. The interviewees differed on vision of how realistic or feasible this is. However, this information is accurate and usable. This analysis was conducted by NS, they do have experience in these matters. Therefore, their input on this aspect was relied upon. NS delivered their information consistently. Boundary conditions that both NS and the freight carriers have been set up was considered. However, one of these was that there should be a fallback option that must be reached within 72 hours in case the testing would fail for any reason. After the decision, it appeared that this could not be reached. The 72 hours rebuild time were researched in a plan study for a different location, and this analysis was adopted for this study. From this it can be concluded that the information was not relevant since each location has unique characteristics. This has resulted in an unacceptable situation for NS which caused the decision not to achieve its goal (Personal communications, February 20, 2024).

Who

Decision authority: This decision was taken by the Steering Committee, which is the highest level in the considered hierarchy. Because this decision impacts the programme's scope, this decision is formally submitted to the State Secretary. The investigations and preparations were made by the taskforces, and were discussed in the appropriate tables, before it was decided on by the MT ERTMS. After the MT ERTMS had decided this project was put on the agenda for the Steering Committee. This is the common way. They received the information appropriately.

Stakeholders: Regarding the decision of the test track section on the Hanzelijn, the main stakeholders were NS and ProRail IEP. NS because they operate on the Hanzelijn and ProRail IEP because they manage the transition to ERTMS concerning infrastructure. The PD collaborated closely with these parties in this project. Other rail parties did not suffer from this. The province of Flevoland could have been managed more appropriately.

Support: Within the PD, the flow of information was open, and there was support for the decision by the involved (external) parties. NS had problems with the Fyra train earlier and the evaluation showed that there had to be a plan B. The need to introduce a test track section at all was thus widely supported. The locations of the test track sections were investigated by a taskforce consisting of representatives from NS and ProRail. However, after the decision was made, the situation eventually became unacceptable to NS, partly because it turned out that their preconditions could not be met (Personal communications, February 12, 2024; February 20, 2024).

When

Timeliness: The information was available in time for all decision-making moments. The taskforce is working out a solution and at a given moment in they have set a deadline before which the work must be completed. This deadline is a MT ERTMS or a Steering Group session, so the work can be examined thoroughly, and a decision can be made, these deadlines were met any time Personal communications, February 20, 2024).

Where

Streamline: To speed up decision-making, the work executed by a taskforce was presented in the form of a report that consisted of thirty-two pages and was summarised to a memo of two pages. To ensure

efficient meetings of the MT, a processing sheet was added to the documents. This document is presented in a pre-defined way. In this way, the MT members know how they must deal with a certain document item. This ensures that confusion is avoided, and the efficiency of the meetings are increased. Regarding the Steering Committee, the information was condensed as well (Appendix B: DAPA8; Personal communications, February 12, 2024).

Accessibility: Within the PD, collaboration primarily takes place via Microsoft SharePoint. This is a cloud environment in which documents can be stored and shared. There are possibilities to collaborate with external parties via SharePoint as well. The interviewees of Project A stated that the information was accessible for all parties and that the information system works efficiently, the documents can be sorted by date, title, and reference number (Personal communications, February 12, 2024; February 20, 2024).

How

Control: The information that was provided by the external parties is integrally controlled through collaboration in the taskforces. In these taskforces close collaboration takes place between internal and external specialists to make the programme a success. The specialists look over the information that external parties provide. Therefore, it can be said that reliable information is ensured but it happens integrally (Personal communications, February 20, 2024).

Rationality: The rationality of this decision-making process was a complex issue in this case. As mentioned before, there were multiple decisions that led towards this decision, to execute the test track section on the Hanzelijn. In an earlier decision, the choice was already made to do this on the Hanzelijn, but that was with a different technical interpretation (Dual Signalling B3). With the current technical interpretation (L2B3only), it has not been reviewed whether the Hanzelijn was still the most suitable location, because this was already decided. To increase rationality, the different locations on which it was best to execute the test track section should have been reanalysed. It can be concluded that the decision-making process was not performed in a rational way (Personal communications, February 12, 2024).

4.1.3. Summary

The comparison between the theoretical and empirical findings are summarised in Table 6.

Table 6. Pattern matching results Project A

Framework	Theoretical patterns	Empirical patterns	Match
Why	*Rationale:* The rationale of the decision-making process should be known.	The rationale behind the decision-making process was known	+
What	*Information sources:* Governments should consider both internal and external information sources.	Both internal and external information is considered.	+
	Information types: All relevant types of information should be considered.	Not all aspects were thoroughly covered.	0
	Information quality: The information quality should be appropriate.	The information quality was not entirely relevant	0
Who	*Decision authority:* The appropriate decision-making body should receive the information.	The appropriate decision-making body received the information	+
	Stakeholders: The involved and affected parties should be considered and dealt with appropriately.	Most stakeholders have been dealt with appropriately, the province was not sufficiently informed	0
	Support: There should be support for and participation in internal and external parties.	The partners are sharing the vision for the need of a test track section; however, NS had retreated after the decision	0
When	*Timeliness:* Internal and external information should be available in time.	The information was available in time and the decision was made timely	+
Where	*Streamline:* Information should be condensed when it goes up the hierarchical ladder of the organisation.	Information was condensed up the hierarchical ladder.	+
	Accessibility: There should be accessible and efficient information systems to support work for all parties.	There are accessible and efficient systems to support the work for both internal and external parties.	+
How	*Control:* External information should be controlled by experienced staff.	The information is integrally controlled by specialised employees within the taskforce.	+
	Rationality: The information should be processed in a rational way.	The decision-making process is not performed in a rational way.	-

4.1.4. Reflection

When reflecting on this project, it can be stated that this decision did not lead to the desired result to achieve a representative test track section. This is because the consequence of the decision was not found acceptable by NS. Therefore, a new decision regarding the test track section must be taken. It is remarkable that in the initial decision the considered technical design was Dual Signalling, therefore the location of the Hanzelijn seemed attractive because it was already equipped with Dual Signalling. When it was found that this was not possible, a switchable alternative was chosen to investigate further. When it turned out that this design was not possible as well, it was decided to still consider the Hanzelijn under level 2 only. By adopting this technical design, the consequences are quite different. It is now questioned by the decision-makers why the location was not reconsidered when the technical design was redecided. It looks like this should have been done.

There are multiple arguments on why this project did not produce the desired result. For example, the rebuild time of 72 hours was mentioned, which is also discussed in this analysis. The covid crisis causing a staff shortage at NS was also mentioned, which meant that available personnel had to be deployed to their primary process. Progressive insights were also mentioned since the scope and the strategy of the programme has changed over the time. There is a shortage of budget to realise the initial programme plan. As a result, choices must be made in the sections of track to be rolled out. All these arguments have led to the situation in which the benefits for the location of the Hanzelijn were eliminated.

In this case the aspects considered in the theory give a good and complete overview of what took place, and the things that went wrong in the project can be reasoned back to the theoretical framework. On the aspects where a mismatch or a partial match has been noted, there are points of improvement that, if sufficiently considered, could have made the decision-making process look different. Regarding the informational aspects, not all aspects have an equal influence on the decision. Therefore, a critical look should be taken at how the various aspects may impact the decision-making process.

4.1.5. Conclusions project A

When comparing the theoretical patterns with the empirical patterns, one can conclude that there is room for improvement regarding this case. From the 12 aspects that the theoretical framework covers, five can be improved. This chapter focuses on the lessons that can be learned from this project.

It is observed that a decision was made early by the Steering Committee to execute a test track section on the Hanzelijn with Dual Signalling. Later, this was no longer possible due to legal reasons. Therefore, other technical variances were explored for the same location. However, it turned out that a different technical interpretation can have major difference of impact to the hindrance for the train travellers (social information aspect). The consequence of the L2B3only test track section was no regular train traffic on the Hanzelijn for 82 days. This was known before the decision took place. Because a different technical interpretation creates new risks and disturbances, it would have been better to re-examine the location of the test track section as well (What).

As mentioned, it was known prior to the decision, that no train traffic is possible on the Hanzelijn for 82 days. In response, NS had set a boundary condition that when the test track section would not work out for any reason, it must be able to be built back within 72 hours (fallback option), so that the service schedule would be back on track quickly. The time for rebuilding to a fallback option had already been investigated by ProRail, and they thought it was feasible. However, they investigated this for a different location. Later, it appeared that rebuilding would not be possible in 72 hours but would take months. This was an unacceptable risk for NS and caused their commitment to collapse. This should have been investigated more in detail in advance of the decision. The aspect of support in this case is closely related to that of the information types and information quality. Other stakeholders (e.g. province of Flevoland) must be informed as well as possible why this project should take place (on this location), they can otherwise put-up considerable opposition in this case and create negative publicity (Who).

Because a decision was made earlier to execute the test track section on the Hanzelijn, the location was not re-considered in this decision-making process. From this it can be concluded that this was not a rational decision because not all information was considered (How).

4.2. Project B: European Instructions in Experience Driving

The main goal of this project was to implement the most recent version of the European Instructions when Experience Driving takes place for NS train personnel. First, some context and a description of the projects European Instructions and Experience Driving, and how they are interconnected, is given.

Before this project, train drivers in the Netherlands use so-called directions (aanwijzingen) in case a special action must be performed, these directions come from ProRail traffic management (VL) and are sent to the driver. Examples are permission to drive through a red signal or passing a level crossing in failure, these directions must be noted on paper. These directions are being digitised and made uniform in Europe; it is therefore renamed to European Instructions.

The European Instructions (EIs) are a set of standardised operational instructions for train drivers that are applied in Europe. The implementation of the EIs in the Netherlands can be viewed separately from the ERTMS programme (and thus Experience Driving), because it must be implemented into the Dutch operation anyway. The EIs are updated about every four years and NS wants to combine their education programme for Experience Driving with the most recent version of the EIs, so that train drivers do not have to be educated twice in a short period, this will save time and money.

Experience Driving was for NS train drivers to gain operational experience in driving under ERTMS, after they are educated. In the phasing of ERTMS implementation, the trains are converted first, and train drivers are trained to work with ERTMS, and then the track sections are converted in stages. NS is the concession holder for the main rail network in the Netherlands which means that they operate on most sections of track. It is important that enough train drivers know how to operate under ERTMS at the time the track sections are upgraded.

The decision that is analysed is from October 20, 2022, by the MT ERTMS to get ahead of legislation for the establishment of the EIs 2023.

4.2.1. Story line

At the start of this project, most NS personnel was not educated to work with ERTMS yet. Therefore, a training plan had to be set-up. NS wanted to combine the ERTMS education with the education of the most recent version of the European Instructions. In July 2020, the MT ERTMS, and in October 2020, the Steering Committee decided to implement the EIs 2019 on May 1, 2023 (instead of the EIs 2015, which was defined in the programme decision). The planned start of the Experience Driving was on July 1, 2023.

About two years later, in early October 2022, it became clear that the European Rail Agency (ERA) was working on the EIs 2022. It was expected that this version would be agreed upon in November 2022. All Dutch rail carriers have been asked how long they need to prepare for a new version of the EIs, this appeared to be up to five months. This means that an even more recent version of the EIs could be used for Experience Driving without impacting the planning of ERTMS programme. However, later it appeared that the establishment of the EIs 2022 was delayed to at least February 2023 (Therefore this version is now called EIs 2023). Since it was a boundary condition from NS to only educate their train operators once, and therefore the ERTMS training and the European Instructions training was combined, a pressure is arisen on the planning of Experience Driving, and thus on the planning of the ERTMS programme. The MT ERTMS has established a taskforce that investigated several alternatives to this problem. This taskforce consisted of people from NS and ProRail VL.

The alternatives that are set up by the taskforce are as follows (Appendix B: DAPB1, DAPB6):

- 1A Delay implementation of EIs, Experience Driving occurs with the current directions
- 1B Delay implementation of EIs, Experience Driving starts with directions and a.s.a.p. with the EIs
- 2A Implementation of EIs 2019, a.s.a.p. implementation of EIs 2023
- 2B Implementation of EIs 2019, implementation of EIs 2023 will be done much later

- 3A The form list will be adapted according to EIs 2023, but continues to be called directions
- **3B Establishment of EIs 2023 without official adoption from the EU**
- **4 Implementation of EIs 2023, and expecting that it will be in force from February 2023**
- 5 Implementation of EIs as pilot only for Experience Driving (thus not for regular train operation)

These alternatives were discussed in a special combined meeting of the system integration and planning- and migration table on October 11, 2022. Eventually there was consensus to work out alternative four. The starting point is to avoid delaying the Experience Driving. Besides alternative four, they want to work out alternative 3B, in case that the establishment will be delayed further than February 2023. For this alternative, the legal feasibility had to be examined first (Appendix B: DAPB1, DAPB6).

This advice is adopted by the MT ERTMS on October 20, 2022. Following on this meeting, the taskforce was expanded with people from the IenW and PD. They further investigated the legal possibility to implement the EIs 2023 on May 1, 2023. In the meantime, it appeared that the EIs are unlikely to be adopted by the ERA in February 2023, this means that scenario 4 was discarded. Shortly after this decision, ProRail VL took place in the Tafel van Vergroting to discuss this decision and to ask them feedback. Their reaction is unknown (not adopted in the minutes of the meeting).

> *Tafel van Vergroting: (table of magnification): Reconciliation meeting from ProRail with carriers. This table has two core functions: consultation and announcements. The participating parties are (representatives from) all parties that have an access agreement to the Dutch railroad (and thus are not operating under a concession) (Appendix B: DAPB6).*

In November 2022, IenW indicated that there was no possibility to get ahead of legislation, unless the DG Move (Directorate-General for Mobility and Transport of the European Commission) can give a statement that it is possible, which may also be an informal statement.

In early December 2022, there was a meeting with advisors of the PD, IenW and the DG Move regarding the early implementation of the EIs 2023. The DG Move reacted positively on the proposal from the PD and IenW. The DG Move suggests putting the proposal in writing and assures that there will not be infraction procedures for not implementing the EIs 2019 before the deadline (Appendix B: DAPB6). By this assurance, the uncertainties for alternative 3B seemed to be out of the way.

On January 30, (three months ahead of May 1st) ProRail VL sent a letter to the Tafel van Vergroting, in which it was described that ProRail is intended implement the EIs 2023 on May 1, 2023. On January 31, 2023, the freight carriers were informed through the 'Logistiek Portaal' that ProRail was intended to do this.

> *Logistiek Portaal: Formal environment where decisions are displayed (with background information) after consultation, accessible to all parties with an access agreement.*

In March 2023, in several (ERTMS-related and not ERTMS-related) meetings, the implementation date was discussed among the freight carriers, in these meetings some freight carriers mentioned that the educations were in progress, and some freight carriers had indicated that they would not be ready in time. They mentioned late communication, and the lack of a legislative basis as reason for this.

On March 8, 2023, IenW received the official letter from the EC in which it was stated that they do not see any legal barriers for an early implementation of the EIs 2023.

After this, the implementation date of the EIs was still discussed multiple times with the freight carriers. Three freight carriers would not be ready for the deadline of May 1, 2023. DB Cargo mentions that they had never seen an implementation decision, RailGood was questioning the legal basis for this implementation date. They wanted IenW to publish the legal basis and then look at a realistic and acceptable implementation date. After this meeting, the implementation date of May 1, 2023, was dropped (Appendix B: DAPB6).

On April 11, 2023, there was an extra Steering Committee about the EIs. In this meeting consensus was made and the Steering Committee decides that the EIs will be implemented on September 1, 2023. The freight carriers mentioned that they will do their best to reach this date (Appendix B: DAPB4, 5). An overview with the key events is summarised in Table 7.

Table 7. Main events related to Project B

Date	Who	Activity
May 2019	ERA	Establishment of EIs 2019.
June 3, 2020	MT ERTMS	Decision to implement EIs 2019, on May 1, 2023, before Experience Driving that starts on July 1, 2023
October 28, 2020	Steering Committee	Decision to implement EIs 2019, on May 1, 2023, before Experience Driving that starts on July 1, 2023
October 6, 2022	MT ERTMS	The ERA works on a new version of EIs
October 20, 2022	MT ERTMS	Decision to continue with alternative 4 and 3B
March 21, 2023	Freight carriers	It appears that some freight carriers are unable to finish the education in time, implementation date is dropped
April 11, 2023	Steering Committee	Decision to set implementation date on September 1, 2023

4.2.2. Analysis

Why

Rationale: Regarding the decision of the MT ERTMS of October 20, 2022, to continue with scenario 4, to execute Experience Driving under the European Instructions, expecting that the European Instructions will be in force in time, and to continue with scenario 3B to make it legally possible to execute Experience Driving under the European Instructions version 2023, if these have not been officially established yet. The goal was to execute Experience Driving under the newest versions of the European Instructions, so that NS personnel did not have to be educated twice. From the interviews (Personal communications, February 15, 2024; February 26, 2024) it became clear that the rationale behind this decision-making process was known by all participating parties. The participating parties were NS, ProRail and the PD. Experience Driving is only conducted by NS, therefore the choice whether to do it is done by NS, ProRail VL and the PD. The freight carriers are already operating with ERTMS on the Betuweroute (Personal communications, February 26, 2024).

What

Information sources: The taskforce in which the scenarios have been established was led by ProRail VL, and NS participated in this taskforce. This is external information because it came from outside the PD. After that, their findings were discussed in a combined session of the SI table and the planning- and migration table. Based on the findings of the taskforce and the tables of the PD (where the external parties were present as well), the decision was made.

Information types: The informational aspects that were considered leading up to this decision included planning information, which also considers the financial aspect, since a delay on the planning is costly. The carriers examined themselves to see how long it would take them to get the trainings programme done, this can be considered the logistical aspects. Legal aspects are considered as well because the legal possibility had to be examined. Environmental, political, technical, and social aspects were not applicable to this case, because the European instructions only impact the working methods of train drivers and ProRail traffic control (Personal communications, February 15, 2024; February 26, 2024).

Information quality: The decision to get ahead of legislation for the establishment of the EIs 2023 that was taken by the MT ERTMS of October 20, 2022, were in fact two decisions. On the one hand it was decided to continue with Experience Driving under the EIs 2023, expecting that the EC will empower it in February 2023. In this situation, it was assumed that the official establishment was on time for the

industry to make the necessary preparations (five months were needed). On the other hand, it was decided that a back-up plan had to be worked out in case that the official establishment of the EIs was delayed further by the ERA. However, at the time of the decision of October 20, 2022, it was not known how to implement the most recent version of the EIs before legislation. Therefore, the information was not complete. The information was furthermore accurate, consistent, relevant, and usable (Appendix B: DAPB6).

Who

Decision authority: The analysed decision was taken by the MT ERTMS. It is however questionable whether they were authorised to make this decision. The scope of the programme was that Experience Driving would take place with the EIs 2019 version. The decision to change it to the EIs 2023 is a change in the scope of the ERTMS programme, therefore it should have been decided upon by the Steering Committee. In addition, the earlier decision to change from the 2015 to 2019 version, was also taken by the Steering Committee. After the MT ERTMS decision, this issue was not put on the agenda for the Steering Committee. The Steering Committee ultimately decided upon this issue, after escalation. The reason for escalation was that this project was about to become a danger on the overarching programme's schedule.

Stakeholders: There are many stakeholders to this project, NS was roughly the only party to benefit from this decision, all other rail carrying parties are affected by this decision. The affected parties had not been adequately communicated with, they opposed. Some claimed for a long time that the legal basis for this project did not exist, this could have been avoided by adequate communication. Furthermore, ProRail informed the parties in the Tafel van Vergroting twice, one time to discuss this decision with the parties and to ask for any feedback in November 2022 shortly after the decision of October 20, 2022 and once through a formal letter in late January (three months in advance) that they are intended to implement the European Instructions 2023 on May 1st, on January 31, 2023, it was communicated through the Logistiek Portaal. This formal communication was too late, since the railway parties had indicated that they needed up to five months to prepare for the new version of the European Instructions.

Support: The internal flow of information within the PD was open. All decisions taken within the MT are shared with the colleagues and everything that is discussed on the SI-table and planning and migration table is shared through the minutes of the meetings that can be viewed by all employees of the PD. Whether there was support for the decision-making process by the external parties, differed per party. This was an important decision for the PD, NS and ProRail. However, this decision did impact the entire industry because everyone had to change their working methods and create a training programme for train operations. The parties that were not directly involved in this decision-making process had no commitment to this decision because they were hiding behind the argument of not having a legal basis. Because they could not train their staff in time, the deadline could not be met. A formal consultation round took place within the 'Tafel van Vergroting', and the (representatives of the) parties have also indicated their agreement. Only later it turned out that three parties did not agree after all (Personal communications, February 26, 2024).

When

Timeliness: For a long time, there was a lack of clarity about the legal basis on which it was possible to implement the new version of the European Instructions before they were official adopted by the ERA. This was from the moment the decision was made in the MT ERTMS on October 20, 2022, until the escalation to the Steering Committee in April 2023. This should have been clear to all parties much earlier (Personal communications, February 26, 2024).

Where

Streamline: Whether information was condensed when it went up in the hierarchical level of the organisation, is interesting. The taskforce, which consisted of people from ProRail VL and NS first explored the environment and identified six alternatives, this eventually was discussed in the combined table meeting. Eventually in the MT ERTMS, it was chosen to further work out alternative 3 and 4. This process proceeded in the usual manner. However, this information did not reach the Steering Committee. When this decision escalated in April 2023, the Programme Director wanted all scenarios to be examined so it can be discussed in the Steering Committee. Usually, the Steering Committee receive this information in aggregated form, with a proposal for the decision to be made. Because of the escalation, this did not happen in this situation. The information was thus not condensed when it went up in the organisation (Personal communications, February 26, 2024).

Accessibility: Within the PD, there are accessible and efficient systems to support work for all parties. The parties involved can work together through SharePoint or are informed through e-mail. The work conducted by the taskforce was shared with those involved in the combined table sessions. SharePoint is used a lot and can be used for collaborating internally as well as with external parties. In advance of the MT ERTMS, the relevant documents are always presented in a predefined way and for a Steering Committee, there is an annotated agenda.

How

Control: The taskforce that established the six scenarios consisted of people from NS and ProRail VL. The external information was analysed by PD staff in the combined table session (planning and migration table and system integration table). In these table sessions, the external parties are usually present as well. Therefore, a substantial discussion can take place where all the different views come to light. Therefore, it can be stated that the external information is controlled by experienced staff, this happens integrally in discussion to find the most suitable solution.

Rationality: The process leading up to the decision of October 20, 2022, did not take place in a rational way. Even though different scenarios have been established and examined by the taskforce consisting of employees of NS and ProRail VL, NS had set preconditions. This resulted in a situation where some scenarios had already been sidelined without being thoroughly examined. In this way, NS ensured that the decision benefits them rather than what is best for the industry.

4.2.3. Summary

The comparison between the theoretical and empirical findings are summarised in Table 8.

Table 8. Pattern matching results project B

Framework	Theoretical patterns	Empirical patterns	Match
Why	*Rationale:* The rationale of the decision-making process should be known.	The rationale behind the decision-making process was known.	+
What	*Information sources:* Governments should consider both internal and external information sources.	Both internal and external information were considered.	+
	Information types: All relevant types of information should be considered.	All applicable aspects are covered.	+
	Information quality: The information quality should be appropriate.	The information was not complete on the legal aspects.	0
Who	*Decision authority:* The appropriate decision-making body should receive the information.	The decision was made by a non-authorised body.	-
	Stakeholders: The involved and affected parties should be considered and dealt with appropriately.	The communication with affected stakeholders was insufficient.	-
	Support: There should be support for and participation in internal and external parties.	Some external parties opposed to the decision.	-
When	*Timeliness:* Internal and external information should be available in time.	Not all information was known in time.	-
Where	*Streamline:* Information should be condensed when it goes up the hierarchical ladder of the organisation.	The information was condensed up the hierarchical ladder, until the escalation to the Steering Committee, there the alternatives were discussed with the directors.	-
	Accessibility: There should be accessible and efficient information systems to support work for all parties.	All parties had access to information through efficient systems.	+
How	*Control:* External information should be controlled by experienced staff.	The external information is overseen by experienced staff in the table sessions.	+
	Rationality: The information should be processed in a rational way.	Scenarios were established and examined. However, some parties imposed conditions that prevented the scenarios from being analysed objectively.	-

4.2.4. Reflection

When reflecting on this project, it becomes clear that this decision has been escalated, and why. This project has resulted in a delay of the programme because the start date of Experience Driving could eventually not be met. What is remarkable is that Experience Driving was a project of NS and ProRail, but by the interaction with the EIs, all sector parties were affected. This is because NS necessarily wanted the latest EIs to be in force at the same time they would train their train drivers, after which they would start with Experience Driving.

There is something to be said for NS not wanting to train their train drivers twice in a short period, but ultimately this precondition did impact the planning of the programme, because all other carriers operating in the Netherlands had to train their personnel in a short time as well. This caused a lot of resistance, especially among the freight carriers because these EIs had not yet been officially established by the ERA, there are no benefits in it for them (to get ahead of legislation), furthermore it was also poorly communicated.

The transition to ERTMS is not much supported throughout the sector. The organisation of the programme makes it difficult to make decisions that are best for the programme, since there are many stakeholders with their own benefits. In the organisation of the Dutch railroad system, the parties have the freedom to manage their own link in the chain. With ERTMS, choices and developments affect multiple sector parties simultaneously, this means that decisions cannot be taken by one overseeing

party on its own but must be taken in conjunction. This causes that it sometimes takes time to reach consensus and causes that the outcome can be influenced. For example, several alternatives had been worked out, but some appeared to have been ruled out in advance by parties such as NS.

Freight carriers had been asked in advance how long they would need to prepare training for the EIs 2023, and they said that this would take up to five months. It is then remarkable why this implementation date was officially communicated three months in advance.

The final notable aspect was the confusion and disagreement over the legal possibilities of getting ahead of legislation. The legal possibility has not been adequately substantiated or communicated in time with the freight carriers.

The aspects considered in the theory give a good and complete overview of what took place, and the things that went wrong in the project can be reasoned back to the theoretical framework.

4.2.5. Conclusions project B

When comparing the theoretical patterns with the empirical patterns, one can conclude that there is room for improvement regarding this case. From the 12 aspects that the theoretical framework covers, 7 can be improved. This chapter focuses on the lessons that can be learned from this project.

Experience Driving for NS is an essential migration step for the ERTMS programme, because the personnel of NS, which is the main train service operator, will gain experience and ensures that operational risks are reduced when the first track sections will become operational under ERTMS. Therefore, this project was also important for the programme's planning. Regarding this decision, multiple things seem to have gone wrong.

First, the decision was not made by the right decision-making body. The MT ERTMS decided to execute Experience Driving under the most recent version of the EIs. However, this decision should have been put on the agenda for Steering Committee afterwards. This did not occur, only until this project was escalated to the Steering Committee (Who).

Second, to avoid delay of the programme (which is costly), the option to get ahead of legislation was examined. This, however, took some time, and caused confusion among some implementing parties. This confusion was also the cause for the resistance of the parties, these aspects seem interconnected in this case. The resistance and thus confusion would have been eliminated by communicating the appropriate legal frameworks in a timely manner. (Who and When).

Third, the communication with the stakeholders was not appropriate. Seven months before the start of Experience Driving, it was known that a new version of the EIs was approaching, fairly soon after, the MT ERTMS took the decision to implement this new version. The rail carriers have indicated that they need up to five months to implement the newest version of the European Instructions. Eventually, this decision was communicated three months in advance. This should have been communicated more quickly and clearly. From this it can be concluded that ProRail was too late in its official communication of the decision and that the letter they have sent to the Tafel van Vergroting should have been sent at least 5 months in advance towards these carriers (Who).

It is also observed that in the escalation meeting of the Steering Committee, in April 2023, the directors, who take place in this meeting had to examine the alternatives, which had been re-established, themselves. This work normally is executed by a taskforce. Because of the crisis, the work was executed on a higher hierarchical level within the decision-making. This also makes the information less controlled. Therefore, the work was not streamlined appropriately. It is worth noting that through managing this risk in this way, the impact on cost overrun and delay on the programme did remain limited (Where).

The rationality of the decision-making process can be questioned because the main stakeholder of this project, NS, had set boundary conditions. By setting these boundary conditions, some scenarios were automatically eliminated without objectively considering these. The boundary conditions for NS ensures that the decision outcome fits them well, but this is not necessarily the best decision for the entire industry. For example, this project had impact on the planning of the entire ERTMS programme. Delaying this project would have a major financial impact because there are lots of interconnected activities that affect many stakeholders. Whereas if NS has to train their drivers twice instead of once, this will have a more financial impact for NS, but this has a much more limited overall impact on the entire industry, thus tax money is better spent (How).

4.3. *Project C: STM ATB-EG*

In the Netherlands, there are broadly two versions of the ATB system in the infrastructure. The ATB-EG (first generation) and the ATB-NG (new generation). This project focuses specifically on the Specific Transition Module (STM) for the ATB-EG. The STM ATB-EG (from now on: STM) facilitates the interaction between ERTMS trains and the ATB-EG infrastructure. The primary objective of this project is to develop an STM to reduce market dependency on only two suppliers of the STM for the European Vital Computer (EVC) tenders. The EVC serves as the core computer for trains' ETCS equipment, with the STM being a crucial module for integration into the EVC. The dependency on two suppliers, Alstom, and Bombardier (in September 2020 Bombardier merged into Alstom), has created an uneven playing field for the EVC tenders. This means that Alstom holds a knowledge advantage over other potential bidders. Therefore, this project aims to address the disparity by establishing an alternative STM, thereby restoring the level playing field to the tendering process.

The decision that is analysed in this project is the one that is taken by the MT ERTMS of February 10, 2022, to make available the improved version to the market.

4.3.1. Story line

The risk for the uneven playing field for the EVC tender was identified early in the programme. In April 2014, a taskforce was established, that consisted of people from NS, IenW and ProRail. They were tasked with exploring various scenarios in some detail. In 2015, six scenarios were established:

- Scenario 0: ETCS supplies who do not have an STM, acquire these through Alstom or Bombardier, or create one themselves.
- Scenario 1: The programme acquires an STM, by one of the current suppliers and delivers it to the selected ETCS supplier.
- Scenario 2: The programme acquires a to be developed STM, with boundary condition that the ownership of the design will be transferred to the programme. The developed product will be delivered to the selected ETCS supplier.
- Scenario 3: The programme develops an STM design themselves and delivers the design to the selected ETCS supplier.
- Scenario 4: The programme develops an STM design themselves and have it produced and delivers the product to the selected ETCS supplier.
- Scenario 5: The programme only develops a decoder; have it produced and delivers this system to the selected ETCS supplier. The ETCS supplier then needs to produce an STM (excluding the decoding) (Appendix B: DAPC2).

In June 2016, based on advice of the taskforce, the PMO (Programma Management Overleg, precursor of the MT ERTMS) decided to continue with scenario 2 and 3. These scenarios were executed parallel and are each others back-up. In September 2017, the tender of the STM was published on TenderNed (scenario 2). This leaded to two interested parties, eventually only one party submitted an offer, and this was accepted on June 6, 2019 (Appendix B: DAPC1).

In the MT ERTMS on August 29, 2019, it was chosen to stop with scenario two, and to continue with scenario three. This was decided based on eight reasons, one of which is that scenario three would lead to a better product. In the meantime, the in-house development of the design of the STM was performed (scenario 3). In September 2019, it was organised how this STM design (blueprint) would be handed over to the market (Appendix B: DAPC3).

From June 2020, the STM blueprint was for sale. Interested parties can acquire a licence for the blueprint that they can use for their EVCs. By the availability of the STM, the goal to create level playing field for all EVC suppliers, was reached.

In September 2020, NS bought a blueprint licence. Later, it turned out that there were some technical errors in this blueprint, NS proposed to further develop this design, under the condition that NS could make use of the original project that was owned by the PD.

In the MT ERTMS of December 2, 2021, it was decided that NS was given access to the original project and that they will submit the improved version back to the PD 'for the good of the sector'. NS made an improved design which is the STM v1.1 (Appendix B: DAPC4, 5).

On February 10, 2022, it was decided by the MT ERTMS to make available the new version to the market. For this decision, NS had two conditions: 1) they want to make available the STM v1.1 to the sector at no additional costs (on top of the blueprint version), 2) they do not want to make the STM v1.1 available for the sector themselves. The PD had one condition which is that they did not want to take responsibility for the further developed design by NS. ProRail LJV (legal department) agreed if no additional rights are placed with them (ProRail LJV formally issued the blueprints because the PD is not a legal entity). Considering the conditions, this resulted in a solution in which the PD delivered the information regarding the STM v1.1 to the other parties who have already bought the blueprint, and to deliver the information to the parties who will buy the blueprint. The PD thus only sells (through ProRail LJV) the original version, and in addition they deliver the information regarding the STM v1.1. In this way, the conditions of NS, PD and ProRail are met (Appendix B: DAPC6, 7, 8).

In December 2022, the ownership of the blueprint was transferred from the PD to ProRail LJV. The blueprints have formally been issued by ProRail LJV, but LJV is now the contact as well. This means that decisions are now being made through ProRail's regular line management.

The STM v1.1 needed to be certified even as the blueprint version, NS wants the certification of this version to be in name of ProRail. On May 10, 2023, the Director of ProRail LJV agreed to certify the STM v1.1 on ProRail's name (Appendix B: DAPC9).

In November 2023, the RvB of ProRail performed some legal activities related to the STM v1.1. This included signing an act of transfer of the STM v1.1 design (from NS to ProRail), licence agreement which makes NS a licence holder of the new version (that they developed themselves), licence agreement with ProRail and third parties (that enables other parties to become a licence holder) (Appendix B: DAPC10). An overview with the key events is summarised in Table 9.

Table 9. Main events related to Project C

Date	Who	Activity
January 2015	Taskforce	Establishment of six scenarios by the programme
June 2016	PMO	Decision to continue with scenario two and scenario 3
August 29, 2019	MT ERTMS	Decision to stop scenario 2 and continue with scenario 3
June 2020	ProRail LJV	Licence of the blueprint is for sale to interested parties
September 2020	NS	NS bought a licence of the blueprint
December 2, 2021	MT ERTMS	Decision to let NS continue develop the blueprint
February 10, 2022	MT ERTMS	Decision to make available the new version to the market within the conditions of NS and PD.
May 10, 2023	Director LJV	Decision to make the certification of the 1.1 version on the name of ProRail.
November 2023	RvB ProRail	Performed legal activities to transfer ownership of the 1.1 version and to enable market parties to become licence holder.

4.3.2. Analysis

Why

Rationale: Regarding the decision of the MT ERTMS of February 10, 2022, the rationale behind the decision was known to all parties. The rationale was to make available the improved design, that NS had further developed, to the market. This decision has some context, since IenW and the PD wanted to create level playing field for the STM ATB-EG. This is because initially there were two suppliers, and later these suppliers were merged, which means that a monopoly position would have been created. This could make a unit price for such a device high. To prevent this, IenW and the PD, in collaboration with NS and ProRail had created a blueprint design. This design is certified, and a licence can be issued by ProRail. NS then bought a license to further develop on this blueprint and to make it suitable for their trains. In this development they found some errors and have applied some corrections. NS suggested the idea to give the improved (1.1) version back to the PD so that the entire industry could benefit of it, and other license holders did not have to fix these issues themselves. NS offered this initially and the PD saw merit in it (Personal communications, March 3, 2024).

What

Information sources: This decision was based on information sources from NS, who came with the proposal. The PD also investigated how this proposal fits within their frameworks. Therefore, it can be concluded that this decision is made on the basis of a mix of internal and external information (Personal communications, March 3, 2024; March 11, 2024).

Information types: This decision was made based on different information types. Technical information was considered in this decision-making. The technical specifications of the Polarion project show that this variant is more compatible with the EVC systems with which it is to be integrated. Financial impacts were considered but NS has offered to return it to the PD at no cost, and this has a financial benefit for other license holders because there is less development work with the new version. Legal information had a role in this project because the dependency on the suppliers who already had a developed STM would have created a distortion of the level playing field for the procurement for the EVC for each carrier. This means that each carrier that must convert trains to ERTMS put a tender out for the EVC, because Alstom is the only party who possess an STM, they have a knowledge advantage in comparison to other potential procuring parties, which means there is not a level playing field. The goal of this STM project is to ensure that the trains can continue operate on ATB infrastructure, thereby this project automatically contributes to the logistical aspect. Environmental, political, and social information types are not applicable to this decision-making process (Personal communications, March 3, 2024; March 11, 2024).

Information quality: The quality of the information that was considered leading up to the decision of February 10, 2022, was appropriate. The information was accurate, complete, relevant, usable and had a consistent representation. However, both interviewees from the PD mentioned that after the decision there was some discussion regarding the liability of the new design (Personal communications, March 3, 2024; March 11, 2024). This was during the effectuation process of the decision. Both parties, NS and ProRail, did not want to take the liability on them, eventually both parties had to compromise on this. Here it can be argued whether the legal consequences of the transfer from NS to ProRail were sufficiently considered, thus whether the information was complete. Eventually, constructive consultations did resolve this aspect (Personal communications, March 3, 2024).

Who

Decision authority: This decision was taken by the MT ERTMS, they were authorised to take this decision. In the effectuation of this decision, the director of ProRail LJV, and the RvB had also to agree on this decision. They were sufficiently provided with the information.

Stakeholders: This project was primarily a collaboration between PD and NS and ProRail LJV was a stakeholder in this project because the PD needed them to accomplish this legally. They were informed sufficiently. Furthermore, no stakeholders were directly involved in this project, although market participant can benefit from this project.

Support: Within the PD, the flow of information was open. This does not necessarily mean that all employees of the PD could access any document related to any project. However, if an employee participates in any project, then this person always has access (Personal communications, March 3, 2024). What is discussed and decided during MT ERTMS meetings, table meetings, steering committee sessions can be accessed through the minutes/ reports that are presented in SharePoint. There is also often verbal feedback from an MT ERTMS or Steering Committee meeting, thus the internal flow of information within the PD is good. Regarding external parties, there was commitment and support for the decision as well, since NS came up with the proposal of doing this, it can be stated that they support the decision anyway. The PD saw potential in this. Thus, there was commitment and support for the decision in the decision-making process by the internal and external parties. In the effectuation of the decision when it turned out that legal documents and liabilities still had to be worked out. The legal experts of ProRail and NS have had constructive meetings in which they had to compromise on some liabilities. If there was no commitment there, it would have collapsed, and the decision had to be made again in the MT ERTMS. (Personal communications, March 3, 2024). This is in this case closely related to the completeness of the information.

When

Timeliness: The initial trigger for this project had already been identified in 2015, and NS was the first party to begin the conversion of their trains for which the STM ATB-EG had to be available. This project was not delayed due to late availability of the STM ATB-EG design. Therefore, reasoned from the main goal, this decision was timely, and the information was available in time as well (Personal communications, March 11, 2024).

Where

Streamline: The information was condensed when it went up the hierarchical ladder of the organisation. This can be concluded from the memo (Appendix B: DAPC6) that presents in condensed form the main findings and most important recommendations of the taskforce that is managed by the MT ERTMS. Also, the memos (Appendix B: DAPC9, 10) that were addressed to the Director of ProRail LJV and the Board of Directors, representatively consist of two pages, thus it is limited to the core. The PD actively focused on the way information is presented. The new Programme Director emphasised this. He wants the information to be more composed, more factual presented and in a certain structure. (Personal communications, March 3, 2024). From this it can be concluded that the PD pays close attention to this aspect.

Accessibility: In this project, there was not much collaboration involved. The original Polarion project with technical information, whose ownership was with ProRail, was shared with NS. NS made improvements and further developed on this design. Eventually, this improved (1.1) version was delivered back to the PD. Furthermore, information systems that are used is E-mail. This is considered accessible and efficient, in this case, if everyone in the mailing is included, because close collaboration was not necessary. There was not a mutual SharePoint environment for this project (Personal communications, March 3, 2024).

How

Control: The technical information that NS put into the Polarion project was controlled by certifying authorities, because the design needs to be certified, legally. Furthermore, there was no information that had to be controlled by experienced staff. Providing an STM ATB-EG is like fulfilling a small ‘must’

within the entire programme. There is not much information in that sense (Personal communications, March 3, 2024; March 11, 2024).

Rationality: This decision-making process was performed in a rational way. They state that the PD/ ProRail is the most logical place to give out such design, especially since the original 'blueprint' design is issued by ProRail as well. In the memo (Appendix B: DAPC6), four solution directions have been presented with a small explanation. It is furthermore logical and clearly reasoned why the preferred solution direction is that the 1.1 version should be brought back to the PD. There were some rumours that there were underlying motives for NS behind this decision, but the argumentation presented was strong enough to argue that this is the best solution direction (Personal communications, March 3, 2024).

4.3.3. Summary

The comparison between the theoretical and empirical findings are summarised in Table 10.

Table 10. Pattern matching results project C

Framework	Theoretical patterns	Empirical patterns	Match
Why	*Rationale:* The rationale of the decision-making process should be known.	The rationale behind the decision-making process was known.	+
What	*Information sources:* Governments should consider both internal and external information sources.	Internal and external information sources have been considered.	+
	Information types: All relevant types of information should be considered.	All applicable aspects have been covered.	+
	Information quality: The information quality should be appropriate.	Information quality was appropriate, legal consequences were not sufficiently considered in the decision-making process.	0
Who	*Decision authority:* The appropriate decision-making body should receive the information.	The MT ERTMS was authorised to make this decision and received the information.	+
	Stakeholders: The involved and affected parties should be considered and dealt with appropriately.	All stakeholders have been considered dealt with appropriately.	+
	Support: There should be support for and participation in internal and external parties.	There was support for and commitment the decision and its process.	+
When	*Timeliness:* Internal and external information should be available in time.	The information was available in time.	+
Where	*Streamline:* Information should be condensed when it goes up the hierarchical ladder of the organisation.	Information is condensed when it goes up the hierarchical ladder of the organisation.	+
	Accessibility: There should be accessible and efficient information systems to support work for all parties.	There were accessible and efficient systems to support work for all parties.	+
How	*Control:* External information should be controlled by experienced staff.	Technical information is controlled by a certifying body.	+
	Rationality: The information should be processed in a rational way.	The decision-making process was performed in a rational way.	+

4.3.4. Reflection

When reflecting on this project, this decision turns out to be a success because the goal was reached without further negative consequences. This project was primarily a collaboration between NS and the PD. There are no further parties directly affected by this decision. Both parties were committed to this

decision because both saw the benefit of it. This also means that the parties will do their best to ensure in the post-decision process that what has been decided will be effectuated.

When reflecting on this project compared to the theoretical framework, the theory overall gives a good and complete overview of what took place. However, regarding the aspect of the information quality, there is a partial match observed. This is because after the decision it turned out that it had not been properly though out how, in effectuating the decision, legal liabilities were to be distributed. It does appear that because of the commitment of both parties, this has not a negative effect on the decision outcome. The aspects considered in the theory give a good and complete overview of what took place, and the things that went wrong in the project can be reasoned back to the theoretical framework. Because this is a relatively simple project, with few stakeholders and different interests, it seems easier to adequately meet the information aspects as considered in the theoretical framework. Because the goal of this project was achieved as intended, it can be considered a success.

In this decision-making process, related to the train component of ERTMS, information related to logistics were not applicable to this project. It is expected that in other projects related to the train component, this type of information could be important.

4.3.5. Conclusions project C

When comparing the theoretical patterns with the empirical patterns, it can be concluded that on most aspects there is a match. However, there is still room for improvement on one aspect. This chapter focuses on the lessons that can be learned from this project.

Regarding the information quality, the legal frameworks had not been sufficiently considered in the decision-making process, the reason for which is unclear. Because of this, in the effectuation of this decision, some legal documents still had to be worked out and liabilities had to be divided, while both parties want as little liability as possible. If in the effectuation of a decision no consensus can be taken on such matters, the purpose of the decision will not be achieved. This highlights the importance of having complete information in advance of the decision. Or else it must be absorbed by commitment, as what happened in this case (What).

4.4. Within-case conclusions

In this chapter, the second sub-question – *How does decision-making take place within the ERTMS programme concerning the three ERTMS components, and how is information dealt with?* – is answered.

The ERTMS programme is an implementation programme carried out together with the Dutch railway parties. The programme includes dozens of projects on which decisions have to be taken. Each project affects one of the three ERTMS components: infrastructure, train, and personnel. The implementation and coherence between the projects affect the progress of the overall programme.

Projects arose in part from the programme decision, in which the overall strategy was approved by the State Secretary. However, due to advancing insights and a changing environment it is sometimes more effective to deviate from this strategy. When projects are implemented, it starts with a decision from the MT ERTMS or Steering Committee to set up a taskforce consisting of representatives from the Programme Directorate (which is the coordinating body of the ERTMS programme) and from the involved sector parties (who must implement the project) to gather information and develop various alternative scenarios to achieve the project's goals. This concerns information related to alternatives and criteria, then alternatives are further specified and limited to an appropriate number of alternatives and are assessed. The taskforce assesses the alternatives integrally, and in addition, the alternatives are assessed in corresponding table meetings as well. Such table meetings can be seen as an assessment of the proposed decision. For example, how the project impacts, and aligns with, the programme. After this assessment, the work is effectively summarised to reports that presents the key considerations and

justification of the proposed decision. These reports and summaries are delivered to the MT ERTMS, where a decision is made. Depending on whether the decision affects the programme's scope, it will be agendised to the Steering Committee, and ultimately to the State Secretary.

Regarding the three components of ERTMS – infrastructure, train, personnel – it can be concluded that information plays a significant role in the decision-making process. The information aspects related to the decision rationale, sources, types, quality, decision authority, stakeholders, support, timeliness, streamline, accessibility, control, and rationality that are considered in the literature review are analysed based on three projects from the ERTMS programme.

The examination of project A, which relates to the infrastructure component, reveals deviations between theoretical and empirical patterns, indicating that there are room for improvements. Five of the twelve aspects that are considered can be enhanced. These five aspects relate to the aspects of: 1) information type because the social and political aspects were not fully considered before the decision was made. 2) Information quality because the information regarding the fallback option was not relevant. 3) Stakeholders because the communication with the province was late. 4) Support because after the decision NS did not want to proceed with the effectuation (because their preconditions could not be met). 5) Rationality because not all options were considered prior to the decision.

For project B, which relates to the personnel component, seven of the twelve aspects show potential for improvement. These seven aspects relate to the aspects of: 1) information quality because the information was not complete when the decision was made. 2) decision authority because the decision was initially not made by the appropriate decision authorised body. 3) Stakeholders because the affected parties were not informed appropriately. 4) Support because external parties opposed to the decision. 5) Timeliness because the legal frameworks for the possibility of the decision were not known in time. 6) Streamline because information was not condensed when management had to decide. 7) Rationality because prior to the decision, preconditions had been set by involved parties which had influenced the outcome of the decision.

The analysis of project C, that relates to the train component, revealed that on one of the twelve aspect there was a room for improvement. This aspect relates to the information quality because the liabilities of the decision were not divided prior to the decision.

Based on the analyses it is evident that information is crucial for projects touching on all ERTMS components. The aspect relating to information type of information is the only aspect of which the applicable ones differ per component, the information types to be considered per ERTMS component are summarised in Table 11.

Table 11. Information type to be considered per ERTMS component

Information type	Infrastructure	Train	Personnel
Environmental	No	No	No
Financial	Yes	Yes	Yes
Logistical	Yes	Yes	Yes
Social	Yes	No	No
Technical	Yes	Yes	No
Legal	Yes	Yes	Yes
Political	Yes	No	No

5. Trends and recommendations for decision-making

This chapter focuses on the cross-case analysis, combining the empirical findings from all three case studies with the theoretical framework. Through this analysis, this chapter aims to identify the trends and areas of improvement from which actionable recommendations can be derived for the Programme Directorate. This chapter concludes with answering the third sub-question.

5.1. Trends

The results of comparing the empirical findings from all three projects with the theoretical findings are presented in Table 12. By horizontally analysing the data, trends can be identified. The trends are elaborated upon below the table.

Table 12. Pattern matching results overview all projects

Element	Description	Project A	Project B	Project C
Why	*Rationale:* The rationale of the decision-making process should be known.	+	+	+
What	*Information sources:* Governments should consider both internal and external information sources.	+	+	+
	Information types: All relevant types of information should be considered.	0	+	+
	Information quality: The information quality should be appropriate.	0	0	0
Who	*Decision authority:* The appropriate decision-making body should receive the information.	+	-	+
	Stakeholders: The involved and affected parties should be considered and dealt with appropriately.	0	-	+
	Support: There should be support for the decision and participation in internal and external parties.	0	-	+
When	*Timeliness:* Internal and external information should be available in time.	+	-	+
Where	*Streamline:* Information should be condensed when it goes up the hierarchical ladder of the organisation.	+	-	+
	Accessibility: There should be accessible and efficient information systems to support work for all parties.	+	+	+
How	*Control:* External information should be controlled by experienced staff.	+	+	+
	Rationality: The information should be processed in a rational way.	-	-	+

1. **Positive trends:** In all projects, the rationale behind the decision-making processes seem to be successfully covered. Even as considering both internal and external information sources where decisions are based on. Furthermore, in the projects there is made use of accessible and efficient information systems and external information is properly controlled. These are four aspects in which a positive trend is observed.

2. **One aspect consistently underperforms:** The information quality seems to partially match. It appears that in one project the information was not relevant and in two projects the information was not complete. This shows that of the five identified information quality aspects, one scores substandardly in each project. Furthermore, this is the only aspect that constantly fails to match.

3. **No negative trends:** On the other seven aspects, there are no negative trends observed. At least one match is scored on every aspect. It varies by aspect whether there is one or two matches, partial matches, or mismatches. However, the rationality aspect has two mismatches and a match, in this aspect the room for improvements is greatest.

The cases can also be compared to each other by vertically analysing the projects results.

4. **Side by side comparison:** When comparing the projects side by side, project B stands out with a significantly higher number of mismatches across multiple aspects. This underperformance is a consequence of ineffective stakeholder management, an unclear scope of the project and lack of timely access to the critical information. Project A and C show better alignment with the theoretical framework. Even though project A shows quite some partial mismatches. However, these are only partial mismatches and not full mismatches because on these aspects a 'minor' miss was observed across the multiple items that an aspect covers in the framework. For example, the stakeholders aspect scores a partial mismatch in project A, because one stakeholder out of the many was not sufficiently considered. In project B, a full mismatch was observed because a large group of stakeholders were not considered, which is more severe. In project C, all stakeholders were considered sufficiently.

5.1.1. Reflection

When reflecting on Table 12, one can observe that the aspects are scored on quite different. On four aspects considered in this framework, the PD scores well overall. These aspects are the rationale, information sources, accessibility, and control of information. These aspects show that there is a match between the empirical and theoretical patterns, and based on these aspects, no other remarkable things have emerged. On the information quality aspect, the PD does not achieve sufficient quality over the projects. These are not complete mismatches but there is constantly one quality aspect (from five considered) in which there is room for improvement. In project A, this was relevance and in project B and C, this was completeness. The context for this information aspect varies from project to project. Regarding project A, a study was used which was conducted at a different geographical location from that covered by the decision, the results of which were not thought to be very different. Regarding project B, the legal frameworks were not known, and regarding project C the legal consequences were not fully thought out. This shows that information quality depends on the unique context of a project and therefore it is also difficult to fully consider these aspects.

That the information aspects highly depend on the unique specifications of each project is also evident from the other aspects that are scored on differently across the projects. For example, stakeholders: each project has different stakeholders that need to be dealt with appropriately. Project A and B had many stakeholders, Project C had few. However, project C is much smaller in size and only has a few stakeholders and therefore is seems easier to manage them properly.

Rationality for example depends on the benefits of the parties involved. Based on their interest in a decision, they try to manipulate the outcome to make the outcome more convenient for them, regarding Project C, this was also the case, but the PD also saw the benefit in this preferred outcome of NS. It is difficult for the PD to deal with this properly because the organisation is arranged in such way that decisions must be made together with the sector parties, and if these work against it, it is difficult to take steps.

5.1.2. Conclusions

It appears that when scoring a '0' or a '-' on any aspect of the framework, a higher risk may arise that the decision-making process does not lead to the desired outcome. The project with most mismatches compared to the theoretical framework can be considered to have the least desiring decision-making process. However, this does not necessarily mean that the decision-making outcome is the least desiring as well, or that the consequences are the greatest. The mismatches between theory and practice lead to points of improvement in the decision-making process. What is observed, is that the project that has most matches with the theoretical framework (on eleven out of twelve aspects) has resulted in the desired decision outcome.

5.2. Cross-case conclusions

In this chapter the sub-question – *What are the differences and similarities between the theoretical and empirical findings of information in the decision-making process, and what recommendations can be drawn from it for the Programme Directorate?* – is answered.

It can be concluded from the comparison between the theoretical findings and the empirical findings that the things that went wrong in the case projects can be traced back to the information aspects considered in the theoretical framework. This can for example be seen in project C. In this project, the legal consequences of the decision were not worked out in advance of the decision. Based on this, it can be stated that the information was not complete. This affects the information quality aspect in the theoretical framework.

The cross-case analysis shows that there are similarities on four of the twelve aspects between theoretical and empirical patterns. These have been observed on the following information aspects: 1) Decision rationale, which addresses that the goal of decisions must be known to all involved parties. 2) Information sources, which addresses that information from inside the organisation as information from outside the organisation should be considered. 3) Accessibility of information, that addresses that all information must be accessible to all involved parties in the decision-making process. 4) Control of external information, that addresses that external information should be controlled by experienced staff.

There is one aspect that consistently underperforms, which is the aspect of information quality. The information quality aspect consists of accuracy, completeness, consistency, relevance, and usability of information. The comparison with the empirical findings reveals that there are differences regarding the relevance (project A) and completeness (project B and C) items of the information quality.

For the remaining seven aspects, it can be concluded that the similarities between theoretical and empirical pattern vary per project. These relate to the following aspects: 1) Information types: all relevant types of information should be considered. 2) Decision authority: the appropriate decision-making body should receive the information. 3) Stakeholders: the involved and affected parties should be considered and dealt with appropriately. 4) Support: there should be support for the decision and participation in internal and external parties. 5) Timeliness: internal information should be available in time. 6) Streamline: information should be condensed when it goes up the hierarchical ladder of the organisation. 7) Rationality: the information should be processed in a rational way.

Furthermore, it is observed that project B has the most mismatches with the theoretical framework, project A also has some mismatches as well, and project C only has matches except for one ‘partly match’. Project C can be considered a success project because in retrospect it can be said that the goal of decision-making was met and there were no delays or further impact on the programme as a result of the decision-making process. Although project A has fewer deviations from the theoretical framework than project B, it is considered more challenging in practise. This is because the impacts of this project are more significant. Furthermore, it can be concluded that not all aspects weigh equally towards the outcome of the decision. From project C it can be concluded that for example that an inadequate information quality can be compensated by commitment of the involved parties. Of course, this is the case up to a certain lack of information quality. It depends on the unique context and specifications of a project what information is relevant.

However, these conclusions are drawn by investigating finished decision-making processes. The goal of this thesis is to provide the Programme Directorate ERTMS with recommendations to enhance informed decision-making for future projects. The recommendations are based on the aspects where a (partial) mismatch has been observed. Thus, on the four aspects where only matches have been observed, the Programme Directorate should continue like this. Furthermore, seven specific recommendations can be drawn:

1. *Rationality:* Regarding the rationality of the decision-making process, the literature showed that subjective stakeholders are a danger to rationality of the decision-making process and can cause that maximum social benefit of projects are not reached. This is partly beyond the control of the Programme Directorate itself. The recommendation to the Programme Directorate is **to be aware that subjective stakeholders may try to influence the decision. Anticipate on this by identifying the different interests of the stakeholders in the analysis phase**.

2. *Stakeholders:* The transition to ERTMS requires much effort from some stakeholders, without them experiencing immediate or short-term benefits. Stakeholders can have a lot of influence on the projects and thus ultimately on the ERTMS programme. Therefore, the recommendation to the Programme Directorate is **manage stakeholders appropriately based on their interest and influence on the project.** A comprehensive stakeholder analysis can be used for this.

3. *Support:* This aspect distinguishes the internal support for the projects and the external support for projects. Regarding internal support to decisions, the PD is doing well and there is consensus across the different hierarchical levels. There are multiple communication ways to keep everyone involved in the programme. Regarding support for external parties, the recommendation to the Programme Directorate is **ensure consensus and involvement of internal and external stakeholders by regularly updating them on project progress.** This promotes involvement and support for decisions and activities, increasing the likelihood of success.

4. *Information quality:* Regarding information quality, which encompasses accuracy, completeness, consistency, relevance and usability of information, room for improvements can be achieved for the completeness and relevance quality dimensions. A decision requires careful consideration of how in its effectuation various issues should be worked out and who bears legal consequences, instead of figuring this out after the decision has been made. The recommendation to the Programme Directorate is **determine how matters should be taken into effect after the decision, discuss this in advance with the involved stakeholders and, be aware that technical interpretations may turn out differently depending on the specific characteristics of the environment.** By carefully considering this, the completeness and relevance of the information can be improved.

5. *Timeliness:* The timeliness aspect covers that the information should be in time, this includes that the decision should be taken in time for the effectuation to take place before the deadline as reflected in the overarching programme plan. The recommendation to the Programme Directorate is **provide a clear timeline of the effectuation process of a decision and communicate and validate it with the appropriate stakeholders as soon as possible.** This reduces the chance that a decision cannot have its effect in time, also because the parties are already prepared prior to the official decision. Furthermore, risks to the planning can be identified and mitigated early.

6. *Streamline/ decision authority:* This aspect covers whether the appropriate decision-making authorised body received the right information in a summarised way. This goes well among the projects. The recommendation to the Programme Directorate is **identify in an early phase in the decision-making process what decision-making body is authorised to make the decision, work towards this, and display the information effectively.**

7. *Information types:* Each project is unique and therefore different information types apply that must be considered. A distinction can be made to the three components of ERTMS: infrastructure, train, and personnel. The recommendation to the Programme Directorate is **critically assess for each project whether the information types related to finance, logistics, technical, politics, society and legal aspects apply and, if so, have been sufficiently considered.**

6. Implications for decision-making

This chapter focuses on the implications of this research, first the general implications are described, then the application to the MerwedeLingelijn case is presented, followed by the conclusions.

6.1. General implications

Based on the performed analyses and the resulting recommendations, this research provides actionable points for improvement that can enhance decision-making processes within the Programme Directorate. These points address key aspects identified in the study and offer practical recommendations for ERTMS implementation. These are presented in Table 13.

Table 13. General implications for decision-making

Aspect	Implication
Rationality	Identify conflicting interests, and deal with it them the analysis phase.
Stakeholders	Manage the stakeholders appropriately based on their interest and influence.
Support	Update the involved parties regularly about the programmes process.
Information quality	Consider prior to the decision on how things should be effectuated.
Timeliness	Ensure a clear timeline of the effectuation process.
Streamline/ decision authority	Work towards the appropriate decision-authorised body.
Information types	Assess whether applicable information types are sufficiently considered.

In addition to these implications, a checklist is established that can guide the Programme Directorate in making more informed decisions, this checklist is added in Appendix D. The goal of this checklist is to provide guidance to the Programme Directorate by ensuring that the critical information aspects are sufficiently considered by asking focused questions. This checklist can be used in the decision-making process regarding projects within the ERTMS implementation programme.

The checklist can be used at multiple phases of the decision-making process. Furthermore, the checklist distinguishes the ERTMS components to which the project applies. The questions in the checklist are based on the content of the information aspects and are phrased in such a way that they can only be answered with ‘yes’ or ‘no’. If in this checklist all aspects can be answered with ‘yes’, the project will get matches with the aspects as shown in the theoretical framework and will likely be a success. If a ‘no’ is filled in, this aspect may lead to risks in the decision-making process. Further instructions on how to use the checklist are added in Appendix D.

By considering the recommendations and checklist the operational efficiency in real-world decision-making processes can be enhanced. The questions established in the checklist provide a focused look at how information is handled and make it easier to identify possible areas of improvement.

6.2. Checklist application to MerwedeLingelijn case

In this section the checklist is applied to the MerwedeLingelijn case. As explained in the introduction, the MerwedeLingelijn case is a project which is not in the scope of the current ERTMS programme. However, it is a typical decision-making challenge that the Programme Directorate faces. Qbuzz raised the question of whether the infrastructure of the MLL could be equipped with ERTMS in the short term, for example together with the section Utrecht – Meteren, or together with non-ERTMS related adjustments on the infrastructure of the MerwedeLingelijn because due to new trains, the energy supply must be adapted and platform lengths must be increased. The interacting sections of track: Kijfhoek – Belgian border, and Utrecht – Meteren will be equipped with ERTMS in 2028 and 2031, respectively.

This project is not in the current scope of the ERTMS programme. Therefore, it must be made clear how it contributes to the programme’s goal. Especially since the locations for testing and experience have already been decided on, and the MerwedeLingelijn is neither part of a TEN-T corridor. It is

mentioned that it is undesirable to have an ATB isolated track between ERTMS sections. The arguments that are mentioned are that it brings operational risks when switching between the safety systems, however this has not been researched in-depth. The ERTMS trains that will arrive in 2027, are equipped with an STM. The checklist can systematically be used to assess whether the information is sufficiently available and substantiated whether the MerwedeLingelijn should be converted.

The MerwedeLingelijn case covers the infrastructure component. The ERTMS components regarding train and personnel are covered. In other words, the ERTMS trains have been ordered and will arrive in 2027, and the personnel can also be trained in time. In that regard, only the infrastructure component remains to be addressed for a working ERTMS system on the MerwedeLingelijn. Thus, on the other hand it would be a benefit to take advantage of the new system as soon as possible.

When applying the checklist to this project, it can be concluded that this project is in the first phase of the considered decision-making process. This is the ‘set objectives’ phase. This means that only the first two questions apply.

1. Is the goal of the decision, and how it contributes to the programme, known for all parties?

In the ERTMS programme, the effectiveness of implementing each project is not considered on a project-by-project basis but the project must fit into the strategy of the overarching programme. This is because there are limited resources (e.g. time, money, manpower) to execute the ERTMS programme. At this moment, it is unknown how this project contributes to the programme goal. Therefore, it does not seem efficient at this moment to convert the infrastructure of the MerwedeLingelijn in the short term. Therefore, this is a ‘no’.

2. Is all information on time for the decision?

The preparations for the upgrading of the MerwedeLingelijn prior to the new trains are currently in design, therefore this project is not in time to combine this effectively. Furthermore, the preparations of the transition to ERTMS of the adjacent tracks are also underway. These projects will be delayed if the MerwedeLingelijn should be considered together with any of these projects. This may create a risk to the further planning of the programme. Therefore, this is a ‘no’.

Because in phase A of this decision-making process both questions are answered with ‘no’, on both aspects a risk may arise. The first risk is that the involved parties are not sufficiently provided with information why this decision must be made. The second risk is that the benefit by combining this project with the other mentioned activities that have to take place on the MLL may not be achieved, because such project have long preparation time and the other projects are already in preparation. The available information does for now not seem to match to contribute to the programmes goal. Therefore it seems better not to consider this project at this time. This is until there is new information changing the situation or it is known how to deal with these risks.

It is important to note here that this is regarding a decision that can start a decision-making process because in practise, decisions are made to start investigating a project. In this phase, there is barely information available, such decisions are made on the basis of the alignment and feasibility on the strategy of the overarching programme. If both questions are answered with ‘yes’ in this phase, it does seem worth setting up a taskforce to analyse the project in detail and eventually to specify alternatives.

However, it is important to note the limitations of this analysis. The assessment is based on the available information and the current scope of the ERTMS programme. Detailed empirical data was not gathered for this analysis. Additionally, there may be different factors that are important to consider as well to make a decision in this phase.

6.3. Conclusions on implications

In this chapter, the fourth sub-question – *What are the implications of this research for a real-world case such as the MerwedeLingelijn?* – is answered.

The implications of this research for a real-world case such as the MerwedeLingelijn are significant. From the comparison between the theoretical framework with the empirical data obtained from three case studies that are faced by the Programme Directorate, recommendations have been distilled and these are further specified to actionable points for the Programme Directorate. These implications are: 1) identify conflicting interests, and deal with them in the analysis phase, 2) manage stakeholders appropriately based on their interest and influence, 3) update the involved parties regularly about the programmes process, 4) consider prior to the decision how things should be effectuated, 5) ensure a clear timeline of the effectuation process, 6) work towards the appropriate decision-authorised body, 7) assess whether applicable information types are sufficiently considered. In addition to these actionable points, a checklist is established. This checklist can help ensure the Programme Directorate that the critical information aspects are sufficiently considered by asking focused questions. This checklist distinguishes projects related to the three ERTMS components: infrastructure, train, and personnel. Furthermore, this checklist can be used in different phases of the decision-making process.

The checklist is applied to the project of the MerwedeLingelijn, exploring the feasibility and added value of equipping the infrastructure of the MerwedeLingelijn with ERTMS in the short term. This project is in the first phase of the decision-making process. Therefore two questions apply. The first question focuses on whether the project is in line with the programme's strategy. It is essential to know whether this project aligns with the overarching goals of the ERTMS programme. The second question focuses on whether the project can be executed in time. For example, it had been brought up by Qbuzz, the operator on the MerwedeLingelijn, to implement this project together with other infrastructure adjustments.

From the application of the checklist to the MerwedeLingelijn project it becomes apparent that key information aspects, such as the rationale of the decision and timeliness of information, are currently lacking in the MerwedeLingelijn project. Therefore, on the two applicable aspects in this decision-making phase, a risk arises. Consequently, it is advisable not to consider this project's execution at this stage. This is at least until there may be new information that allows these risks to be addressed. This conclusion underscores the importance of aligning projects with broader programme objectives and ensuring timely and well-informed decision-making to maximise efficiency and effectiveness.

7. Discussion

This chapter discusses the key findings derived from the analyses of comparing empirical findings from three case studies with the theoretical framework. The analyses aimed to identify trends and areas for improvement that lead to actionable recommendations for the Programme Directorate. Positive trends were observed in aspects such as decision rationale, information sources, accessibility, and control of information. However, the information quality aspect consistently underperformed across projects, with issues regarding the relevance and completeness. Furthermore, no negative trends were identified across the remaining aspects showing that the projects execution depend on the specific context.

This chapter first presents how this research contributes to the body of knowledge in Chapter 7.1. Then, the limitations of this research are discussed in Chapter 7.2.

7.1. Contributions

This research contributes to both the scientific literature and practical applications in the field of public sector decision-making by examining the information aspects that should be considered.

7.1.1. Contributions to scientific literature

Policy cycle insights

The study supports the general framework of the public policy process as described by Fischer and Miller (2007), particularly in the context of the ERTMS programme's implementation phase. However, this thesis supports the criticism of Sabatier and Jenkins-smith (1993) that the public policy cycle is a simple representation of how things work in practise. In practise, the programme's scope is adjusted regularly, while the programme maintains in the implementation phase. This is because this programme has a long lead time and progressive understandings arise during the process.

Information aspects

This study contributes to literature by analysing essential information aspects for projects within a public sector implementation programme. These information aspects empirically substantiated, demonstrating their important role in decision-making processes. The research underscores the importance of various information aspects outlined in the theoretical framework. The analysis of three projects demonstrates that deficiencies in these aspects correlate with project issues, while it was observed that the project with the most matches with the theoretical framework, also was considered the most successful. Therefore, based on this analysis, it can be mentioned that if all aspects match, the decision is likely to lead to a success, supporting the work of Citroen (2011), highlighting the crucial value of information in the decision-making process.

Stakeholder management

The study highlights the significance of effective stakeholder management and communication, supporting the views of Aaltonen (2011) and Yang *et al.* (2011), who highlighted inadequate stakeholder management as a primary cause of project failure. In this study, five out of the seven concrete recommendations for the Programme Directorate emphasise stakeholder engagement and communication.

Impossible to achieve full rationality

It is observed in this thesis that decisions concerning the programme are not always made rationally. This is mostly beyond the influence of the Programme Directorate. In the dynamic context of decision-making regarding ERTMS implementation in the Netherlands, the sector parties must be kept satisfied or enticed to collaborate on the project. In practise, this means that sometimes the wishes or demands of stakeholders in one decision must be conceded to get them on board in a next decision. Because of this 'playing field' it is impossible to achieve full rationality. Furthermore, there are for example always

political influences that cannot be measured or that contradict with what is best based on the available information. This underwrites the work of Hambrick and Mason (1984) who visually represented the decision-making process under bounded rationality constraints, in which the values of the decision-makers directly impact the strategic choice.

7.1.2. Contributions to practise

Actionable recommendations

The study provides practical guidelines for public sector decision-makers to enhance comprehensive information management. It highlights the connection between aligning information aspects with the theoretical framework and achieving successful outcomes. The research underscores the necessity of stakeholder management and communication. The recommendations show how to improve alignment between theory and practise for future decision-making processes, addressing areas where mismatches have been observed.

Checklist

The checklist that has been established can be used in future decision-making processes regarding projects in the ERTMS programme. This checklist serves as a guide to that helps ensuring thorough evaluation and consideration of all relevant information aspects before a decision is taken. By asking targeted questions in various phases of the decision-making process, it helps to identify whether all aspects have been sufficiently considered.

During the initial phase, the questions are focused on alignment with the overarching strategy and timeliness. When the decision-making process is in the analysis phase, multiple questions are applicable such as whether information is accessible for all involved parties, and whether external information is controlled appropriately. Whether the decision-making process evolves, other questions apply such as whether the information is objectively summarised for the decision-makers and whether it only contains the key considerations between alternatives. In the final phase of the decision-making process a question apply whether the decision is based on facts. By considering such questions in the various phases of the decision-making process, potential risks can be identified and dealt with prior to a decision. Through this, decision success may increase.

7.2. Research limitations

Despite the contributions of this research to literature and practise, there are also limitations. This chapter addresses the limitations of this research.

Scope and data collection

The scope of this thesis is limited to the Programme Directorate, the coordinating body of the ERTMS programme in the Netherlands. Consequently, all empirical data used in this study originates from the PD. However, it is important to acknowledge that decisions concerning projects within the programme are made and discussed with other sector parties. Therefore, the analysis presented in this thesis may not give a comprehensive view of how information aspects are managed prior to a decision. To make this research generalisable to foreign contexts, it must first be examined how the foreign context differs from the Dutch application. In the Netherlands, decisions regarding the rail sector must be made in consultation with key stakeholders.

The analysis of the decision-making process regarding the three ERTMS components – infrastructure, train, and personnel – relies on one case study per component. While these case studies provide valuable insights into typical project scenarios within the programme, variations in the types of information considered may exist between projects involving the same component. To improve the credibility of this research, conducting additional case studies per component would provide a more comprehensive understanding of the involved type of information in regarding the ERTMS components.

Triangulation was used to collect the empirical data, ensuring the validity of the study findings. It involved a combination of document analysis and two interviews regarding each case study, this was seemed appropriate because the questions were detailed since the interviews were conducted after the document analyses had taken place. However, by conducting more interviews, the validity can be increased more. Moreover, not all interviewees were directly involved in the decision-making process itself, some participated in the effectuation of the decision. Even though these employees can reason back why decisions turned out the way they did, this disadvantages the overall reliability of this study.

Bounded rationality approach

This thesis uses the bounded rationality approach to analyse decision-making in the public sector (Parsons, 1995). The choice of this specific approach may limit the consideration of other potentially relevant information aspects. Different theories on public sector decision-making might yield different insights and conclusions. For example, while the bounded rationality approach strives for rationality in the decision-making process, a different theory might have a different starting point.

Simplification of the decision-making process

This thesis focuses on the role of information in the decision-making process of projects within an overarching programme. While the decision-making process for individual projects may be well executed, the decision might still end up in a failure when the overarching strategy is not effective, even though the projects are well aligned with the overarching strategy. Notably, this thesis did not consider the effectiveness of the overarching ERTMS strategy. Consequently, it presents a simplified view of the decision-making context. However, it is crucial to recognise that decision-making processes within programmes of such scale, are influenced by a magnitude of dynamic factors. These factors include evolving market conditions, emerging technologies, and shifting political landscapes. Therefore, it is important to acknowledge that a well-informed decision does not guarantee success. Unforeseen advancements or political changes may impact the outcome of decisions in ways that could not have been anticipated at the time they were made. Additionally, it is not possible to always have the context researched and worked out in detail, due to limited budgets and time.

Information aspects ranking

Although it is shown that all considered information aspects in this thesis somehow contribute to the likelihood of decision success, they do not all contribute equally. This thesis does not address ranking of the various considered aspects. The impact of an individual information aspect depends on the unique characteristics (e.g. number of stakeholders, impact of the project) of each project.

Generalisability

The findings of this thesis are limited to projects within the Dutch ERTMS programme. To apply these findings to different national and international decision-making environments, additional research is needed to compare these contexts and generalise the results appropriately. This can be done

Recommendations specificity

Although seven actionable points for the Programme Directorate emerged from the analyses performed in this thesis, these can be made more specific. This thesis researched how decision-making processes regarding the ERTMS programme can be more informed. The recommendations can be applied in different stages of the decision-making process but is focused primarily on the operating core of the organisation as considered in this thesis. Although the operating core can exert major influence on how a decision can be made while striving for rationality, much is beyond their control.

8. Conclusions & Recommendations

8.1. Conclusions

In this chapter the conclusions are drawn and the main research question – *How is information dealt with in decision-making within the Programme Directorate ERTMS regarding ERTMS implementation projects in the Netherlands, and what recommendations can be drawn from the comparison between theory and the current decision-making process to enhance the success of the programme?* – is answered.

To answer this main research question, this thesis was divided into four phases. The first phase was aimed at establishing a theoretical framework that considers information aspects that should be considered in public sector decision-making processes in projects. The second phase was aimed at identifying the current decision-making process, based on three case projects. This analysis is performed on the basis of the theoretical framework. In the third phase, a cross-case analysis was performed to identify areas of improvement. These lead to actionable recommendations for the Programme Directorate. In the fourth phase, the implications for future decision-making processes for the Programme Directorate are presented.

Within the Programme Directorate ERTMS, decision-making regarding the implementation of ERTMS projects in the Netherlands is a multifaceted process that relies on the management and use of information. The crucial role of information is examined by comparing the case study analyses with the theoretical framework. The most important findings of the projects are presented below:

1. In project A, five of the twelve aspects that are considered can be enhanced. These five aspects relate to the aspects of: 1) information type because the social and political aspects were not fully considered before the decision was made. 2) Information quality because the information regarding the fallback option was not relevant. 3) Stakeholders because the communication with the province was late. 4) Support because after the decision NS did not want to proceed with the effectuation (because their preconditions could not be met). 5) Rationality because not all options were considered prior to the decision.
2. In project B, seven of the twelve aspects show potential for improvement. These seven aspects relate to the aspects of: 1) information quality because the information was not complete when the decision was made. 2) decision authority because the decision was initially not made by the appropriate decision authorised body. 3) Stakeholders because the affected parties were not informed appropriately. 4) Support because external parties opposed to the decision. 5) Timeliness because the legal frameworks for the possibility of the decision were not known in time. 6) Streamline because information was not condensed when management had to decide. 7) Rationality because prior to the decision, preconditions had been set by involved parties which had influenced the outcome of the decision.
3. The analysis of project C, revealed that on one of the twelve aspect there was a room for improvement. This aspect relates to the information quality because the liabilities of the decision were not divided prior to the decision.

By analysing the results cross-case it reveals several positive characteristics that closely match with the findings presented in the literature. The information aspects that are scored on good across all projects are: 1) decision rationale, this means that the rationale of the decision was known. 2) Information sources, there was made good use of both internal and external information sources. 3) Accessibility, there was made use of efficient information systems that were accessible for all involved parties. 4) Control, external information was controlled sufficiently by experienced staff of the Programme Directorate. Despite varying project sizes in the ERTMS programme, no consistent negative patterns on the emerge, suggesting that the challenges faced by each project are unique. Nonetheless, mismatches between theoretical frameworks and empirical findings highlight the importance of thorough communication and stakeholder management.

The comparison between theory and the current decision-making process lead to seven actionable recommendations:

1. Identify conflicting interests, and deal with them in the analysis phase.
2. Manage the stakeholders appropriately based on their interest and influence.
3. Update the involved parties regularly about the programmes process.
4. Consider prior to the decision how things should be effectuated.
5. Ensure a clear timeline for the effectuation process.
6. Work towards the appropriate decision-authorised body.
7. Assess whether applicable information types are sufficiently considered.

In addition to these actionable points, a checklist was established that can be used to enhance the success of the programme. This was performed by asking targeted questions in the decision-making process. In this way, potential risks can be identified and mitigated prior to the decision.

Concluding, effective decision-making within the Programme Directorate ERTMS depends on clear communication, solid justification, thorough analysis of project environments, and stakeholder engagement. Addressing shortcomings in the information aspects as analysed in this thesis can enhance the success of the programme by ensuring decisions align with both theoretical frameworks and practical realities.

8.2. Future research

The recommendations for further research that emerged during the execution and discussion of this research are covered in this chapter.

Firstly, due to the time constraints of the research, three projects within the ERTMS programme were analysed based on which recommendations were made. Even though these projects are representative for the ERTMS programme, the validity and reliability of this thesis can be increased by analysing more ERTMS projects. In addition, each of the projects covered a different ERTMS component: infrastructure, train, or personnel. When examining multiple projects per ERTMS component, decision-making, it is possible that trends arise within the ERTMS component. The recommendations may become more specific if they apply on a specific ERTMS component.

Secondly, the empirical data is based on internal documents and interviews. The interviewees were all employees from the Programme Directorate. The transition to ERTMS affects more parties, such as NS, ProRail IEP, regional- and freight carriers. For a comprehensive view of the situation within the projects, the views of these stakeholders should also be considered. In addition, it should be determined prior to the interview whether the interviewee was directly involved in the analysed decision-making process.

Thirdly, the scope of this thesis is limited to the Dutch ERTMS implementation programme. This was because the trigger of this research was focused on the situation of the Programme Directorate, since this is the coordinating body of the ERTMS programme in the Netherlands. To apply these findings to different decision-making environments, both national and international, it is essential to investigate how this specific context differs from others and to generalise the findings accordingly. This approach helps developing a more comprehensive understanding and applicability of the research in various decision-making environments.

Lastly, further research should focus on making the implications more specific. This can be done by addressing the ‘how’ question related to the seven implications as mentioned in the conclusion. This may help create a more detailed strategy for the Programme Directorate.

Bibliography

Aaltonen, K. (2011). Project stakeholder analysis as an environmental interpretation process. *International Journal of Project Management, 29*(2), 165-183. doi:10.1016/j.ijproman.2010.02.001

Al-Hashimi, K., Weerakkody, V., Elbanna, S., & Schwarz, G. (2022). Strategic Decision Making and Implementation in Public Organizations in the Gulf Cooperation Council: The Role of Procedural Rationality. *Public Administration Review, 82*(5), 905-919. doi:10.1111/puar.13447

Anumba, C. J., Issa, R. R. A., Pan, J., & Mutis, I. (2008). Ontology-based information and knowledge management in construction. *Construction Innovation, 8*(3), 218-239. doi:10.1108/14714170810888976

Bekius, F. (2019). Towards understanding and supporting complex decision-making by using game concepts: A case study of the Dutch railway sector. doi:10.4233/uuid:4470eb1d-c71a-4de1-b11e-36d93a77ad78

Borek, A., Parlikad, A. K., Webb, J., & Woodall, P. (2013). *Total Information Risk Management: Maximizing the Value of Data and Information Assets*: Elsevier Science.

Bowen, G. A. (2009). Document Analysis as a Qualitative Research Method. *Qualitative Research Journal, 9*(2), 27-40. doi:10.3316/QRJ0902027

Bowen, S., & Zwi, A. (2005). Pathways to "Evidence-Informed" Policy and Practice: A Framework for Action. *PLoS medicine, 2*, e166. doi:10.1371/journal.pmed.0020166

Button, K. J. (1979). Models for decision-making in the public sector. *Omega, 7*(5), 399-409. doi:10.1016/0305-0483(79)90109-9

Cabitza, F., & Batini, C. (2016). Information Quality in Healthcare. In C. Batini & M. Scannapieco (Eds.), *Data and Information Quality: Dimensions, Principles and Techniques* (pp. 403-419). Cham: Springer International Publishing.

Cai, L., & Zhu, Y. (2015). The Challenges of Data Quality and Data Quality Assessment in the Big Data Era. *Data Science Journal*. doi:10.5334/dsj-2015-002

Caniëls, M. C. J., & Bakens, R. J. J. M. (2012). The effects of Project Management Information Systems on decision making in a multi project environment. *International Journal of Project Management, 30*(2), 162-175. doi:10.1016/j.ijproman.2011.05.005

Cao, G., Clarke, S., & Lehaney, B. (2004). The Need for a Systemic Approach to Change Management—A Case Study. *Systemic Practice and Action Research, 17*, 103-126. doi:10.1023/B:SPAA.0000018906.16607.cc

Chang, J. Y., Garcia, J. M., Xie, X., Moretti, N., & Parlikad, A. (2022). Information Quality for Effective Asset Management: A literature review. *IFAC-PapersOnLine, 55*(19), 235-240. doi:10.1016/j.ifacol.2022.09.213

Citroen, C. L. (2009). *Strategic decision-making processes: the role of information*.

Citroen, C. L. (2011). The role of information in strategic decision-making. *International Journal of Information Management, 31*(6), 493-501. doi:10.1016/j.ijinfomgt.2011.02.005

Coenraad, W. (2023). ATB eerste generatie (ATBEG).

Constantin, A. (2013). Rationalist model in public decision making. *Journal of Public Administration, Finance and Law, 4*, 43-54.

Dalglish, S., Khalid, H., & McMahon, S. (2020). Document analysis in health policy research: the READ approach. *Health Policy and Planning, 35*. doi:10.1093/heapol/czaa064

Dye, T. R. (1984). *Understanding public policy*: Fifth edition. Englewood Cliffs, N.J. : Prentice-Hall, [1984] ©1984.

ERTMS. (2020). Programmadirectie ERTMS. Retrieved from https://www.ertms.nl/programmaorganisatie/over-programmadirectie/default.aspx

ERTMS. (2021). Where will ERTMS be deployed? Retrieved from https://www.ertms.nl/english/about-ertms/where/default.aspx

EUMonitor. (1994). Interoperabiliteit van het Europese netwerk voor hogesnelheidstreinen. Retrieved from https://www.eumonitor.nl/9353000/1/j9vvik7m1c3gyxp/vi8rm2xeofzo

EuropeanCommission. (n.d.-a). ERTMS. Retrieved from https://transport.ec.europa.eu/transport-modes/rail/ertms_en

EuropeanCommission. (n.d.-b). ERTMS - What is ERTMS? Retrieved from https://transport.ec.europa.eu/transport-modes/rail/ertms/ertms-what-ertms_en

Fang, Z., Liu, Y., Lu, Q., Pitt, M., Hanna, S., & Tian, Z. (2022). BIM-integrated portfolio-based strategic asset data quality management. *Automation in Construction, 134*, 104070. doi:10.1016/j.autcon.2021.104070

Fariq, N., Ismail, S., & Ab Rani, N. (2020). Cost Risk of Railway Project and Its Effective Mitigation Strategies. *Journal of Critical Reviews, 7*, 1275-1280. doi:10.31838/jcr.07.08.262

Farnham, R., Aslaksen, E. W., & Merz, S. K. (2009). *Applying Systems Engineering to infrastructure projects.* Paper presented at the INCOSE Spring Conference.

Fischer, F., & Miller, G. J. (2007). *Handbook of Public Policy Analysis: Theory, Politics, and Methods (1st ed.)*: Routledge.

Gharehbaghi, K., Tee, K. F., & McManus, K. (2023). Challenges in Determining the Scope of Rail Megaprojects: Responding to Ever-Increasing Infrastructure Demand. *4*(2), 538-550. doi:10.3390/civileng4020031

Greeven, C. S., & Williams, S. P. (2022). Enterprise collaboration systems: addressing adoption challenges and the shaping of sociotechnical systems. *International Journal of Information Systems and Project Management, 5*(1), 5-23. doi:10.12821/ijispm050101

Gürdür Broo, D., & Schooling, J. (2021). A Framework for Using Data as an Engineering Tool for Sustainable Cyber-Physical Systems. *IEEE Access, PP*, 1-1. doi:10.1109/ACCESS.2021.3055652

Hambrick, D. C., & Mason, P. A. (1984). Upper Echelons: The Organization as a Reflection of Its Top Managers. *The Academy of Management Review, 9*(2), 193-206. doi:10.2307/258434

Hansen, S. (2021). *Characterizing Interview-Based Studies in Construction Management Research: Analysis of Empirical Literature Evidences*: The 2nd International Conference on Innovations in Social Sciences Education and Engineering (ICoISSEE),.

Harris, G. (2017). Incremental Theory of Decisionmaking. In A. Farazmand (Ed.), *Global Encyclopedia of Public Administration, Public Policy, and Governance* (pp. 1-5). Cham: Springer International Publishing.

Head, B. W. (2016). Toward More "Evidence-Informed" Policy Making? , *76*(3), 472-484. doi:10.1111/puar.12475

Heale, R., & Forbes, D. (2013). Understanding triangulation in research. *Evidence Based Nursing, 16*(4), 98. doi:10.1136/eb-2013-101494

Jansen, A., Bosch, J., & Avgeriou, P. (2008). Documenting after the fact: Recovering architectural design decisions. *Journal of Systems and Software, 81*(4), 536-557. doi:10.1016/j.jss.2007.08.025

Jylhä, T., & Suvanto, M. E. (2015). Impacts of poor quality of information in the facility management field. *Facilities, 33*(5/6), 302-319. doi:10.1108/F-07-2013-0057

Khan, A., Waris, M., Panigrahi, S., Sajid, M. R., & Rana, F. (2021). Improving the Performance of Public Sector Infrastructure Projects: Role of Project Governance and Stakeholder Management. *37*(2). doi:10.1061/(ASCE)ME.1943-5479.0000886

Kinneging, T., de Graaf, R., Siebelink, S., & van Dijck, T. (2021). The documentation of design decisions in engineering projects: A study in infrastructure development. *International Journal of Information Systems and Project Management, 8*(1), 44-64. doi:10.12821/ijispm080103

Koliba, C., Merrill, S. C., Zia, A., Bucini, G., Clark, E., Shrum, T. R., . . . Smith, J. M. (2022). Assessing strategic, tactical, and operational decision-making and risk in a livestock production chain through experimental simulation platforms. *9*. doi:10.3389/fvets.2022.962788

Kovac, R., Lee, Y., & Pipino, L. (1997). *Total Data Quality Management: The Case of IRI*.

Lee, Y. W., Strong, D. M., Kahn, B. K., & Wang, R. Y. J. I. M. (2002). AIMQ: a methodology for information quality assessment. *40*, 133-146. doi:10.1016/S0378-7206(02)00043-5

Lunenburg, F. (2010). *The decision making process.* Paper presented at the National Forum of Educational Administration & Supervision Journal.

Lunenburg, F. (2012). Organizational structure: Mintzberg's framework. *International Journal of Scholarly, 14*(1), 1-8.

Mahto, R., & Davis, P. (2012). Information Flow and Strategic Consensus in Organizations. *International Journal of Business and Management, 7*. doi:10.5539/ijbm.v7n17p1

Mashuri, S., Sarib, M., Alhabsyi, F., Syam, H., & Ruslin, R. (2022). Semi-structured Interview: A Methodological Reflection on the Development of a Qualitative Research Instrument in Educational Studies. doi:10.9790/7388-1201052229

Mena, Á., López, F., Framiñan, J. M., Flores, F., & Gallego, J. M. (2010). XPDRL project: Improving the project documentation quality in the Spanish architectural, engineering and construction sector. *Automation in Construction, 19*(2), 270-282. doi:10.1016/j.autcon.2009.10.001

Mintzberg, H. (1979). *The Structuring of Organizations: A Synthesis of the Research*: Prentice-Hall.

Mintzberg, H. (1989). The Structuring of Organizations. In D. Asch & C. Bowman (Eds.), *Readings in Strategic Management* (pp. 322-352). London: Macmillan Education UK.

Morgan, H. (2022). Conducting a Qualitative Document Analysis. *The Qualitative Report, 27*(1), 64-77. doi:10.46743/2160-3715/2022.5044

Mustafa, G., Yaseen, Z., Arslan, M., Imran, M., & Nisa, Z. (2021). Theoretical Approaches To Study The Public Policy: An Analysis of the Cyclic/Stages Heuristic Model. *18*, 1307-1321.

NS. (2023). 16 -18 juni Aangepast treinverkeer rond Amsterdam vanwege werkzaamheden. Retrieved from https://nieuws.ns.nl/16--18-juni-aangepast-treinverkeer-rond-amsterdam-vanwege-werkzaamheden/

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Adm Policy Ment Health, 42*(5), 533-544. doi:10.1007/s10488-013-0528-y

Parsons, W. (1995). *Public Policy: An Introduction to the Theory and Practice of Policy Analysis*: Edward Elgar.

Peters, B. G., & Barker, A. (1993). *Advising West European Governments: Inquiries, Expertise and Public Policy*: Edinburgh University Press.

Pratt, J., Plamping, D., & Gordon, P. (2007). Distinctive characteristics of public sector organisations and implications for leadership.

Sabatier, P. A., & Jenkins-smith, H. C. (1993). *Policy Change And Learning: An Advocacy Coalition Approach*: Avalon Publishing.

Schiller, C., Winters, M., Hanson, H. M., & Ashe, M. C. (2013). A framework for stakeholder identification in concept mapping and health research: a novel process and its application to older adult mobility and the built environment. *BMC Public Health, 13*(1), 428. doi:10.1186/1471-2458-13-428

Schoenmaker, P., & Russo, J. E. (2014). decision-making. doi:10.1057/9781137294678.0160

Schuitemaker, K., van Spaandonk, H., Kuijsten, M., & Rajabalinejad, M. (2018). Evaluating Key Factors Influencing ERTMS Risk Assessment: a Reference Model. *International Journal oOn Advances in Systems and Measurements, 11*, 22-35.

Simonsson, M., Lindström, Å., Johnson, P., Nordström, L., Grundbäck, J., & Wijnbladh, O. (2005). *Scenario-Based Evaluation of Enterprise Architecture*.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333-339. doi:10.1016/j.jbusres.2019.07.039

Stuckey, H. (2013). Three types of interviews: Qualitative research methods in social health. *Journal of Social Health and Diabetes, 1*, 56. doi:10.4103/2321-0656.115294

Treinreiziger. (2018). ProRail verwacht in 2030 tot 45% meer reizigers per trein. Retrieved from https://www.treinreiziger.nl/prorail-verwacht-in-2030-tot-45-meer-reizigers-per-trein/

Trochim, W. M. K. (1989). Outcome pattern matching and program theory. *Evaluation and Program Planning, 12*(4), 355-366. doi:10.1016/0149-7189(89)90052-9

Unife. (2021a). Factsheet #9 A unique signaling system for Europe. Retrieved from https://www.ertms.net/wp-content/uploads/2021/06/9.-A-unique-signaling-system-for-Europe.pdf

Unife. (2021b). Factsheet #13 ERTMS Deployment in Netherlands. Retrieved from https://www.ertms.net/wp-content/uploads/2021/06/13.-ERTMS-deployment-in-Netherlands.pdf

Unife. (2021c). Factsheet #28 ERTMS Advantages. Retrieved from https://www.ertms.net/wp-content/uploads/2021/06/28.-ERTMS-Advantages-factsheet_final.pdf

van der meer, J., Hartmann, A., Horst, A., & Dewulf, G. (2015). Challenges of using systems engineering for design decisions in large infrastructure tenders. *Engineering Project Organization Journal, 5*, 133-145. doi:10.1080/21573727.2015.1113401

Varajão, J. (2022). The many facets of information systems (+projects) success. *International Journal of Information Systems and Project Management, 6*(4), 5-13. doi:10.12821/ijispm060401

Varvasovszky, Z., & Brugha, R. (2000). A stakeholder analysis. *Health Policy and Planning, 15*(3), 338-345. doi:10.1093/heapol/15.3.338

Wess, S. (2021). What Is a Public Organization: 10 Examples. Retrieved from https://clutch.co/resources/financial-services/public-organization

Woodall, P., Gao, J., Parlikad, A. K., & Koronios, A. (2013). Classifying Data Quality Problems in Asset Management. *19*. doi:10.1007/978-3-319-09507-3_29

Wynen, J., Verhoest, K., & Rübecksen, K. (2014). Decentralization in Public Sector Organizations: Do Organizational Autonomy and Result Control Lead to Decentralization Toward Lower Hierarchical Levels? *Public Performance & Management Review, 37*, 496-520. doi:10.2753/PMR1530-9576370307

Yagnik, A., & Chandra, Y. (2019). Using Creativity to Defeat Fear and Manage Ambiguity for Enhancing Entrepreneurial Decisions. In (pp. 9-28).

Yang, J., Shen, G. Q., Ho, M., Drew, D. S., & Xue, X. (2011). Stakeholder management in construction: An empirical study to address research gaps in previous studies. *International Journal of Project Management, 29*(7), 900-910. doi:10.1016/j.ijproman.2010.07.013

Zadeh, P., Wang, G., Cavka, H., Staub-French, S., & Pottinger, R. (2017). Information Quality Assessment for Facility Management. *Advanced Engineering Informatics, 33*, 181-205. doi:10.1016/j.aei.2017.06.003

Zadelaar, J. N., Rentergem, J. A. A. v., Schaaf, J. V., Dekkers, T. J., Vent, N. d., Dekkers, L. M. S., . . . Huizenga, H. M. (2021). Development of decision making based on internal and external information: A hierarchical Bayesian approach. *Judgment and Decision Making, 16*(6), 1413-1438. doi:10.1017/S1930297500008482

Zidane, Y. J. T., Johansen, A., & Ekambaram, A. (2013). Megaprojects-Challenges and Lessons Learned. *Procedia - Social and Behavioral Sciences, 74*, 349-357. doi:10.1016/j.sbspro.2013.03.041

Appendices