Performance dashboard for the Twente Joint Corridor

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Preface

Dear reader,

This thesis marks the ending of my final assignment for BSc in Industrial Engineering and Management at the University of Twente. For the accomplishment of my degree, I am submitting my work related to the creation of performance dashboard prototype for the Port of Twente. With this milestone, I would like to mention the people, who have been part of my journey.

My family members and friends, who have helped me with enormous support to push in periodical challenging times of the university years. I appreciate it.

Much obliged to my academic supervisors Dr. Jean Paul Sebastian Piest and Dr. Renata Guizzardi. Weekly update meetings with quite insightful feedback and suggestions let me stay on track and continue my work on the assignment. This indeed was a pleasure to be working with you.

Mentioning the faculty of the Behavioral, Management, and Social Sciences (BMS), I am thankful for the insights and information you shared about the Digital Twin project. Without the provided information my understanding on this topic including the content of this thesis would be incomplete.

Once again, many thanks to all the people who have been a part of this journey, be it big or small.

Mirza Farzaliyev

Management Summary

The project goal was to develop a performance dashboard for the Twente Joint Corridor. This is expected to improve logistics efficiency, reduce the environmental footprint, as well as ensure reliable operations. It can be developed to serve as an information source to certain interested parties in terms of the Key Performance Indicators (KPIs), such as water level within the corridor, infrastructure status, etc. This project focuses on the Twente Joint Corridor, however, can be extended and adapted in scaling up for any other Joint Corridor.

The Joint Corridor Off-Road Programme is considered to be the initiative of Top Sector Logistics, the idea that focuses on synchromodal Joint Corridor Development - the concept of a program to ensure collaboration between shippers, carriers, and stakeholders with accessible tools. According to the program website, this social innovation aims to get as much cargo as possible off the road, by offering other modalities such as freight transport and rails. The goal of this shift towards other nodes is to improve sustainability by reducing CO_2 emissions and increasing availability and accessibility for domestic and international transport.

Twente Joint Corridor faced notable challenges like the environmental factor of droughts, flooding as well as infrastructure outages. These challenges caused significant economic losses in the transportation industry leading to increased operating costs. Thus, a system that does not track real time performance metrics of the Joint Corridor is non-strategic. The current KPIs for the program are static and not available for providing data on water levels and outage of infrastructure. Therefore, it leads to the limited insights gathered for the performance of the Joint Corridor.

This project executed with the DSRM framework of Peffers et al. (2007) to identify relevant KPIs, collect and integrate data from various sources. Design and develop the mock-up for the stakeholders iteratively. The resulting artifact provided insights to monitor corridor characteristics to promote sustainability, operational efficiency and overall resilience of the corridor.

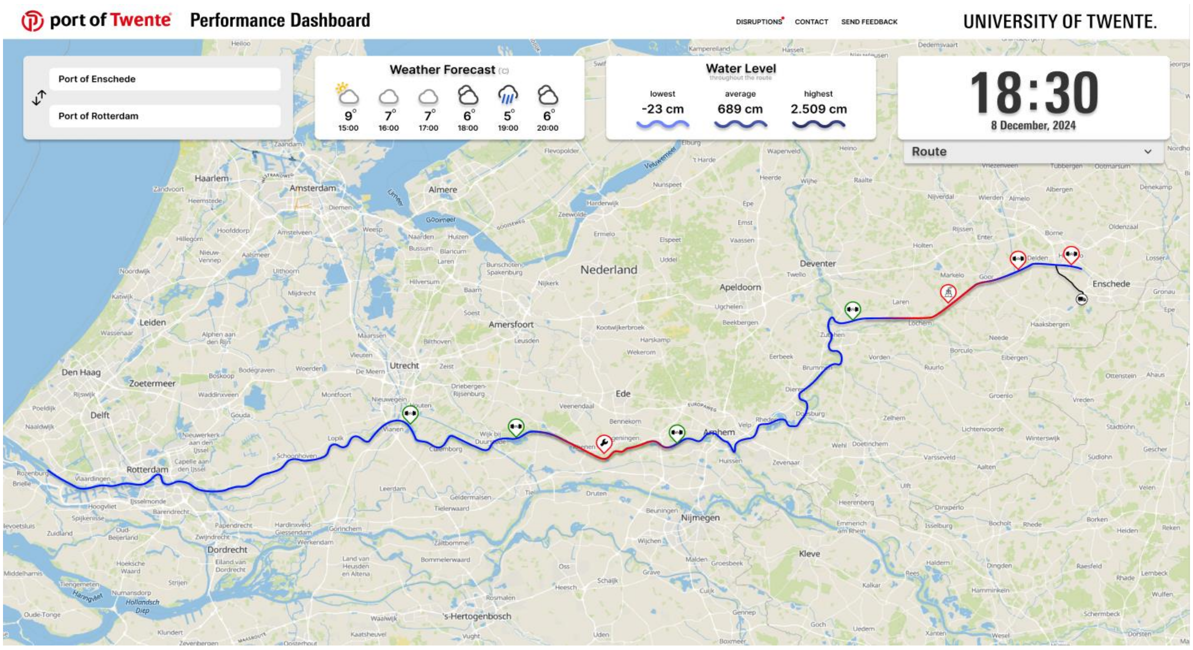

Figure 1 Mock-up performance dashboard.

Intended deliverables include the minimum viable product (MVP) of the dashboard, a research report on KPIs, and recommendations for future implementation. This project provided the Port of Twente and involved parties with the mock-up performance dashboard for improving the performance and resilience of the Twente Joint Corridor through collaborative decision-making.

The dashboard implementation is according to the steps of Orts (2007): plan, design, build, and deploy. The planning phase covers the identification of project team roles, budget/time restrictions, setting objectives, and alignment with stakeholder requirements. The design stage is based on the development of visual features for the KPIs gathered from the datasets of governmental institutions. During the build phase technical development, back-end features, and security protocols are emphasized to signify the transfer of the product from prototype to the functional state. The final deployment phase focuses on launching the dashboard into the operations of Twente Joint Corridor and continuously incorporates feedback for further improvements.

The prototype lacks back-end functionality, real-time data processing, and operational testing due to time constraints. The route planning KPIs don't account for vessel type or load. Validation of the prototype was only made by the Port of Twente infrastructure advisor. Additional opinions should be gathered from skippers and other stakeholders. For further research, the dashboard needs to emphasize the other multimodality nodes of transportation and expand the KPIs based on a node. Acknowledging these limitations can enhance the practicality potential of a dashboard.

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List of abbreviations

KPI: Key performance Indicator.
Erasmus UPT: Erasmus center for Urban, Port and Transport economics.
FTE: Full - Time Equivalent.
CTT: Combi Terminal Twente.
DSRM: Design Science Research Methodology.
RQ: Research Questions.
SLR: Systematic Literature Review.
JCA: Joint Corridor Agreement.
JCPD: Joint Corridor Performance Dashboard.

Definition of Key-Constructs and Terminology

Joint Corridor - The following definition in scope of this research is used and considered to be the assumption. Joint corridor is a collaborative transportation route or network that incorporates numerous stakeholders, infrastructure providers, and modes of transportation working together to safely and efficiently move goods and resources.

Joint Corridor Agreement (JCA) - is a collaboration agreement signed between stakeholders mentioned in section 1.1. The agreement allows these companies to use the Twente Corridor for logistics. The Joint Corridor Agreement (JCA) also allows for the under-listed key values of the relationship. The agreement has distinct mutual interest for inland shipping and truck transport.

Joint Corridor Performance Dashboard (JCPD) - will evaluate the performance of the Twente Corridor, giving insight into how effectively the various participants are functioning based on the KPIs. The data feeding this dashboard will be supplied by all entities which are signatories for this defined Joint Corridor Agreement.

Multimodal Transportation Methods - Movement of goods/services, in which two or more modes of transportation are linked end-to-end from the point of origin to the destination (Reis & Macário, 2019). Similar term for this form of transportation is *intermodal transportation* where when there is a shift in carriers' packages must be transferred smoothly from one mode to another to achieve maximum performance, cost-effectiveness and sustainability.

Co-modality - The definition provided by Varese and Marigo (2020) states that co-modality briefly seeks to achieve an optimum in efficient utilization of different transport modes, which can possibly be done in combination and on their own. According to Lin and Zhang (2024), the concept of co-modality of transportation aims to reduce the number of trucks in urban areas.
Synchromodality - According to Ferjani et al. (2024), the term was originally introduced in 2010 by Dutch scholars, which signifies the optimization of possible transportation networks within the operated network. The synchro modality allows for increased flexibility even for the needed last-minute changes and implementation utilization of various nodes. Authors of the source highlight that synchro modality brings clarification to the definition of multimodal transport, with the aspect of including real-time and dynamic components, and is the unavoidable aspect of multimodality.

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1. Introduction

According to Choi and Yeo (2023), inland waterways play a significant role in multimodal logistics, which is a competent mode of transportation that is safer and more cost-effective than land transportation. However, the operational performance of the corridors is challenged by factors such as infrastructure downtime, maintenance of the canal, fluctuating water levels, and extreme weather conditions. The Twente Joint Corridor is an essential link connecting ports and inland terminals in the Netherlands. The JCA stakeholders, skippers, and port authorities rely on the efficiency, performance, and resilience of the corridor.

This research aims to develop a performance dashboard for the Twente Joint Corridor to provide interested parties with insights. By integrating publicly available data in the prototype for metrics such as water levels, weather conditions, disruptions alert notifications, and infrastructure availability. The artifact provides insights to help in collaborative decision-making and minimize delays.

These objectives were achieved by executing the research with a systematic literature review to answer the research questions explained in section 1.5. The results of this research went further to the design and development of a prototype dashboard, which served as a solution for operational gaps and promotion of sustainable logistics. This study contributes to the practicality of the tools for the management of multimodal transportation.

The initial chapter will introduce the research and overview of the project that is planned to achieve for the Port of Twente and various stakeholders by making the performance dashboard. Afterward, the description of the problem is illustrated to point out what obstacles are faced by the stakeholders during the process of shipping in the current situation and how this project can potentially benefit from different aspects (financially, environmentally, and efficiency-wise). Upcoming sub-sections of this chapter will give information regarding the project description and problem and discuss the current situation of the Port of Twente operations. Additionally, it will give the reader general information about the involved stakeholders and terminology used, for a clear understanding of the concept.

1.1 Context

Current situation in practice:
As there are three different dashboards right now implemented by the stakeholders of the programme using Twente Joint Corridor: Havenmonitor Rotterdam & Twente, and Joint Corridor dashboard. According to the Joint Corridor Off-Road program website, specifically in the section of the *Joint Corridors*, it can be seen the possibilities of the program. The user chooses the departure location and desired destination for the shipment to proceed with. After which the options are given for the user with the attached data. The existing system provides the user with the modality, availability (times per week), scalability, durability and mobility KPIs for each selected route.

The Havenmonitor (Rotterdam & Enschede) was commissioned by the Ministry of Infrastructure and Water Management and Erasmus centre for Urban, Port and Transport economics (shortly Erasmus UPT), which strongly cooperates with the Central Bureau of Statistics (CBS) and Dutch seaport companies. The Havenmonitor is an annual publication of research to provide insights into the economic significance of the Dutch seaports. It covers the employment level (in employee FTE), added value (in euros), and other macroeconomic effects, such as public, private investments and market share of the ports. Limitations of current artefacts are indicated in upcoming section 1.3 which emphasizes the need for implementing the dashboard with real-time data.

Stakeholders:
It is crucial to point out that the Twente corridor has been initiated by several organizations according to the inland shipping newspaper (Binnenvaartkrant), even mentioning the article regarding the launch of the corridor.

Grolsch - A significant Dutch beer brewer, forms part of Asahi Europe & International Brewery Group. It is located in Enschede and uses an annual production of 3.35 million hectoliters which is exported globally by using the Twente Corridor to nearly 60 countries.

Kees Smit Meubelen - is a family-owned business specializing in garden furniture, based in Almelo. The company uses Twente canals for the import of products.

Bolk Transport - is a trucking company focusing on both regional and international transport, with a specialization in complex logistics that require special permits and expertise. The company provides first and last mile transport of containers.

Combi Terminal Twente (CTT) - operates intermodal transport terminals in Hengelo, Almelo, and Rotterdam, facilitating connections between road, rail, and inland waterway transport. CTT is considered to be the stakeholder with an important role within the Twente Corridor.

Port of Twente - consists of Havenbedrijf Twente, the Logistic Association, and XL Business Park. Its mission is to leverage Twente's logistical strengths to boost the sector's sustainability and economic impact. Acting as industry representative, Port of Twente supports its members' interests. Founding partners, among others, include CTT and Bolk.

Topsector Logistiek - is a partnership between government, academia, and business entities, focusing on enhancing the Dutch logistics sector. According to the company itself, among the main themes are synchromodal transport and the integration of multimodal transportation methods being prioritized.

The Lean & Green - The Lean & Green Off-Road program is supported by Topsector Logistics, whereas the company (L&G) promotes itself as the recognition program for the CO2 reduction in the logistic sector. Partner companies of the L&G receive the stars for all the CO2 reduction in the logistic activities. Goal of the L&G to reduce 55% of the CO2 emissions by 2030.

Province Overijssel - The regional partner of the Joint Corridor Off-Road program and responsible for developing the corridors in Overijssel.

Stakeholder Onion Diagram:

According to Alexander and Robertson (2004) in complex project sociology, a simple-looking onion model of stakeholder relationships can assist in concealing the acknowledgment and involvement of different stakeholders. The Stakeholder Onion Diagram for the Twente Joint Corridor project is given below, and it demonstrates different stakeholders' involvement and influence in the development of the performance dashboard. Stakeholders that directly interact with the dashboard are CTT, Grolsch, Kees Smit Meubelen, Topsector Logistiek while the research team is represented by the researchers who collected and reported data. Secondary stakeholders such as the Port of Twente, the Province of Overijssel, don't directly interact with the dashboard, however can possibly benefit from the existence. Finally, at the outermost level, one has the more general societal and regulatory aspects for the environment, including society and government policymakers, whose regulations and public interests drive the operational and environmental performance of the project. The goal in Figure 2 is to emphasize inter-connection (with arrows) and acknowledgment of the stakeholders in the project to make logistics more efficient and improve resilience in the Twente Joint Corridor.

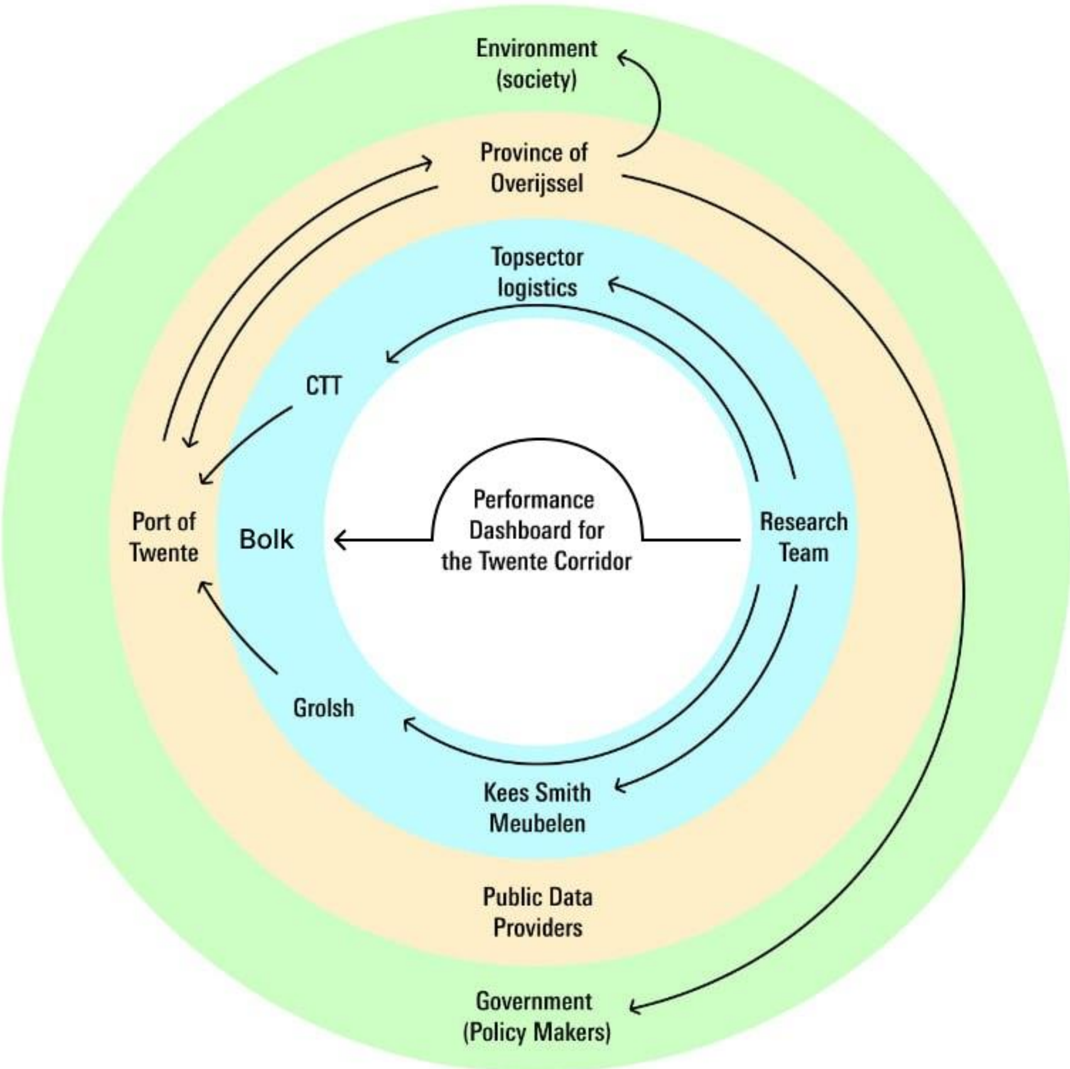


Figure 2 Stakeholder Onion Diagram.

1.2 Project Description

Port of Twente is located in the province of Overijssel specifically with the office in Almelo, and acts as the central hub, by bringing together the logistic strengths, to boost the resilience and sustainability in the sector and support the local economy. According to the maritime business brochure from the Ministry of Infrastructure and Environment (2021), there are more than 1200 merchant vessels (incl. dredging vessels). Also, it is important to note from the brochure that the Port of Rotterdam is considered to be the largest in EU and acts as main port in the Netherlands, with the "Gateway to Europe ", emphasizing the crucial role of the Dutch inland shipping activities, including the logistics operations. As this project focuses on the Twente corridor, it would be crucial to give general information regarding it. There are 7 inland ports located in Twente. The Twente corridor is the initiative for the companies to promote inland shipping to Rotterdam via the National Joint Corridor Off-Road Program with 40 corridors across the Netherlands. In 2023, a research project started to develop a digital twin as a solution for this project.

Digital Twin: According to Digital Twin Consortium (2020) a digital twin is a virtual portrayal of a physical attribute, person, or activity that is contextualized in a digital replica of its surroundings synchronized at a specified frequency and accuracy. Digital twins can assist an organization recreate real-world circumstances and results, allowing it to make better decisions (McKinsey & Company, 2023). The Digital Supply Chain Twin (DSCT) definition by Busse et al. (2021) states that it is a digital simulation model of the system that includes behaviors, relations, data and states. Within the 3-year research project of digital twin, this specific research focused on developing a performance dashboard for the involved parties of the Joint Corridor Off-Road Program.

1.3 Problem Description

The Twente Joint Corridor faced challenges related to weather changes and infrastructure downtime. Droughts and flooding can disrupt transportation, as seen with the 2012 Eefde Lock failure, which caused a complete blockage of the Twente Canal. The summer of 2018 and 2022, a drought caused financial losses in the corridor. Low water levels in the IJssel River extended the wait time for ships accessing the Twente Canal at Eefde to 75 minutes, up from the usual 25 minutes. This 50-minute delay trouble ship operators. Drought reduced the canal's capacity by two-thirds, with consequences for the transport sector. The disruptions affect goods movement, consequently leading to economic losses to the companies that rely on transportation through the Twente corridor.

Infrastructure downtime is another risk. Incidents of the 2012 lock failure led to long delays, disrupting supply chains and causing financial losses. The corridor's reliance on various transport modes, like trucks, ships, and trains, also raises concerns about carbon emissions and sustainability, which are essential issues for the corridor's long-term viability.

To address the challenges, there is a need for performance monitoring of the corridor. Currently stakeholders and port authorities have tools that are not capable of measuring and monitoring the real-time performance. Therefore, a performance dashboard is necessary to strengthen the corridor's resilience, sustainability, and efficiency.

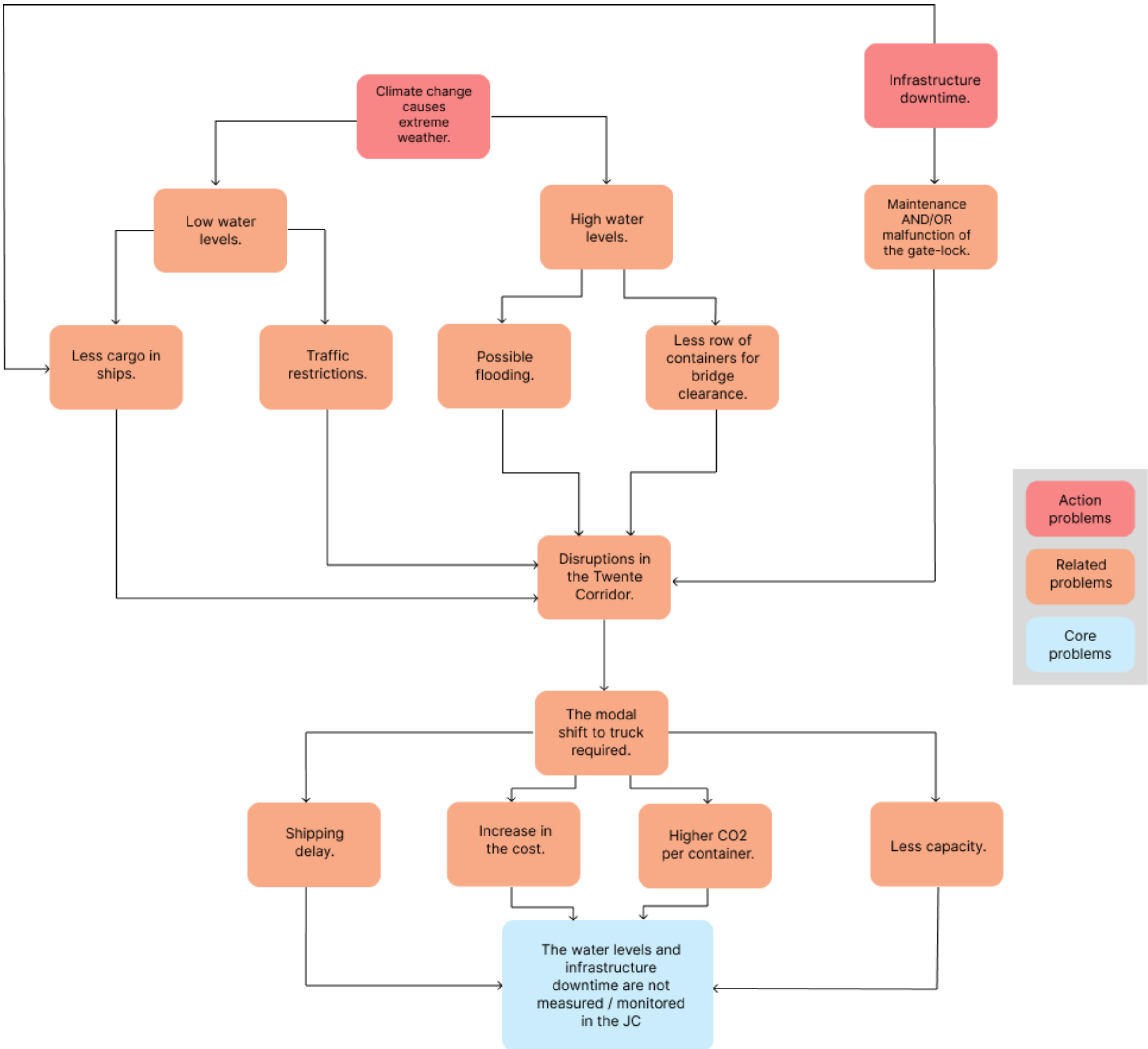


Figure 3 Problem cluster.

The core problem in Figure 3 is outlined as KPIs of the Joint Corridor dashboard are static and not updated based on the current water levels and downtime of the infrastructure. The action problems are caused by the extreme change in weather conditions as well as infrastructure downtime. Change in climate leads to the water levels being either low or high. Low water levels cause ships carrying less cargo, or traffic restrictions. High water levels can indicate possible flooding, or the necessity of carrier companies to fill fewer rows of containers so the ships would be able to pass the bridge clearance. Since this corresponds to a loss in transport capacity, it follows that this would lead to higher costs, especially if there are more containers to be used or higher tonnages, which also equates to an increase in costs. Flooding means that the supply chains are disrupted by this and that shipping and bringing goods are not possible at a certain time, equating to the corridor's inefficiency. Infrastructure downtime also means that it brings delays and increases emissions per container, which is a primary issue right now pertaining to the environment and this means that there are more operational costs. All these disruptions are shaped within the Twente Corridor so that it is the logistics costs that are charged higher.

With the performance dashboard, stakeholders can effectively address the issues mentioned in the problem cluster and make decisions. Stakeholders will obtain up-to-date information about the state of the canal's operations and infrastructure by using KPIs which will be visualized. As well, stakeholders will be able to make collaborative decisions with the use of visualized data on corridor performance. Promoting sustainability, resilience, and efficiency throughout the canal infrastructure network.

Norm & Reality:

The primary objective of this research for the Port of Twente and partner companies of JCA is "To create a performance dashboard including visualized KPIs for collaborative decision making". This dashboard is aimed to provide the partners with the up-to-date characteristics of Twente Joint Corridor with metrics. This addition of the dashboard will help to prevent the operational issues, which were seen before in the unfortunate situations regarding the flooding and drought of the canal. The table shows the difference between norm and reality according to the current situation of the canal.

Norm	**Reality**	**Dashboard sets the norm**
All logistics activities are expected to be resilient in the Twente Corridor, even in the event of disturbances, will be included.	Current systems rely on static data and thus cannot provide much-needed mitigation of disruptions and after-effects on operations, such as fluctuations in water levels and infrastructure downtime.	The dashboard provides insights by integrating needed data (e.g., water levels, disruptions, infrastructure status) to ensure better planning and cost efficiency.
Infrastructure statuses are consistently monitored for smooth operations with minimal loss on waiting time and optimal route planning.	Static system doesn't provide insights on the availability, disturbances on the infrastructure (gate lock, bridge clearances)	The dashboard introduces infrastructure availability statuses, helping stakeholders to identify obstacles throughout the route, which will allow them to adapt accordingly.
Stakeholders actively collaborate and share the useful data in contribution to the prosperity of the canal.	Challenges in stakeholder engagement and data-sharing practices with the Port Authority can decrease the effectiveness of the dashboard, making it difficult to achieve a united view of the corridor's performance characteristics.	The dashboard acts as a centralized platform for the stakeholders, providing transparency and insights on the performance of Twente Joint Corridor, promoting collaboration, and ensuring better decision-making.

Table 1 Norm & Reality.

According to table 1, the dashboard can be seen as the desired option to achieve the norm. All these abilities would become central to the delivery and realization of norms that are wanted: smooth, efficient logistics and cost-saving operations within the Twente Corridor by providing the visualized water levels, infrastructure availability, and notification for future scheduled maintenance. The dashboard can support real-time monitoring and central sharing of information to make logistics more efficient. Additionally, it could be used as the basis for future research in predictive analytics and simulations for the Joint Corridor.

1.4 Action & Knowledge Problems

Action problem:

According to Heerkens & Winden (2021, page 22) the definition of an action problem is: the discrepancy between the norm and the reality, as perceived by the problem owner. Additionally, problem owner - is the entity, person, group or an organization that feels certain about the existence of the problem. In our case creating the dashboard would be considered as an action taken for tackling the problem.

Based on the problem description, it can be clearly seen that partners of the JCA are struggling with not enough insights of the performance characteristics of the Twente Corridor. The lack of enough insights leads to the non-strategic and inadequate decision making, acquired similarly with the situation of the corridor flooding, drought and gate-lock issues affecting the partners operating in the corridor. Currently, there is no dashboard that measures the water levels in relation to the corridor availability and performance levels of critical infrastructure (e.g., locks).

The above is translated into the following action problem: "Partners of the Joint Corridor Agreement are not gaining up-to-date insights on the performance characteristics of the Twente Corridor".

Knowledge problem:

"A knowledge problem is a description of the research population, the variables and, if necessary, the relations that need to be investigated." (Heerkens & Van Winden, 2021), page 23.

After examining the problem/project description for the Twente Joint Corridor, and problem cluster, there are still other formalitis such as Research Questions (RQs) that still need to be investigated for the proper execution of the research. The main and sub research questions in the upcoming section 1.5 should assist us in gaining the prior knowledge on the different topics. Hence it is crucial to point out these research questions with elaborative descriptions for each.

1.5 Research Questions

Main RQ:

- *"How can a dashboard be designed and developed to measure and monitor performance of the Twente Corridor?"   (1)*

The core problem of this project is the need for the performance dashboard of the Twente Joint Corridor to be created, to prevent the operational obstacles by the means of monitoring and providing stakeholders insights. By preventing those, operational obstacles can also be counteracted. In order to approach the core problem, there should be a list of sub research questions, with the help of which this problem could be resolved in a step-by-step manner.
Sub RQs:

- *"Which performance management approaches and dashboards exist to measure the performance of multimodal corridors?"   (2)*

This question identifies and analyzes existing dashboards meant for monitoring performance within multimodal transport corridors. The purpose of which is to understand the landscape of approaches and tools regarding performance measurement that are currently used in the same scope or within the same range of features, functionality, and effectiveness. The findings most likely will show the potential practices that can possibly be used for the Twente Joint Corridor. This sub-RQ approached by conducting the Systematic Literature Review (SLR)

- *"Which KPIs should be considered and measured for the Joint Corridor Performance Dashboard?"   (3)*

This RQ indicates what KPIs are most relevant in the Joint Corridor Performance Dashboard. KPIs are used to measure both efficiency and effectiveness in terms of corridor performance. A selection of KPIs should be guided by the strategic goals of the corridor, which may be in terms of improving logistics efficiency, reducing costs and minimizing environmental impacts. This research will identify KPIs that are important to stakeholders, critical to performance in all areas of transit times, cost, reliability, and sustainability. This sub-RQ also approached by conducting the SLR.

- *"How to operationalize these KPIs?"   (4)*

This RQ focuses on defining the practical steps, or frameworks how to measure and operationalize the KPIs from previous RQ. It explores how the KPIs can potentially be integrated into the dashboard effectively. The final goal would be to provide the stakeholders of the Joint Corridor agreement with insights on how to ensure the performance metrics in the corridor.

- *"How does the national network of joint corridors function, and what is the position of the Twente Joint Corridor within this network?"   (5)*

This RQ related to the problem identification stage in DSRM and aimed at understanding how a national network of joint corridors works and at determining the role of the Twente Joint

Corridor in the system of national corridors. The study should establish the connections and management of the corridors, the standard to which they operate, and any other operational insights. In similar fashion, the areas where the Twente Joint Corridor fits into the network, including aspects of importance, performance, comparison with other corridors. Which might be considered as an opportunity to scale up the use of the performance dashboard.

1.6 Intended Deliverables & Thesis Structure

This section outlines the key deliverables which are expected to be by the end of this project.

Prototype / Minimum Viable Product (MVP): A functional prototype that emphasizes the core features and capabilities of the performance dashboard.

Research report: A comprehensive document covering the KPIs selection, measurement of those, dashboard characteristics.

Recommendation for the stakeholder: Key findings and actionable recommendations made for the interested parties of the JCA to improve the efficiency/performance and the sustainability monitoring of Twente Joint Corridor. Including implementation plan for the dashboard and evaluation criteria.

Thesis structure: The document is constructed into the five chapters.

Chapter 1 introduces the study, by giving the context, project & problem description, research questions, and intended deliverables.

Chapter 2 outlines the research methodology, with the selected problem-solving approach, the framework for constructing the literature review, and points out the validity and reliability of this research.

Chapter 3 presents the findings of the literature review and interviews made by the digital twin project colleague. The operationalization of indicators consequently leads to the creation of the prototype.

Chapter 4 describes the functionality of the prototype, and validation improvements gathered from the Port of Twente infrastructure advisor.

Chapter 5 indicates the recommendations, limitations of the study, and suggestions for further research. Additionally introduced the evaluation criteria, and implementation plan for implementing the fully functional dashboard to the operations of Twente Joint Corridor. The chapter ends with a conclusion to this research.

2. Research methodology

This chapter provides a reader with an overview of the research methodology used to achieve the study's objectives.

Sub-section 2.1 introduces the problem-solving approach by generally illustrating the six principles of the Design Science Research Methodology (DSRM). Sub-section 2.2 emphasizes how the six steps of DSRM apply within the context of this research. In sub-section 2.3, the Systematic Literature Review (SLR) is introduced, specifically looking into the search strategies, inclusion criteria, and results of the SLR. Sub-section 2.4 describes how validity and reliability are ensured in both the quantitative and qualitative perspectives of this research.

2.1 Problem - Solving Approach

This section will cover the approach that will be used to tackle this problem step-by-step. According to Peffers, et al. (2007) DSRM creates and assesses IT artifacts that are potentially intended to resolve the organizational problems. Considering this definition and comparing it specifically to our situation in the project, the dashboard acts as the IT artifact which will be created and further evaluated for monitoring the performance metrics in the Twente Canal. Therefore, the multiple organizations problems in the context will be the disruptions, which are studied more in section 1.2 with the problem cluster, that illustrates potential consequences of operational characteristics of the stakeholders and canal itself. The DSRM includes six activities provided below in Figure 5.

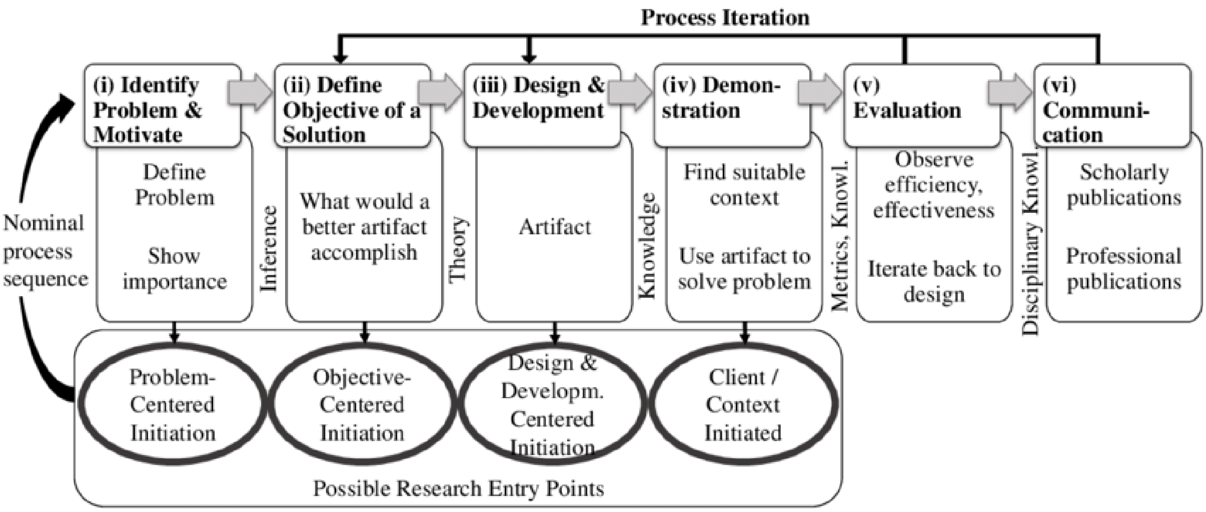


Figure 4 Design Science Research Methodology by Peffers et al. (2007).

The brief description by Peffers et al. (2007) will be provided in table 2 for each step of the methodology, so the reader will gain a clear understanding of the general idea behind it.

Steps of methodology.	**Description.**
Identify problems & Motivate.	This activity informs the specific research problem and justifies the value of a solution. Justification assists both the researcher and the reader. Researchers are motivated to pursue the solution with justifications, and for readers, it helps to appreciate the work done by researchers.
Define the objective of a solution.	A description of how the proposed artifact is expected to support the solution to problems.
Design & Development.	Creation of artifacts, including the design aspects. This activity also emphasizes the desired functionality of the artifact.
Demonstration.	The use of artifact can involve experimentation, simulation, case study, or any other appropriate activity.
Evaluation.	The evaluation of the artifact functionality is how effective and efficient it is.
Communication.	The aspects of artifacts are communicated to the relevant stakeholders.

Table 2 Brief description for each step of DSRM.

According to Peffers et al. (2007), artifacts are potential constructs, models, or methods. Conceptually, an artifact of this methodology *‘can be any designed object in which research contribution is embedded in the design”* (Peffers et al. (2007), page 55). Given these definitions and clarifications, the selected methodology to proceed with is DSRM.

2.2 Application of DSRM

This section will convey how DSRM will be applied to this research in creating the prototype dashboard for the Twente Joint Corridor.

1. Problem identification and Motivation.

Twente Joint Corridor faces challenges related to environmental obstacles (droughts, flooding) and infrastructure downtime (lock-gate failures), leading to the issues with flow of goods and financial losses of invested parties.

Motivation for this project, to tackle and resolve the core problem of water levels and infrastructure availability not being monitored or measured, is the created performance dashboard prototype as the decision-making tool for the stakeholders of partnering companies within the corridor.

2. Definition of the objectives for a solution.

Development of a performance dashboard for the Twente Joint Corridor to visualize and monitor the characteristics (e.g. water levels, infrastructure availability) throughout the transport chain. This will be achieved by implementing data from open sources, internal insights, and literature reviews.

3. Design and Development.

Data integration: Data will be gathered mainly from the data sources (Routescanner, Elwis, Rijkswaterstaat, Waterpeilen, etc.), especially for the environmental data. In case of the need for the company specific date, it will be requested and processed further according to the ethical norms.

Dashboard Interface: User friendly interface, adaptable design (should be accessible on any other devices such as phone, laptop, tablet), Data should be updated on the regular intervals. The goal of the dashboard is to provide the viewer with the visualized KPIs.

The process will begin with identifying KPIs relevant to water levels, infrastructure, and other environmental factors. Data will be gathered and integrated from public sources, ensuring accuracy and reliability. Using iterative prototyping, design of the dashboard's user interface should be informative. Incorporation of features like real-time data visualization and cooperation within the involved parties. The feedback from stakeholders will guide improvement to meet their needs. The final solution will provide insights to enhance the corridor's overall performance.

4. Demonstration.

Firstly, demonstrate the mock-up of the performance dashboard to the supervisors and possibly to the members of JCA. During the demonstration, the functionality will be explained and elaborated upon. For clarity, it would be beneficial to show an example from historical data, illustrating what would have happened financially and operationally if the stakeholders had used the performance dashboard for decision-making. After the demonstration, feedback should be gathered and used for further improvements.

5. Evaluation

Feedback gathered from the previous step should be assessed by the evaluation criteria based on the solution objectives which would be derived further in the project. Areas for improvement should be identified and, if necessary, added to the performance dashboard.

6. Communication.

As the final step of this methodology, the research report and the MVP of the performance dashboard will be presented to the readers. This report will cover the elaboration of KPIs, the design and development process of the dashboard, recommendations for stakeholders, future implementations of the dashboard in the context of scaling up, and the limitations of the research.

2.3 Systematic Literature Review

As part of the thesis, it is crucial to perform SLR on two of the sub-research questions (RQ 2 and RQ 3) which is eventually considered to be the knowledge problem. This section aims to provide the reader with the step-by-step execution of the systematic literature review, by introducing the research question, inclusion & extrusion criteria, used databases and terms, search strategy, and results. Mainly research includes quantitative and qualitative data analysis, within these sub-research questions there is one to be selected to proceed with the SLR.

It is crucial to acknowledge the fact that this systematic literature review will be done within the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) checklist. The PRISMA statement was initially published in 2009. Page et al. (2021) state that PRISMA was designed to assist the systematic reviewers to transparently report the purposes of research, what the reviewers did for the research, and findings of the literature review.

"Which performance management approaches and dashboards exist to measure the performance of multimodal corridors?"

The aim of the research question was provided in the previous section 1.5. This research question can support the upcoming potential usage of the performance dashboard for the Twente Joint Corridor. The existing knowledge regarding the performance dashboards only was acquired and used in practice during one of the academic modules for the University project, due to this it is crucial to revise the general knowledge and tailor it to the current situation for the Port of Twente and involved parties, so the satisfactory results would be achieved.

Inclusion and Exclusion Criteria: One of the crucial parts of the SLR is the criteria on how literature for the research will be gathered. Explicitly stating what the systematic literature will include and avoid. As my research question focuses on the performance of the multimodal corridors, therefore it should be included as a criterion. As well as existing practices of (performance) dashboards for the logistics operations. Technical reports from the participating companies of the Lean & Green Summit could be used as one of the possibilities to gather the data, peer-reviewed articles, conferences, case studies, and empirical research are also considered to be included as the criteria. Articles published in the years 2010 and 2024, and in English, without the restriction regarding the geographical location.

However, studies that are irrelevant to the main topic of this research are not included. As well as articles that are out of the above-mentioned time frame should be out of the equation for the SLR. News articles, opinions from the forum, non-peer-reviewed papers, and any documents not in English. It is possible to include articles that don't strictly use the performance dashboard as the visualized method for the KPIs since this research can benefit in terms of information from the search.

Databases: Note that Google Scholar will not be used for the SLR part of the research for this specific research question. Since Google Scholar is considered to be the search engine, not the database, it supports the idea of getting the general knowledge regarding the topic.

However, is not considered to be the academic way of conducting the systematic literature review. Databases to be used: Scopus and ScienceDirect (only for RQ 2)

Used terms: “dashboard”, “performance dashboard”, “performance manage*”, “logistics performance”, “multimodal transport*”, “logistics manage*”, “multimodal corridor”, “inland ship*”.

Boolean Combinations	**Reasoning of choice.**
1) (“Dashboard” OR “Performance Dashboard”) AND (“multimodal transport*”) AND (“supply chain” OR “inland ship*”) 2) (“Quantitative” OR “Qualitative”) AND (“Dashboard” OR “Performance Dashboard” OR “performance monitor*” OR “performance manage*”) AND (“logistics manage*” OR “supply chain” OR “inland ship*”) AND (“multimodal transport*”)	1) Used for getting the landscape of existing practices for dashboards in the context of multimodal transportation. 2) How the quantitative and qualitative data is used in the context of this research within the performance dashboard.

Table 3 Search strategy for RQ 2.

Results of the search:

Database	**Boolean Combination**	**# of hits (selected results)**
Scopus	1	12 (3)
	2	25 (2)
ScienceDirect	1	2 (1)

Table 4 Search results for RQ 2.

The SLR for other sub-RQs is done in the same manner as the second RQ. It will include a search strategy with Boolean Combinations, and the results of this search. In the appendix the search log will include the sources that will be used further in the research. Additionally, it is crucial to note due to the search engine changes of the Science Direct (cannot use * component and max Boolean combination per field is 8) forces the researcher to exclude the database for the upcoming RQ. As these limitations provide a greater number of hits (approximately 15-20 thousand with the simplified versions, which also considers inclusion and exclusion criteria) with the given Boolean combinations.

Boolean Combinations	Reasoning of choice.
1) ("Key Performance Indicator*" OR "KPI*" OR "performance" OR "performance metric") AND ("multimodal transport*" OR "transport* corridor" OR "freight corridor" OR "inland ship*") AND ("logistic*" OR "supply chain") 2) ((Key AND Performance AND Indicator) OR "KPI*" OR "performance" OR "performance metric") AND ("transport* dashboard" OR "logistic* dashboard" OR "performance dashboard") OR ("measure*" OR "optimiz*")	1) This combination assists in the exploration of general relevant KPIs for multimodal transportation or specifically targeting the freight corridor or inland shipping that will track logistic performance. 2) The combination targets KPIs demonstrated or designed specifically for the case of integrating to the dashboard for the industry of logistics and transportation.

Table 5 Search strategy for RQ 3.

Database	Boolean Combination	# of hits (selected results)
Scopus	1	187 (2)
	2	350 (2)

Table 6 Search results for RQ 3.

The detailed view for the search log, advanced query for search strategies, PRISMA 27-item checklist, and flowchart for the number of hits can be found in the Appendix A.

2.4 Validity & Reliability Measurement

Both reliability and validity ensure that the quality of research and its results are applicable. According to Noble and Smith (2015) validity is referred to as the application and integrity of undertaken methods in line with the findings reflected in the data. Reliability describes the consistency of analytical procedures.

This research will include quantitative and qualitative data, therefore for each of the data types of separate validity and reliability measurements should be provided.

Quantitative: To maintain the validity of the research, content validity could be implemented. According to Heale and Twycross (2015) whether the instrument (dashboard) covers the content and relation concerning the variables. Variables and KPIs for the performance dashboard should be clearly stated and documented properly, by building the relationship between each other, and with the primary objective of the project. Face validity is the sub-section of content validity, indicating where the experts are asked for their opinion regarding the process, findings, etc. Supervisors and company representatives could provide feedback to maintain the face validity of the performance dashboard. Reliability of the quantitative data if implemented with the same procedure and analyzed accordingly, would result in consistent findings.

Qualitative: This research involves interview-based qualitative data-gathering methods conducted by the fellow PhD research from the Digital Twin Project, conducted interviews with the experts of the field, to gather insights of corridor operating and issues faced by them. Ethically speaking, building trust with the respondent by informed consent, the possibility to reject the interview at any moment, and ensuring confidentiality can significantly improve the data quality. Data triangulation where different methods and perspectives are incorporated helps to produce a wide-ranging set of findings and can boost potentially both the validity and reliability of the research (Noble & Smith, 2015). In the scope of this research, the interviews have been done in different companies also using the inland waterway services that gathered nearly identical thoughts about the disruptions occurring in the Twente Joint Corridor, which potentially validates the same perspectives and issues the users of Twente Joint Corridor Agreement are having.

2.5 Conclusion

To conclude, this chapter has indicated the methodological framework and research strategies applied in the research. The problem-solving approach of DSRM provided a structured and iterative approach for the development and evaluation of the performance dashboard prototype, to ensure its relevance and applicability. The SLR done via the PRISMA guideline helped to identify the KPIs that will be used in the creation of the prototype for the Port of Twente and involved stakeholders. The findings on the KPIs will be discussed in section 3.1. Overall, the used methodologies established a systematic approach to addressing the research questions, creating the foundation for the subsequent chapters of this study.

3. Dashboard Conceptualization and Development

This chapter mentions the design and development stage of the DSRM framework of the Joint Corridor Performance Dashboard prototype, specifically focusing on the adoption and operationalization of KPIs. With these KPIs possible to address the challenges for the Twente Joint Corridor. Exploiting the insights of SLR and interviews conducted with the experts in the field will lead to the integration of data sources and the selection of relevant KPIs for the objectives of this research.

Sub-section 3.1 presents the findings from the SLR where the selection of KPIs will be indicated based on cited sources. Sub-section 3.2 dives into the operationalization of the KPIs from section 3.1, illustrating how they are often updated, and sourced, and the role of incorporation to the dashboard prototype. Conducted interviews done by the digital twin project member, and documented insights are given in sub-section 3.3 which highlights the opinions and issues faced in the inland waterway of the Netherlands, including the Twente Joint Corridor which will validate the relevance of the selected KPIs. Sub-section 3.4 covers the result of combining the gathered insights into the development of the prototype.

3.1 Findings of Systematic Literature Review

To answer the research questions properly, the SLR was conducted. This section will provide the reader with insights and thoughts gathered.

“Which performance management approaches and dashboards exist to measure the performance of multimodal corridors?”

According to Les et al. (2014) one of the factors affecting the performance of multimodal corridors is unstable and competitive market dynamics, which despite the private sector companies, also enlarges the global supply chains. Making it appropriate for the Port of Twente as the processes are done via inland shipping, which is considered to be one of the nodes of transportation for the Twente region, as majority of shipments are sent to Rotterdam, with the “Gateway to Europe”.

D’Amico et al. (2021) points out that the use of digital technologies into the port logistics are getting increasingly decisive and informative. This data-based approach supports the promotion of smart and sustainable logistics developments. The authors also note that technologies for port logistics provide transparent real-time collection, tracking, monitoring, processing, analysis and evaluation of the data. One of these digital technologies is the dashboard in support of other technologies such as sensors, monitoring stations, tracking systems, etc. Can assist reliable extraction of data to be monitored and analyzed. The paper also points out the Port of Rotterdam case, of using the digital technology of the dashboard with IBM, Cisco, Tele2 and Axians with the following KPIs: weather, currents, visibility and wind.

"Which KPIs should be considered and measured for the Joint Corridor Performance Dashboard?"

According to Calderón-Rivera et al. (2024), inland waters are classified as canals, rivers, lakes, and some estuarial waters. In the case of our research Twente Joint Corridor is considered the canal and KPIs for it can be used accordingly. Calderón-Rivera et al. (2024) on pages 12 and 13 categorized it into 4 different factors (governance & policies, management, operational, and infrastructure) each including numerous features. From *operational:* environmental factors (for this project to be used is wind and weather forecast), River Information Services for the traffic planning and information communication. *Infrastructure:* Development and Improvement of infrastructure (traffic channels, gate locks, bridges). *Governance & Policies:* Inland waterway ports lack incentives and uneven development along the river, with the possible solution pointing out to develop policies and reinstatement of terminal facilities. *Management:* The authors point out that barriers in this group can be caused by the relationship with ports, facilitation cooperation, and variation in the working hours of ports and different infrastructures. A proposed solution for resolving these barriers is to improve managerial processes and connections between important system nodes. Sharing information through the port community system and being in strong hand-in-hand work.

Baig et al. (2024) emphasizes possible opportunities and challenges in the domestic ferry sector. Overlook of the foul weather conditions is mentioned as an unpredictable and highly damaging threat, especially for the seasons of rain and monsoon flooding. Consequently, the safety operations of the ferry sector are under question. The authors also mention that navigational aids for route planning depend on the purpose of technology and the region of the given ferry sector operating. For instance: Some of the technologies are meant solely for the route planners, while others can be designed in a way to decrease the environmental impact of the ferry.

Despite all the other opportunities and challenges of the ferry sector discussed by Baig et al. (2024), few insights would be useful for the Port of Twente research in the environmental dimension. The authors state that most of the accidents around the environmental dimension include strong winds, visibility issues due to the fog, currents, and complex water environmental dimensions. These types of challenges present matters of high importance for maritime safety and negatively affect operations to be as resilient as possible within the corridors.

Jonkeren (2009) states that based on the interview report for the Port of Rotterdam low and high water affects the operational efficiency of the shipments. This emphasizes the crucial need for the water levels to be represented as the KPIs for the maritime industry. It was conducted that there is loss of cargo in periods of different levels, and the need for additional storage capacity for the bulk cargo in the port. However, due to the competitive position of the port itself, these factors don't hinder the performance, which is quite arguable for the case of Port of Twente based on the historical events of flooding and drought discussed in the section of the problem description.

Patnala et al. (2023) describe quite explicitly the occurrence of disruptive events in the inland waterways and the ways to boost resilience throughout the locations. There are four adaptation plans presented in the paper, one of which would be relevant and applicable to the scope of the research for the Port of Twente. Quote of Patnala et al. (2023) p.254 “Enhancing real-time monitoring, emergency reporting, surveillance before, during, and immediately following disruptive events”. The dashboard will assist in managing the resilience of Twente Joint Corridor, by providing various data and insights regarding the performance of the corridor for the users.

The coordinating system allows the exchange of data for the possible bottlenecks in specific parts of the route and the Internet of Things (IoT) is the cost-effective solution to monitor the vessels and any other environmental factors such as water levels, fog, flood risk, water quality and overall traffic (De Barros et al., 2022). These technologies underscore the importance of the dashboards as potential tools for performance monitoring of the multimodal corridors.

To conclude, the insights from these studies emphasized the need for KPIs that focus on environmental factors, operational efficiency, and the need for technological integration for operations. These tools will provide transparency by integrating data from multiple sources, and visualization of these metrics such as maps, alerts, infrastructure, and water levels. The efficiency of operations of skippers can readjust the route in case of disruptions occurring along the way, metrics will provide insights into the status of routes and ensure the resilience of the Twente Joint Corridor.

Selected KPIs that relate to studies from SLR: Water level, Weather forecast, Alert for the disruptions (Moderated by the system administrators and/or port authorities), Average waiting time at the gate lock. Infrastructure Availability (Operating hour of locks, Openings of the Bridge, Status of the gate)

3.2 Operationalization of KPIs in the Prototype

This section will evaluate the use of selected KPIs from the SLR to the prototype. The following table 7 will indicate the KPIs accordingly.

The information or datasets that can potentially be used for the prototype are gathered from the open data sources of governmental organizations and institutions.

KPIs (Source)	***Data type (Sample value)***	***Purpose of the source***	***Update rate***	***Use in the prototype***
Water level (Rijkswaterstaat)	Integer (689 cm)	Capture the water levels, wind, waves, water temperature, and salinity.	Every 12 hours, data is updated.	Will provide the water levels in the inland waterways across the Netherlands.
Weather forecast (KNMI)	String (Sunny, 9℃)	KNMI provides nearly 49 (38	Each dataset has a specific	This data source will

		being open data) datasets regarding the weather.	update rate and can be used accordingly.	provide the weather forecast as a KPI for the prototype.
Alert for disruptions [(Rijkswaterstaat Vaarweg informatie)]	String, as they will be indicated on the disruption page in prototype ("Gate lock Hengelo, maintenance on XX/XX/XX date")	Specific parts of the website provide collected notifications regarding the fairway traffic, maintenance, and disruptions across the fairways.	Data is updated upon the occurrence of the events, such as disruption, maintenance.	The disruption page of the prototype will provide text-based alerts or notifications for the stakeholders.
Avg. waiting time at the gate lock. [(Source)]	Integer (15,20,25 minutes)	Research made by the TU Delft for the Port and Waterways, including a lot of specifications.	Latest update 2021	KPI will guide route planning, including delays
Infrastructure availability [(Rijkswaterstaat Vaarwegen en objecten)]	Boolean (TRUE – Green indications, FALSE – RED indications)	The open source provides various objects (gate locks, bridges, harbor, ports, etc) of Netherlands inland waterways.	There are different versions of the provided data. Overall, the updates for important information such as waterways, bridges, and gate-locks are regular.	KPIs provide the prototype with information regarding the objects and operating times across the waterways.

Table 7 KPIs overview.

It is crucial to emphasize the waiting time at the gate lock, which is covered in one of the sources. According to Verheij et al. (2021), the research of TU Delft specifically made for the Port and Waterways states that various factors depend on the waiting time of the shipment at the gate lock. Formula:

$$t_w = kT_c + t_{wr} \qquad (k = 0,1,2,....)$$

Formula (1) of waiting time (Verheij et al., 2021)

Where t_{wr} is the remaining waiting time after the last cycle before entrance has been completed, k stands for the number of looking cycles in case of heavy traffic. In the occurrence of heavy traffic, the k can be varied and affect the waiting time at the gate-lock.

Additionally, Verheij et al. (2021) illustrate that the opening and closing time of the gates for the lock can depend on the type of the gate and the width of the lock. The authors provide three examples of operating times for three variations of gates operating electrically indicated in table 8.

Gate type	Chamber width (m)	Closing time T_{close} (min)	Opening time T_{open} (min)	Total gate operation time (min)
Rolling gate	12	1.2	0.7	1.9
Vertical lift gate	14 – 18	3.0 – 3.3	2.0 – 2.3	5.0 – 5.6
Mitre gate	16 – 24	1.3 – 2.5	1.2 – 2.6	2.5 – 4.1

Table 8 Gate operating times (Verheij et al. (2021), TU Delft)

Observations and calculations provided by the authors of the research can potentially benefit the digital twin project in observing the waiting times of the shipment passing the gate lock. Data collecting the information of what type of vessels used and gate locks in the Joint Corridors can be used for clear and precise calculations. For this part of the research, the average waiting time can be calculated from the total waiting time of the shipments.

The KPIs for the Joint Corridor Dashboard are chosen to measure critical aspects of the performance throughout the corridor. Additionally, it will collectively provide comprehensive insights into the operational, environmental, and logistical state of the Twente Joint Corridor. The integration into the dashboard prototype will provide monitoring, decision-making enhancement, and support for the resilience of the corridor.

Important to note how the Rijkswaterstaat and KNMI does the data gathering due to the fact the insights provided by these governmental institutions will be used in the performance dashboard prototype. Therefore, table 9 will provide details backing up with the official posts from the governmental organizations.

Rijkswaterstaat.	This governmental institution founded in 1798 collects enormous amounts of data every day, ranging from water levels, bridge loads, and other infrastructure availability. There are more than 300 water level measuring stations in the Netherlands that measure the characteristics across rivers, canals, and other waterways. Additionally, there are approximately 35000 Normal Amsterdam Peil (NAP) benchmarks that are used for protection against flooding. It also serves for water management, planned constructions, and soil movement study. According to the official website of Rijkswaterstaat NAP is vital for the purposes of supporting the geodetic infrastructure in the Netherlands. The water level information is mostly given in relevance to the NAP. Data registers of Rijkswaterstaat can be found here.
KNMI.	Founded in 1854 by the Dutch chemist and meteorologist C.H.D. Buys Ballot. The KNMI has 48 measuring stations across the Netherlands and North Sea receiving weather models data every 3 hours. Providing the data for measurement of temperature, humidity, wind speed, precipitation, and air pressure. Data registers of KNMI can be found here.

Table 9 Description for the data gathering of Rijkswaterstaat and KNMI.

To illustrate the principle of data usage from the sources in the prototype, the following data pipeline and entity relationship diagram are indicated in Figures 5 and 6, respectively.

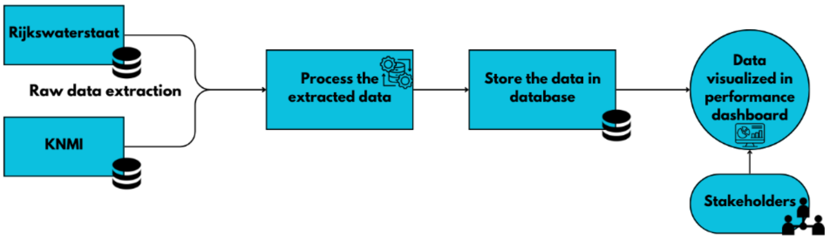


Figure 5 Data pipeline.

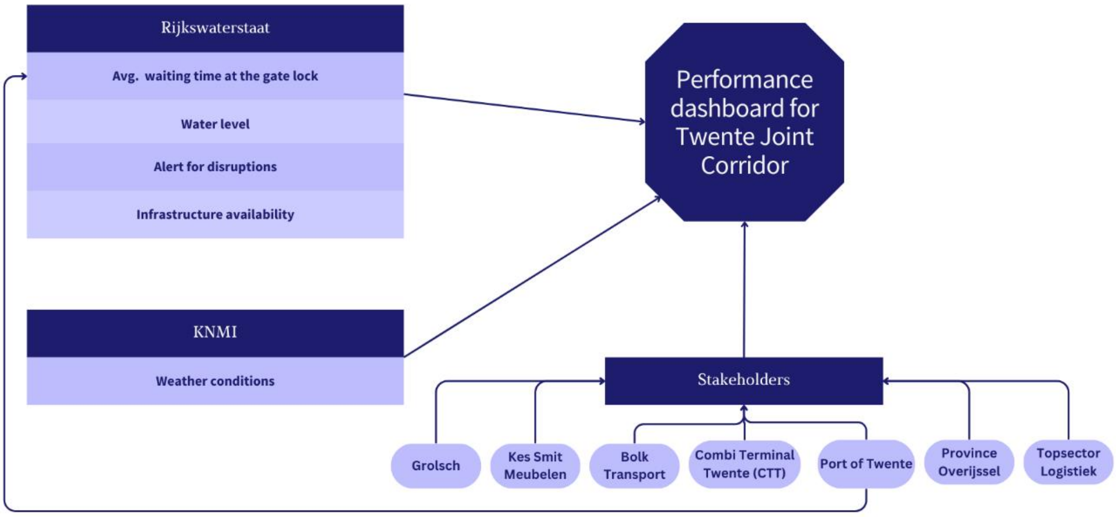


Figure 6 Entity Relationship Diagram.

The data pipeline illustrates the flow of information from the sources (Rijkswaterstaat and KNMI) to the performance dashboard. Data is extracted and processed from public sources to be stored in the database. The stored data would be used to visualize KPIs. The entity relationship diagram illustrates the interconnection between the roles of data providers, dashboards, metrics, and stakeholders of the Twente Joint Corridor.

3.3 Interview findings

This section will serve as the findings for the last sub-RQ regarding the interviews with the field experts. Its content will summarize insights that could be useful for this research. Information has been gathered from the 7 interviews conducted in different companies with the skipper of the ship and port authorities by the doctorate researcher Y. Tao (Tommy), who is part of the digital twin project. This section would be relevant to understand what sort of obstacles companies face while using the waterways in practice.

Water Level Issues:
Low and fluctuating water levels potentially reduce the load capacity of the vessel, increasing transportation costs. It forces operators to shift towards alternative nodes of the multimodal transportation network. High water levels can restrict passage under bridges, especially in the case of containers carrying ships, while extremely low levels can trigger government restrictions on one-way traffic of Twente Canal and longer lock operations which adds up to the waiting time of ships at the gate-locks. The real-time predictions and information of water

levels in different parts of the corridor would be essential to approach the minimization of delays and optimization of routing and scheduling.

Logistics & Operations:
Based on the experience of interviewed personnel, change in water conditions negatively affects logistics and operations. The stakeholder companies should be able to adapt their strategies in the occurrence of disruptions. The single-direction traffic flow and passage restriction of bridges in case of change in water level is one of the examples that pushes stakeholders to change the route planning, and resource allocation which is costly.

Weather conditions:
Strong winds, heavy rain, extreme temperatures, or any other disadvantageous weather conditions can disrupt loading, unloading, and vessel stability. Integration of real-time weather monitors and preferably forecasts with early warning signals allows companies to adjust plans, mitigate costly delays, and damages, and overall adapt towards the situation.

Collaboration & Communication:
Inefficient communication methods, which often rely on phone inquiries, and email newsletter subscriptions, can cause disruptions occurring at the latest moment and companies wouldn't be able to adapt to it which will damage the operations. Implementation of communication throughout the dashboard by notifying the stakeholders of possible alerts, notifications, and disruptions of the corridor would be useful to mitigate risks. The collaboration between governmental institutions, companies, and port authorities can improve resource utilization, minimize water capacity, and overall, significantly simplify operations of the supply chains.

Important to note that the digital twin interpretation with real-time data platforms can boost the resilience of the Twente Joint Corridor by knowing the predictability of water levels, weather information/forecast, route planning with all possible obstacles, objects (bridges, harbors, gates), and schedule optimization. The prototype performance dashboard will act as a supporting point to this project that will be able to visualize these indicators for the stakeholders to gather insights and make collaborative decisions.

3.4 Results

The design and development process of the DSRM framework resulted in the creation of the prototype for the Twente Joint Corridor, which integrates KPIs, addresses operational bottlenecks, and enhances collaborative decision-making for stakeholders. The prototype combines data from governmental institutions such as Rijkswaterstaat and KNMI, specifically collecting data that could be useful based on industry-specific insights, via interviews and literature review.

The KPIs - water level, weather forecast, alerts for disruptions, average waiting time at gate locks, and infrastructure availability are visualized in the prototype by providing the involved parties with the ability to make collaborative decision-making through a minimalistic and user-friendly interface. Which consequently allows the use of the Twente Joint Corridor effectively. For example, the integration of water level predictions in the dashboard helps stakeholders to pre-estimate delays and act accordingly to adapt to the challenges in operations. Not to mention that including infrastructure availability as one of the KPIs helps to track critical issues such as gate locks, bridges, and specific parts of canal maintenance for minimizing the downtime of the shipments.

The developed illustrative prototype in section 4 with integrated visualized key performance indicators and relevant data sources is expected to serve as a robust tool for acknowledging the operational bottlenecks and communication gaps of the Twente Joint Corridor. This process, described in the chapter, sets a probable foundation for enhancing decision-making and operational efficiency toward the overall effectiveness and sustainability of the corridor.

4. Prototype

This section illustrates the various attributes of the proposed solution. The performance dashboard prototype provides a clear, minimalistic view of the KPIs that matter, integrating the findings of this research for the stakeholders. Each attribute of the dashboard has been designed to offer insights, support collaborative decision-making, and improve efficiency along the Twente Corridor. Additionally, this section will help readers navigate the prototype, which was created using Figma. The requirements for the prototype dashboard are following:

Monitoring and Visualization: The prototype should provide insights into operational parameters of the Twente Joint Corridor. Information with visualized objects for the water levels, weather conditions, and infrastructure availability.
Alert and Notification system: It should notify users in case of disruptions or critical events in a timely manner. In case of low or high-water levels, infrastructure failure or maintenance users should be notified. The future maintenance scheduled by the government institution should be indicated also, so the users will have to adapt for the route planning.
Contact and Feedback: If the users are willing to provide or in need of some sort of assistance, there are two different pages that can be used for the given purposes.
User friendly interface: The prototype should be intuitive and easy to navigate.

The full view on the prototype can be found in figure 20 of Appendix B. Additionally, the illustrated product is not considered to be a fully functional dashboard, it is a prototype that serves as the way the dashboard should be visualized. By the end of this section, validation process with description to the changes for prototype acquired during the meeting with Anne-Ruth Scheijgrond, the infrastructure advisor of Port of Twente, including the evaluation criteria for the dashboard.

4.1 Route Planning

Figure 7 Route selection.

The initial stage of using the prototype is to select the desired destination for the vessel/ship to travel. After the selection, the route will be constructed and highlighted. Throughout the route, objects are highlighted. In this case, only gate locks in different locations are indicated.

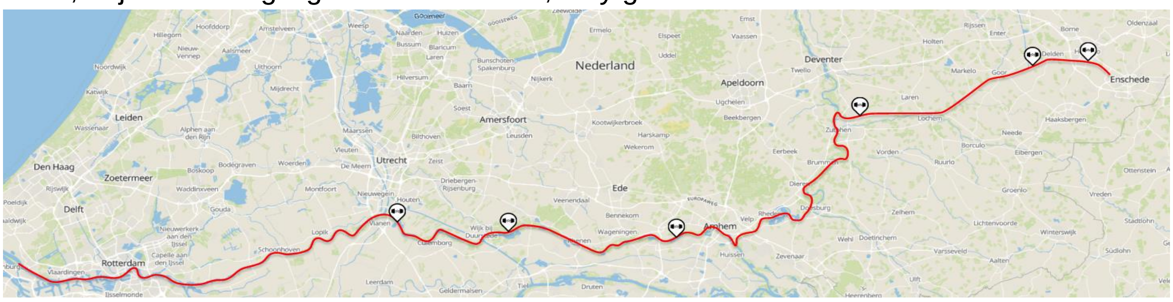


Figure 8 Highlighted route with indicated objects.

4.2 The Route Overview

If the user wants a detailed overview, there is a specific attribute designed for it. At first glance, only the date and route buttons are visible. By pressing the route button, the user gains access to the detailed information provided in Figure 21 of Appendix B.

The detailed information regarding the route illustrates the various objects, obstacles, and water levels at the different locations. Each gate lock also indicates the Opening and Closing water levels for more insights and more precise route scheduling. Additionally, each gate either has a green or red small dot next to it indicated in Figure 9. The green indicates that the gate is fully operating, and no problems are occurring at the moment. Whether there are two variations of red dots. First, a plain red dot without additional text indicates the malfunction, and maintenance that consequently leads to the gate being closed and couldn't be used. The second one illustrates that there are variations from the average waiting time, in case of disruptions, and heavy traffic and indicates approximate additional waiting time at the gate lock.

Figure 9 Green & Red indication for the gate lock.

The bridge indication and water levels at the different locations serve as indicators for enhancing decision-making. According to the interview findings low and high-water levels are causing operational inefficiencies for the operators. The knowledge regarding the water levels on bridges and locations will affect whether the vessel/ship will be available to pass the specific bridge or part of the route. With this knowledge, operators will be able to adapt to the situation.

4.3 The Environmental Factors

The other attribute mentioned in a few sources and interview findings that conveys significant importance is the environmental factors. Despite the water levels and objects provided in the detailed overview of the route, there is an attribute with average, minimum, and maximum water level (in cm) alongside the route. The weather conditions also play a role and can potentially help the operators to make decisions.

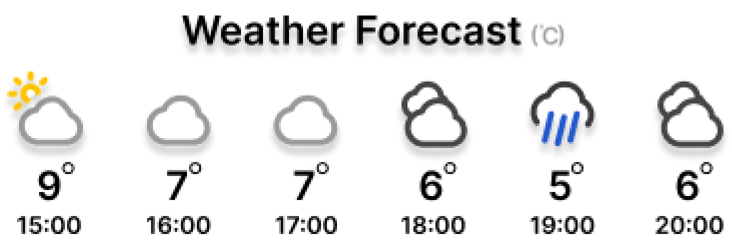


Figure 10 Weather forecast.

Figure 11 Lowest, average, highest water level (in cm).

4.4 Disruptions, Feedback

As part of the Design Science Research Methodology (DSRM), the feedback is essential for the evaluation stage. The users, after using the prototype, will be available to send the feedback to the system administrators which will allow this research to continue and improve the Performance dashboard for Twente Joint Corridor on a continuous basis.

The planned maintenance, blockage, or delays will be indicated in advance on the disruptions page. It will allow for easier communication between the operators, so they will be able to make the route planning accordingly. Operators can also notify with the assistance of the contact page the system administrators to indicate the disruption/event happening at the exact moment, so it would be added to the list as soon as possible. Attachments can be found in Figure 22 and 23 of Appendix B.

4.5 Validation

The validation process involved presenting the prototype of the Joint Corridor Performance Dashboard to a representative from the Port of Twente, specifically to the infrastructure advisor who is familiar with the operational challenges of the corridor, also the needs of skippers and stakeholders of JCA. The objective of the meeting was to obtain feedback on the prototype's functionality, relevance, and usability, ensuring that it aligns with the practical needs. During the meeting, the Port of Twente worker provided suggestions for the operational factors and limitations of the prototype. The changes to the visualized elements will be mentioned further in the sub-section.

While the design and functionality of the prototype were generally well-received, still some minor adjustments for improvement needed to be taken into consideration. The changes done to the prototype will be added below.

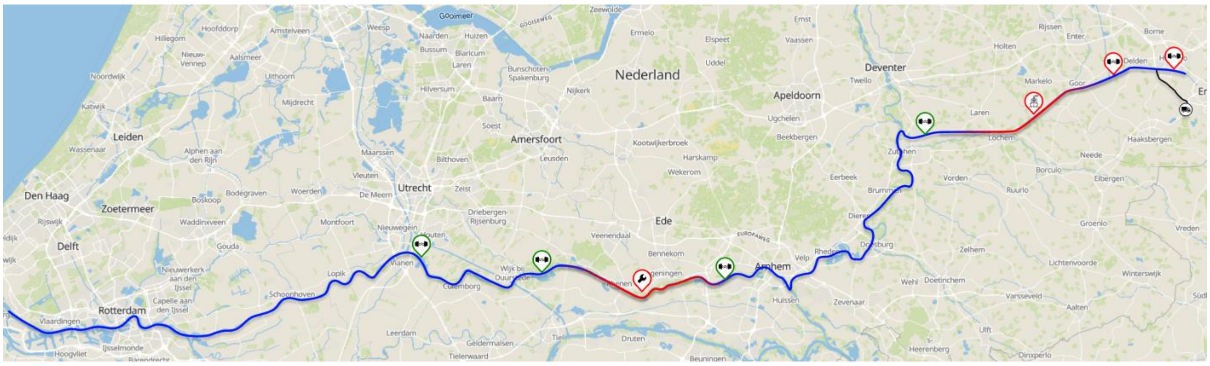


Figure 12 Validated version for the route visualization of the prototype.

Initially, only gate locks were displayed as visible disruptions on the prototype. However, in the validated version, additions were made to the objects and color-coding.

The route was entirely indicated in red. In the validated version, a more detailed color-coding scheme has been implemented: the route from point A to point B is now indicated in blue, while disruptions along the corridor are highlighted in red. Updated disruptions include maintenance activities that may occur in specific parts of the canal. In some cases, ship carriers face technical issues and are forced to stop in the canal (both indicated in figure 13).

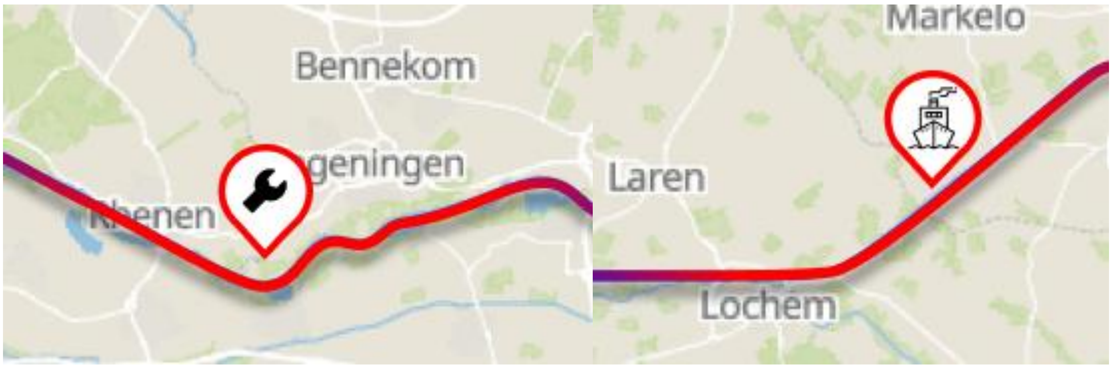


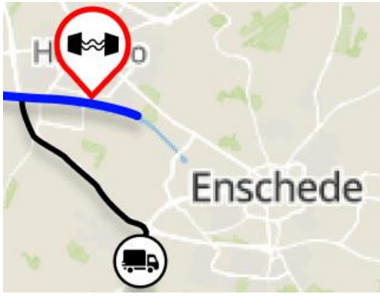
Figure 13 Maintenance & Ship with technical issues on the canal.

The gate lock attribute was indicated in red despite the fact it is fully functional or there are some disruptions occurring at the gate lock (maintenance, delay, etc.). Validated version includes color-coding of green (Figure 15) for fully functional, and red (Figure 14) for the disruptions occurring at the gate lock which is like the route overview (Figure 21, Appendix B) attribute of the prototype.

Figure 14 Disruption occuring at the gate lock with red color coding.

Figure 15 Fully functional gate lock with green color coding.

As this project is done for the stakeholders of the JCA, it would be important to implement the scenario of one of the stakeholders using the Twente Joint Corridor which will also be able to emphasize the use of other transportation nodes. The multimodality of the scenario by implementing the truck icon will be implemented in Figure 16.



Grolsch Scenario: The truck is loaded with the product at the Grolsch factory in Enschede and travels by truck (black line) to the CTT located in Hengelo after the shipment is processed for further activities to Rotterdam.

Figure 16 Truck leaving Grolsch factory to CTT.

To conclude, this chapter has provided information on the development, functionality, and validation of the prototype, by integrating KPIs such as water levels, infrastructure availability, and various disruptions. The design includes features such as: visualized routes, disruptions, infrastructure, environmental data, water levels, and a detailed route overview.

The validation process further clarified the prototype by considering the feedback from the Port of Twente representative, resulting in adjustments for the artifact. Improved color coding for the route, disruption indicators, and gate lock statuses. The validated prototype not only reflects the findings from the prior sections but also sets the stage for further improvement and practical applications with a user-friendly interface and actionable insights. It is expected that it would serve as a tool to improve the operational efficiency and resilience of the Twente Joint Corridor involved parties.

4.6 Evaluation Criteria

This section will review and suggest how the dashboard should be evaluated to meet the operational goals of Twente Joint Corridor by acquiring knowledge from the existing frameworks and practices. According to Venrooij et al. (2016), there are three crucial criteria from the perspective of human factors that any dashboard should meet given table 10 which will be compared to how the validated prototype for the Twente Joint Corridor meets the criteria.

Criteria.	**Description of the criteria.**	**Validated prototype for Twente Corridor.**
1. Single screen fit.	The majority of the conveyed information that could potentially satisfy the	The essential information of the prototype is displayed on one screen to gather

	operational goals should be indicated on one screen.	necessary insights.
2. Dashboard contains the most important needed information to achieve one or more objectives.	The potential of the dashboard can be measured by whether the product contains the required information for the users to meet his/her goals. Can be assessed by the digital questionnaires.	The visualized KPIs gathered with SLR let users achieve various tasks by enhancing decision-making. Additionally, it can be measured by the *Feedback* window for gathering the different perspectives of the users.
3. Briefly users can monitor and understand the displayed information.	The efficiency and effectiveness measurement for the dashboard.	Can also be assessed by creating digital questionnaires or gathering feedback from the users.

Table 10 Dashboard three essential criteria by Venrooij et al. (2016).

Level	Criterion
EV1: Metacognitive	Understanding
	Agreement
	Impact on awareness and reflection
EV2: Cognitive	Impact on performance
EV3: Behavioural	Impact on behaviour
	Usage of the system
EV4: Emotional	Impact on motivation
	Impact on affect
EV5: Self-regulation	Self-regulated learning
EV6: Tool usability	Satisfaction
	Usability
	Usefulness

Table 11 Levels & Criteria for evaluation by Jivet et al. (2018).

Additionally, Jivet et al. (2018) provide a detailed dashboard evaluation by dividing it into six different categories (Metacognitive, Cognitive, Behavioral, Emotional, and Tool usability) based on the 26 researched papers from the literature review. Each of the six levels is also divided into sub-points and is provided in table 11.

The framework can be considered relevant to this research, by examining the possibilities of the dashboard on impacting the understanding, performance impacts, awareness & reflection, usage of the system, usability, and usefulness. These factors can enhance operational efficiency, additionally by pointing out whether stakeholders interact and benefit from the dashboard.

As the disruptions of the inland waterways are alerts for the skippers, it is crucial to note whether the visualization of them is made properly. Karami et al. (2017) presents the study to offer applicable criteria for dashboards in healthcare organizations. Despite the fact the paper is aimed at the medical industry, there are still points that could be taken into consideration for this research. Table 12 provides the criteria of Karami et al. (2017).

Key Criteria	
Customizing and managing the alerts	Defining the alerts
	Highlighting by color coding for unexpected values
	Determining the timing of alerts
	Placing the alerts in context
Delivering alerts through	Dashboard website
	Email
	pager
	Cell phone

Table 12 Criteria for alerting in dashboard by Karami et al. (2017).

For the context of this research, the disruptions are defined (with different icons for clarification) and color-coded to emphasize the functionality and availability of the infrastructure. On the *Disruptions* page of the prototype indicated in Figure 23, the scheduled disruptions with timings are also provided. The icons emphasize the context of the disruption, whether it is the maintenance at the gate lock, canal, or broken ship at the route. The alerts of the validated prototype are expected to be delivered with the assistance of the feedback page to the email of regulatory entities of the dashboard. The other possibilities can be implemented in further research if requested by the stakeholders or users.

These evaluation criteria frameworks are essential for validating the prototype's effectiveness and usability, by assessing the functionality and impact for the Twente Corridor. Consequently, it can ensure that the prototype would meet the needs of stakeholders, and users by enlightening the areas of improvement and benefit to the corridor operations.

To conclude, this chapter has provided information on the development, functionality, validation and evaluation criteria for the prototype, by integrating KPIs such as water levels, infrastructure availability, and various disruptions. The design includes features such as: visualized routes, disruptions, infrastructure, environmental data, water levels, and a detailed route overview.

The validation process further clarified the prototype by considering the feedback from the Port of Twente representative, resulting in adjustments for the artifact. Improved color coding for the route, disruption indicators, and gate lock statuses. The validated prototype not only reflects the findings from the prior sections but also sets the stage for further improvement and practical applications with a user-friendly interface and actionable insights. It is expected that it would serve as a tool to improve the operational efficiency and resilience of the Twente Joint Corridor involved parties.

5. Conclusion

This section focuses on the components of the main results, implementation plan, limitations, and potential scalability. Firstly, revisit to the main results in sub-section 5.1, including the research contribution. Following with an implementation plan from sub-section 5.2 describing the steps required for implementing the dashboard into the operations of the Twente Joint Corridor. Further research possibilities are discussed in the sub-section 5.3, with the description for each of the opportunities. Sub-section 5.4 provides the limitations of the study, highlighting the constraints faced during the research, and additionally pointing out the areas of improvement for further research. Final sub-section 5.5 sets the summary for the research.

5.1 Results of Research.

The primary aim of this research was to design and develop the dashboard prototype to measure the performance of the Twente Joint Corridor. DSRM was applied to ensure that research was executed according to the framework. The research operationalized KPIs for water levels, infrastructure availability, disruptions notification, and weather conditions to form the starting point of the prototype. The prototype is expected to enhance the corridor's performance via collaborative decision-making for the involved parties of JCA.

Main RQ: "How can a dashboard be designed and developed to measure and monitor the performance of the Twente Corridor?"

The RQ was addressed by researching insights from SLR, interviewing experts in the field, developing prototypes, and receiving feedback from Port of Twente. The results demonstrate that gathered insights are visualized and demonstrated using the Figma tool, integrating Rijkswaterstaat and KNMI governmental institutions' datasets.

Contribution: The research aimed to contribute scientifically and practically to performance management and multimodal logistics. Scientifically, the application of frameworks for executing the research (DSRM) and literature review (PRISMA) gathered insights on KPIs and created the prototype for the inland waterway in Twente. Practically, the delivered prototype is expected to address the critical operational bottlenecks and improve decision-making for the users and stakeholders of JCA.

5.2 Implementation Plan

The implementation of the dashboard into the company's operational activities is complex and requires a step-by-step process (Orts, 2007). Therefore, to approach the detailed format of the implementation, this section will cover the implementation plan steps suggested by Orts (2007). According to the author, there are a series of tasks for the dashboard implementation: plan, design, build, and deploy.

Plan: Identification of the project team members (roles for each member), objectives, time constraints, budget, content for the dashboard, KPIs, involved parties' suggestions on the product, etc.

As this research has already made the prototype with the set of suggested KPIs based on the SLR, interviews with the experts of the field, there are still some steps that should be considered for further research. In order to implement technical aspects, there is a need for a tech team that will convert the prototype to the functional product. The technical team should be managed by the project leaders who would be responsible for setting the budget and time constraints, which should be discussed in advance with the stakeholders of JCA.

Design: After the planning stage, if the team approves the content of the future dashboard, the next step is implementing the aspects of the design.
The validated prototype provides the design of the user interface and visualized KPIs for the users. Additionally, it includes potential data sources from governmental institutions. Further, the technical team should implement the persistent datasets for the KPIs from provided data sources.

Build & Validate: The development stage is where the product should be created and validated. Additionally, it is crucial to point out there are sub-steps that need to be considered, such as front-end, query implementations, scheduling & refresh configurations, and validation.

The prototype for the Twente Corridor provides the front end with a user interface with visualized KPIs. The design has already been validated with the port authorities. For the next step, the technical team needs to create the queries for retrieving the information from the data sources to the dashboard datasets. As the data planned to be implemented into the fully functional dashboard, the needed governmental institutions should be informed regarding this matter, and security measurements should be proceeded accordingly. After which, the functionality of the operating dashboard should be validated with the involved stakeholders of JCA.

Deploy & Maintain: After the building and testing the dashboard, the product should be deployed and used. Over the time, feedback should be gathered for the purposes of continuously improving the user experience with the fully functional product.

5.3 Further Research & Scaling Up

As the final output of this research is the prototype that can be benefited for the purposes of the further and future research. This section will cover the possibilities and relevant topics for this research that can be implemented.

Functional dashboard: Creation of fully functional dashboard, with the documented functionality that should be validated with the involved parties.

Predictive analytics integration: The analytics that can provide more accurate inputs for the dashboard variables of water levels, disruptions & traffic patterns in the inland waterways. Also, the possibility to integrate the algorithm for the route rescheduling or alternative routes to achieve the destination.

KPIs: The research can be made to validate existing or identify new suitable KPIs for the Twente Joint Corridor dashboard. The research can focus on KPIs for improving environmental monitoring and achieving the sustainable goals: CO2 emissions, fuel efficiencies, etc. The other perspective can include the interview, questionnaire-based research to improve the visual factors of the prototype, and generally continuously improving the dashboard by gathering the feedback/opinions from the users.

Multimodality & Scalability: The further research can investigate possibilities of the dashboard to be implemented in other corridors or other nodes of multimodality, such as truck and rails. The collaborations between stakeholders of JCA, governmental entities (Rijkswaterstaat, KNMI) can enhance the ability to scale the dashboard on different corridors with precise data on the disruptions, water levels, etc.

Comparison: If the dashboard would be implemented, after the use for several months/years, compare the operational performance before/after the implementation of dashboard. The result can make the comparisons whether the dashboard is providing expected results in scope of improving the operational efficiency for the Twente Joint Corridor.

5.4 Limitations of the Study

The research provides a detailed overview of designing a performance dashboard prototype for the Twente Joint Corridor, however, certain limitations must be acknowledged in this section. Mentioning these limitations highlights opportunities for future work and frames the findings of this research.

Based on the SLR findings, the prototype includes various visualized KPIs, one of which is the route planning indicated on the map. This route is not adapted by the vessel type or load, if the research would be conducted further, it should be considered for route planning as not all the types of vessels and loads can pass specific parts of the inland waterways in the Netherlands. Other remark, Twente Joint Corridor (dashboard) is aimed for the transportation of containers, not for bulk and liquid goods movement.

The study focuses on the design and visualization of the performance dashboard, using design-oriented software, which results in a prototype rather than a fully functional system. However, the validated prototype effectively demonstrates the logic and intended functionalities of the KPIs, it lacks back-end features, real-time data processing, and operational testing.

The operational testing is also considered as a separate part of the limitation, due to the time constraints of this research and the inability of the researcher's coding skills. Therefore, limited expertise in software coding moved towards relying more on the design software for prototype rather than a functional dashboard, which could have provided a practical application and understanding for the research.

The feedback for validating the prototype was only acquired from the Port of Twente infrastructure advisor. It would be advised further research to gather the perspectives also from the skippers and other stakeholders, as they will be the main users of the software during the shipments.

The prototype is generally focused on the inland waterways, however, stakeholders of the JCA agreement also try to focus on the multimodality between the different nodes. This prototype includes visually the case scenario of Grolsch, how the truck leaves the factory full of product to the CTT for further shipments, but there are no KPIs indicated specifically for the truck. Expanding the scope to include other nodes of multimodality would be a significant addition to the dashboard.

5.5 Summary

This research has addressed the performance challenges of the Twente Joint Corridor by researching KPIs with SLR done by PRISMA and visualizing it with the design-oriented software Figma into the prototype. The problem-solving approach chosen is DSRM, which provided the methodological framework for executing this research, in a 6-step manner. The selected KPIs, discussed in sub-section 3.1 implemented into the prototype, are expected to enhance collaborative decision-making for involved parties of JCA, and overall aimed to optimize the operational efficiency of the corridor. Then the validated prototype was introduced in section 4, covering the functionality and documentation of the artifact.

The research indicates the importance of having the non-static, real-time data implemented to the dashboard for the Twente Joint Corridor with the minimalistic and user-friendly interface, to address the disruptions occurring throughout the corridor. Furthermore, the study set the ground for further development, pointing out predictive analytics, additional KPIs for fully functional prototypes, possibilities for scalability, and multimodality integration.

Despite the study's limitations, such as time constraints and a lack of software coding experience, a fully functional product was not created. However, a prototype with the documented functionalities and interface is expected to establish the significance of creating the operating dashboard.

To summarize, this research has created prototype as the starting point of creating a performance dashboard that addresses the operational challenges of the Twente Joint Corridor and the JCA's involved parties. It also indicates opportunities for future research and development of practical and effective tools.

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Appendix A. Systematic Literature Review (SLR)

Search log:

Authors & Publication year	Title	Description	Boolean combination & Database
Les, A., Morella, P., Lambán, M. P., Royo, J., & Sánchez, J. C. (2024)	A new indicator for measuring efficiency in urban freight transportation: Defining and implementing the OEEM (Overall Equipment Effectiveness for Mobility).	Measures the efficiency in one of the modes of multimodal transportation, to be precise the urban freight forwarding. With the implemented KPIs, to be visualized on the control panel, namely the dashboard	Combination 1, Scopus.
Sabouni, A. A., Freiberger, A., Grosse, B., Hübers, A., Kamenz, S., & Kaser, S. (2023)	Drivers for multimodal traffic management	Paper covers the multimodal traffic management, with interpreted enormous data and covers the economical, legal, stakeholder cooperation aspects.	Combination 1, Scopus.
D'Amico, G., Szopik-Depczyńska, K., Dembińska, I., & Ioppolo, G. (2021).	Smart and sustainable logistics of Port cities: A framework for comprehending enabling factors, domains and goals.	Use of technologies in logistics of the port cities. By focusing on the different technologies that provide the mobile or static platforms (dashboards) for the logistics operators and improvement of operational flow.	Combination 1, Scopus.
Martins, V. W. B., Anholon, R., Quelhas, O. L. G., & Filho, W. L. (2019)	Sustainable practices in logistics Systems: An overview of companies in Brazil.	The case study of the logistic companies operating in Brazil, that covers the cooperation of other involved stakeholders in sharing the annual reporting of logistical operations.	Combination 2, Scopus.
Callefi, M. H. B. M., Ganga, G. M. D., Filho, M. G., Queiroz, M. M., Reis, V., & Reis, J. G. M. D. (2022)	Technology-enabled capabilities in road freight transportation systems: A multi-method study	Study covers the the role of technology adoption to the industry of freight transport, and reveals potential 32 technology capabilities with 28 of them to be as examples from the already applied companies, some of them including use of	Combination 2, Scopus.

		control panels (dashboards)	
Zhang, Z., Song, C., Zhang, J., Chen, Z., Liu, M., Aziz, F., Kurniawan, T. A., & Yap, P. (2024).	Digitalization and innovation in green ports: A review of current issues, contributions and the way forward in promoting sustainable ports and maritime logistics.	This paper examines the role of digital technologies in improving the efficiency and sustainability of green ports. Additionally gives the examples from successful implementation of already existing green ports.	Combination 1, ScienceDirect.

Table 13 Systematic Literature Review search log for RQ 2.

Authors & Publication year	**Title**	**Description**	**Boolean combination & Database**
Calderón-Rivera, N., Bartusevičienė, I., & Ballini, F. (2024)	Sustainable development of inland waterways transport.	Even though this source covers sustainable development it also includes various insights into the fleet, ports, and waterways. Which applies to the scope of this research.	Combination 1, Scopus.
Baig, M. Z., Lagdami, K., & Mejia, M. Q., Jr. (2024)	Enhancing maritime safety: A comprehensive review of challenges and opportunities in the domestic ferry sector.	This source mainly dives into the challenges and opportunities of the ferry sector. Considering the crucial factors such as training for the crew, resilience, oversights, etc. However, for the scope of our research environmental factors are applicable.	Combination 1, Scopus.
Olaf Jonkeren (2009)	Impact of low and high-water levels on reliability and transport costs in inland waterway transport.	Despite the fact that it is slightly out of the inclusion-exclusion criteria from the publication date perspective (2010-2024). This paper provides quite informative interview-based reports on the importance of water levels in inland shipping.	Not done via the SLR, the source has been found manually.
Patnala, P. K., Regehr, J.	Resilience for freight	The paper explains	Combination 2,

D., Mehran, B., & Regoui, C. (2023)	transportation systems to disruptive events: A review of concepts and metrics.	challenges and opportunities during the disruptions of inland waterways, which is closely related to the research.	Scopus.
De Barros, B. R. C., De Carvalho, E. B., & Brasil, A. C. P., Junior. (2022)	Inland waterway transport and the 2030 agenda. Taxonomy of sustainability issues.	The source provides potential solutions from the sustainable and technological perspectives for the inland waterways.	Combination 2, Scopus.

Table 14 Systematic Literature Review search log for RQ 3.

RQ 2 | Combination 1.	("Dashboard" OR "Performance Dashboard") AND ("multimodal transport*") AND ("supply chain" OR "inland ship*") AND PUBYEAR > 2012 AND PUBYEAR < 2025 AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all"))
RQ 2 | Combination 2.	("Quantitative" OR "Qualitative") AND ("Dashboard" OR "Performance Dashboard" OR "performance monitor*" OR "performance manage*") AND ("logistics manage*" OR "supply chain" OR "inland ship*") AND ("multimodal transport*") AND PUBYEAR > 2011 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all"))
RQ 3 | Combination 1.	("Key Performance Indicator*" OR "KPI*" OR "performance" OR "performance metric") AND ("multimodal transport*" OR "transport* corridor" OR "freight corridor" OR "inland ship*") AND ("logistic*" OR "supply chain") AND PUBYEAR > 2009 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all"))
RQ 3 | Combination 2.	((Key AND performance AND indicator) OR "KPI*" OR "performance" OR "performance metric") AND ("transport* dashboard" OR "logistic* dashboard" OR "performance dashboard") AND PUBYEAR > 2009 AND PUBYEAR < 2025 AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (

	DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "bk") OR LIMIT-TO (DOCTYPE , "ch"))

Table 15 Advanced search query for the databases with exclusion/inclusion criteria.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	2.3
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	-
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	1.5 (RQ 2,3)
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	2.3
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	2.3
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	2.3, Appendix A, 3.2
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	2.3
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	-
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Appendix A
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	-
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	-
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	-
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	-
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	-
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	-
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	-
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	-
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	-
Reporting bias	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	2.4

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
assessment			
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	-
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	3.1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Appendix A
Study characteristics	17	Cite each included study and present its characteristics.	3.1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	-
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimates and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	-
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	-
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	-
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	-
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	-
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	-
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	-
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	3.1
	23b	Discuss any limitations of the evidence included in the review.	2.3
	23c	Discuss any limitations of the review processes used.	2.3
	23d	Discuss implications of the results for practice, policy, and future research.	-
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	-
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	-
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	-
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	-
Competing interests	26	Declare any competing interests of review authors.	-
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Appendix A

Figure 17 PRISMA 27-item checklist.

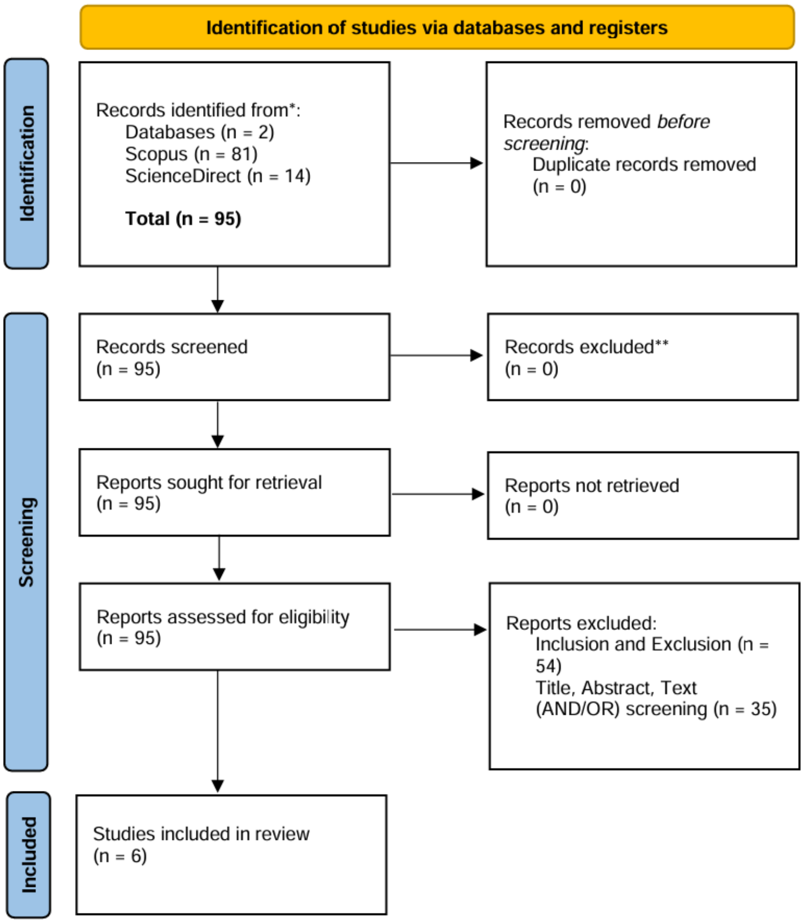

Figure 18 PRISMA flowchart for the RQ 2.

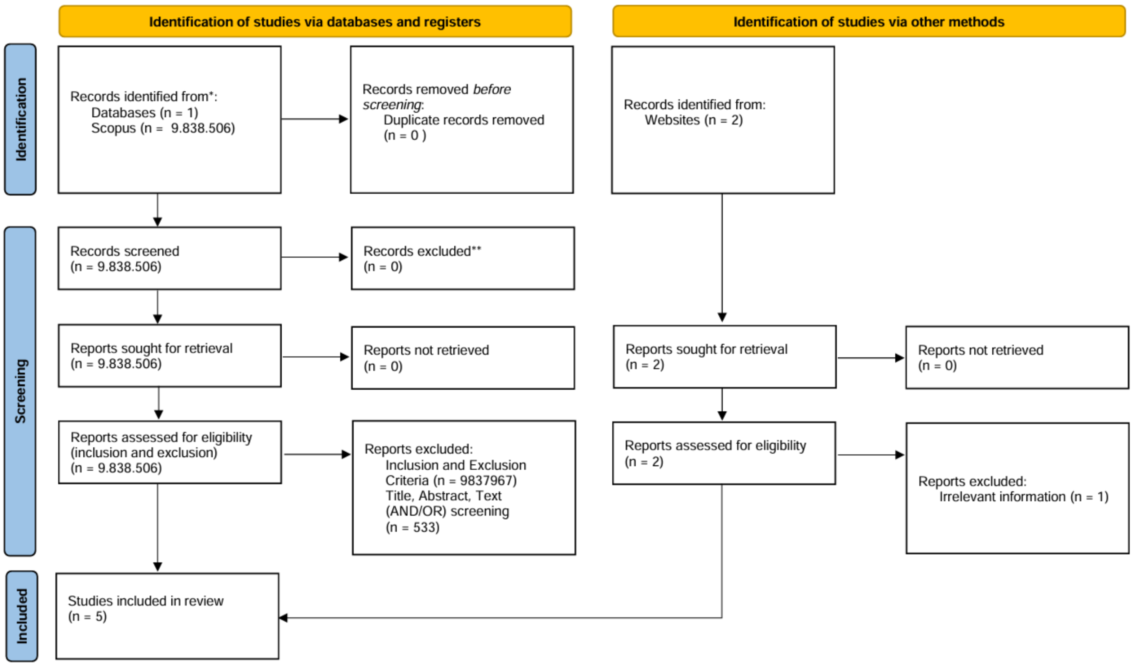

Figure 19 PRISMA flowchart for the RQ 3.

Appendix B. Performance Dashboard Prototype

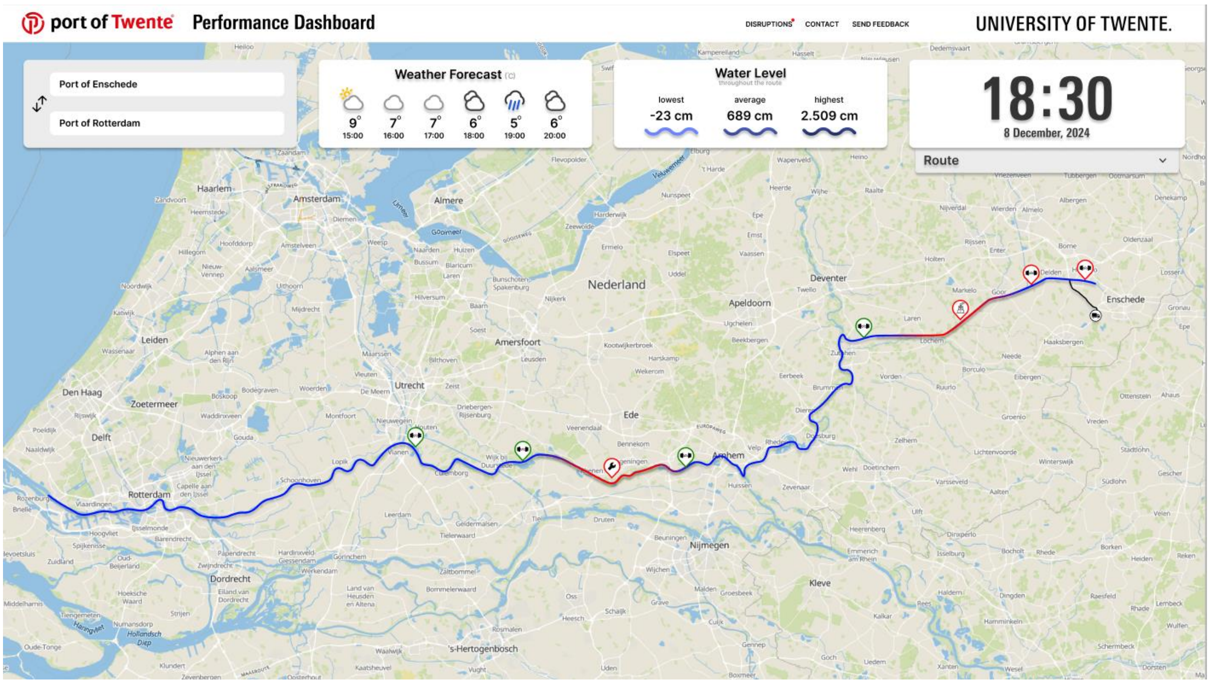

Figure 20 Performance dashboard validated prototype for the route: Port of Enschede → Port of Rotterdam.

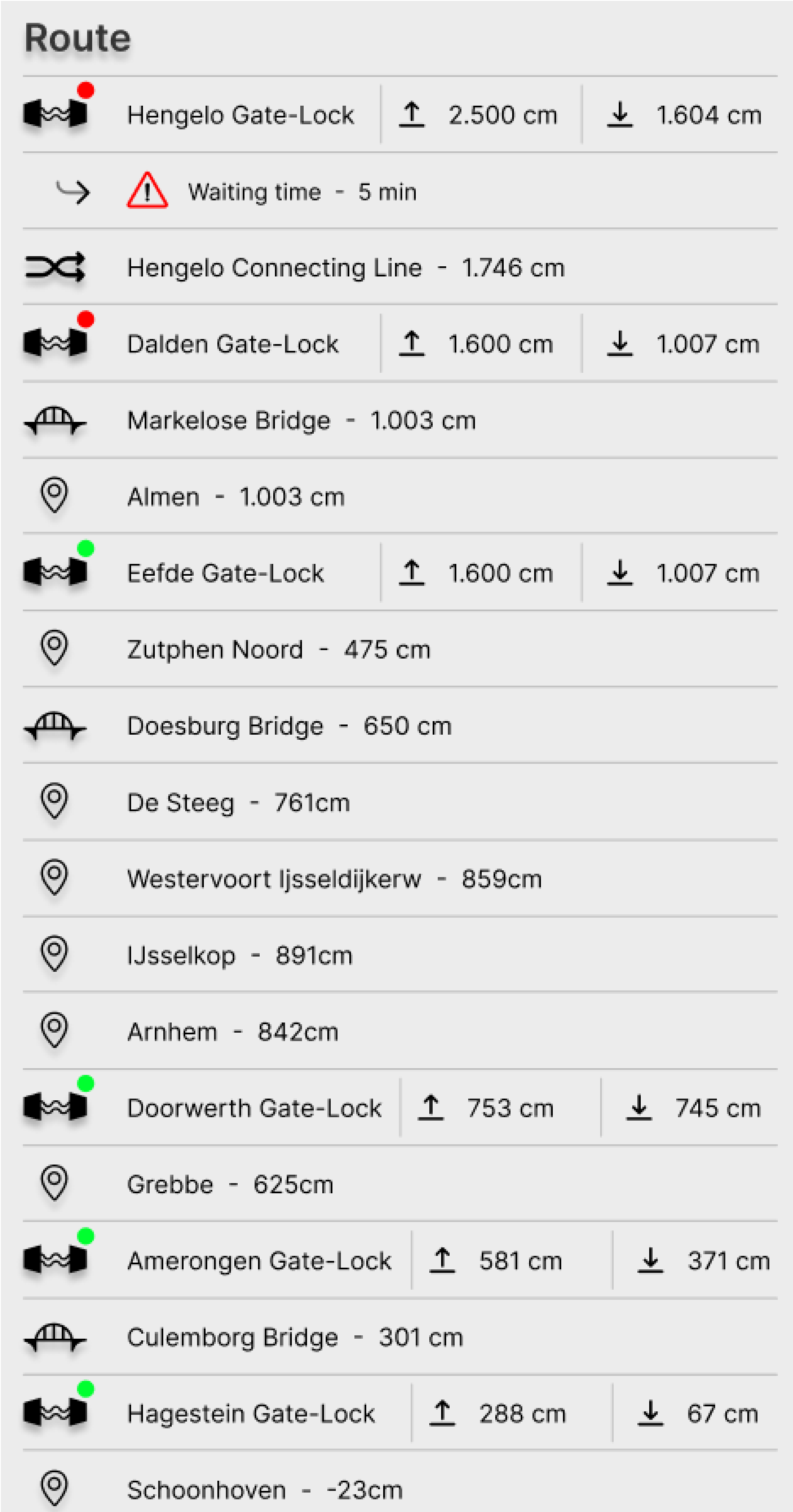

Figure 21 Detailed route overview.

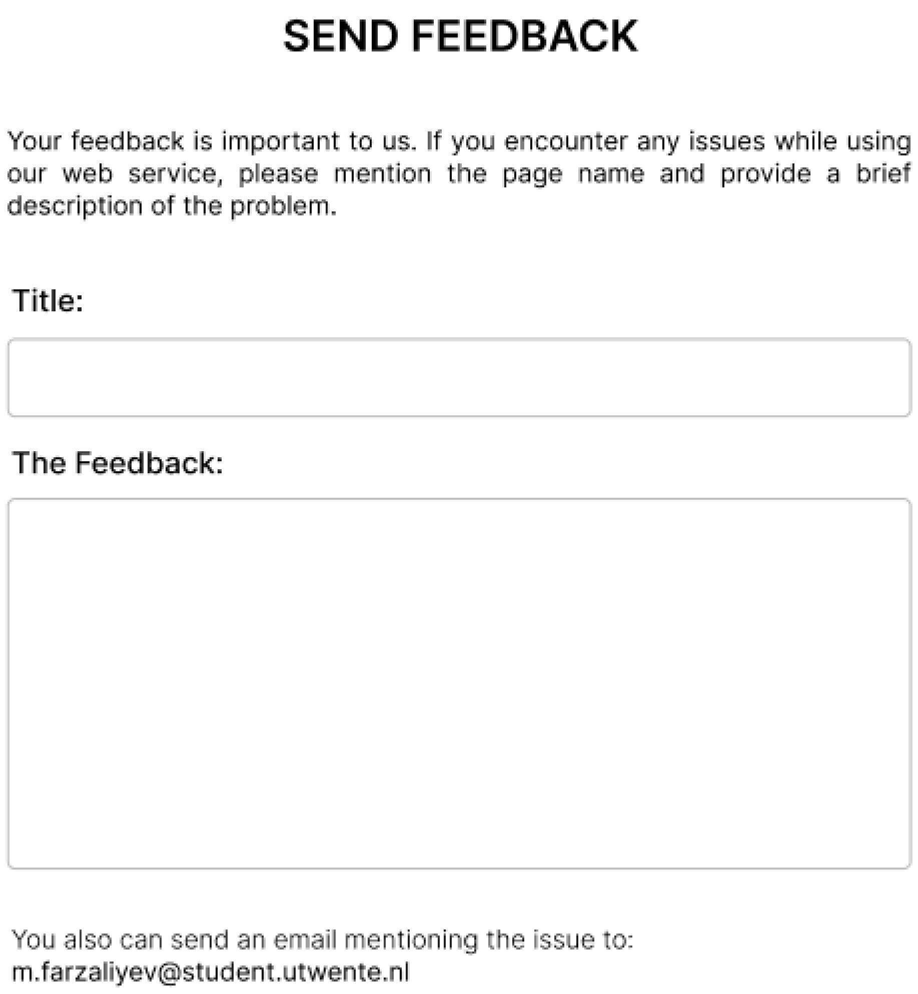

Figure 22 Feedback page of the prototype.

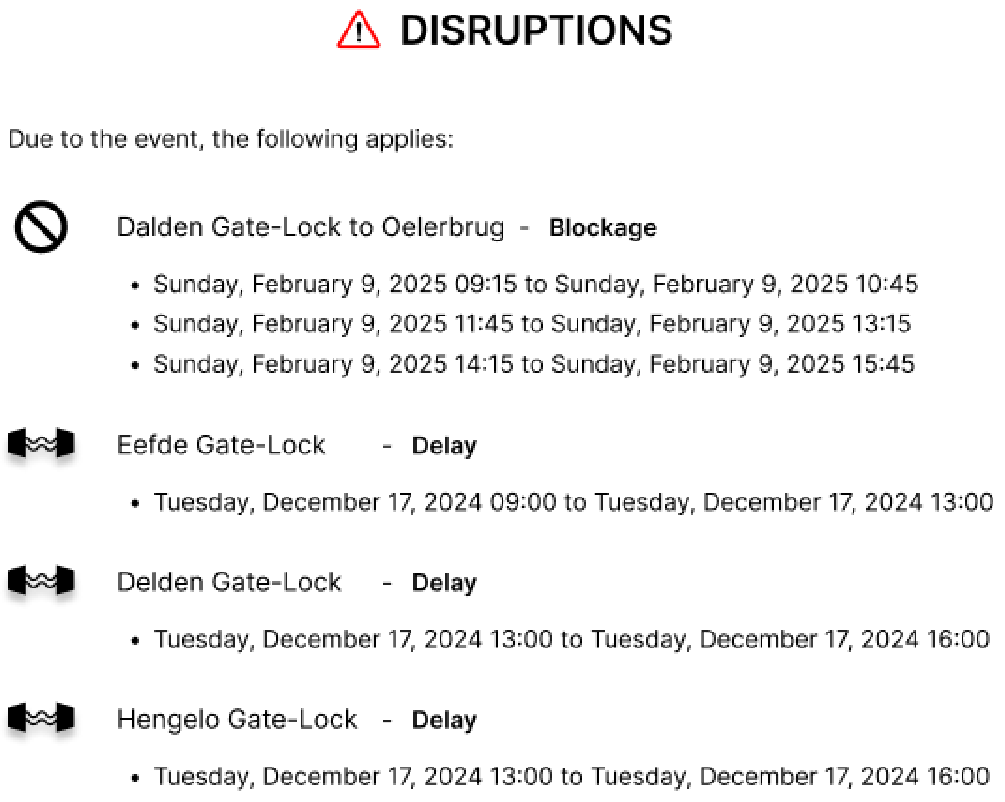

Figure 23 Disruptions page.