# Feasibility and Societal Impact of Replacing Short-Haul Flights from Schiphol with International Rail


*Image source: OV-Magazine (2022)*

By

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Dear reader,

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I hope you enjoy reading this thesis.

# Executive Summary

Amsterdam Schiphol Airport is looking to redefine its role and transform into a multimodal transport hub. Increasing environmental pressures and airport capacity constraints make replacing short-haul flights with direct international rail services a promising strategy to reduce greenhouse gas emissions, optimize airport capacity and improve regional accessibility. While many European airports are evolving into integrated transport nodes, Schiphol remains primarily air-focused, with limited coordination between air and rail in scheduling, ticketing and passenger connectivity. The Dutch aviation sector faces ambitious $CO_2$ reduction targets, requiring a 30% cut by 2030 exceeding national climate goals. Research by the Dutch Mobility Knowledge Institute estimates that between 5.600 and 16.000 flights could be replaced by rail by 2030, rising to 11.000-23.000 by 2040, representing 6-22% of flights on 13 European routes. Although this accounts for only 1-5% of Schiphol's total flights, the societal benefits including emissions reductions, freed-up airport slots and improved connectivity could be substantial. In response, stakeholders such as KLM, NS, ProRail and the Ministry of Infrastructure and Water Management have launched initiatives like the *Actieagenda Trein en Luchtvaart* to promote a modal shift from air to rail for trips under 700 kilometres.

This thesis investigates how improved direct rail connections from Schiphol to Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin can substitute short-haul flights, the barriers to implementing these services, and their societal costs and benefits. The study assesses feasible rail alternatives including infrastructure, operational, institutional, regulatory and financial requirements, and evaluates their societal impacts through a social cost-benefit analysis (SCBA). The focus is on realistic planned improvements implementable by 2030, with the scope limited to Schiphol and the six destinations. This study does not investigate broader European rail network effects and developments beyond 2030.

The central research question is: *What barriers need to be addressed to improve direct international rail connections from Schiphol to the six destinations identified in the Actieagenda Trein en Luchtvaart, and what are the societal costs and benefits of replacing short-haul flights with these improved rail connections?* The study is structured around four sub-questions exploring feasible project alternatives, required infrastructure and operational improvements, institutional, regulatory and financial barriers, and societal impacts analysed through the SCBA.

Building on prior studies that assessed the potential for shifting short-haul flights to rail, this study identifies London and Berlin as the destinations with the greatest potential for replacement. The Dutch Mobility Knowledge Institute studied 13 European destinations where flights could be replaced by rail by 2030. Following this, the *Actieagenda Trein en Luchtvaart* focused on six destinations within 700 km: Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin. London and Berlin are the most promising because they currently have the highest (London) and third-highest (Berlin) passenger volumes of the six destinations and are the only two destinations with short-term project alternatives in the Eurostar Expansion and the Dual Service Model.

The research uses a mixed-methods approach, combining detailed document analysis, expert interviews and quantitative SCBA over the period 2026-2050. Two project alternatives emerged as feasible and promising by 2030. The first is the expansion of Eurostar services on the Amsterdam-London route, increasing daily frequencies from three to five trains via the newly opened UK terminal at Amsterdam Centraal. This alternative requires no major infrastructure investments but faces operational challenges related to customs staffing and rolling stock availability. The second alternative is a dual-service model on the Amsterdam-Berlin corridor

featuring hourly ICE L trains with reduced travel times and elimination of the locomotive change at the border. This alternative requires six new trainsets, a minor platform upgrade at Deventer and an expansion of operational staff.

Barrier analysis identified fourteen general and four alternative-specific obstacles, grouped into five categories: market and competition, planning and capacity, cross-border technical fragmentation, governance fragmentation, and political/investment constraints. In the short term, the most urgent priority is resolving fragmented cross-border regulatory and staffing constraints, particularly for Eurostar services. Long-term challenges include regulatory and fiscal asymmetries between air and rail, requiring EU-wide reforms. Planning and capacity issues are comparatively easier to address through bilateral agreements, targeted investments, and operational improvements.

The societal impact assessment, conducted via SCBA for the Eurostar Expansion and Dual Service Model alternatives, shows substantial operational and environmental benefits. Together, these alternatives could reduce short-haul flights by more than 240.000, lowering passenger volumes by approximately 39 million and reducing external costs related to greenhouse gas emissions and air pollution by up to €2,5 billion. Rail ridership is projected to increase by 66 million passengers, promoting sustainable mobility in the region. Financial analyses present a more nuanced picture: the Eurostar Expansion alternative reaches financial viability under a pessimistic cost scenario, producing a positive net present value (NPV) of €32 million, whereas the Dual Service Model demonstrates a strongly negative NPV exceeding €500 million due to high operational costs and CAPEX.

In conclusion, this thesis demonstrates that shifting from short-haul flights to international rail is both feasible and societally beneficial on the Amsterdam-London and Amsterdam-Berlin corridors by 2030, even with limited infrastructure investment. Achieving these benefits requires overcoming significant institutional, regulatory and financial barriers, as technical upgrades alone are insufficient. Long-term success depends on integrated governance, meaning close coordination between multiple authorities and operators. For example, the Dutch Ministry of Infrastructure, NS, ProRail, Eurostar and German counterparts working together to align funding, staffing, timetables and cross-border procedures. Notably, the pessimistic scenario outperformed others, suggesting that even modest rail improvements can deliver strong outcomes under realistic assumptions. The most urgent policy actions involve resolving fragmented cross-border regulatory and staffing constraints on the Amsterdam-London route by ensuring sufficient customs and security personnel, clarifying funding responsibilities and streamlining procedures across countries.

The most economically feasible implementation strategy follows the pessimistic scenario. Under this approach, the Eurostar expansion adds one train in 2026 while the planned 2027 train is postponed and the Dual Service Model launches in 2032 with eight daily trains supported by four ICE L trainsets and platform upgrades at Deventer. Future research should refine cost modelling, simulate the effects of targeted policy interventions, incorporate behavioural dynamics to reflect gradual modal shift, explore high-impact infrastructure projects beyond 2030, improve data transparency, engage aviation stakeholders and analyse the distributional impacts of modal shift, meaning how the benefits and costs are shared across different groups (e.g., airport employees, local residents, rail passengers and airlines) to design inclusive and politically viable strategies.

# Table of Contents


**Acknowledgements** ........ i

**Executive Summary** ........ ii

**Table of Contents** ........ iv

**List of Abbreviations** ........ vi

**List of Tables** ........ vii

**List of Figures** ........ ix

**1. Introduction** ........ 1

1.1 Context and Relevance of the Problem ........ 1
1.2 Problem Definition and Research Questions ........ 1
1.3 Objectives and Scope ........ 2
1.4 Methodology Overview ........ 3
1.5 Relevance to Cosem ........ 3
1.6 Thesis Structure ........ 3

**2. Theoretical Background and Literature Review** ........ 4

2.1 Air-to-Rail Substitution and High-Speed Rail Integration ........ 4
2.2 Environmental and Economic Benefits ........ 4
2.3 Infrastructure and Investment Requirements ........ 5
2.4 Knowledge Gap and Research Questions ........ 5

**3. Methodology** ........ 6

3.1 Research Approach ........ 6
3.2 Sub-Questions and Corresponding Research Methods ........ 7
3.3 Data Collection Methods ........ 8
3.4 Data Analysis Methods ........ 10

**4. Feasible Alternatives for Improving Direct Rail Connections** ........ 12

4.1 Feasibility Criteria for Evaluating Rail Alternatives ........ 12
4.2 Existing Connections and Service Characteristics ........ 15
4.3 Feasible Project Alternatives ........ 18
4.4 Summary and Conclusion ........ 22

**5. Required Infrastructure and Operational Changes** ........ 24

5.1 Infrastructure and Operational Adjustments Needed for the Eurostar Expansion ........ 24
5.2 Infrastructure and Operational Adjustments Needed for the Dual Service Model ........ 27
5.3 KLM Air&Rail Model ........ 29
5.4 Summary and Conclusion ........ 31

**6. Institutional, Regulatory and Financial Barriers to Implementation** ........ 34

6.1 Analysis of Barriers per Project Alternative ........ 34
6.2 General Barriers ........ 37
6.3 Summary and Conclusion ........ 43

**7. Societal Impact Assessment of Alternatives to Short-Haul Flights** ........ 47

7.1 Preparatory Phase ........ 47
7.2 Step 4 and 5: Identification and Monetisation of Effects ........ 50
7.3 Step 6: Scenarios ........ 58

7.4 Step 7: Discounting and Calculation of SCBA Indicators ..... 62
7.5 Step 8: Results ..... 64
7.6 Sensitivity Analysis ..... 75
7.7 Summary and Conclusion ..... 79

**8. Conclusion and Recommendations ..... 82**

8.1 Summary of Research Objectives and Methodology ..... 82
8.2 Answering the Sub-Questions ..... 83
8.3 Answer to the Main Research Question ..... 87
8.4 Policy Recommendations and Way Forward ..... 88
8.5 Limitations and Reflection ..... 91
8.6 Future Research Directions ..... 92
8.7 Reflection on Societal Relevance ..... 93

**Declaration ..... 94**

**References ..... 95**

**Appendix ..... 104**

A. Literature Review Details ..... 104
B. Trainset Requirements ..... 106
C. Interview Transcripts ..... 109
D. Supporting Calculations SCBA ..... 126

# List of Abbreviations

SCBA — Social Cost-Benefit Analysis

HSR — High Speed Rail

Deutsche Bahn — DB

O&D — Origin-Destination

CDG — Charles de Gaulle

HSL — High-Speed Line

KMar — Koninklijke Marechaussee

EU — European Union

VAT — Value Added Tax

SAF — Sustainable Aviation Fuel

ASK — Available Seat Kilometres

PKM — Passenger-Kilometres

CAPEX — Capital Expenditures

NPV — Net Present Value

IRR — Internal Rate of Return

BCR — Benefit-Cost Ratio

PAX — Passengers

VOT — Value of Time

ROC — Rail Operating Costs

OE — Own Elasticities

CE — Cross Elasticities

DR — Discount Rate

# List of Tables

**Table 4-2:** Travel Time, Frequency and Transfers Required for Trips between Schiphol and the Six City Centres. ....16
**Table 4-3:** Travel time, Frequency and Transfers Required for Trips between Amsterdam and the Major Airports for the Six Destinations....17
**Table 4-4:** Train Punctuality at Departure and Arrival Stations....17
**Table 4-5:** Air Passenger Volumes between Amsterdam Schiphol and Six European Airports in 2023 ....18
**Table 4-6:** Flight Frequency and Duration for Amsterdam-Destination Routes....18
**Table 4-7:** Overview of Improvements in Proposed Rail Alternatives and Their Expected Implementation Years....23
**Table 5-1**: Eurostar Timetable for Amsterdam-London Route in 2025 (Local Times)....25
**Table 5-2:** Proposed Eurostar Timetable for Amsterdam - London Route in 2026 (Local Times) .25
**Table 5-3:** Current Intercity Timetable for Amsterdam-Berlin Route in 2025 ....28
**Table 5-4:** Proposed Intercity Timetable for Amsterdam-Berlin Route in 2030 ....28
**Table 5-5:** KLM Flight Schedule and Aircraft Capacity for the Schiphol-Brussels Airport Route..30
**Table 5-6:** KLM Flight Schedule and Aircraft Capacity for the Schiphol-Frankfurt Airport Route .30
**Table 5-7:** KLM Flight Schedule and Aircraft Capacity for the Schiphol-Paris CDG Airport Route30
**Table 5-8:** Comparison of KLM Flights and Rail Alternatives ....31
**Table 5-9:** Overview of Operational Requirement by Alternative and Year....32
**Table 7-1:** Total Travel Times for Amsterdam-London and Amsterdam-Berlin Air and Rail Connections ....58
**Table 7-2:** EUROCONTROL Air Traffic Growth Rates by Scenario and Period for the EU ....59
**Table 7-3:** Estimated Air Traffic Growth Rates for the Netherlands ....60
**Table 7-4:** Rail Passenger Growth Scenarios and Compound Annual Growth Rates 2024-2050.60
**Table 7-5:** Operational Metrics for Base Case by Route and Growth Scenario ....64
**Table 7-6:** Aggregate Operational Metrics for Base Case by Growth Scenario....65
**Table 7-7:** Operational Metrics for Eurostar Expansion by Growth and Policy Scenario ....66
**Table 7-8:** Financial Metrics for Eurostar Expansion by Growth and Policy Scenario ....66
**Table 7-9:** Operational Metrics for Dual Service Model by Growth and Policy Scenario ....68
**Table 7-10:** Financial Metrics for Dual Service Model by Growth and Policy Scenario....69
**Table 7-11:** Operational Metrics for Both Alternatives Implemented by Growth and Policy Scenario ....71
**Table 7-12:** Financial Metrics for Both Alternatives Implemented by Growth and Policy Scenario ....72
**Table 7-13:** Breakdown of Discounted Benefits by Alternative and Benefit Category ....74
**Table 7-14:** Breakdown of Discounted Costs by Alternative and Benefit Category....75
**Table 7-15:** Sensitivity Results for the Eurostar Expansion ....77
**Table 7-16:** Sensitivity Results for the Dual Service Model....77
**Table 7-17:** Sensitivity Results for the Both Alternatives Implemented ....78
**Table 7-18:** Overview of Operational Metrics across Alternatives for the Base Scenarios ....79
**Table 7-19:** Overview of Financial Metrics across alternatives for the Base and Pessimistic Scenarios....80
**Table A-1:** Overview of Selected Articles for Literature Review....104
**Table B-2:** Indicative Daily Deployment of Five Eurostar Trainsets on the Amsterdam-London Corridor Based on the Proposed 2026 Timetable ....106

**Table B-3:** Indicative Daily Deployment of Seven Intercity Trainsets on the Amsterdam-Berlin Corridor Based on the Current Timetable ........ 107
**Table B-4:** Indicative Daily Deployment of Thirteen Intercity Trainsets on the Amsterdam-Berlin Corridor under the Proposed Hourly Service ........ 108
**Table D-1:** Shares of SAF throughout the Years ........ 128

# List of Figures

**Figure 3-1:** Overview of the Three-Phase Sequential Research Design ........................................6
**Figure 4-1:** Proposed international Rail Alternatives between Amsterdam and the European Destinations.......................................................................................................................22
**Figure 7-1:** Cumulative Discounted Cash Flows of Eurostar Expansion across All Scenarios ....67
**Figure 7-2:** Cumulative Discounted Cash Flows of Dual Service Model across All Scenarios ....70
**Figure 7-3:** Cumulative Discounted Cash Flows of Both Alternatives Implemented across All Scenarios...........................................................................................................................73
**Figure 7-4:** Breakdown of Discounted Benefits by Alternative and Share ..................................74
**Figure 7-5:** Breakdown of Discounted Costs by Alternative and Share......................................75

# 1. Introduction

## 1.1 Context and Relevance of the Problem

Airports are being redefined as multimodal transport hubs, integrating different modes of transport to improve accessibility, efficiency and sustainability. However, most major European airports including Amsterdam Schiphol, still primarily focus on facilitating air-to-air transfers rather than enabling seamless transitions between air, rail and other transport modes (Boersma & Toet, 2024). As aviation faces growing environmental and capacity challenges, improving air-rail integration, which is known as the alignment of train and air travel in terms of scheduling, ticketing and infrastructure, has become a solution to ensure sustainable and efficient mobility.

At Schiphol, several developments are underway to strengthen this integration. Through the Multimodal Hub Schiphol project, the airport is upgrading its public transport facilities including rail, bus and metro connections, to improve accessibility, capacity and spatial quality (Schiphol, 2024b). In parallel, Schiphol is actively exploring alternatives to short-haul flights in order to reduce $CO_2$ emissions and optimize scarce aviation capacity. Research commissioned by Schiphol indicates that Dutch aviation must reduce its $CO_2$ emissions by at least 30 percent by 2030 to align with the Paris Agreement, far exceeding the national target of 9 percent (Schiphol, 2024a).

Projections by the Dutch Mobility Knowledge Institute estimate that between 5.600 and 16.000 flights could be replaced by rail by 2030, rising to between 11.000 and 23.000 by 2040 (Kennisinstituut voor Mobiliteitsbeleid, 2023). These replacements represent approximately 6% to 22% of all flights for Schiphol Airport on 13 European routes. While this represents a reduction of only 1% to 5% of Schiphol's total flights, the societal benefits in terms of emissions reductions, freed-up airport slots and improved connectivity could be significant.

Following this research, the Dutch Ministry of Infrastructure and Water Management, together with Schiphol, KLM, NS and ProRail, developed the *Actieagenda Trein en Luchtvaart* to focus efforts on six destinations within 700 km: Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin (Ministerie van Infrastructuur en Waterstaat, 2020). Together these accounted for about 14% of Schiphol's total flight movements before the COVID-19 pandemic. Replacing flights with trains on these routes could significantly reduce emissions, free up airport capacity and improve the efficiency of the Dutch transport network.

However, several challenges hinder the adoption of international rail as a viable alternative to air travel. While train travel times are already competitive for most destinations, other factors limit its attractiveness. Limited train frequency and connectivity particularly for transfer passengers, reduce its convenience compared to flights (Ministerie van Infrastructuur en Waterstaat, 2020). Gaps in early morning and late evening connections restrict travel flexibility, making rail a less viable option for time-sensitive journeys. Furthermore, operational and infrastructural constraints including station capacity, rail congestion and inefficiencies in cross-border ticketing and baggage handling create additional barriers to smooth integration between air and rail travel.

## 1.2 Problem Definition and Research Questions

Although the benefits of replacing short-haul flights with rail are clear, a significant number of flights could still be substituted by rail if existing international rail connections from Schiphol

Airport were improved. Building on the *Actieagenda Trein en Luchtvaart*, which targets six destinations: Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin, this study focuses specifically on these same routes. However, the development and improvement of improved services on these routes are hindered by various types of barriers.

This leads to the main research question:
***What barriers need to be addressed to improve direct international rail connections from Schiphol Airport to the six destinations identified in the Actieagenda Trein en Luchtvaart, and what are the societal costs and benefits of replacing short-haul flights with these improved rail connections?***

To answer this question four sub-questions are explored:
- **SQ1:** *What are feasible project alternatives for improving direct international rail connections between Schiphol and the six destinations?*
- **SQ2:** *What infrastructure investments and operational improvements are required to implement the proposed alternatives?*
- **SQ3:** *What institutional, regulatory and financial barriers affect the implementation of the proposed alternatives, and how can these barriers be addressed?*
- **SQ4:** *What are the expected environmental, economic and social impacts of implementing the proposed alternatives to replace short-haul flights, and how do these impacts compare to the associated implementation costs?*

Each sub-question addresses a distinct component of the main research question and builds towards a complete answer. **SQ1** identifies the feasible project alternatives for improving direct international rail connections, which defines the scope of what can realistically be implemented. **SQ2** examines the infrastructure investments and operational changes required for these alternatives, providing the technical and operational foundation for assessing feasibility. **SQ3** investigates the institutional, regulatory, and financial barriers to implementation and considers solutions, clarifying the practical constraints and drivers beyond the technical level. **SQ4** evaluates the expected environmental, economic and social impacts of replacing short-haul flights with improved rail connections, and compares these benefits to implementation costs, determining the overall societal value. Taken together, the sub-questions cover the technical feasibility, implementation challenges and societal outcomes necessary to fully address the main research question.

## 1.3 Objectives and Scope

The goal of this research is to evaluate how short-haul flights at Schiphol Airport can be replaced by improved direct international rail connections to Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin, and to assess the societal impacts of implementing these rail alternatives. The study aims to support climate goals, reduce airport congestion and strengthen multimodal accessibility to and from Schiphol.

This research has two main objectives:
- Identify and assess feasible alternatives for improving direct international rail services from Schiphol, including the infrastructure and operational requirements as well as the institutional, regulatory and financial factors affecting implementation.
- Evaluate the societal impacts of replacing short-haul flights with rail, through a structured and context-specific social cost-benefit analysis (SCBA).

The analysis focuses on realistic and planned improvements that can be implemented by 2030. The scope of the study is limited to Schiphol Airport and the six aforementioned destinations. Broader impacts on the wider European rail network, as well as longer-term developments, fall outside the scope of this research.

## 1.4 Methodology Overview

To answer the research questions a sequential exploratory mixed-methods design that integrates qualitative case study analysis with a SCBA is used. This method combines qualitative and quantitative techniques in which insights from expert interviews and document analysis are used to build a foundation and guide the SCBA.

The research is conducted in three phases:

- Phase 1 identifies feasible alternatives and explores barriers through expert interviews and document analysis
- Phase 2 quantifies the societal impacts of these alternatives using cost-benefit analysis
- Phase 3 synthesizes the findings and draws conclusions and recommendations

This approach ensures that the cost-benefit analysis reflects practical limitations and opportunities which increases the usefulness of the results for decision-makers.

## 1.5 Relevance to Cosem

The transition from short-haul flights to rail at Schiphol Airport aligns with the research objectives of the COSEM MSc program, which emphasizes systems engineering and the analysis of complex socio-technical systems. This study contributes to the transport and logistics domain by examining the sustainability and efficiency of multimodal transport integration. The technical dimension of the analysis focuses on identifying and assessing the infrastructure and operational requirements for implementing the proposed rail alternatives. The stakeholder and governance dimension examines the institutional, regulatory and financial factors that influence, enable or constrain implementation. By utilizing the SCBA method, an approach covered in the COSEM curriculum, this research addresses the program principles related to infrastructure evaluation and its broader societal implications. The SCBA will provide a structured interdisciplinary framework to assess the feasibility, trade-offs, and long-term effects of these investments, making it a relevant study within the COSEM MSc program.

## 1.6 Thesis Structure

The structure of this thesis is as follows. Chapter 2 presents the literature review and theoretical framework that support the research. Chapter 3 outlines the research methodology and data sources used throughout the study. Chapter 4 identifies and evaluates feasible project alternatives for improving direct international rail connections from Schiphol. Chapter 5 analyses the infrastructure investments and operational improvements required to implement these alternatives. Chapter 6 examines the institutional, regulatory and financial barriers that affect implementation. Chapter 7 presents a SCBA to assess the societal impacts of replacing short-haul flights with rail. Finally, Chapter 8 present the conclusions and recommendations.

# 2. Theoretical Background and Literature Review

This chapter reviews literature on air-to-rail substitution, multimodal transport hubs, SCBAs and infrastructure investments. The review examines studies assessing the feasibility, benefits and challenges of replacing short-haul flights with rail connections. By synthesizing operational, environmental and economic findings, this chapter identifies a knowledge gap that informs the research question. The following sections outline the core concepts in the literature and the specific challenges relevant to Schiphol Airport's transition into a multimodal hub. The search strategy and an overview table of all the selected literature can be found in Appendix A and Table A-1.

## 2.1 Air-to-Rail Substitution and High-Speed Rail Integration

Air-to-rail substitution involves replacing short-haul flights with rail services, typically facilitated by High-Speed Rail (HSR) networks offering competitive travel times. The European Commission's Flightpath2050 goal, aiming for 90% of intra-European trips to be completed within four hours, adds constraints to this transition (Reiter et al., 2022). The main drivers for this shift include reducing carbon emissions, reducing airport congestion and improving connectivity (Avogadro et al., 2021).

However, integrating air and rail networks poses challenges, as seen in Lufthansa Express Rail and Deutsche Bahn's (DB) Rail&Fly service, which struggles to maintain competitive travel times, reliability and cost efficiency (Wandelt & Sun, 2022). Moreover, Liu et al. (2019) show that HSR connectivity affects airport traffic unevenly, benefiting hub airports while negatively impacting non-hub airports. At major airports, air-HSR linkage can strengthen international connectivity, potentially increasing traffic. Targeted investments in air-HSR integration at regional airports could reduce congestion at major hubs like Schiphol.

## 2.2 Environmental and Economic Benefits

Air-to-rail substitution has significant environmental benefits, particularly in reducing $CO_2$ emissions. Studies estimate that replacing short-haul flights with rail could reduce emissions by up to 56,8%, depending on route characteristics and passenger willingness (Rajendran & Popfinger, 2022). However, reducing short-haul flights could alleviate airport congestion increasing capacity for long-haul routes which could increase emissions from aviation (Avenali et al., 2024).

Despite the environmental benefits challenges exist. Weak mode substitution or low delay costs may increase hub traffic instead of alleviating it (Reiter et al., 2022). Rail substitution could also harm airlines, particularly low-cost carriers that rely on short-haul routes for profitability. Additionally, HSR can increase travel times for business travellers, outweighing the environmental benefits. Zhang et al. (2019) show that while HSR can reduce traffic at smaller airports, it could make regional disparities worse. The impact of HSR on emissions remains uncertain and requires further analysis. Branković & Kalem (2021) emphasize that despite high infrastructure costs, HSR offers significant economic and social benefits, including reduced congestion and a lower environmental impact.

## 2.3 Infrastructure and Investment Requirements

A challenge in substituting short-haul flights with rail is the adequacy of existing rail infrastructure. Studies indicate that current rail capacity is insufficient to fully support the transition without substantial investment (Rajendran & Popfinger, 2022). A phased approach to capacity expansion, aligning upgrades with demand growth avoids operational inefficiencies (Lu et al., 2024).

Branković & Kalem (2021) note that Europe lacks a unified HSR network, with varying operational models across member states. This fragmentation complicates efforts to develop an integrated HSR system. Delays, disruptions and intermodal inefficiencies remain significant barriers, as seen in Frankfurt Airport's air-rail integration (Wandelt & Sun, 2022). Significant infrastructure investments are required for successful air-to-rail substitution (Avogadro et al., 2021). SCBAs suggest that while HSR investments offer long-term benefits, the high capital costs and uncertain demand pose challenges (Adler et al., 2010). Upgrading Trans-European Networks could justify the investment, but economic feasibility depends on passenger demand, pricing and competition (Zhang et al., 2019).

## 2.4 Knowledge Gap and Research Questions

While research explores the environmental and economic impacts of air-to-rail substitution, few SCBAs have been conducted on this topic in general. Most existing studies focus on broader European contexts or specific countries, such as Germany and France often considering domestic flights, while detailed analyses on the implementation of air-to-rail substitution are scarce. The literature review therefore indicates that, internationally, there is limited empirical evidence on the feasibility, barriers and societal costs and benefits of replacing short-haul flights with rail services.

The Dutch context is particularly interesting because Schiphol is well-positioned for such a transition: the distances to major European destinations are relatively short, international rail infrastructure is reasonably developed and there is potential for multimodal integration. This makes Schiphol a relevant case to explore the practical implementation of air-to-rail substitution.

There is a clear knowledge gap regarding:

- Feasible alternatives for improving direct rail connections between Schiphol and the six destinations
- The barriers to implementing these alternatives and how they can be addressed
- The societal costs and benefits of reducing short-haul flights through these rail services

This research aims to address these gaps and to answer the following main question:
***What barriers need to be addressed to improve direct international rail connections from Schiphol Airport to the six destinations identified in the Actieagenda Trein en Luchtvaart, and what are the societal costs and benefits of replacing short-haul flights with these improved rail connections?***

Existing studies highlight air-to-rail substitution's benefits and challenges but leave questions on Schiphol's implementation unanswered. By examining feasible alternatives, barriers and societal costs and benefits, this research aims to provide insights into the process of Schiphol's transition into a multimodal transport hub and the societal costs and benefits of this transition.

# 3. Methodology

This chapter outlines the methodological approach used to answer the main research question. It is structured as follows: Section 3.1 outlines the research design and rationale behind the mixed-methods approach. Section 3.2 explains how each sub-question is methodologically addressed. Section 3.3 describes the data collection process consisting of document analysis, expert interviews and the collection of secondary statistical data. Section 3.4 details the data analysis procedures for both the qualitative and quantitative phases.

## 3.1 Research Approach

To address the main research question, this study employs a sequential exploratory mixed-methods design that integrates qualitative case study analysis with a SCBA.

This combined approach is well-suited to fulfil the dual objectives of the research:

- Identify and assess feasible alternatives for improving direct international rail services from Schiphol, including the infrastructure and operational requirements as well as the institutional, regulatory and financial factors affecting implementation.
- Evaluate the societal impacts of replacing short-haul flights with rail, through a structured and context-specific SCBA.

The study begins by identifying feasible alternatives for improving direct rail connections between Schiphol and the six destinations through document analysis and expert interviews. It then identifies infrastructure needs, operational changes and barriers using the same methods, followed by quantifying the societal costs and benefits. This combined approach supports a thorough analysis of the feasible alternatives and their societal impacts (Sharma et al., 2023).

As shown in Figure 3-1, the study follows three phases: Phase 1 involves a qualitative case study to identify feasible rail alternatives and assess infrastructure needs, operational changes and barriers. Phase 2 uses these findings to conduct an SCBA, defining input variables, parameters and scenarios for economic assessment. Phase 3 synthesizes both qualitative and quantitative insights to produce a contextualized evaluation grounded in real-world conditions (Taherdoost, 2022).

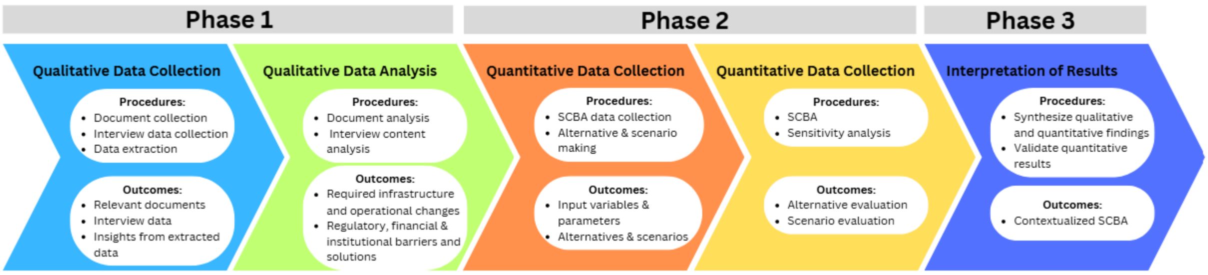


**Figure 3-1:** Overview of the Three-Phase Sequential Research Design

While this sequential exploratory case study design strengthens the validity and practical applicability of the findings, it also presents methodological challenges. The integration of qualitative and quantitative methods requires careful alignment of data sources and assumptions. Additionally, the focus on Schiphol Airport and the six destinations limits the generalizability of the results to other airports or transport hubs with different conditions.

Despite these challenges, this research contributes valuable insights into the feasibility and societal impact of shifting from short-haul flights to direct rail connections and identifies important barriers to implementation.

## 3.2 Sub-Questions and Corresponding Research Methods

This study addresses four sub-questions, focusing on: (1) feasible project alternatives for improving direct international rail connections from Schiphol, (2) required infrastructure and operational improvements, (3) institutional, regulatory and financial barriers, and (4) societal costs and benefits of substituting short-haul flights with rail. In this section, the research methods used to evaluate each sub-question are described.

### 3.2.1 Identifying Feasible Alternatives

**SQ1:** *What are feasible project alternatives for improving direct international rail connections between Schiphol and the six destinations?*

This sub-question will primarily be addressed through document analysis of existing infrastructure plans, policy reports and service development proposals from rail operators, infrastructure managers and government agencies. These sources provide insight into the planned and possible measures to improve international rail services, including new rolling stock, timetable changes, upgraded infrastructure and improved integration with Schiphol Airport. In addition, expert interviews will be conducted to complement the selected alternatives.

This sub-question provides the foundation for the remainder of the study by identifying realistic and relevant alternatives to improve international rail connectivity from Schiphol. These alternatives form the basis for further analysis of infrastructure and operational requirements (SQ2), implementation barriers (SQ3) and societal costs and benefits (SQ4). The selection of alternatives is guided by clearly defined feasibility criteria based on literature, which are presented in Section 4.1.

### 3.2.2 Assessing Infrastructure and Operational Requirements

**SQ2:** *What infrastructure investments and operational improvements are required to implement the proposed alternatives?*

This sub-question will be addressed through a combination of document analysis and expert interviews. The document analysis will use infrastructure plans, policy documents, industry reports and relevant news articles to identify the needed infrastructure and operational changes. In addition, expert interviews will be used to supplement the document analysis by identifying operational and infrastructural changes not explicitly addressed in existing plans.

This sub-question contributes to the main research objective by clarifying what physical infrastructure and operational measures are necessary to improve the international rail services. It also helps to operationalize the project alternatives so they can be systematically evaluated for societal costs and benefits in SQ4.

### 3.2.3 Analysing Institutional, Regulatory and Financial Barriers

**SQ3:** *What institutional, regulatory and financial barriers affect the implementation of the proposed alternatives, and how can these barriers be addressed?*

This question will be addressed through a document analysis including policy frameworks, regulatory requirements and relevant news articles. News articles will provide current insights into challenges, stakeholder positions and ongoing debates surrounding rail infrastructure projects and regulatory developments. To complement this, expert interviews will be conducted to help identify additional institutional, regulatory and financial barriers not fully documented in existing literature and determine solutions for overcoming these challenges.

This question helps to answer the main research question by examining the non-technical obstacles of the alternatives, contextualizing them for evaluation in SQ4 and supporting the development of different policy scenarios to assess feasibility and societal impact.

### 3.2.4 Evaluating Societal Costs and Benefits

**SQ4:** *What are the expected environmental, economic and social impacts of implementing the proposed alternatives to replace short-haul flights, and how do these impacts compare to the associated implementation costs?*

This assessment captures the full range of direct and indirect impacts of the transition. Given Schiphol Airport's established use of the SCBA framework, this methodology is well-suited to evaluate these effects (Schiphol, 2024c). The SCBA will make use of secondary statistical data, and systematically quantify environmental benefits, economic effects and social consequences.

As a legally mandated framework for large-scale infrastructure projects in the Netherlands, SCBA provides a transparent and accountable evaluation of all relevant costs and benefits. Schiphol, being majority-owned by the Dutch state (69,77%) (Schiphol, n.d.-c), is subject to these government requirements (Ministerie van Algemene Zaken, n.d.). Using the SCBA as the evaluation method aligns the study with Schiphol's sustainability objectives and the Dutch government's legal framework.

The SCBA will offer a detailed evaluation of the trade-offs involved in substituting short-haul flights with direct rail services, providing insights into the feasibility, societal benefits, and costs of this transition, and represents the outcome of the project alternatives identified in SQ1, operationalized in SQ2 and contextualized in SQ3.

## 3.3 Data Collection Methods

This study uses three different data collection methods: document analysis, expert interviews and collection of secondary statistical data to ensure that all relevant data needed to answer each of the sub-research questions and the main research question is collected. The following subsections will explain how the data was collected using the different methods.

### 3.3.1 Document Analysis

Document analysis is the most used data collection method in this study, which will provide a foundation of detailed information from existing written sources. The data from this method is used for answering sub-questions 1, 2 and 3, as well as gathering relevant data for sub-question 4. The data collection process involves systematically identifying, selecting and reviewing a wide range of documents related to the international rail connections between Schiphol Airport and the six destinations, in addition to the substitution of short-haul flights by rail.

Initially, sources are identified through targeted searches on official government portals, railway operators' websites, international transport organizations and railway news sites. These sources include infrastructure plans, policy documents, service development proposals, national and European transport master plans, capacity assessments and a wide variety of news articles.

Secondly, the selected documents are examined to extract detailed information that can directly help answer the sub-questions. This includes technical specifications, project timelines, capacity forecasts and barriers to implementation. In addition, reports from environmental agencies and socio-economic studies are reviewed to gather data on the expected impacts of substituting short-haul flights with rail alternatives, such as $CO_2$ reductions, economic benefits and social outcomes.

### 3.3.2 Semi-Structured Expert Interviews

Expert interviews complement the document analysis by providing qualitative, practical insights from professionals directly involved in the transition from air to rail. These interviews specifically address sub-questions 1, 2 and 3, helping to refine the project alternatives, identify required changes and clarify barriers that may not be fully captured in documents. Experts were selected based on their direct knowledge, experience and influence in national and European rail and aviation policy.

The sample included:

- **A representative from the Rover passenger association**, who also serves on the board of the European Passengers' Federation. In this capacity, the expert is actively involved in national and European discussions on international rail services, sustainable mobility and alternatives to short-haul flights, and participates in stakeholder consultations related to Amsterdam Airport Schiphol. This perspective ensures that the study captures passenger needs, preferences and likely responses to rail alternatives.
- **A senior policy officer in aviation economics** and **an expert from the Directorate for Public Transport and Rail at the Ministry of Infrastructure and Water Management**, both of whom are involved in national policy development related to international rail services and aviation. Their expertise provides insight into institutional, regulatory and financial frameworks affecting implementation.
- **A Coordinating Policy Officer for Public Transport and Rail at the Ministry of Infrastructure and Water Management**, specifically responsible for the Amsterdam-Berlin rail corridor and involved in developing national policy for international rail services. This ensures the study incorporates detailed operational and corridor-level knowledge.

Including both passenger advocacy and governmental perspectives allows the study to cover the main stakeholder groups influencing project feasibility, operational planning and policy implementation. Semi-structured interviews were conducted to allow flexibility while maintaining focus on five dimensions: infrastructure, operational, institutional, regulatory and financial aspects across the different project alternatives. Interview questions were designed to identify constraints that may not be fully documented in existing literature.

All interviews were audio-recorded and transcribed. The transcripts were then reviewed to extract relevant insights, which are integrated throughout the thesis to improve understanding of project feasibility and potential implementation obstacles. In addition to informing the qualitative analysis, several experts also provided comments on the assumptions used in the calculations and on the interpretation of the results of the SCBA, which helped refine and validate the quantitative components of the study. The full interview transcripts are available in Appendix C.

### 3.3.3 Secondary Statistical Data Collection

Secondary statistical data were collected to provide the quantitative basis for assessing the societal impacts to address sub-question 4. The collection process involved identifying and obtaining relevant data from authoritative sources such as railway operators, infrastructure managers and official transport databases.

Variables collected included train frequencies, travel times, capacity utilization rates and scheduling details. These data were gathered through desk research from international roadmaps, plans and studies. Once collected, the data were organized and adjusted where necessary to ensure consistency and comparability across different routes and time periods.

The processed statistical data were then integrated into the SCBA. This involved quantifying and monetizing environmental impacts, economic outcomes and social effects. The SCBA also incorporated investment and operational cost data identified via document analysis and expert interviews.

### 3.3.4 Validity Considerations

To ensure the validity of the data, four criteria were applied. First, authenticity was safeguarded by sourcing documents from credible and reliable institutions such as government agencies, railway operators and international transport organizations, as well as conducting interviews with experts who have direct experience in railway operations, infrastructure planning and transport policy. Credibility was assessed by evaluating both the objectivity and expertise of document authors and interview participants to minimize bias and gain relevant insights. Representativeness was considered by selecting sources and interviewees that reflect industry-wide trends and best practices rather than isolated cases. Finally, meaning was analysed to confirm that both document content and expert insights are clear, relevant and detailed, making them directly applicable to the study's objectives (Morgan, 2022). This has resulted in data collection that is grounded in reliable sources and improves the validity and relevance of the findings.

## 3.4 Data Analysis Methods

After data collection, the data was systematically analysed using a combination of qualitative and quantitative methods to address the sub-research questions and the main research question.

### 3.4.1 Qualitative Analysis

The qualitative data will be analysed through manual thematic analysis. This process begins with repeated close reading of all collected materials to identify themes and recurring patterns.

These themes will then be organized to gain insights about the proposed alternatives. The findings from the document analysis will be cross-referenced with those from the expert interviews to identify points of convergence or discrepancy. The thematic analysis will follow best practices outlined by Braun and Clarke (2006), to ensure transparency and reliability.

### 3.4.2 Quantitative Analysis

For the quantitative analysis, a SCBA will be used to evaluate the societal advantages and disadvantages of substituting short-haul flights with international rail services. The analysis will quantify and monetize impacts to assess the financial implications of infrastructure and operational changes. A sensitivity analysis will be conducted to explore how different assumptions influence the outcomes. However, SCBA is subject to several limitations. Monetizing non-market impacts such as passenger convenience and the long-term resilience of rail investments can be difficult and some qualitative benefits may not be fully reflected in the model. Furthermore, SCBA tends to prioritize economic efficiency, which may lead to underrepresentation of equity-related concerns. These limitations will be clearly acknowledged during interpretation and findings will be considered with an awareness of distributional effects and inherent uncertainties (Hansjürgens, 2004).

# 4. Feasible Alternatives for Improving Direct Rail Connections

This chapter answers sub-question 1, which explores feasible project alternatives for improving direct international rail connections between Schiphol Airport and the six European destinations.

**SQ1:** *What are feasible project alternatives for improving direct international rail connections between Schiphol and the six destinations?*

To answer this question, potential alternatives are evaluated using a set of feasibility criteria derived from the literature. These criteria are specifically designed to account for the distinct travel needs of both origin-destination (O&D) passengers and transfer passengers. Once the criteria are established, existing air and rail connections are mapped and assessed.

The analysis begins with an exploration of current rail connections for each of the six routes. These connections are examined across three travel categories: for travel from Amsterdam to the destination city centres (O&D passengers), from Schiphol Airport to destination city centres and from Amsterdam to the destination airports (both last two relevant for transfer passengers). This categorization is used because it reflects the three main passenger flows affected by a shift from short-haul air to rail: local market demand (point-to-point trips between city centres) and hub-to-hub connectivity for transfer passengers (efficient links from airports to either the city centre or another airport), both of which are essential for assessing the feasibility and appeal of rail as an alternative.

Following this, the existing air connections are analysed using data on passenger volumes, flight frequencies and average flight durations. These figures provide insight into which routes have the highest potential for modal shift from air to rail. Afterwards, the analysis explores whether there is room for improving rail services on each route and examines existing infrastructure or service improvement plans proposed.

The objective is to identify realistic improved rail-based alternatives that can substitute short-haul flights between Schiphol and the six European airports: Brussels, Paris Charles de Gaulle (CDG), London Heathrow, Düsseldorf, Frankfurt and Berlin. For London and Paris, Heathrow and CDG have been selected as they are the largest airports in their respective cities and hubs for intercontinental connections.

## 4.1 Feasibility Criteria for Evaluating Rail Alternatives

The criteria for O&D passengers are based on the *Actieagenda Trein en Luchtvaart* (Ministry of Infrastructure and Water Management, 2020), which evaluates the potential of international rail to substitute air travel from a passenger experience and network readiness perspective. In contrast, the criteria for transfer passengers are derived from a study by Bruinsma (2023), which focuses specifically on the conditions necessary for successful Air-Rail integration.

This distinction ensures that rail alternatives are evaluated fairly and realistically, a solution suitable for O&D passengers may not work for transfer passengers and vice versa.

### 4.1.1 Criteria for Origin-Destination Passengers

To determine whether a project alternative is feasible for O&D passengers, it must improve at least one of the following three performance metrics: travel time, frequency or capacity, while being realistic to implement within the existing or planned rail infrastructure.

These criteria are based on the conclusions of the *Actieagenda Trein en Luchtvaart* (Ministry of Infrastructure and Water Management, 2020), which identifies travel time, frequency and comfort as the most important factors in making international rail more attractive for O&D passengers. While comfort is a major concern, this analysis uses capacity as a practical and quantifiable proxy. Increased capacity helps reduce crowding and ensures greater seat availability, thereby improving the overall passenger experience in a way that is operationally measurable and relevant for infrastructure and service planning.

The three core criteria are defined as follows:

- **Travel Time**
  The alternative should offer a shorter end-to-end journey time compared to existing rail services between Amsterdam and the destination.
- **Frequency**
  The alternative should increase the number of daily direct train departures between Amsterdam and the destination, improving flexibility and convenience for passengers.
- **Capacity**
  The alternative should improve seat availability on the route. This helps reduce crowding and indirectly improves passenger comfort.

In addition to improving one or more of these performance indicators, each alternative must meet two baseline feasibility conditions to ensure it is realistically implementable in the short to medium term. These conditions are also derived from the *Actieagenda Trein en Luchtvaart* (Ministry of Infrastructure and Water Management, 2020), which emphasizes operational compatibility and manageable infrastructure requirements as the key to practical implementation:

- **Rail Network Compatibility**
  The proposed service must be operationally compatible with the current European rail network. Minor timetable adjustments or rerouting are acceptable, but alternatives that require major network changes (e.g. new lines or terminals) are excluded from this analysis.
- **Infrastructure and Operational Readiness**
  Alternatives must be achievable with limited upgrades to tracks, stations, platforms, or rolling stock. Projects requiring long-term construction efforts or large-scale capital investments are considered beyond the scope of this study.

#### 4.1.1.1 Feasibility Assessment Approach for Origin-Destination Passengers

This study considers a project alternative feasible for O&D passengers if it improves at least one of the three key performance metrics, while satisfying baseline feasibility conditions. Alternatives that do not meet these requirements are excluded from further consideration.

The feasibility judgments combine these criteria with an analysis of existing infrastructure, current service levels and planned upgrades or investments described later in the chapter. Improvements are assessed using available data on scheduled travel times, planned frequency increases and expected capacity expansions.

### 4.1.2 Criteria for Transfer Passengers

For intercontinental transfer passengers, rail can only function as a viable substitute for short-haul feeder flights if seamless Air-Rail integration is achieved. This group is highly sensitive to transfer time, delay risks and overall journey predictability. Therefore, the rail segment must be embedded into the air travel chain in such a way that it offers comparable levels of convenience, reliability and integration as a connecting flight. According to Bruinsma (2023), five specific conditions must be fulfilled to achieve this level of integration.

To meet the needs of this segment, five essential criteria must be fulfilled:

- **Direct HSR Service to the Airport**
  The train must stop directly at the airport eliminating the need for additional metro or shuttle transfers. This ensures minimal access time and maximum convenience.
- **IT System Integration**
  Airline and railway IT systems must be able to communicate, supporting single-ticket bookings, through check-in and real-time passenger tracking. This allows passengers to receive a single boarding pass and for airlines to proactively manage disruptions. A lack of IT integration hinders service reliability and passenger confidence.
- **Timetable Coordination**
  Train timetables must be aligned with major intercontinental flight arrival and departure times, including early-morning and late-evening slots. Poor alignment, such as limited early or late train services, undermines the competitiveness of rail for transfer passengers.
- **Fast Terminal Transfers**
  Efficient transfers from train platform to gate are important for smooth Air-Rail connections. While KLM prefers a direct airside route, this is costly and complex at Schiphol due to underground platforms. Priority lanes are an alternative but have eligibility issues. Convenient transfers improve the passenger experience but are not essential for Air-Rail success (Bruinsma, 2023).
- **Integrated Baggage Handling**
  Seamless baggage transfer between air and rail requires on-board compartments or efficient terminal systems. Space constraints and weak business cases make this challenging, and some operators note that successful German Air-Rail services operate without integrated baggage handling (Bruinsma, 2023).

While full implementation of all criteria is ideal for complete Air-Rail integration, IT system integration, timetable coordination and direct airport service are the essential criteria for transfer passengers. Fast terminal transfers and integrated baggage handling, though highly desirable, remain ideal conditions that may not be strictly required for a feasible and functional Air-Rail product.

#### 4.1.2.1 Feasibility Assessment Approach for Transfer Passengers

A project alternative is considered feasible for transfer passengers if it meets the three essential criteria: direct rail service to the airport, IT system integration and timetable coordination with intercontinental flights. These criteria support Air-Rail integration for transfer passengers.

Fast terminal transfers and integrated baggage handling are ideal but not mandatory, as successful Air-Rail products exist without them (Bruinsma, 2023). Alternatives lacking any of the three core criteria are excluded due to the high sensitivity of transfer passengers to delays and connection risks.

To further assess feasibility, punctuality of relevant routes will be examined. Transfer passengers depend on trains running reliably and on time to avoid missed flight connections. The High-Speed Line (HSL) threshold was chosen because it represents a strict punctuality standard for important intercity and international services in the Netherlands. According to (NS, n.d.), the minimum acceptable punctuality threshold for the HSL in 2024 is 82,1%. Routes with punctuality rates below this level are unlikely to provide the reliability required for transfer passengers and are excluded from the analysis.

## 4.2 Existing Connections and Service Characteristics

Now that the feasibility criteria and assessment approach are known, this section provides an overview of the current rail and air connections between Amsterdam, Schiphol and the six European destinations. The section is divided into two parts: existing rail connections and air travel data. The first examines current rail services, focusing on travel time, frequency, punctuality for transfer routes and required transfers between Amsterdam, Schiphol and the destinations. The second outlines flight frequencies, durations and passenger volumes. Together, these subsections offer an overview of current travel options, forming the basis for evaluating potential rail alternatives to short-haul flights.

### 4.2.1 Existing Rail Connections

Since travel patterns differ between O&D passengers and transfer passengers, different routes must be examined for each group.

The analysis is structured into three tables, each representing a distinct passenger flow:

- **Table 4-1:** centre to city centre (O&D passengers)
- **Table 4-2:** Schiphol to city centres (transfer passengers)
- **Table 4-3:** Amsterdam to airports in destination cities (transfer passengers)

#### 4.2.1.1 Amsterdam City Centre to City Centre Connections

Amsterdam has direct rail connections to all six city centres. Brussels is served by Eurocity Direct (16x/day, 2h08m) and Eurostar (14x/day, 1h56m), offering a combined 30 daily services and an average journey time of 2h02m (NS International, n.d.-a, NS International, n.d.-b). Eurostar also operates 10 daily trains to Paris (3h25m) and 3 to London (4h17m) (NS International, n.d.-b, NS International, n.d.-c, De Reus, 2025).

Germany is served by ICE International and InterCity Berlin. Düsseldorf (2h14m) and Frankfurt (3h53m) are served 7 times daily as part of the same ICE service (Nederlandse Spoorwegen, 2024a, NS International, n.d.-d). Berlin is reached 5 times per day via InterCity Berlin, with a journey time of 5h51m (ANWB, n.d., NS International, n.d.-e). An overview of travel time, daily frequency and transfers for each city pair is presented in Table 4-1.

**Table 4-1:** Travel Time, Frequency and Transfers Required for Trips between Amsterdam and the Six City Centres.

| Destination | Travel time | Daily frequency | Transfers |
|---|---|---|---|
| Brussels | 2h2m | 30 | 0 |
| Paris | 3h25m | 10 | 0 |
| London | 4h17m | 3 | 0 |
| Düsseldorf | 2h14m | 7 | 0 |
| Frankfurt | 3h53m | 7 | 0 |
| Berlin | 5h51m | 5 | 0 |

Table 4-1 shows that Amsterdam has frequent and fully direct rail services to all six city centres, with no transfers required. Brussels and Paris are especially well-connected, with high service frequency and competitive travel times. London is served less frequently and at longer durations. Connections to German cities are less frequent and the travel time to Berlin is significantly longer compared to other routes, which could reduce the competitiveness of rail for long-distance O&D passengers.

#### 4.2.1.2 Schiphol to City Centre Connections

Schiphol has direct or one-transfer rail connections to all six city centres. Brussels is served by Eurocity Direct (16x/day, 2h00m) and Eurostar (14x/day, 1h39m), totalling 30 daily services with an average journey time of 1h50m (NS International, n.d.-a, NS International, n.d.-b). Eurostar runs 10 daily trains to Paris (3h08m) (NS International, n.d.-b). London requires a transfer in Brussels, with a total journey time of 4h24m, served 3 times daily (NS International, n.d.-c, De Reus, 2025).

To Germany, Düsseldorf (2h30m) and Frankfurt (4h13m) are reached with a transfer in Utrecht, both operated by ICE International (Nederlandse Spoorwegen, 2024a, NS International, n.d.-d, NS International, n.d.-f). Berlin requires a transfer at Hilversum, with a total travel time of 6h12m (ANWB, n.d., NS International, n.d.-e). Table 4-2 provides a summary of the travel times, frequencies and required transfers for connections between Schiphol and the six city centres.

**Table 4-2:** Travel Time, Frequency and Transfers Required for Trips between Schiphol and the Six City Centres.

| Destination | Travel time | Daily frequency | Transfers |
|---|---|---|---|
| Brussels | 1h50m | 30 | 0 |
| Paris | 3h08m | 10 | 0 |
| London | 4h24m | 3 | 1 |
| Düsseldorf | 2h30m | 7 | 1 |
| Frankfurt | 4h13m | 7 | 1 |
| Berlin | 6h12m | 5 | 1 |

Schiphol has good rail access to several city centres, particularly Brussels and Paris, which are directly connected and served at high frequencies. However, all connections to Germany and London require at least one transfer, reducing convenience for transfer passengers. Travel times from Schiphol to Brussels and Paris are slightly shorter than from Amsterdam Centraal, as Schiphol is located south of Amsterdam and therefore closer to the Belgian border.

#### 4.2.1.3 Amsterdam to Other Airport Connections

Amsterdam has direct or one-transfer rail connections to all six major airports. Brussels Airport is reachable via Eurocity Direct (16x/day, 2h25m via Rotterdam) and Eurostar (14x/day, 2h04m via Antwerp), for an average travel time of 2h15m (NS International, n.d.-h). Paris CDG is served directly by Eurostar only on Fridays to Mondays, with 2 daily services taking 3h31m (NS International, n.d.-i, Omio, n.d.). London Heathrow is accessed via Eurostar to London St. Pancras (4h17m), then Piccadilly Line (1h direct) or Heathrow Express (45m with transfer), totalling ~5h17m (Heathrow Airport, n.d.).

For Düsseldorf Airport, passengers take ICE to Düsseldorf Hbf (2h14m), then S-Bahn (12m, same ticket) or SkyTrain (6m, separate ticket), for a total of 2h26m (NS International, n.d.-i). Frankfurt Airport is served directly by ICE International, with a total journey time of 3h38m (NS International, n.d.-k). Berlin Brandenburg requires a transfer at Berlin Hbf, totalling 6h21m (Berlin Airport, n.d., VBB, n.d.). Details on travel time, service frequency and transfer requirements for routes to major airports are shown in Table 4-3.

**Table 4-3:** Travel time, Frequency and Transfers Required for Trips between Amsterdam and the Major Airports for the Six Destinations

| Destination | Travel Time | Daily Frequency | Transfers |
|---|---|---|---|
| Brussels Airport | 2h15m | 30 | 1 |
| Paris CDG Airport | 3h31m | 2 (Fri-Mon) | 0 |
| London Heathrow Airport | 5h17m | 3 | 1 |
| Düsseldorf Airport | 2h26m | 7 | 1 |
| Frankfurt Airport | 3h38m | 7 | 0 |
| Berlin Brandenburg Airport | 6h21m | 5 | 1 |

While all six major airports are reachable by rail from Amsterdam, only Frankfurt Airport and Paris CDG are served by direct high-speed trains. However, the direct Eurostar service to Paris CDG operates only from Friday to Monday and just twice per day, which is far less frequent than the Amsterdam-Paris city centre connection. This limits its usefulness for transfer passengers. All other airport connections require at least one transfer, reducing convenience and increasing travel times.

#### 4.2.1.4 Punctuality of Transfer Routes

As shown in Sections 4.2.1.2 and 4.2.1.3, only a limited number of routes offer direct rail connections to or from airports which is one of the core criteria identified in Section 4.1.2. These include Schiphol-Brussels, Schiphol-Paris, Amsterdam-Paris CDG Airport and Amsterdam-Frankfurt Airport. The punctuality of these routes is examined below in Table 4-4.

**Table 4-4:** Train Punctuality at Departure and Arrival Stations

| Route | Departure Punctuality | Arrival Punctuality |
|---|---|---|
| Schiphol-Brussels (Eurocity Direct) | 72% | 78% |
| Schiphol-Brussels (Eurostar) | 87% | 88% |
| Schiphol-Paris | 86% | 93% |
| Amsterdam-Paris CDG Airport | Data Unavailable | Data Unavailable |
| Amsterdam-Frankfurt Airport | 94% | 92% |

For each route, punctuality has been measured separately for the departure and arrival stations over a two-month period. Punctuality is defined as the percentage of trains that departed or arrived with less than five minutes of delay. A higher percentage indicates a more reliable service. All data was sourced from Rijden de Treinen (n.d.) and percentages are rounded.

Punctuality data for the Amsterdam-Paris CDG route is currently unavailable due to the limited and infrequent service on this connection. Since this route operates only a few times per week, detailed punctuality statistics are not published. Although punctuality cannot be directly assessed, the low service frequency alone suggests that this route is likely less suitable for transfer passengers compared to more frequent alternatives. This issue will be examined in greater detail in Section 5.3.1.

Overall, punctuality rates vary between routes and operators. The Amsterdam-Frankfurt route demonstrates the highest reliability, with punctuality consistently above 90% at both departure and arrival stations. On the Schiphol-Brussels route, the two operators show noticeable differences in punctuality, with Eurostar performing significantly better than Eurocity Direct. For transfer passengers, these differences are key, as even small delays can lead to missed flight connections. While most routes show relatively high punctuality, indicating that rail travel can be a dependable alternative for transfers, the variability between operators and routes must be taken into account when assessing suitability. Specifically, the Eurocity Direct service on the

Schiphol-Brussels route, with punctuality rates of 72% at departure and 78% at arrival, falls well below the required reliability threshold of 82,1% established in 4.1.2. Consequently, Eurocity Direct will not be considered a suitable option for transfer passengers in further analysis.

### 4.2.2 Air Travel Data

This subsection presents data on passenger volumes, flight frequencies and average flight durations for the six European destinations. These figures identify routes with the highest potential for rail substitution.

The 2023 air passenger data sourced from CBS (2024) and FlightConnections (n.d.) include total passenger volumes as well as arrivals and departures to and from the Netherlands. This breakdown provides a clearer understanding of demand distribution across international routes. These air traffic patterns are summarised in Table 4-5 and Table 4-6.

**Table 4-5:** Air Passenger Volumes between Amsterdam Schiphol and Six European Airports in 2023

| Destination | Total Passengers | Arriving | Departing |
|---|---|---|---|
| Brussels Airport | 192.586 | 106.970 | 85.616 |
| Paris CDG Airport | 1.098.389 | 548.550 | 549.839 |
| London Heathrow Airport | 1.385.669 | 693.279 | 692.390 |
| Düsseldorf Airport | 213.832 | 109.300 | 104.532 |
| Frankfurt Airport | 646.045 | 320.828 | 325.217 |
| Berlin Brandenburg Airport | 814.549 | 408.655 | 405.894 |

**Table 4-6:** Flight Frequency and Duration for Amsterdam-Destination Routes

| Destination | Weekly Arriving Flights | Weekly Departing Flights | Average Flight Duration |
|---|---|---|---|
| Brussels Airport | 27 | 25 | 45m |
| Paris CDG Airport | 73 | 74 | 1h10m |
| London Heathrow Airport | 98 | 98 | 1h20m |
| Düsseldorf Airport | 32 | 32 | 45m |
| Frankfurt Airport | 76 | 77 | 1h5m |
| Berlin Brandenburg Airport | 51 | 50 | 1h20m |

These figures reveal that London, Paris and Berlin are the most heavily travelled air corridors from Schiphol, both in terms of passenger numbers and weekly flight frequencies. These routes are prime candidates for rail substitution, especially if rail services can match or exceed the overall journey time competitiveness and scheduling flexibility offered by air travel. In contrast, routes like Brussels and Düsseldorf already show lower air travel volumes, which together with the higher train frequencies indicate that rail already plays a more dominant role on these corridors.

## 4.3 Feasible Project Alternatives

This section outlines the feasible project alternatives for reducing short-haul flights by improving rail connections from Amsterdam to the six European cities. For each route, the current infrastructure conditions, planned upgrades and potential solutions for improving travel time, frequency and capacity will be examined. The analysis examines the feasibility of various alternatives based on existing operational constraints and timelines for infrastructure improvements. Each alternative will be assessed using the feasibility criteria established in Section 4.1.

### 4.3.1 Eurostar Expansion Amsterdam-London

Due to the current condition of the HSL-Zuid, project alternatives for improving rail connections to London, Paris and Brussels are limited. The line suffers from structural issues in ten viaducts between Hoofddorp and the Groene Hart tunnel, including concrete damage, foundational shifts and construction flaws. Although some repairs allowed a speed increase from 80 km/h to 120 km/h in December 2024, full restoration allowing maximum speeds of 300 km/h is not expected before 2027. For nine of the ten viaducts, detailed planning schedules remain pending and will not be available before 2026 due to the complexity of the engineering work and strict safety requirements (Ministerie van Infrastructuur en Waterstaat, 2025). These ongoing issues limit the feasibility of infrastructure-driven improvements for the Amsterdam-London, Amsterdam-Paris and Amsterdam-Brussels corridors.

Despite these challenges, the Amsterdam-London corridor benefits from recent developments making it a strong candidate for feasible improvements. Significant progress has already been made in 2025. On February 10, Eurostar resumed direct services between Amsterdam and London following the opening of a new terminal at Amsterdam Central Station. This terminal includes border control, security screening and modern passenger facilities, eliminating the need for passengers to disembark in Brussels for passport checks, saving up to an hour of travel time (Vosman, 2025).

Building on these developments, this project alternative consists of a planned frequency increase by Eurostar from three to five direct daily trains in the 2026 timetable. This expansion relies on existing infrastructure and operational investments and is not dependent on future upgrades to the HSL-Zuid (Vosman, 2025).

The Amsterdam-London corridor holds the greatest potential for rail expansion among all the destinations studied and is also the most urgent to address, given the high volume of air traffic between the two cities, as shown in section 4.2.2. The Channel Tunnel provides a solid infrastructural basis for a fully competitive rail alternative. ProRail's recent study on train path availability concluded that up to 24 daily paths are technically feasible which is far more than the current three daily Eurostar services and the planned increase to five (Expert, personal communication, June 2, 2025). From a strategic substitution perspective, the Amsterdam-London route offers high potential for air-to-rail shifts: a single additional Eurostar service could theoretically replace up to five short-haul flights, making the impact of increased rail capacity particularly significant (Expert, personal communication, June 2, 2025).

The project alternative improves the frequency and meets the baseline feasibility conditions established in section 4.1.1, since it uses existing infrastructure and is operationally ready. Therefore, it represents a feasible short-term project alternative.

### 4.3.2 Dual Service Model Amsterdam-Berlin

The Amsterdam-Berlin rail connection is set for substantial improvements by 2030, featuring a new timetable with two coordinated services: a faster limited-stop option and a modernized regular intercity service (Treinreiziger.nl, 2021). This planned timetable and service upgrade is the core element of this project alternative.

The biggest aspect of this alternative is a fast intercity service with a journey time of 5 hours and 27 minutes, skipping intermediate stops such as Stendal and limiting calls to Rheine, Osnabrück, Hannover and Berlin Spandau. Operating every two hours, it will use new ICE L trains capable of speeds up to 230 km/h, now expected to be rolled out in December 2025 (NS

International, 2024). The regular intercity service will serve most current stops but will skip Stendal and reduce dwell times at Bad Bentheim, shortening travel time to 5 hours and 51 minutes and also using ICE L trains. Together, these services will provide hourly departures between Amsterdam and Berlin.

This project alternative improves travel time and frequency, while keeping the capacity about the same with the new ICE L trains offering the same number of seats compared to the current rolling stock (around 600) (Treinreiziger.nl, 2025a, Treinenweb, 2024). Additionally, these services are operationally compatible with existing infrastructure and do not require significant new investments within the Netherlands, thereby meeting the baseline criteria.

Although the Dutch government and ProRail are exploring long-term infrastructure upgrades along the Amersfoort-Deventer-Bad Bentheim corridor, these plans remain in early stages and likely fall outside the 2030 timeframe. Thus, these potential upgrades are excluded due to uncertain timelines and lack of commitments (ProRail, 2024).

The Amsterdam-Berlin route also presents a promising case for air-rail substitution, particularly for O&D passengers. While the volume of short-haul flights on this corridor is lower than between Amsterdam and London, this allows rail improvements to deliver a relatively visible modal shift with fewer service additions. Even small improvements can lead to a proportionally meaningful reduction in air traffic on this route (Policy Officer 1, personal communication, June 13, 2025).

### 4.3.3 KLM Air&Rail Model

For a project alternative to be feasible for transfer passengers, it must satisfy the three core criteria established in Section 4.1.2: direct HSR service to the airport, integrated airline-rail IT systems for seamless ticketing and check-in, and coordinated timetables to ensure reliable connections.

Only a limited set of routes currently meets these requirements, as shown in Sections 4.2.1.2 and 4.2.1.3. These include Schiphol-Brussels, Schiphol-Paris, Amsterdam-Paris CDG Airport, and Amsterdam-Frankfurt Airport. The Eurocity Direct service on the Schiphol-Brussels route is excluded due to low punctuality, making it unsuitable for transfer passengers (Section 4.2.1.4).

In 2022, KLM launched a pilot program replacing short-haul transfer flights between Brussels and Schiphol with high-speed Thalys (now Eurostar) trains for intercontinental transfer passengers (KLM, 2024). The success of this pilot is largely due to KLM's fully integrated IT system, which allows single-ticket booking, through check-in and boarding pass issuance for both rail and flight segments (Bruinsma, 2023). Following the pilot one daily feeder flight was discontinued and by March 2023 the service expanded to five daily trains, with KLM reserving dedicated seats to guarantee availability and operational control (Luchtvaartnieuws, 2023).

Timetable coordination between rail and air services is the final core criterion. Based on the available train and flight frequency data, timetable coordination is considered generally feasible in this surface-level assessment. A more detailed analysis of schedules and synchronization is provided in Section 5.3.1 to confirm operational feasibility and identify any necessary adjustments.

Given this assessment, KLM-operated flights are prioritized for substitution because the airline's IT system is already in place and timetable coordination appears feasible. Only routes that meet the three essential criteria: direct HSR, integrated IT and coordinated timetables are considered viable for transfer passengers.

Based on these findings, the proposed project alternative aims to scale up the Air&Rail model by expanding to additional KLM-operated transfer routes by 2026. The targeted routes include:

- KLM-operated transfer flights passing through Schiphol and either beginning or ending in Brussels or Paris, both directly connected to Schiphol by HSR.
- KLM-operated transfer flights passing through Paris CDG Airport or Frankfurt Airport and either beginning or ending in Amsterdam, both served by direct HSR from Amsterdam.

While this expansion does not fully meet all five criteria, it satisfies the three core requirements. The other two criteria of fast terminal transfers and integrated baggage handling are not strictly necessary, as demonstrated by the successful Brussels pilot. Therefore, this Air&Rail expansion is considered feasible, showing that even moderate integration can make rail a competitive substitute for short-haul feeder flights.

### 4.3.4 Routes without Feasible Project Alternatives: Paris, Brussels, Düsseldorf and Frankfurt

**Amsterdam-Paris and Amsterdam-Brussels:**
Both the Paris and Brussels corridors are constrained by the HSL-Zuid's current condition, just like London. The Brussels route, however, has already undergone a significant upgrade. Since December 2024, the Eurocity Direct service has introduced 16 daily direct trains between Amsterdam Zuid and Brussels Midi, improving the frequency. This upgrade complements existing Eurostar services and makes further improvements unnecessary for the Brussels corridor.

In contrast, no recent upgrades have been made to the Amsterdam-Paris route and no additional trains or infrastructure improvements are planned until HSL-Zuid restoration is completed. Because the Brussels corridor has already undergone a major upgrade and the Paris corridor is on hold pending future infrastructure decisions and since no further improvements are currently planned for either route, no additional project alternative can be formulated at this time. Both corridors remain constrained by HSL-Zuid's limitations and uncertain planning timelines, with new development not expected until at least 2026. Because none of the three performance metrics can currently be improved and the baseline criteria of infrastructural and operational readiness do not allow for major upgrades, no project alternatives can be defined that would be feasible according to the criteria outlined in Section 4.1.1.

**Amsterdam-Düsseldorf and Amsterdam-Frankfurt:**
In late 2024, ICE 3neo trains were introduced on the Amsterdam-Düsseldorf and Amsterdam-Frankfurt routes, improving comfort, accessibility, luggage space and reliability (Nederlandse Spoorwegen, 2024a). However, travel times, frequency, capacity and schedules remain unchanged, with no increase to the seven daily round trips to Frankfurt and Düsseldorf.

Current efforts between the Netherlands and Germany focus on larger projects like the Amsterdam-Berlin overhaul and a future ICE service to Munich. As a result, no additional plans have been proposed to upgrade the Amsterdam-Düsseldorf and Frankfurt routes.

Because the ICE 3neo rollout does not improve the performance metrics, it does not meet the feasibility criteria for this study and is therefore not considered a viable project alternative to replace short-haul flights. Moreover, as there are no concrete plans in the near future to improve the Düsseldorf and Frankfurt connections, no project alternative is proposed for these two destinations.

## 4.4 Summary and Conclusion

This chapter established and applied a structured framework to evaluate the feasibility of international rail alternatives aimed at reducing short-haul flights from Amsterdam Schiphol Airport. For O&D passengers, the assessment focused on improvements in travel time, frequency and capacity while ensuring compatibility with the rail network and manageable infrastructure needs. For transfer passengers, feasibility was based on achieving seamless air-rail integration, including direct HSR access to airports, IT system integration and timetable alignment with long-haul flights.

The current state of rail and air services, analysed in Section 4.2, revealed that while some routes already offer competitive rail alternatives for O&D passengers, significant limitations remain for transfer passengers. Rail services to city centres are generally strong but direct airport access and punctuality vary widely. Most notably, Frankfurt Airport and Paris CDG Airport are the only airports that are directly reachable by HSR from Amsterdam and even these services are infrequent or lack the reliability needed for dependable air-rail transfers.

Several realistic project alternatives were identified through the feasibility framework:

- The **Eurostar Expansion Amsterdam-London** stands out as a highly feasible and impactful short-term alternative. The new UK terminal at Amsterdam Central, restored direct services and planned frequency increases by 2026 make this route capable of replacing multiple short-haul flights without requiring major infrastructure investments.
- The **Dual Service Model Amsterdam-Berlin** is a promising mid-term alternative, with the introduction of new ICE L trains, a redesigned timetable offering hourly services and travel time reductions by 2030. These upgrades are compatible with existing infrastructure and improve both frequency and journey time.
- The **KLM Air&Rail Model** focuses on replacing feeder flights. The KLM has demonstrated that even partial integration can make rail viable for transfer passengers. Building on this success, the concept can be scaled to additional routes such as Brussels, Paris and Frankfurt, targeting transfer passengers without needing full baggage or terminal integration.

Figure 4-1 visualizes the routes of these three proposed alternatives and Table 4-7 summarizes their expected improvements and implementation years.


**Figure 4-1:** Proposed international Rail Alternatives between Amsterdam and the European Destinations.

**Legend:**

- **Blue line:** Amsterdam-London Eurostar alternative
- **Grey line:** Amsterdam-Berlin intercity alternative
- **Orange lines:** Proposed KLM Air&Rail alternatives (transfer airports indicated in brackets)
- **Base map:** D-maps.com (n.d.)

**Table 4-7:** Overview of Improvements in Proposed Rail Alternatives and Their Expected Implementation Years.

| Alternative | Metric | Change | Year |
|---|---|---|---|
| Eurostar Expansion | Frequency | 3x → 5x Daily Departures | 2026 |
| Dual Service Model | Frequency | Every 2 Hours → Every Hour | 2030 |
| | Travel Time | 5h51m → 5h27m (Fast) & 5h51m (Regular) | 2030 |
| KLM Air&Rail Model | Routes | Brussels → Brussels, Paris, Paris CDG Airport and Frankfurt Airport | 2026 |

Other corridors, such as Amsterdam-Paris and Amsterdam-Brussels, currently offer high-frequency services but are constrained by infrastructure bottlenecks on the HSL-Zuid and lack feasible upgrade plans before 2026. Therefore, no new alternatives could be defined under current feasibility conditions. Likewise, while ICE 3neo trains improve comfort and reliability on the Düsseldorf and Frankfurt routes, these do not provide measurable gains in travel time, frequency or capacity, disqualifying them as feasible alternatives.

In conclusion, the analysis confirms that meaningful modal shift from short-haul air to international rail is possible on select corridors, particularly where existing infrastructure and operations allow for service improvements without major new investments. For O&D passengers, London and Berlin offer the most promising opportunities. For transfer passengers, expanding air-rail integration using a proven IT offers a big opportunity. However, the success of these proposed alternatives will depend on making the necessary changes. These will be further explored in the next chapter, which assesses the specific infrastructural and operational measures required to implement the identified alternatives.

# 5. Required Infrastructure and Operational Changes

This chapter answers sub-question 2, which examines the infrastructure investments and operational improvements required to implement the project alternatives identified in the previous chapter.

**SQ2:** *What infrastructure investments and operational improvements are required to implement the proposed project alternatives for improving direct rail connections between Schiphol and the six destinations?*

Building on the three project alternatives developed in response to SQ1, this chapter analyses the infrastructural and operational changes necessary for their effective implementation. For each alternative, the required changes are identified individually and include the type and number of trainsets needed, staffing implications, adjustments to service patterns and stopping schedules for the alternatives aimed at O&D passengers, as well as any necessary station upgrades or platform construction. For the Air&Rail alternative, attention is paid to feasibility considerations and timetable coordination to ensure effective integration between rail and long-haul air services.

The analysis is structured around the three project alternatives:

1. The Eurostar Expansion
2. The Dual Service Model
3. The KLM Air&Rail Model

This chapter identifies the infrastructural and operational changes that are either already planned or additionally required to implement each of the proposed project alternatives.

## 5.1 Infrastructure and Operational Adjustments Needed for the Eurostar Expansion

This section analyses the infrastructure and operational requirements for implementing the proposed expansion of Eurostar services between Amsterdam and London. No additional infrastructure investments are required for this expansion: a recent ProRail study confirmed that up to 24 international train paths are technically feasible on this corridor far exceeding the planned frequency. As a result, the requirements relate to the availability of trainsets, as well as the operational implications for scheduling and staffing. These aspects are examined below to assess what is needed to realise this project alternative.

### 5.1.1 Trainset Requirements and Operational Scheduling

To improve the Amsterdam-London rail connection, Eurostar plans to increase the route's capacity by adding more daily services. The existing Siemens Velaro e320 trainsets, which seat over 900 passengers (Siemens, 2018), already exceed the projected peak boarding demand of 800 passengers per train (NS International, 2025). Therefore, larger trainsets are not required to accommodate the passenger increase from Amsterdam.

However, increasing the daily frequency of Eurostar services will require additional trainsets. As shown in Table 5-1, Eurostar currently operates three daily departures in each direction, spaced throughout the day (Eurostar, n.d.). Each one-way journey takes approximately 4 hours and 17 minutes, as previously indicated in Table 4-1 (Section 4.2.1.1), with a scheduled turnaround time of approximately 60 minutes at both the Amsterdam and London terminals. All services operate during daytime hours, there are no overnight operations. Because of the one-hour time difference between the Netherlands (CET/CEST) and the United Kingdom (GMT/BST), westbound journeys appear shorter and eastbound journeys longer in the published timetable, although actual travel times are identical in both directions. A complete round trip (Amsterdam-London-Amsterdam or vice versa), including both turnarounds therefore takes roughly 10 hours and 30 minutes.

**Table 5-1***:* Eurostar Timetable for Amsterdam-London Route in 2025 (Local Times)

| Direction | Departure Time (Local) | Arrival Time (Local) |
|---|---|---|
| Amsterdam - London | 06:40 | 09:57 |
| Amsterdam - London | 13:40 | 16:57 |
| Amsterdam - London | 18:40 | 21:57 |
| London - Amsterdam | 06:16 | 11:33 |
| London - Amsterdam | 11:04 | 16:21 |
| London - Amsterdam | 18:04 | 23:21 |

While it is technically possible for a single trainset to perform more than one round trip under ideal conditions on this route, this would leave little margin for delays, maintenance or crew changes which are needed for reliable high-speed operations. For instance, although a trainset returning to Amsterdam at 16:14 could technically depart again at 18:40, this tight scheduling would introduce operational risks.

As shown in Appendix B, Table B-1, three trainsets are sufficient to accommodate the current schedule: two trainsets operate round trips starting in Amsterdam and one trainset operates a round trip starting in London.

Table 5-2 below shows a proposed 2026 schedule for the Amsterdam-London Eurostar route, increasing daily departures to five in each direction while maintaining evenly spaced service throughout the day.

**Table 5-2:** Proposed Eurostar Timetable for Amsterdam - London Route in 2026 (Local Times)

| Direction | Departure Time (Local) | Arrival Time (Local) |
|---|---|---|
| Amsterdam - London | 06:40 | 09:57 |
| Amsterdam - London | 09:40 | 12:57 |
| Amsterdam - London | 13:40 | 16:57 |
| Amsterdam - London | 16:40 | 19:57 |
| Amsterdam - London | 18:40 | 21:57 |
| London - Amsterdam | 06:16 | 11:33 |
| London - Amsterdam | 09:04 | 14:21 |
| London - Amsterdam | 11:04 | 16:21 |
| London - Amsterdam | 14:04 | 19:21 |
| London - Amsterdam | 18:04 | 23:21 |

As shown in Appendix B, Table B-2, five trainsets are sufficient to accommodate the proposed schedule: three trainsets operate round trips starting in Amsterdam and two trainsets operate round trips starting in London. Since the current operation uses three trainsets, this means two additional trainsets must be acquired.

Eurostar's past investments (seventeen e320 trainsets between 2010 and 2014) demonstrate its capacity for fleet expansion (Railway Gazette, 2010, Eurostar, 2014). These trains comply with

Channel Tunnel safety standards and operate across European rail networks, making them well suited for expanded Dutch services.

No infrastructure upgrades are needed to support the increased frequency because the new Amsterdam Centraal UK terminal already addresses terminal and platform management requirements and existing infrastructure on HSL-Zuid and the Channel Tunnel is sufficient.

### 5.1.2 Staffing Implications

The new schedule has clear staffing implications, primarily due to the increase in passenger volume and service frequency. Expanding the timetable from three to five daily departures will require additional train crew (including drivers, conductors and onboard service personnel) who must be scheduled and trained to operate the expanded service effectively.

At the terminal level, the staffing situation differs between the Netherlands and the UK.
In Amsterdam, larger passenger flows require more Koninklijke Marechaussee (KMar) personnel to conduct passport checks. As of April 2025, only two KMar officers are stationed at the new Amsterdam Centraal terminal, which is insufficient to process the current boarding capacity of up to 600 passengers per train. This staffing shortfall led Eurostar to extend journey times by 30 minutes starting 24 April 2025, to accommodate longer manual checks (Treinreiziger.nl, 2025b, Bremmer, 2025).

Eurostar originally planned to increase service from three to five daily trains in 2026. However, due to persistent staffing shortages at the KMar, this expansion has been delayed. Only one additional daily train is now expected in 2026, with the fifth departure postponed to 2027 (Expert, personal communication, June 2, 2025). At the opening of the new Eurostar terminal at Amsterdam Centraal, Eurostar cited the limited availability of KMar officers and the requirement to finance border control operations themselves as the causes of the delay. This combination of staffing and financial constraints has directly limited Eurostar's ability to scale up operations.

While media reports suggest that automated passport control scanners could be installed at Amsterdam Centraal after summer 2025 to alleviate the burden on manual checks (Bremmer, 2025), experts remain sceptical that this will be sufficient or implemented in time. In practice, the persistent KMar staffing shortage has already resulted in extended journey times and delays in service expansion.

On the UK side at St Pancras International, Eurostar has proactively upgraded border control infrastructure to manage higher passenger volumes. Since February 2025, the number of e-gates has increased from eight to eleven and 49 EU Entry/Exit System pre-registration kiosks have been installed (Caswell, 2025). These upgrades will support the increase from three to five daily departures without requiring additional customs staff.

In summary, the increase in daily services will require additional train crew to operate the expanded timetable, as well as more KMar personnel to manage border control at Amsterdam Centraal. While border control staffing levels at St Pancras International are expected to remain the same, persistent shortages of KMar staff and Eurostar's financial responsibility for these services on the Dutch side have already delayed the planned service expansion.

## 5.2 Infrastructure and Operational Adjustments Needed for the Dual Service Model

The Amsterdam-Berlin alternative consists of two components: the introduction of a dual intercity service model by 2030 and the deployment of new ICE L trains starting in December 2025. The dual service model will combine a limited-stop fast intercity service with an upgraded regular intercity service, together providing hourly departures between Amsterdam and Berlin. The ICE L trains will operate on both service types. Implementing this alternative will require acquiring new trainsets, adjusting operational scheduling and increasing staffing. Additionally, a small infrastructure upgrade is needed: a fourth platform track at Deventer, where peak-hour capacity is already strained. This expansion is essential to accommodate the planned hourly Amsterdam–Berlin service by 2030 without delays.

### 5.2.1 Trainset Requirements and Operational Scheduling

The first element of this alternative is the introduction of new ICE L rolling stock. DB has ordered 56 ICE L trainsets from the Spanish manufacturer Talgo to replace the aging intercity trains currently operating on the Amsterdam-Berlin corridor (Treinreiziger.nl, 2023). These trains are specifically designed for international services and offer several advantages: full technical compatibility with both Dutch and German networks, elimination of time-consuming locomotive changes at the border, a top speed of 230 km/h, improved acceleration and braking performance for better punctuality and improved passenger comfort.

The deployment of the ICE L trains had some delays. Originally planned for introduction in 2023, the start of regular service is now expected no earlier than December 2025 (Treinreiziger.nl, 2025c). Once certified and delivered, the ICE L trains will improve cross-border operations without requiring any major infrastructure or platform modifications (NS International, 2024, Treinenweb, 2024). Their introduction in 2025 will enable the implementation of the upgraded timetable in 2030.

Implementing the new service model will require additional trainsets, as the frequency will increase from one train every two hours to an hourly service.  At present, there are five daily departures in each direction on the Amsterdam-Berlin route, spaced evenly throughout the day (see Table 5-3 below). Each one-way journey takes approximately 5 hours and 51 minutes, as indicated in Table 4-1 (Section 4.2.1.1) (NS International, n.d.-l). All departure and arrival times are shown in local time and since both the Netherlands and Germany are in the same time zone, the scheduled travel time remains consistent across the border. Turnaround times in this schedule are approximately 15 minutes. A full round trip, including both turnarounds, therefore takes roughly 12 hours and 12 minutes.

Because the Amsterdam-Berlin Intercity operates entirely within the Schengen Area, no customs or passport controls are required during boarding or arrival. This reduces passenger processing time compared to international services crossing non-Schengen borders, such as the Eurostar between Amsterdam and London. Consequently, turnaround times can be shorter, focusing on routine activities such as cleaning, crew changes and train preparation. A 15-minute turnaround is therefore operationally feasible and aligns with the current timetable.

**Table 5-3:** Current Intercity Timetable for Amsterdam-Berlin Route in 2025

| Direction | Departure Time | Arrival Time |
|---|---|---|
| Amsterdam - Berlin | 08:00 | 13:51 |
| Amsterdam - Berlin | 10:00 | 15:51 |
| Amsterdam - Berlin | 12:00 | 17:51 |
| Amsterdam - Berlin | 14:00 | 19:51 |
| Amsterdam - Berlin | 16:00 | 21:51 |
| Berlin - Amsterdam | 08:06 | 13:57 |
| Berlin - Amsterdam | 10:06 | 15:57 |
| Berlin - Amsterdam | 12:06 | 17:57 |
| Berlin - Amsterdam | 14:06 | 19:57 |
| Berlin - Amsterdam | 16:06 | 21:57 |

As shown in Appendix B, Table B-3, at least seven trainsets are required to operate the current schedule: three trainsets perform full round trips within a single day with two starting from Amsterdam and one from Berlin. Four additional trainsets are used for single-leg journeys without a same-day return. Since the number of single-leg journeys is balanced with two departing from Amsterdam and two from Berlin, these trainsets can alternate their starting point each day, helping to optimize fleet utilization and reduce the need for empty repositioning movements. The new proposed schedule for 2030 with the faster intercity that takes 5 hours and 27 minutes and creates an hourly service can be seen below in Table 5-4.

**Table 5-4:** Proposed Intercity Timetable for Amsterdam-Berlin Route in 2030

| Direction | Departure Time | Arrival Time |
|---|---|---|
| Amsterdam - Berlin | 08:00 | 13:51 |
| Amsterdam - Berlin | 09:00 | 14:27 |
| Amsterdam - Berlin | 10:00 | 15:51 |
| Amsterdam - Berlin | 11:00 | 16:27 |
| Amsterdam - Berlin | 12:00 | 17:51 |
| Amsterdam - Berlin | 13:00 | 18:27 |
| Amsterdam - Berlin | 14:00 | 19:51 |
| Amsterdam - Berlin | 15:00 | 20:27 |
| Amsterdam - Berlin | 16:00 | 21:51 |
| Amsterdam - Berlin | 17:00 | 22:27 |
| Berlin - Amsterdam | 08:06 | 13:57 |
| Berlin - Amsterdam | 09:06 | 14:33 |
| Berlin - Amsterdam | 10:06 | 15:57 |
| Berlin - Amsterdam | 11:06 | 16:33 |
| Berlin - Amsterdam | 12:06 | 17:57 |
| Berlin - Amsterdam | 13:06 | 18:33 |
| Berlin - Amsterdam | 14:06 | 19:57 |
| Berlin - Amsterdam | 15:06 | 20:33 |
| Berlin - Amsterdam | 16:06 | 21:57 |
| Berlin - Amsterdam | 17:06 | 22:33 |

To operate the proposed hourly Amsterdam-Berlin service, thirteen trainsets are required, as shown in Appendix B, Table B-4. Seven trainsets are used to operate full round trips with four starting in Amsterdam and three in Berlin. To complete the timetable, six additional trainsets perform single-leg journeys without a same-day return. These single-leg services are evenly distributed, with three departing from Amsterdam and three from Berlin, allowing the trainsets to alternate their starting point each day. Compared to the current service, which operates with seven trainsets, the upgraded schedule requires six additional trainsets to support the expanded frequency. These will be ICE L trains, which are scheduled to enter service on the Amsterdam-Berlin route in December 2025.

### 5.2.2 Staff Implications

The only staffing changes required for this project alternative relate to the planned increase in service frequency. Additional train drivers, on-board crew and maintenance staff will be needed to operate and support the extra services introduced in the revised timetable. These personnel must be recruited, trained and scheduled to support operational continuity, particularly as the frequency increases from one train every two hours to an hourly service.

No new staffing is required for border control, as both the Netherlands and Germany are within the Schengen Area and no passport checks are needed for cross-border rail passengers.

### 5.2.3 Constructing of the Fourth Platform in Deventer

While the Amsterdam-Berlin intercity service is currently operational, it is doing so under a temporary timetable implemented in late 2024 to comply with changes in the German national schedule. These adjustments were implemented both to accelerate the service and to avoid complete cancellation due to timetable conflicts. However, this temporary arrangement has created multiple daily clashes with Dutch domestic trains. These conflicts are now actively being addressed, to ensure the Berlin train can be integrated into the long-term international timetable (Corridor coordinator, personal communication, June 25, 2025).

Although the dual service model proposes an hourly Amsterdam-Berlin connection by 2030 without requiring large-scale infrastructure upgrades, several operational bottlenecks will need to be addressed to support these increased frequencies. Deventer station needs capacity improvements, as platform and track availability are already under pressure, especially during peak hours. The long-standing proposal to construct a fourth platform track aims to lessen these constraints and reduce delays. This infrastructure adjustment is essential and must be completed before 2030 to implement the dual service model. However, as of early 2024, this expansion remains in the exploratory phase, with no funding yet secured and the Dutch State Secretary for Infrastructure has noted that the expected costs exceed the currently available budget (Ubels, 2024).

In summary, the operational changes involved in this project alternative include new train procurement, schedule adjustments and increased staffing. Only a small infrastructure upgrade is needed in the Netherlands to achieve the targeted improvements by 2030.

## 5.3 KLM Air&Rail Model

This alternative involves expanding KLM's existing Air&Rail integration model, targeting intercontinental transfer passengers. In this approach, KLM reserves blocks of seats on specific high-speed trains to replace short-haul transfer flights. The core operational change in this alternative is the coordination of flight and train schedules to support smooth connections and competitive total travel times. To assess the feasibility of this coordination, the analysis will examine whether the selected train services can effectively cover the time range of the short-haul flights they are intended to replace. In other words, whether they depart and arrive at similar times throughout the day. This analysis focuses on direct short-haul flight replacements and does not include connecting (transfer) flights. While flight schedules are often more flexible and can to some extent be adjusted to align with rail timetables, the main focus here is to assess whether existing train services offer sufficient coverage across the typical operating window of short-haul flights.

Since no new stations, track upgrades, or signalling changes are needed, this alternative is fully implementable from an infrastructure perspective.

### 5.3.1 KLM Flight Schedules and Feasibility of Rail Replacement

Tables 5-5, 5-6 and 5-7 present an overview of KLM's current flight schedules and aircraft types on the routes between Amsterdam Schiphol and the three destinations considered in the Air&Rail integration alternative: Brussels, Frankfurt and Paris CDG Airport. For each direction, the tables include the departure and arrival times, the aircraft used and the estimated seating capacity. This information was manually retrieved using KLM's online flight search tool (KLM, n.d.) to reflect a representative weekday schedule. The data provides a basis for evaluating whether existing HSR services can offer comparable frequency and capacity and whether KLM could feasibly replace these short-haul flights by purchasing reserved train seats on designated services.

**Table 5-5:** KLM Flight Schedule and Aircraft Capacity for the Schiphol-Brussels Airport Route

| Direction | Departure Time | Arrival Time | Aircraft Type | Estimated Capacity |
|---|---|---|---|---|
| Schiphol - Brussels Airport | 06:50 | 07:35 | Embraer 175 | 88 Seats |
| Schiphol - Brussels Airport | 08:55 | 09:40 | Embraer 195 | 112 Seats |
| Schiphol - Brussels Airport | 13:50 | 14:35 | Embraer 175 | 88 Seats |
| Schiphol - Brussels Airport | 21:30 | 22:15 | Embraer 190 | 100 Seats |
| Brussels Airport - Schiphol | 06:10 | 06:55 | Embraer 190 | 100 Seats |
| Brussels Airport - Schiphol | 08:00 | 08:45 | Embraer 175 | 88 Seats |
| Brussels Airport - Schiphol | 10:25 | 11:10 | Embraer 195 | 112 Seats |
| Brussels Airport - Schiphol | 15:05 | 15:50 | Embraer 175 | 88 Seats |

**Table 5-6:** KLM Flight Schedule and Aircraft Capacity for the Schiphol-Frankfurt Airport Route

| Direction | Departure Time | Arrival Time | Aircraft Type | Estimated Capacity |
|---|---|---|---|---|
| Schiphol - Frankfurt Airport | 09:50 | 10:55 | Embraer 175 | 88 Seats |
| Schiphol - Frankfurt Airport | 16:40 | 17:45 | Embraer 195 | 112 Seats |
| Schiphol - Frankfurt Airport | 20:40 | 21:45 | Embraer 190 | 100 Seats |
| Frankfurt Airport - Schiphol | 07:00 | 08:05 | Embraer 190 | 100 Seats |
| Frankfurt Airport - Schiphol | 10:15 | 11:20 | Embraer 175 | 88 Seats |
| Frankfurt Airport - Schiphol | 11:45 | 12:50 | Embraer 195 | 112 Seats |

**Table 5-7:** KLM Flight Schedule and Aircraft Capacity for the Schiphol-Paris CDG Airport Route

| Direction | Departure Time | Arrival Time | Aircraft Type | Estimated Capacity |
|---|---|---|---|---|
| Schiphol - Paris CDG Airport | 06:45 | 07:55 | Boeing 737-800 | 160 Seats |
| Schiphol - Paris CDG Airport | 08:05 | 09:15 | Boeing 737-800 | 160 Seats |
| Schiphol - Paris CDG Airport | 17:50 | 19:00 | Boeing 737-800 | 160 Seats |
| Paris CDG Airport - Schiphol | 08:40 | 09:50 | Boeing 737-800 | 160 Seats |
| Paris CDG Airport - Schiphol | 10:15 | 11:25 | Boeing 737-800 | 160 Seats |
| Paris CDG Airport - Schiphol | 20:15 | 21:25 | Boeing 737-800 | 160 Seats |

Based on these schedules, a comparison can now be made between KLM flights and the available train options, as shown in Table 5-8. The analysis indicates that flights between Schiphol and Brussels Airport, Frankfurt Airport and Paris CDG Airport can, in principle, all be substituted by HSR services. These rail services operate more frequently than the flights, offer greater seating capacity and are more evenly spread throughout the day. This distribution allows transfer passengers more flexibility in selecting train departures that align better with their intercontinental flights, thereby reducing waiting times at the airport.

As noted in Section 4.2.1.4, Eurocity Direct trains on the Schiphol-Brussels route are currently not considered due to poor punctuality, which makes them unsuitable for transfer passengers. Significant infrastructure and operational changes would be required to meet the reliability standards for this market segment, and no concrete measures are planned in the short term. As a result, the effective daily train frequency is limited to the 14 Eurostar services, which still exceeds the current number of KLM flights on this route (four per day), making full substitution by HSR feasible.

The only partial exception is the Schiphol-Paris CDG Airport route. While the frequency of trains between Schiphol and Paris is high enough to reliably substitute KLM flights involving a transfer at Schiphol, this is not the case for passengers connecting via Paris CDG Airport. The dedicated train service between Amsterdam and Paris CDG Airport is limited to just two Eurostar departures per day, operating only from Friday to Monday. This low and irregular frequency makes rail an unreliable substitute for short-haul flights connecting through Paris CDG.

**Table 5-8:** Comparison of KLM Flights and Rail Alternatives

| Route | Daily KLM Flights | Daily Train Frequency | Flight Time | Train Time |
|---|---|---|---|---|
| Schiphol - Brussels | 4 | 14 | 45m | 1h50m |
| Schiphol - Paris | 3 | 10 | 1h10m | 3h08m |
| Amsterdam - Paris CDG Airport | 3 | 2 (Fri-Mon) | 1h10m | 3h31m |
| Amsterdam - Frankfurt Airport | 3 | 7 | 1h05m | 3h38m |

The expansion of KLM's Air&Rail model is technically and operationally feasible for most of the examined routes. The main operational constraint lies in the limited frequency of Eurostar services between Amsterdam and Paris CDG Airport, which currently prevents full substitution of flights on that route. For the other routes however, the availability of frequent and reliable HSR services allows for effective flight replacement. This can be achieved by KLM purchasing seat blocks on designated trains.

## 5.4 Summary and Conclusion

This chapter addresses sub-question 2 and examines the infrastructure investments and operational improvements such as rolling stock acquisition, staffing expansions, platform construction and intermodal air-rail integration needed to realize the project alternatives developed in the previous chapter.

**Eurostar Expansion**
The planned increase in Eurostar frequency from three to five daily departures can be implemented without additional infrastructure investment, as the corridor's existing capacity and the new Amsterdam Centraal UK terminal are sufficient to accommodate growth. However, operational feasibility hinges on acquiring two additional Siemens Velaro e320 trainsets and recruiting more crew. The main bottleneck remains the shortage of KMar personnel at Amsterdam Centraal, which delays border controls and has postponed the fifth daily departure to 2027. In summary, while technically and operationally feasible, overcoming border control staffing challenges is crucial for the Eurostar expansion to deliver its intended frequency improvements.

**Dual Service Model**
This alternative introduces a dual intercity service using new ICE L trainsets, scheduled to begin operation in late 2025. These trains are fully interoperable across Dutch and German rail networks, eliminating the need for border locomotive changes and improving both operational reliability and passenger comfort. To support the planned service expansion, six additional ICE L trainsets need to be deployed on this route, along with proportional increases in operational and onboard staff. Thanks to the Schengen Agreement, no additional border control personnel are necessary. While no large-scale infrastructure upgrades are needed, a minor station upgrade (construction of a fourth platform track at Deventer) is necessary to address capacity bottlenecks. Overall, this alternative relies on new rolling stock, additional crew and revised stopping patterns to reduce travel times and improve service quality on the Amsterdam-Berlin corridor without the need for major infrastructure upgrades.

**KLM Air&Rail Model**
The third alternative focuses on expanding KLM's existing Air&Rail integration, targeting intercontinental transfer passengers by substituting flights with reserved seats on high-speed trains between Amsterdam (Schiphol) and Brussels, Frankfurt Airport and Paris (CDG Airport). This approach requires no new infrastructure investments, relying instead on the coordination of existing rail and flight schedules to support smooth, competitive connections. Analysis shows that for Schiphol-Brussels and Paris and Amsterdam-Frankfurt Airport, rail services are more frequent and offer sufficient capacity to fully replace KLM's short-haul flights. This provides greater scheduling flexibility and reduces passenger dwell times. The limited Eurostar service between Amsterdam and Paris CDG Airport restricted to two departures on select days prohibits reliable flight substitution on this route. In conclusion, expanding the KLM Air&Rail model offers an operationally feasible way to reduce short-haul air travel on three routes.

Table 5-9 below shows the operational requirements per project alternative and their respective timelines. For the Eurostar expansion, four operational changes are required by 2027, with the rolling stock and timetable changes partly implemented in 2026 when one train is already added. The Amsterdam-Berlin dual-service model also includes four operational changes, beginning with the deployment of the new ICE L trains in 2025 and the dual service model in 2030. The KLM Air&Rail model consists of three operational measures that will take place in 2026.

**Table 5-9:** Overview of Operational Requirement by Alternative and Year

| Alternative | Operational Requirement | Change | Year |
|---|---|---|---|
| Eurostar Expansion | Rolling Stock | +2 Siemens Velaro e320 Units | 2027 |
| | Crew | More Operational and Onboard Staff | 2027 |
| | Border Control | Extra KMar Personnel | 2027 |
| | Timetable | Revised Schedule 3 to 5 Daily Departures | 2027 |
| Dual Service Model | Rolling Stock | Introduction of ICE L Trains | 2025 |
| | | +6 ICE L Trains | 2030 |
| | Crew | More Operational and Onboard Staff | 2030 |
| | Timetable | Revised Schedule for Fast and Regular Service | 2030 |
| | Infrastructure | Fourth Platform Track Deventer | 2030 |
| KLM Air&Rail Model | Seat Allocation | Reserved Seats for KLM Passengers on Trains | 2026 |
| | Route Coverage | Brussels, Paris CDG and Frankfurt Airports | 2026 |
| | Timetable Coordination | Alignment of Rail and Flight Schedules | 2026 |

Compared to the alternatives as established in Chapter 4, some details of the alternatives have changed. Specifically, the Eurostar expansion will add one additional train in 2026 and the second in 2027, rather than both in 2026 as previously planned. Furthermore, due to the limited train frequency on the Amsterdam-Paris CDG Airport route, flights transferring at Paris CDG Airport are excluded from the KLM Air&Rail alternative.

Overall, the alternatives rely mostly on operational measures such as the deployment of new rolling stock, increases in staffing, timetable optimization and improved coordination between air and rail services. Since these alternatives are primarily dependent on operational improvements, implementation is more feasible before 2030. The next chapter will investigate the institutional, regulatory and financial barriers that could hinder the implementation of each alternative and what has to be done to overcome these barriers.

# 6. Institutional, Regulatory and Financial Barriers to Implementation

This chapter answers sub-question 3, which examines the institutional, regulatory and financial barriers that affect the implementation of the proposed project alternatives for improving direct rail connections between Schiphol and the six destinations.

**SQ3:** *What institutional, regulatory and financial barriers affect the implementation of the proposed project alternatives for improving direct rail connections between Schiphol and the six destinations, and how can these barriers be addressed?*

This chapter identifies and analyses barriers that may hinder their successful implementation and their potential solutions. These barriers play a big role in determining whether technical and operational improvements can be realised effectively, within the set timeframes and at the intended scale.

To do this, Section 6.1 analyses the barriers specific to each project alternative, while Section 6.2 investigates the general institutional, regulatory and financial obstacles that may hinder their implementation. After all barriers and potential solutions have been identified, an overview of the barriers will be provided.

To bring structure and clarity, the general barriers are grouped into the following main subcategories:

1. Market Structure and Competition Barriers
2. Planning, Capacity and Coordination Barriers
3. Cross-Border and EU Integration Barriers
4. Governance and Policy Fragmentation Barriers
5. Political and Strategic Prioritization Barriers

These categories were adapted for clarity and structure and are derived from the findings of the EU Transport Landscape Review, which highlights challenges related to market dynamics, infrastructure planning and funding, cross-border coordination, governance fragmentation, and strategic prioritization in the development and financing of EU transport infrastructure (European Court of Auditors, 2018). This landscape review describes and analyses the key challenges faced by the development and financing of transport in the EU.

## 6.1 Analysis of Barriers per Project Alternative

This section examines the specific institutional, regulatory and financial barriers for each of the three project alternatives. By analysing these barriers per alternative, it shows the unique constraints that affect the implementation and success of the Eurostar Expansion, the Dual Service Model and the KLM Air&Rail Model.

### 6.1.1 Barriers Eurostar Expansion

Expanding Eurostar services between Amsterdam and London is primarily hindered by the UK-Netherlands border control agreement, rooted in the Quadripartite Agreement that requires UK-bound passengers to be pre-cleared at departure stations. This cross-border coordination barrier is reinforced by institutional challenges, such as staff shortages at the KMar and has financial consequences due to disputes over who should fund ongoing border operations.

To enable direct Eurostar services between the UK and the Netherlands, the 1993 Tripartite Agreement which allowed border checks for UK-bound passengers to be carried out at departure stations in France and Belgium had to be amended to also include the Netherlands. Until this was resolved, UK-bound passengers were required to change trains in Brussels for passport checks, which added to the total travel time. After long negotiations, the 2020 Quadripartite Agreement formally incorporated the Netherlands and allowed Dutch and UK border checks to be done together in Amsterdam and Rotterdam.

Eurostar agreed to finance the infrastructure modifications and initial setup costs associated with implementing these controls (House of Representatives of the Netherlands, 2021). However, this arrangement has led to ongoing operational and financial tensions. KMar staff must do border checks at Amsterdam Centraal, which requires a lot of yearly staffing. Eurostar disagrees with having to pay these ongoing costs, saying they are unfair since other transport hubs like Schiphol Airport and the Port of Rotterdam do not have to cover such expenses (Bremmer, 2025b).

Due to ongoing staff shortages at the KMar as mentioned in Section 5.1.2, Eurostar trains have often been delayed, sometimes by as much as 30 minutes. To help solve this, private security company G4S started supporting KMar in May 2025 by taking over non-border duties. Although G4S guards can't carry out passport checks, their help has reduced pressure on KMar, improved punctuality and allowed Eurostar to continue running daily trains (Bremmer, 2025c).

Despite this stopgap measure, the underlying institutional barrier remains unresolved and the financial dispute remains. The continued lack of staffing capacity has already led Eurostar to postpone plans for service expansion. The introduction of a fourth daily train has been delayed to late 2026, with a fifth planned for 2027 (Expert, personal communication, June 2, 2025).

In summary, the expansion of Eurostar services from Amsterdam is hindered by a cross-border regulatory barrier, reinforced by institutional factors. This barrier has led to unresolved disputes over who should bear the costs of border personnel, as well as ongoing shortages of KMar staff. Together, these issues have caused delays and forced Eurostar to postpone planned increases in service frequency. One potential solution could involve a funding arrangement between the Dutch government and Eurostar to cover the costs of border checks, similar to the public financing model for airport security at Schiphol. Improved coordination and policy support will be necessary to overcome this supply-side barrier and help enable a successful shift from air to rail travel on this route (Policy Officer 2, personal communication, June 13, 2025).

### 6.1.2 Barriers Dual Service Model

The dual service model faces three distinct barriers that could limit the effectiveness and implementation of the planned improvements. The first two are institutional and the third is a financial barrier.

#### 6.1.2.1 Conflicts with Domestic Train Traffic in Twente

International services are unreliable due to conflicts with domestic train traffic in the Twente region, where local trains are often given priority. This operational challenge is a result of an institutional barrier, as it reflects the lack of effective coordination and cooperation between domestic and international rail operators and stakeholders, which complicates the scheduling and prioritization of trains. This operational challenge reflects a broader institutional issue of coordination between domestic and international train services, which will be examined in more detail in Section 6.2.2.3. A potential solution could be to establish a formal coordination mechanism or working group between ProRail, NS and DB to jointly plan timetables and infrastructure use, making sure that international services receive sufficient priority in operational planning.

#### 6.1.2.2 Limited Political Urgence to Speed Up Improvements

Another challenge lies in the 2030 target year itself. While infrastructure and timetable improvements are officially planned for that date, earlier interventions could be feasible. The main bottleneck is not technical or financial readiness, but rather the political and institutional willingness to accelerate implementation. This is an institutional barrier because it reflects limited prioritisation and insufficient coordination between national governments, infrastructure managers and operators to bring forward planned improvements. With sufficient coordination, the Amsterdam-Berlin corridor may offer more immediate potential than currently planned (Expert, personal communication, June 2, 2025). A potential solution could be to establish an intergovernmental task force between the Netherlands and Germany dedicated to advancing the Amsterdam-Berlin upgrades, backed by a clear mandate to explore phased implementation and service improvements before 2030.

#### 6.1.2.3 Limited Dedicated Funding for Amsterdam-Berlin Upgrades

However, financial constraints significantly limit what can realistically be achieved in the near term. The Dutch Mobility Fund, which initially allocated €50 million to improve rail connections with Berlin is already largely depleted. Only €30 million remains, most of which is earmarked for overdue maintenance and smaller-scale projects. Permanently implementing the temporary measures already in use is expected to cost significantly more, potentially amounting to hundreds of millions of euros. This is a financial barrier because the lack of sufficient dedicated funding for major infrastructure and service upgrades restricts the ability to realise planned improvements on the corridor. A potential solution could lie in NATO commitments. As part of these commitments, the Dutch government is required to increase annual defence spending to 5% of GDP, of which up to 1.5% may be allocated to infrastructure projects that strengthen military mobility (NATO, 2025). The Amsterdam-Berlin corridor is particularly relevant in this context, as it serves as an eastward route toward Ukraine and the eastern NATO border, playing an important role in the context of the ongoing war in Ukraine and heightened tensions with Russia. This military relevance could open up additional funding and lead to earlier upgrades, possibly even before 2030 (Corridor coordinator, personal communication, June 25, 2025).

### 6.1.3 KLM Air&Rail Model

The extension of KLM's Air&Rail model faces institutional and financial barriers that undermine its viability as a structural solution. Arrangements like the KLM Air&Rail model often serve as "hub-and-spoke preservation strategies" rather than genuine alternatives to short-haul aviation (Expert, personal communication, June 2, 2025). From this perspective, Air&Rail partnerships are mostly designed to retain intercontinental transfer traffic at existing airline hubs rather than to promote a shift toward rail.

#### 6.1.3.1 Lack of Integrated Passenger and Baggage Handling Systems

An institutional barrier is the lack of integrated passenger and baggage handling systems. This barrier is institutional because it is a result of the fragmented responsibilities, competing interests and lack of coordinated governance between multiple organizations, including Dutch rail operators, Schiphol Airport and airlines. While best practices such as station-based baggage check-in by Swiss International Air Lines exist, these have not been realized in the Dutch context despite years of discussion. As a result, transfer passengers choosing rail over short-haul flights face a fragmented and less convenient journey (Expert, personal communication, June 2, 2025). This barrier is unlikely to be resolved quickly, as overcoming it requires fundamental changes in governance structures, financial incentives and stakeholder collaboration, all of which demand significant political will and time.

#### 6.1.3.2 Financial Incentives Favouring Feeder Flights

Financial barriers currently discourage airlines like KLM from expanding Air&Rail integration. Feeder flights remain financially attractive because they help maximize long-haul aircraft occupancy and make full use of scarce and valuable airport slots, generating higher revenue for airlines. Additionally, the aviation sector benefits from lower ticket taxes, favourable international agreements and regulatory protections under frameworks such as the Chicago Convention. These financial advantages create strong economic incentives for airlines to maintain the status quo and continue prioritizing air connections rather than shifting passengers to rail. This barrier is financial because it is about the economic interests and profit motives of airlines. It is unlikely to be resolved in the short term because changing these financial structures and international agreements requires extensive political negotiation and cooperation across multiple countries and regulatory bodies, processes that are usually slow and complex.

KLM's Air&Rail model faces major institutional and financial barriers that limit its potential as a viable alternative to short-haul flights. Institutionally, fragmented governance and competing interests among rail operators, Schiphol and airlines prevent integrated passenger and baggage handling, leading to a fragmented transfer experience. Financially, airlines benefit from incentives to prioritize feeder flights, supported by favourable tax policies and international regulations, creating strong resistance to shifting passengers to rail. These challenges, combined with insights from interviews where experts described the model as not credible and too complex (Expert, personal communication, June 2, 2025, Policy Officer 2, personal communication, June 13, 2025), restrict its scalability and credibility. Although technically feasible, Air&Rail integration is unlikely to significantly reduce short-haul air traffic at Schiphol and will therefore not be further analysed in the SCBA.

## 6.2 General Barriers

While each project alternative faces its own specific challenges, the overall shift from short-haul air travel to rail is constrained by broader systemic barriers. These barriers include institutional complexities, regulatory frameworks and financial limitations that affect the feasibility and scalability of alternatives. To bring clarity and structure to the analysis, the barriers are grouped into five thematic categories: (1) Market Structure and Competition, (2) Planning, Capacity and Coordination, (3) Cross-Border and EU Integration, (4) Governance and Policy Fragmentation and (5) Political and Strategic Prioritization. This section provides an in-depth exploration of these general barriers and discusses possible approaches to overcoming them.

### 6.2.1 Market Structure and Competition Barriers

The shift from short-haul air to rail is shaped not only by infrastructure and service quality, but also by how transport markets are structured and regulated. This section identifies three systemic market barriers that restrict the growth of international rail: (1) limited market access due to dominant operator control, (2) structural dependence on short-haul flights for international connectivity and (3) regulatory and fiscal asymmetries between aviation and rail.

#### 6.2.1.1 Limited Market Access Due to Dominant Operator Control

The dominant position of NS in the Dutch railway market hinders the improvement of international rail services. As both the main operator and a state-owned company, NS faces an inherent conflict of interest. The government, as owner, is responsible for NS's commercial success, while also serving as regulator tasked with maintaining fair market conditions. This dual role can result in biased decision-making that favours NS and undermines competition. New entrants report difficulties accessing routes or stations because NS controls much of the network and its commercial interests often conflict with those of potential competitors. Gerrit Spijksma (CEO of Heurotrain) described the system as "closed by default," highlighting how government ownership influences market openness. Even NS International acknowledges the difficulty of balancing cooperation with competition within the current EU regulatory framework (Treinreiziger.nl, 2025d).

A related barrier is the lack of digital integration and limited ticket access. NS does not sell tickets for competing international trains on its digital platforms, which significantly reduces the visibility and accessibility of these services for passengers. This practice reinforces the dominant position of incumbent operators. According to the Ministry of Infrastructure and Water Management, this issue reflects a broader absence of national strategic oversight for international rail (Policy Officer 1, personal communication, June 13, 2025).

These barriers are institutional, stemming from governance structures and policy choices that limit open access. Overcoming them requires stronger regulatory separation between NS's commercial and regulatory roles and the enforcement of open ticketing platforms. A coordinated national strategy for digital integration would improve market transparency, increase competition and expand passenger choice.

#### 6.2.1.2 Structural Dependence on Short-Haul Flights for International Connectivity

The structure of the aviation market presents a major barrier to replacing short-haul flights with international rail. Airlines like KLM rely heavily on short-haul feeder flights to sustain long-haul operations under the hub-and-spoke model. This dependency is not imposed by regulation but results from the liberalised European aviation market and the absence of policies restricting short-haul air travel. Reducing these feeder flights could compromise the economic viability of long-haul routes that depend on high transfer volumes (Policy Officer 2, personal communication, June 13, 2025).

In contrast to countries like Germany and France, where many short-haul flights are domestic and can be substituted with rail under national jurisdiction, the Netherlands has virtually no domestic commercial flights. This makes substitution reliant on international rail services, which introduces additional complexity such as foreign infrastructure, cross-border coordination and bilateral or multilateral agreements (Policy Officer 1, personal communication, June 13, 2025).

These institutional barriers reflect a mismatch between national responsibilities and international connectivity needs. Solutions include better alignment between rail and air schedules, more formal integration of international rail into national transport planning and stronger bilateral coordination with neighbouring countries to support cross-border substitution strategies.

#### 6.2.1.3 Regulatory and Fiscal Asymmetries Between Aviation and Rail

International aviation benefits from structural advantages in both regulatory and fiscal domains. Airlines operate under harmonised ICAO rules covering safety, crew licensing and operational standards. Rail, by contrast, remains fragmented across national jurisdictions, increasing complexity and costs for cross-border services. Furthermore, international air tickets are typically exempt from Value Added Tax (VAT), while international train tickets are taxed, creating a persistent price disadvantage for rail (Policy Officer 2, personal communication, June 13, 2025).

A further financial barrier arises from exemptions on aviation fuel and the limited scope of air passenger taxes. These fiscal advantages reduce the marginal cost of flying, while rail operators face standard fuel taxes and no comparable subsidies. Although air passenger levies exist, they typically fail to fully internalise the environmental externalities of aviation (Policy Officer 2, personal communication, June 13, 2025).

At the same time, passengers often perceive rail fares (especially international ones) as more expensive than low-cost airline alternatives. This perception discourages modal shift, even when door-to-door rail travel times are competitive (Policy Officer 2, personal communication, June 13, 2025).

These barriers are both regulatory and financial. Addressing them requires fiscal reforms such as VAT exemptions for international rail tickets, the introduction of environmental taxes on aviation (e.g. fuel levies or frequent flyer charges) and the harmonisation of rail standards across EU Member States. Research by CE Delft suggests that fair pricing mechanisms, such as a frequent flyer levy, could reduce air travel demand by 25% and $CO_2$ emissions by 20%, particularly on long-haul routes. These tools could also generate public revenue to reinvest in international rail (Expert, personal communication, June 2, 2025).

### 6.2.2 Planning, Capacity and Coordination Barriers

The development of competitive international rail services is heavily influenced by how infrastructure is planned, priced and coordinated across national and cross-border networks. In the Dutch context, structural limitations in capacity allocation, misalignment between stakeholders and planning uncertainty restrict the growth of international rail. These challenges are compounded by institutional practices and regulatory frameworks that favour domestic services and create financial risk for new entrants. This section examines the four barriers that illustrate the systemic coordination and planning challenges facing international rail operators.

#### 6.2.2.1 Short-Term Access Rights and Missing Capacity Guarantees

In the Netherlands, international rail operators face a lack of long-term track access guarantees. Dutch legislation currently provides only annual access rights, which contrasts with countries such as France and Belgium where multi-year framework agreements are available. This short planning horizon increases financial uncertainty and complicates the acquisition and financing of rolling stock, particularly for new entrants. Since the production and deployment of new trains can take several years, the absence of multi-annual certainty presents a major obstacle to launching or expanding international services (Treinreiziger.nl, 2025d, Policy Officer 1, personal communication, June 13, 2025).

This barrier is both regulatory and institutional in nature. It is a result of legal limitations in Dutch railway law, as well as broader governance practices that fail to provide stable, long-term commitments to operators. Overcoming this barrier would require legislative reform to allow for multi-year capacity contracts, aligning Dutch law with neighbouring countries. Such reform would reduce investment risk and support the long-term planning and development of international rail services.

#### 6.2.2.2 Misalignment between NS and ProRail on Capacity Perspectives

Differences in how NS and ProRail conceptualise rail capacity complicate international service development. NS approaches capacity from a product- and service-oriented perspective, focusing on the commercial viability of specific train routes. ProRail, in contrast, views capacity from a network-wide, technical standpoint independent of commercial considerations. This misalignment results in coordination problems and public miscommunication, particularly when it comes to justifying capacity allocation decisions or planning new services (Policy Officer 1, personal communication, June 13, 2025).

This is an institutional barrier rooted in the division of roles and perspectives between infrastructure managers and train operators. It can be addressed through improved coordination mechanisms, shared strategic planning processes and clearer definitions of international service priorities. Regulatory revisions could help balance commercial interests with network optimisation, ensuring that international operators are not sidelined.

#### 6.2.2.3 Prioritization of Domestic Trains over International Services

Infrastructure managers prioritise domestic train services when allocating capacity, especially during peak hours. This sequencing means international trains must fit into leftover slots, often at less convenient times, limiting their competitiveness and growth potential. The political and economic incentives to prioritise national mobility and commuter flows further contribute to this imbalance (Corridor coordinator, personal communication, June 25, 2025).

This is an institutional and policy-driven barrier, reflecting national transport goals and incentive structures that do not fully incorporate the EU's modal shift objectives. To overcome this, governments and infrastructure managers must revise their capacity allocation frameworks to explicitly prioritise or reserve slots for international services, especially on strategic cross-border corridors.

#### 6.2.2.4 High and Uneven Track Access Charges Across Borders

International rail operators face substantial costs due to high and inconsistent track access charges across different countries. These charges can vary widely, adding complexity to cross-border service planning and undermining competitiveness compared to aviation. While partially shaped by EU directives, pricing decisions are still largely under national control and major reforms have been slow (Expert, personal communication, June 2, 2025).

This is a financial barrier, rooted in the cost structures imposed by national infrastructure managers. Addressing it would require both EU-level action to harmonise track access pricing and national-level policies to reduce fees for international services. Targeted incentives or subsidies could also be introduced to lower entry costs and make international rail more competitive with air travel.

### 6.2.3 Cross-Border and EU Integration Barriers

International rail services face multiple barriers related to fragmented governance, technical differences and regulatory inconsistencies across countries. These challenges increase operational complexity, raise costs and slow down the development of new international routes, ultimately reducing the competitiveness of rail compared to aviation. The barriers can be grouped into two main categories: Fragmented Coordination and Governance Barriers, and Technical and Regulatory Fragmentation Barriers.

#### 6.2.3.1 Fragmented Coordination and Governance Barriers

Fragmented coordination among national infrastructure managers and insufficient intergovernmental cooperation beyond EU mechanisms hinder cross-border rail development. Gareth Williams (Eurostar) observed that launching a new international route can take up to five years in one direction and three years in the other due to disjointed planning processes. Similarly, Elmer van Buuren (European Sleeper) highlighted that their service receives guaranteed capacity in France and priority in Belgium but “priority zero” in the Netherlands, illustrating uneven institutional treatment (Treinreiziger.nl, 2025d).

This barrier is institutional and political in nature, rooted in the lack of harmonized governance and limited political alignment between national governments. The reliance on EU-level coordination alone has proven insufficient, as national strategies, policies and investments remain fragmented (Expert, personal communication, June 2, 2025). Overcoming this requires establishing formal joint planning bodies involving all national infrastructure managers and governments, as well as promoting stronger bilateral and multilateral cooperation frameworks supported by sustained political commitment and aligned investment decisions.

#### 6.2.3.2 Technical and Regulatory Fragmentation Barriers

Cross-border rail operations face significant technical and regulatory challenges due to incompatible standards and fragmented rules. Countries use different electrical and signalling systems, requiring specialized multi-system rolling stock and raising costs. Mandatory driver changes at borders due to language and certification requirements further add operational complexity. While EU Technical Specifications for Interoperability (TSI) aim to harmonize these standards, full implementation remains incomplete (Corridor coordinator, personal communication, June 25, 2025).

Regulatory fragmentation also creates burdens for operators. Differing national rules on track access charges, safety certification, border controls and customs procedures cause inconsistent treatment of international services and add delays. For example, Eurostar must operate dedicated terminals and police presence due to UK border controls, unlike aviation services (Treinreiziger.nl, 2025d). Drivers face multiple national licensing requirements and language obligations, restricting staffing flexibility and increasing costs, unlike pilots who operate under global ICAO standards primarily in English (Treinreiziger.nl, 2025d).

These barriers are regulatory and institutional in nature, coming from national and EU legal frameworks that remain insufficiently harmonized. Addressing them requires accelerating the deployment of unified technical systems, establishing EU-wide driver certification frameworks, harmonizing track access charging and safety rules, and streamlining customs and border procedures to enable smoother, more integrated international rail services.

### 6.2.4 Governance and Policy Fragmentation

International rail development is hindered by fragmented governance structures and limited policy integration across transport modes. This section distinguishes between two institutional barriers: (1) Internal Fragmentation within Government and (2) Lack of Cross-Modal Planning and Strategic Control.

#### 6.2.4.1 Internal Fragmentation within Government

Within the Dutch Ministry of Infrastructure and Water Management, responsibilities for aviation and rail are divided between different directorates, leading to limited coordination on international rail strategy. International connectivity often falls outside the core priorities of national mobility planning (Policy Officer 1, personal communication, June 13, 2025). This compartmentalisation hampers the development of integrated strategies to substitute short-haul flights with international rail. In addition, most international trains (except Intercity Brussels) operate under open-access commercial models. This limits the Dutch government's ability to mandate new routes or service levels. Instead, it must rely on market responses and cannot impose obligations that align with broader policy goals (Policy Officer 1, personal communication, June 13, 2025).

This is an institutional barrier rooted in the governance structure and limited direct control over international rail services. Addressing it requires establishing a dedicated interdepartmental taskforce and exploring the inclusion of select international routes under the national concession framework to allow more influence.

#### 6.2.4.2 Lack of Cross-Modal Planning and Strategic Control

Policy and planning for rail, aviation and road transport are typically developed in parallel but remain disconnected. Even when coordination exists between ministries, each mode is governed by distinct policy frameworks, budgets and priorities (Policy Officer 2, personal communication, June 13, 2025). This separation undermines the formulation of integrated cross-modal strategies that are essential to shifting passengers from air to rail. At both the national and EU levels, this modal separation results in fragmented investment priorities and limited alignment between infrastructure planning and environmental goals. As a result, international rail struggles to compete with short-haul flights on a level policy playing field.

This is an institutional barrier caused by the structural separation of transport modes within policy-making processes. Solutions include the development of a national cross-modal transport strategy that explicitly integrates international rail and aligns investment decisions across modes.

### 6.2.5 Political and Strategic Prioritization

International rail development is constrained by a lack of political prioritization, fragmented governance across national and EU levels and the absence of targeted financial instruments. These barriers undermine long-term planning, discourage investment and weaken the public sector's ability to promote rail as a substitute for short-haul flights. This section groups the relevant political, institutional, regulatory and financial barriers into three categories.

#### 6.2.5.1 Low and Unstable Political Priority for International Rail

International rail continues to receive limited attention in national transport strategies. In countries such as Germany and France, substantial investments are directed toward improving domestic rail services, while international connections (especially those not operated by national incumbents) are often excluded from strategic planning and funding programs (Expert, personal communication, June 2, 2025).

In the Netherlands, political priorities further reinforce this domestic focus. The current caretaker cabinet primarily promotes economic accessibility and national transport goals, rather than sustainability or international modal shift. Corridor development teams within the government are mainly tasked with managing passenger growth and maintaining service quality, not promoting air-to-rail substitution. Furthermore, frequent changes in political leadership, shifting ministerial agendas and regional variations in priorities result in inconsistent support and funding for international rail. This reduces the continuity and coherence required for cross-border service development and hinders sustained cooperation between Dutch ministries and foreign governments (Corridor coordinator, personal communication, June 25, 2025).

This is a political and institutional barrier, driven by national policy agendas that do not consistently incorporate international mobility goals. Overcoming it requires high-level political commitment, cross-party consensus and alignment of international rail ambitions with broader national and regional strategies. Consistent leadership, long-term planning and explicit modal shift targets must be embedded into national transport frameworks.

#### 6.2.5.2 EU-Level Political Constraints and Decision-Making Procedures

At the European level, the implementation of ambitious modal shift objectives is constrained by the structure of EU decision-making. While the European Commission can propose liberalisation, harmonisation and funding measures to improve international rail, legislative progress is often blocked by the unanimity principle in the Council of Ministers. This allows individual member states to veto proposals that conflict with their national interests or threaten incumbent rail operators (Expert, personal communication, June 2, 2025).

This is a regulatory and political barrier, embedded in the formal procedures of the European Union. It reflects the limited enforceability of EU rail strategies and the dependency on national governments' political will. Overcoming this barrier will require procedural reform, such as revising voting rules to limit veto rights or empowering the European Commission to better enforce existing directives. Greater alignment between national interests and EU-wide modal shift targets would also strengthen policy coherence and accelerate progress.

#### 6.2.5.3 Lack of Dedicated Funding Mechanisms for International Rail

Public financial support for international rail remains insufficient and poorly targeted. In the Netherlands, revenues from the air passenger tax are not earmarked for sustainable mobility or rail investment, but instead flow into the general government budget (Expert, personal communication, June 2, 2025). As a result, there is limited funding available for developing international services, subsidising ticket prices or upgrading necessary infrastructure.

This is a financial barrier related not to the absolute availability of funds, but to the way public revenues are allocated. Without dedicated investment streams, it is difficult for international rail to compete with aviation on cost or convenience. Addressing this barrier requires financial reform, such as earmarking part of the air travel tax for green mobility initiatives, establishing dedicated national or EU-level rail funds and providing targeted subsidies for new or underserved international routes. These mechanisms would strengthen the financial viability of international services and accelerate the shift from air to rail.

## 6.3 Summary and Conclusion

This chapter addressed sub-question 3 by identifying the most important institutional, regulatory and financial barriers that affect the implementation of the three proposed project alternatives. These barriers largely determine whether planned infrastructural and operational improvements can be delivered effectively, on time and at the scale required to compete with short-haul flights. Excluding the KLM Air&Rail Model barriers, 4 different alternative-specific barriers and 14 distinct general barriers were identified.

To provide structure and clarity, this analysis grouped the general barriers into five overarching categories derived from the findings of the EU Transport Landscape Review (European Court of Auditors, 2018):

1. Market Structure and Competition Barriers
2. Planning, Capacity and Coordination Barriers
3. Cross-Border and EU Integration Barriers
4. Governance and Policy Fragmentation Barriers
5. Political and Strategic Prioritization Barriers

For the Eurostar expansion between Amsterdam and London, the most pressing issues are a result of complex cross-border regulatory requirements linked to UK-Netherlands border controls, combined with institutional staff shortages in security and customs. Financial disputes over funding for these border checks have led to delays that directly constrain planned increases in service frequency. The Amsterdam-Berlin upgrade faces a different set of obstacles, primarily operational conflicts with domestic services, a limited sense of political urgency to accelerate improvements and a lack of dedicated funding. Nevertheless, the corridor's growing strategic military relevance could become an opportunity to secure additional EU and national resources. Meanwhile, the KLM Air&Rail model is hindered by deeply rooted institutional fragmentation, which makes it difficult to achieve smooth passenger and baggage handling between rail and air. Financial incentives still favour short-haul feeder flights and complex governance arrangements between airlines and rail operators further restrict the potential for rail to replace short-haul air connections for transfer passengers. Given these barriers and because several interviewees indicated that this alternative is not credible and too complex to be implemented in the short term, the KLM Air&Rail model will not be taken forward for further analysis in the SCBA.

**Market Structure and Competition Barriers**

The shift from short-haul air to rail is constrained by transport market structures and regulations. Three interrelated barriers stand out: dominant operator control limiting market access, structural dependence of hub airports on short-haul feeder flights and persistent regulatory and fiscal asymmetries between aviation and rail. Together, these institutional, regulatory and financial challenges reinforce aviation's competitive edge and hinder the creation of a level playing field. Overcoming these barriers requires structural reforms such as separating commercial and regulatory roles within dominant rail operators, coordinated ticketing strategies, improved air-rail integration and fiscal measures like VAT exemptions and environmental levies. Without addressing these foundational issues, scaling international rail as a viable alternative to short-haul flights will remain limited.

**Planning, Capacity and Coordination Barriers**

International rail expansion is constrained not only by infrastructure availability but also by how planning, capacity allocation and coordination are structured across national networks. The barriers include short-term access rights without long-term guarantees, institutional misalignment between operators and infrastructure managers, prioritization of domestic over international services and high uneven track access charges across borders. These regulatory, institutional and financial shortcomings reduce certainty for operators, discourage investment and hinder cross-border coordination. Solutions include introducing multi-year capacity contracts, improving strategic alignment between stakeholders, reserving capacity for international services and harmonizing track access charges at the EU level. Without these reforms, international rail will remain at a disadvantage compared to air travel, especially on high-demand Schiphol routes.

**Cross-Border and EU Integration Barriers**
International rail's competitiveness suffers from fragmented governance and persistent technical and regulatory fragmentation across Europe. Two main barrier categories are identified: fragmented coordination among national infrastructure managers and governments, and inconsistencies in technical standards and regulatory frameworks. These issues cause long lead times for new routes, uneven institutional treatment across countries and complex operational challenges such as driver changes, multi-system rolling stock and duplicated security procedures. Despite EU efforts like the Technical Specifications for Interoperability, full harmonization remains incomplete. Addressing these barriers requires stronger bilateral and multilateral cooperation, formal joint planning mechanisms and faster implementation of unified technical and legal standards across member states. Without such reforms, international rail will continue to face structural disadvantages relative to aviation, especially on routes requiring smooth cross-border integration.

**Governance and Policy Fragmentation Barriers**
Progress is also limited by fragmented governance and weak policy integration both within governments and across transport modes. Within the Dutch Ministry of Infrastructure and Water Management, responsibilities for aviation and rail are disconnected, leading to limited coordination and incoherent international rail strategies. Additionally, the predominance of open-access commercial models restricts government influence over route planning and service levels. More broadly, rail, aviation and road transport planning as well as policymaking happen largely in isolation, governed by distinct frameworks, budgets and priorities. This cross-modal fragmentation hinders the development of integrated strategies essential for substituting short-haul flights with rail, and undermines alignment with environmental and mobility goals. Overcoming these barriers calls for interdepartmental taskforces and national cross-modal strategies that explicitly incorporate international rail and harmonize investments across modes.

**Political and Strategic Prioritization Barriers**
Finally, international rail development is constrained by low political prioritization, fragmented governance across national and EU levels, and a lack of dedicated financial instruments. National governments, including the Netherlands, prioritize domestic transport goals, leading to inconsistent support and funding for cross-border rail. At the EU level, decision-making rules allow member states to block rail liberalization and harmonization efforts, limiting modal shift progress. Financially, international rail suffers from inadequate, poorly targeted public funding, with revenues such as air passenger taxes not earmarked for sustainable mobility or rail investment. Addressing these barriers requires strong, stable political commitment at all levels, procedural reforms to reduce veto powers and dedicated funding streams to improve the financial sustainability and competitiveness of international rail as an alternative to short-haul flights.

Based on the analysis in this chapter, the most critical barrier to address in the short term is the fragmented cross-border regulatory environment, particularly for services like Eurostar where border control capacity directly limits service frequency. Without resolving these regulatory and staffing issues, the project alternative cannot be implemented as desired. In terms of structural impact, the regulatory and fiscal asymmetries between air and rail are the most difficult to overcome, as they require EU-wide reforms and political consensus. By contrast, barriers related to planning and capacity coordination are more feasible to address through bilateral agreements, targeted investments, and operational changes, making them relatively easier to resolve within the coming decade.

In conclusion, the barriers identified in this chapter reveal that expanding international rail as a substitute for short-haul flights is not merely a matter of infrastructure or technology. Institutional inertia, fragmented governance, unbalanced financial incentives and complex cross-border regulations pose significant and interrelated challenges. While the Eurostar expansion and dual service model face practical obstacles that could be resolved through targeted coordination and strategic investment, the KLM Air&Rail model is structurally constrained by deeper market and governance issues. These findings underscore the need for systemic reforms and coordinated action across national and EU levels if rail is to become a credible and competitive alternative to air travel on high-demand corridors. The next chapter will use a SCBA to assess the societal impacts of the proposed alternatives and identify the effects of the established barriers on these alternatives.

# 7. Societal Impact Assessment of Alternatives to Short-Haul Flights

Public policy decisions often involve weighing a wide range of societal advantages and disadvantages. A SCBA is a structured tool that supports this process by systematically identifying, quantifying and comparing the full range of societal effects (both positive and negative) of the proposed interventions (Romijn & Renes, 2013). Unlike financial analyses that focus on profitability for specific stakeholders, SCBA evaluates impacts from the perspective of society as a whole, expressing them in monetary terms wherever feasible. In this study, the SCBA is used to assess the societal costs and benefits of reducing short-haul flights by improving international rail connections from Amsterdam to London and Berlin.

**SQ4:** *What are the expected environmental, economic and social impacts of implementing the proposed alternatives to replace short-haul flights, and how do these impacts compare to the associated implementation costs?*

The SCBA framework consists of eight structured steps. The first three steps form the preparatory phase: analysing the societal problem, defining the baseline (what happens without additional measures) and identifying the alternatives. These steps help clarify the scope of the analysis and determine what type of SCBA is appropriate.

The following steps involve identifying the relevant effects of each alternative (step 4), valuing those effects in monetary terms (step 5) and analysing distributional impacts. Since the analysis is made with various assumptions, different scenarios are established to account for uncertainty and variation in core parameters. (step 6). In step 7, all future costs and benefits are discounted to a common base year, allowing consistent comparison. Finally, the results are presented and interpreted by looking at the financial and operational metrics: operational indicators such as the number of flights, passengers shifted from air to rail and emission costs, as well as financial indicators including capital expenditures, total costs and benefits (both discounted and undiscounted), the Benefit-Cost Ratio, Net Present Value and Internal Rate of Return, which are used to clearly communicate the outcomes in step 8. Finally, to make sure the results are interpreted correctly and to test their robustness, a sensitivity analysis will be conducted examining the impact of assumptions on the final outcomes.

The SCBA provides insight into how each proposed rail alternative performs in terms of environmental sustainability, economic efficiency and social impacts compared to the investment required for implementation. In doing so, it offers a transparent basis for evaluating whether society as a whole benefits from replacing short-haul flights with improved rail services.

## 7.1 Preparatory Phase

Before the proposed rail alternatives can be evaluated in terms of their societal impacts, a preparatory phase is necessary. This phase establishes the foundation for the SCBA by defining the problem, identifying a credible base case for comparison and selecting relevant project alternatives. These steps will be based on the findings of the previous chapters.

### 7.1.1 Step 1: Problem Analysis

As outlined in Section 1.1, the overarching challenge is to replace short-haul flights in Europe with competitive international rail connections, in order to reduce $CO_2$ emissions and relieve airport capacity constraints. For the SCBA, this problem is framed in terms of the societal costs and benefits of such a modal shift on the selected routes.

The six target routes from the *Actieagenda Trein en Luchtvaart*: Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin accounted for roughly 14 % of all flight movements at Schiphol before COVID-19 (Ministry of Infrastructure and Water Management, 2020). Projections by KiM (2023) indicate that by 2030, between 5.600 and 16.000 flights could be replaced by rail, corresponding to 6-22 % of flights on 13 European routes.

For this analysis, two corridors are assessed in detail: Amsterdam-London and Amsterdam-Berlin. These have concrete improvement plans under development by Eurostar, NS and DB, and are therefore the most relevant for estimating near-term societal impacts. The SCBA focuses on quantifying the main effects arising from replacing short-haul flights on these routes.

### 7.1.2 Step 2: Base Case

The base case in this study reflects the expected development of air and rail transport on the routes Amsterdam-London and Amsterdam-Berlin, assuming no further interventions. It functions as the reference scenario against which the project alternatives will be compared. This base case assumes continued growth in both aviation and rail, in line with existing trends and demand projections. However, it also recognises that this growth will happen under increasingly constrained conditions, particularly due to infrastructure limitations and mounting environmental pressures.

In this scenario, the aviation sector continues to operate with the current mix of aircraft, frequencies and service levels, but gradually evolves based on technological improvements and policy measures. Likewise, international rail services are assumed to grow according to current projections, without any additional steps specifically aimed at accelerating the shift from air to rail.

To be able to compare the base case and alternatives over time, a consistent set of quantitative indicators is calculated for each mode, for each route and in total for the base case. For aviation, this includes the number of flights per year, the average flight load factor, aircraft seating capacity, the number of passengers per flight and the total number of air passengers. Operational performance is expressed through available seat kilometres and passenger kilometres. The associated external effects are measured through annual $CO_2$ emissions, $CO_2$ emission costs, air pollution costs, noise costs and operating costs.

For rail, annual metrics for the base case include the number of train services operated, the seating capacity of trains, the maximum number of passengers that can be carried and actual passenger demand. Additional indicators include the number of passengers transported, the average train load factor, passengers per train, total train kilometres operated and total passenger kilometres. As with aviation, the analysis also includes yearly estimates $CO_2$ emissions, $CO_2$ emission costs, noise costs and operating costs for rail transport.

The appraisal period for the SCBA runs from 2026 to 2050. The year 2050 is selected as the end of the analysis horizon to align with long term European transport and climate goals. For rail, the European Commission (2024) has set the objective of tripling HSR traffic by 2050 as part of the revised TEN T Regulation and associated initiatives to improve cross border services and promote modal shift. In the aviation sector, the Destination 2050 roadmap outlines a feasible trajectory to achieve net zero $CO_2$ emissions by 2050 (Destination 2050, 2025). By adopting this timeframe, the SCBA is able to assess the full impact of the proposed project alternatives and how they contribute to these long term objectives.

As mentioned all metrics are calculated separately for each route, as well as in total. This allows a clear comparison between the base case and each proposed alternative, and provides the necessary input for estimating the societal costs and benefits of replacing short haul flights with improved international rail services.

### 7.1.3 Step 3: Project Alternatives

This study evaluates two realistic project alternatives that aim to support a modal shift from short-haul air to international rail transport on the Amsterdam-London and Amsterdam-Berlin corridors. Each alternative represents a feasible and planned improvement in rail service that is scheduled for implementation. To assess their effects on passenger behaviour and societal outcomes, three implementation scenarios are developed and compared against the base case described in the previous section: one in which only the Eurostar expansion to London is implemented, one in which only the Amsterdam-Berlin dual service model is introduced and one combined scenario in which both alternatives are implemented simultaneously.

The first alternative is the expansion of Eurostar services between Amsterdam and London. Under this plan, the number of daily Eurostar departures from Amsterdam will increase from three to five, with the fourth train implemented in 2026 and the fifth in 2027. As described in Chapter 5, the corridor's existing infrastructure is sufficient to accommodate this increase. To implement this alternative the acquisition of two additional Siemens Velaro e320 trainsets is necessary.

The second alternative introduces a dual intercity rail service on the Amsterdam-Berlin corridor, on which the new ICE L trains will be operated. From 2030, the dual service model will double the train frequency in each direction, replacing the current two-hourly service. This is done by introducing a new and faster service of 5 hours and 27 minutes. The only infrastructure adjustment needed is the construction of a fourth platform track at Deventer station.

To estimate the full impact of each scenario, a set of yearly performance indicators is calculated for the entire appraisal period from 2026 to 2050. For each implementation scenario effects are modelled separately for the Amsterdam-London and Amsterdam-Berlin routes, as well as in total. This allows for an accurate comparison between the base case and each implementation strategy and forms the basis for the cost-benefit analysis.

For each implementation scenario, the following metrics are calculated annually for aviation: number of flights, demand for flights, demand flights shifted to rail, actual flights shifted, flight load factor, aircraft seating capacity, passengers per flight, total air passengers, demand passengers, demand passengers shifted, actual passengers shifted, available seat kilometres, passenger kilometres, total travel time, $CO_2$ emissions, $CO_2$ emission costs, air pollution costs, noise costs and operating costs.

Similarly, for rail transport, the following indicators are calculated per year: number of trains, train capacity, maximum passengers carried, total passenger demand, new passenger demand, passenger demand shifted from air, share of new demand, share of demand from air, total passengers carried, new passengers carried, passengers from air, train load factor, passengers per train, train kilometres, passenger kilometres, total travel time, $CO_2$ emissions, $CO_2$ emission costs, noise costs, operating costs, waiting time savings for existing passengers, waiting time savings for new passengers and net travel time costs for passengers switching from air to rail.

For the dual service model and the combined implementation scenario, where the travel time between Amsterdam and Berlin is shortened, additional variables are included to reflect the benefits of faster rail services. These are the travel time savings for existing passengers and travel time savings for new passengers. These additional metrics are necessary to capture the full value of service improvements.

Together, these calculations provide the quantitative foundation for comparing the societal impacts of the proposed rail alternatives. They allow for a detailed understanding of how different rail improvements can reduce the reliance on short-haul flights and contribute to broader environmental and transport policy objectives for 2050.

## 7.2 Step 4 and 5: Identification and Monetisation of Effects

This section outlines the formulas for calculating the societal benefits and costs of the project alternatives. The supporting calculations and their underlying rationale have been moved to Appendix D: Supporting Calculations for the SCBA. Before applying these formulas, the relevant operational calculations must be completed. The following dimensions are used throughout the formulas to specify the context of each calculation, where the policy and growth scenarios will be explained in further detail in Section 7.3:

- **Alternative (a):** Indicates which project alternative is considered
  - 0 = Base case (no improvements)
  - 1 = Eurostar expansion
  - 2 = Dual service model
  - 3 = Both alternatives implemented
- **Policy scenario (s):** Represents different policy environments affecting the outcome
  - N = Neutral policy scenario
  - O = Optimistic policy scenario
  - P = Pessimistic policy scenario
- **Growth scenario (g):** Describes assumptions about future growth in demand
  - B = Base growth scenario
  - H = High growth scenario
  - L = Low growth scenario
- **Route (r):** The specific route to which the calculations apply
  - AMS-LON = Amsterdam-London
  - AMS-BER = Amsterdam-Berlin
  - Total = Combined total of both routes
- **Year (t):** The year for which the effect is calculated

These dimensions define the scope and conditions of the effects being monetised and enable a complete assessment across alternatives, scenarios, routes and time.

### 7.2.1 Operational Calculations

Before the societal benefits and costs of each project alternative can be assessed, the necessary operational data must first be calculated. These operational indicators form the foundation for the monetisation of effects in the subsequent sections. For air transport, the core metrics include the number of flights, the number of air passengers, available seat kilometres, passenger kilometres and $CO_2$ emissions. For rail transport, the required metrics are the number of trains, the number of passengers carried, train kilometres, passenger kilometres and $CO_2$ emissions.

The formulas and methods used to estimate these operational figures are presented in this section. These results are then used to determine the associated benefits and costs in Sections 7.2.2 and 7.2.3.

#### 7.2.1.1 Number of Flights

The baseline flight numbers for the London and Berlin routes in 2023 are derived from the weekly flight data presented in Table 4-6. Using this data, the annual flight volumes were calculated as 10.192 flights to London and 5.252 flights to Berlin. These baseline values form the starting point for projecting future flight numbers under different growth scenarios.

Future flight numbers in year *t* are estimated by applying a series of annual growth factors to the 2023 baseline figures. These growth factors are assumed constant within specific time intervals but vary between intervals. A detailed explanation of these growth factors is provided in Section 7.3. The projection is carried out using the following formula:

$$Flights_t^{0,g}(r) = Flights_{2023}(r) * \prod_{i=1}^{n} \left(1 + \gamma_{i,g}\right)^{\Delta t_i} \tag{1}$$

The growth factor $\gamma_{i,g}$ corresponds to the annual growth rate for a given time period *i* and scenario $g$, which is constant within that interval (for example, 1,6% for 2024-2030 in the base scenario). $\Delta t_i$ indicates the number of years between 2023 and year *t* that fall within each growth period *i*. The product is taken across all relevant time intervals between 2023 and the year being projected.

The number of flights after the modal shift is calculated by subtracting the number of flights actually shifted from the baseline flight number for that year.
This relationship is expressed as:

$$Flights_t^{a,s,g}(r) = Flights_t^{0,g}(r) - FlightsShifted_{actual,t}^{a,s,g}(r) \tag{2}$$

The calculations for estimating the actual number of flights shifted, average passengers per flight, aircraft capacity and load factor are moved to the Appendix.

#### 7.2.1.2 Number of Air Passengers

These formulas describe the number of air passengers in a given year. The first formula calculates the number of passengers still traveling by air after implementation of the rail improvement by subtracting the number of passengers who actually shifted to rail (based on capacity constraints) from the original number of air passengers in the base case. The second formula defines the base case number of air passengers as the product of the number of flights and the average number of passengers per flight. These formulas help quantify the remaining air travel volume, taking into account the actual shift to rail.

$$AirPax_t^{a,s,g}(r) = AirPax_t^{0,g}(r) - AirPaxShifted_{actual,t}^{a,s,g}(r) \tag{3}$$

$$AirPax_t^{0,g}(r) = Flights_t^{0,g}(r) * \ Pax_{flight,}t(r) \tag{4}$$

The calculations for estimating the actual number of passengers shifted, average passengers per flight, aircraft capacity and load factor are moved to the Appendix.

#### 7.2.1.3 Available Seat Kilometres, Air Passenger Kilometres and Air $CO_2$ Emissions

To estimate air transport capacity, the number of flights was multiplied by the average aircraft seat capacity and the observed flight distance from FlightAware (n.d.), resulting in Available Seat Kilometres (ASK), which represent the total passenger-carrying capacity offered. The actual Passenger-Kilometres (PKM) were calculated by multiplying the number of passengers flying by the same observed flight distance. These ASK and PKM values represent the air transport capacity and usage respectively and are calculated in millions. These metrics are used in the SCBA to assess the environmental and economic impacts of air travel, based on real-world flight distances rather than straight-line estimates for greater accuracy.

$$AirASK_t^{a,s,g}(r) = Flights_t^{a,s,g}(r) * AircraftCapacity_t(r) * d_{flight}(r) * \frac{1}{1.000.000} \tag{5}$$

$$AirPKM_t^{a,s,g}(r) = AirPax_{air,t}^{a,s,g}(r) * d_{flight}(r) * \frac{1}{1.000.000} \tag{6}$$

The total $CO_2$ emissions from aviation (in tonnes) for each year are calculated by multiplying the number of flights by the average emissions per flight, which depend on the type and amount of fuel used. The model includes three fuel types: conventional fossil jet fuel, synthetic Sustainable Aviation Fuel (SAF), and non-synthetic SAF. Each fuel type has a specific emission factor, expressed in kilograms of $CO_2$ per kilogram of fuel burned. Fossil jet fuel has a factor of 3,15 kg $CO_2$/kg fuel (EUROCONTROL, 2025b), while synthetic and non-synthetic SAF are associated with lower emission factors due to their reduced lifecycle emissions which are 0,95 kg $CO_2$/kg and 1,26 kg $CO_2$/kg respectively (Eurocontrol, 2024). To estimate emissions per flight, the amount of each fuel type consumed is multiplied by its corresponding emission factor. These values are then summed and multiplied by the total number of flights in the given year. The result is divided by 1,000 to convert the total emissions from kilograms to tonnes.

$$AirCO_2Emissions_t^{a,s,g}(r) = Flights_t^{a,s,g}(r) * \frac{1}{1000} * \\ ((EF_{fossil} * FC_{fossil,t}\ (r) + EF_{syn} * FC_{syn,t}\ (r) + EF_{nonsyn} * FC_{nonsyn,t}\ (r)) \tag{7}$$

The formulas for annual fuel consumption, including fossil, synthetic SAF and non-synthetic SAF, are moved to the appendix.

#### 7.2.1.4 Number of Trains and Rail Passengers Carried

The number of trains per year is calculated by multiplying the daily frequency of trains per direction by 365 days and by 2 (to account for both directions). In the base case this frequency is equal to 3 for the Amsterdam-London route and 5 for the Amsterdam-Berlin route.

$$Trains_t^{a,s}(r) = Train_{freq,t}^{a,s} * 365 * 2 \tag{8}$$

The number of rail passengers actually carried per year is determined by comparing total passenger demand with the carrying capacity of the rail service. Since capacity may limit how many passengers can actually be transported, the number of rail passengers carried is calculated as the minimum of the total rail passenger demand and the maximum number of passengers that can be transported based on train frequency, seating capacity and load factor.

$$RailPaxCarried_t^{a,s,g}(r) = MIN\ (RailPaxCarried_{max,t}^{a,s,g}(r), RailPaxDemand_t^{a,s,g}\ (r)) \quad (9)$$

The formulas for the maximum amount of rail passengers carried and rail passengers demand is moved to the appendix.

#### 7.2.1.5 Train Kilometres, Rail Passenger Kilometres and Rail $CO_2$ Emissions

The formula calculates the total train-kilometres. Train-kilometres represent the total distance covered by all train services operating on that route in a year. This is done by multiplying the number of train services scheduled for that year on the route by the one-way rail distance of the route. For the Amsterdam-London route, the rail distance is 585 kilometres, while for the Amsterdam-Berlin route, it is 624 kilometres. These distances reflect the actual rail routes between the cities as reported by *The Man in Seat 61* (n.d.-a, n.d.-b).

$$TrainKilometres_t^{a,s}(r) = Trains_t^{a,s}(r) * d_{train}(r) \quad (10)$$

The formula for rail PKM calculates the total distance travelled by all rail passengers on a specific route in a given year, scenario, and alternative. It does this by multiplying the total number of passengers carried by train that year by the one-way rail distance of the route. The result is then divided by one million to express the outcome in millions of passenger-kilometres.

$$RailPKM_t^{a,s,g}(r) = RailPaxCarried_t^{a,s,g}(r) * d_{train}(r) * \frac{1}{1.000.000} \quad (11)$$

Eurostar currently reports an emission factor of approximately 60 tonnes of $CO_2$-equivalent per million passenger-kilometres (Eurostar, n.d.). From 2030 onwards, Eurostar plans to operate entirely on renewable electricity, which is expected to reduce this emission factor to zero (Eurostar, 2024b). The model assumes a linear decline in the emission factor between the current value and zero by 2030. Since Eurostar services are fully electric, they also produce no direct emissions of air pollutants such as $NO_x$, $SO_x$ or particulate matter. Similarly, the Amsterdam-Berlin Intercity service, operated by NS and Deutsche Bahn, already runs fully on renewable electricity in both the Netherlands and Germany, resulting in zero direct operational $CO_2$ emissions (NS, n.d., DB, n.d.). The associated formula calculates total annual rail $CO_2$ emissions by multiplying the total rail passenger-kilometres by the emission factor applicable in that year:

$$RailCO_2Emissions_t^{a,s,g}(r) = RailPKM_t^{a,s,g}(r) * EF_{rail,t}(r) \quad (12)$$

### 7.2.2 Societal Benefits

This section identifies and quantifies two main categories of societal benefits resulting from the proposed rail alternatives. For each category, the relevant formulas used to monetise the effects are presented.

The first category consists of benefits generated by the reduction in short-haul flights. Aviation results in several external costs on society, including $CO_2$ emissions, air pollution, noise and operating costs. When a portion of air travel demand shifts to rail, the number of flights decreases compared to the base case. This leads to measurable cost savings, which are calculated annually and aggregated over the appraisal period.

The second category includes benefits that are specific to rail transport. These arise from improvements in the level of service namely, increased train frequencies and shorter travel times. Higher frequency reduces average waiting times, while travel time savings occur on the Amsterdam-Berlin corridor due to the introduction of faster services. Both effects improve passenger experience and generate societal value, which is monetised using standard valuation methods for travel time savings.

The following subsections provide the exact formulas used to calculate these benefits, based on changes in operational performance, passenger volumes, and standard valuation coefficients. To do this some numbers need to be adjusted for inflation and this formula is also given.

#### 7.2.2.1 Adjusting for Inflation

The average inflation rate in the Netherlands over the past decade has been approximately 2,6% (FocusEconomics, n.d.) and this rate is used to adjust all monetary values to real 2026 euros. This ensures consistency and comparability across years in the analysis. The adjusted cost in 2026 euros is calculated using the formula:

$$AdjustedCost_{2026}^{a,s,g}(r) = BaseYearCost_{t}^{a,s,g}(r) * (1+i)^{2026-t} \tag{13}$$

#### 7.2.2.2 Savings Shifted Flights

The expected $CO_2$ price is €129 per tonne until 2030, rising to €348 per tonne by 2050 (EUROCONTROL, 2025c). This value for 2030 is broadly in line with the €152 per tonne used by a policy officer at the Ministry of Infrastructure and Water Management (Policy officer 1, personal communication, August 13, 2025). This increase reflects an annual real growth rate of approximately 5,1% over that period. To account for this trend, a linear increase in the $CO_2$ cost is assumed between 2030 and 2050, representing the growing societal cost of carbon emissions. The annual $CO_2$ emission cost from aviation is calculated by multiplying the total aviation $CO_2$ emissions by the corresponding $CO_2$ price in each year.

$$AirCO_2Costs_{t}^{a,s,g}(r) = AirCO_2Emissions_{t}^{a,s,g}(r) * C_{CO_2,t} \tag{14}$$

To calculate the external costs of air pollution from aviation, marginal cost estimates provided by EUROCONTROL (2025c, May) are used. The distinction between routes based on their respective reference aircraft is the correct assumption according to (Policy Officer 2, personal communication, August 18, 2025). For the Amsterdam-London route, the Airbus A320 is taken as the reference aircraft, corresponding to air pollution costs of €0,09 per passenger-kilometre. For the Amsterdam-Berlin route, the Boeing 737 is used, with higher marginal costs of €0,14 per passenger-kilometre. These values are expressed in real 2024 terms and are kept constant in real terms throughout the analysis. When expressed per million PKM and adjusted for inflation, this results in €94.741 for Amsterdam-London and €147.375 for Amsterdam-Berlin in 2026.

Research shows that SAF significantly reduces non-$CO_2$ emissions due to its cleaner burning characteristics, especially in the case of synthetic paraffinic kerosene SAF (RSB & To70, 2024). SAF can reduce soot emissions by 90% and nearly eliminate sulphur emissions, both of which improve local air quality and reduce contrail formation. As particulate matter and $SO_x$ are estimated to account for around two-thirds of aviation air pollution costs, SAF use is assumed to reduce total air pollution costs by 60%. As a result, the adjusted air pollution costs for SAF are €37.896 per million PKM for Amsterdam-London and €58.950 per million PKM for Amsterdam-Berlin. These differentiated cost values are used in the model based on the annual fuel mix and are integrated using the following formula that multiplies the PKM flown with each fuel type by its corresponding pollution cost.

$$AirPollutionCosts_t^{a,s,g}(r) = C_{fossil\ pollution,t}(r) * AirPKM_t^{a,s,g}(r) * (Share_{fossil,t}) + C_{SAF\ pollution,t}(r) * AirPKM_t^{a,s,g}(r) * (Share_{syn,t} + Share_{nonsyn,t}) \quad (15)$$

The real-term noise cost for 2024 is estimated at €2,65 per passenger for short-haul flights under 1.500 km, based on EUROCONTROL (2025d). This cost is expected to remain constant in real terms over the coming years. Adjusted for inflation the updated cost is €2,79 per passenger. The total noise cost for aviation on a given route in year *t* is calculated by multiplying the number of air passengers by the adjusted per-passenger noise cost, as shown in the formula:

$$AirNoiseCosts_t^{a,s,g}(r) = AirPax_t^{a,s,g}(r) * C_{noise} \quad (16)$$

Operating cost data from EUROCONTROL (2025a) are given in 2022 USD per ASK. The distinction between routes based on their respective reference aircraft also applies here, as confirmed by (Policy Officer 2, personal communication, August 18, 2025). For Amsterdam-London, costs for the Airbus A320 Family were used, reflecting the Airbus A321neo operated by KLM. For Amsterdam-Berlin, Boeing 737 Classic costs were applied. Operating costs are approximately 36.000 USD/million ASK for AMS-LON and 29.600 USD/million ASK for AMS-BER. These were converted to euros at the 2022 exchange rate (0.951 EUR/USD Exchange Rates UK, n.d.-a) and adjusted for inflation to 2026 values, resulting in €37.938 and €31.193 per million ASK, respectively. These unit costs are then multiplied by the projected ASK for each year to calculate total operating costs.

$$AirOperatingCosts_t^{a,s,g}(r) = AirASK_t^{a,s,g}(r) * C_{operating}(r) \quad (17)$$

This formula calculates the annual air cost savings for each cost category on a specific route. It does this by subtracting the air costs of a given project alternative in a certain year and route from the air costs of the base case in the same year and route. The result shows how much cost is saved by implementing the alternative compared to the current situation.

$$Air \dots CostsSavings_t^{a,s,g}(r) = Air \dots Costs_t^{0,g}(r) - Air \dots Costs_t^{a,s,g}(r) \quad (18)$$

#### 7.2.2.3 Benefits from Improved Train Service

For scheduled international train services where passengers typically have flexible departure and arrival times, the average waiting time is estimated as one-quarter of the headway, rather than half, following Esfeh et al. (2020). This is applied with a factor of 1/4 instead of 1/2, since international trains require different headways compared to regular services. This assumption was confirmed by Policy Officer 2 (personal communication, August 18, 2025). Headway is calculated by dividing the length of the operating day by the number of daily trains. The Amsterdam-London route has a 16,7-hour operating day (06:40-23:21), and Amsterdam-Berlin runs for 14,55 hours (08:00-22:33).

Time savings are evaluated for both existing and new rail passengers. For existing users, waiting time savings are based on the value of time (VOT), the number of passengers in the baseline scenario and the reduction in average waiting time. For new users (either shifting from air or newly attracted to rail) the estimated benefit is halved to reflect the gradual nature of behavioural change and the idea that not all time savings translate into full welfare gains (Romijn & Renes, 2013). This approach helps capture the consumer surplus created by service improvements for all passengers. The value of time used in the analysis is €38,45 per hour in 2024 (EUROCONTROL, 2025e), adjusted to €40,48 in 2026.

$$WaitingTimeSavings_{old,t}^{a,s,g}(r) = VOT * RailPaxCarried_t^{0,g}(r) \\ (WaitingTime_t^{0,g}(r) - WaitingTime_t^{a,s,g}(r)) \tag{19}$$

$$WaitingTimeSavings_{new,t}^{a,s,g}(r) = \frac{1}{2}VOT * (WaitingTime_t^{0,g}(r) - WaitingTime_t^{a,s,g}(r)) \\ * (RailPaxCarried_t^{a,s,g}(r) - RailPaxCarried_t^{0,g}(r)) \tag{20}$$

$$WaitingTime_t^{a,s,g}(r) = \frac{1}{4} * \frac{OperatingHours}{Train_{freq,t}^{a,s}} \tag{21}$$

The average travel time on the Amsterdam-Berlin route decreases from 5 hours and 51 minutes to 5 hours and 39 minutes due to the introduction of a faster train service that completes the journey in 5 hours and 27 minutes and accounts for half of the total frequency. For existing rail passengers, the total time savings are monetized by multiplying the average time saved per trip by the number of passengers in the baseline scenario and the average value of time. For new passengers, half of the total time savings are counted, following the rule of halves. On the Amsterdam-London route, there are no time savings because the travel time stays the same.

$$TravelTimeSavings_{old,t}^{a,s,g}(r) = VOT * RailPaxCarried_t^{0,g}(r) * TravelTimeSaved(r) \tag{22}$$

$$TravelTimeSavings_{new,t}^{a,s,g}(r) = \frac{1}{2} * VOT * TravelTimeSaved(r) * \\ (RailPaxCarried_t^{a,s,g}(r) - RailPaxCarried_t^{0,g}(r)) \tag{23}$$

### 7.2.3 Societal Costs

There are several types of societal costs related to the proposed rail alternatives. First, the investment costs required to implement each alternative. Second, because shifting passengers from air to rail increases overall rail demand, the higher operational and emission costs of the expanded rail services must also be accounted for, reflecting both the modal shift and the additional passengers attracted by improved service quality. Finally, a significant cost arises from the travel time loss experienced by passengers who switch from faster air travel to slower rail journeys, representing a disutility that reduces overall welfare. Together, these costs provide a picture of the economic trade-offs involved in promoting rail as a substitute for short-haul air travel.

#### 7.2.3.1 Investment Costs

The CAPEX formula calculates the total investment costs for each project alternative by combining the costs of acquiring new trainsets and infrastructure expenses. The trainset cost is found by multiplying the number of trainsets acquired by the average cost per trainset. Eurostar ordered seven Siemens e320 trainsets for $600 million in 2014, which converts to roughly €452 million or about €64,6 million per trainset (SWI swissinfo.ch, 2014, Exchange Rates UK, n.d.-b). Adjusted for inflation to 2026, this amounts to €87,9 million per trainset. Similarly, in 2023, DB agreed to purchase 56 Talgo ICE L trains for €1,4 billion, equating to about €25 million per trainset or €27 million when adjusted for inflation (RailTech.be, 2023). Infrastructure costs include platform construction or upgrades, estimated at $250.000 per platform in 2014 for a regional station like Deventer, with dual tracks doubling the cost to $500.000 which is equal to €513.000 after inflation and currency conversion (Hot Rails, 2014). These costs are summed in the CAPEX formula to estimate total capital expenditure for each rail alternative. In the Base policy scenario the number of trainsets required is two for the Amsterdam-London route and six for the Amsterdam-Berlin route, as detailed in Sections 5.1.1 and 5.2.1 respectively.

$$CAPEX_t^{a,s,g}(r) = C_{trainset}(r) * TrainSetsAcquired_t^{a,s,g} + InfrastructureCosts_t^{a,s,g}(r) \tag{24}$$

#### 7.2.3.2 Costs of Increased Rail Usage

This formula calculates the $CO_2$ costs associated with rail travel for a specific project alternative. It multiplies the amount of $CO_2$ emissions produced by the rail by the cost per unit of $CO_2$ emitted.

$$RailCO_2Costs_t^{a,s,g}(r) = RailCO_2Emissions_t^{a,s,g}(r) * C_{CO_2,t} \tag{25}$$

The average noise cost for electric passenger trains, including high-speed services, was estimated at €1,20 per 1.000 passenger-kilometres based on 2018 data. Furthermore, noise emissions and their associated costs per train are considered constant throughout the analysis period (CE Delft, 2022). When adjusted for inflation, this cost corresponds to €1.474 per million PKM. The formula calculates total rail noise costs by multiplying the number of PKM with the noise cost.

$$RailNoiseCosts_t^{a,s,g}(r) = RailPKM_t^{a,s,g}(r) * C_{noise} \tag{26}$$

Total operating costs for rail services are estimated at approximately €38 per train-kilometre based on 2012 data for the Netherlands (European Commission Directorate-General for Mobility and Transport, 2015). When adjusted for inflation to 2026, this is €54,38 per train-kilometre and this value is kept constant throughout the years. A policy officer confirmed that keeping this value constant across the years is a logical approach, as the same method is also applied for aviation operating costs (Policy officer 1, personal communication, August 13, 2025). The formula calculates total rail operating costs by multiplying the number of train-kilometres by the per-kilometre operating cost. Importantly, because train-kilometres are determined by the specific rail alternative and policy scenario and do not vary across the different growth scenarios, the resulting operating costs remain constant for a given alternative and policy, regardless of the assumed passenger growth.

$$RailOperatingCosts_t^{a,s}(r) = TrainKilometres_t^{a,s}(r) * C_{operating} \tag{27}$$

This formula calculates the additional rail-related costs resulting from a shift in transport mode from air to rail. It does so by subtracting the rail costs in the project alternative from the baseline rail costs. The baseline scenario reflects existing rail usage without any policy or service intervention, while the project alternative includes the effects of improved rail services and induced demand. The difference represents the net increase in rail costs due to the alternative, this includes higher operating, external and societal costs associated with more passengers using rail.

$$ExtraRail \ldots Costs_t^{a,s,g}(r) = Rail \ldots Costs_t^{0,g}(r) - Rail \ldots Costs_t^{a,s,g}(r) \quad (28)$$

#### 7.2.3.3 Net Travel Time Costs Air Passengers

To determine the total travel time for both the Amsterdam-London and Amsterdam-Berlin connections, additional time components are added to the in-vehicle travel times for each mode. For rail, the published journey time does not include station procedures. Therefore, based on Eurostar's guidance, a 1-hour check-in time is included for the Amsterdam-London train service. In addition, a uniform value of 1 hour is added for access and egress (pre- and post-transport) on both rail routes, representing time spent reaching and leaving the station (KiM, 2023).

Air travel times are similarly expanded beyond gate-to-gate flight durations. Based on parameters used by the Netherlands Institute for Transport Policy Analysis (KiM, 2023), a 2-hour check-in time and 2 hours for access and egress are added for air journeys on both routes. This results in a higher total travel time for rail compared to air.

The in-vehicle travel times for rail are 4h17m for Amsterdam-London and an average of 5h39m for Amsterdam-Berlin (resulting from a mix of 5h51m and 5h27m services), as can be seen in Table 7-1. For both air routes, the flight time is 1h20m. Including all components, total travel time for rail is 6h17m (Amsterdam-London) and 6h39m (Amsterdam-Berlin), while total air travel time is 5h20m for both. This results in a travel time loss of 57 minutes for Amsterdam-London and 1 hour and 19 minutes for Amsterdam-Berlin for passengers shifting from air to rail.

**Table 7-1:** Total Travel Times for Amsterdam-London and Amsterdam-Berlin Air and Rail Connections

| Route | In-Vehicle Travel Time | Access & Egress Time | Check-In Time | Total Travel Time |
|---|---|---|---|---|
| Amsterdam-London (Rail) | 4h17m | 1h0m | 1h0m | 6h17m |
| Amsterdam-London (Air) | 1h20m | 2h0m | 2h0m | 5h20m |
| Amsterdam-Berlin (Rail) | 5h39m | 1h0m | 0h0m | 6h39m |
| Amsterdam-Berlin (Air) | 1h20m | 2h0m | 2h0m | 5h20m |

These additional time costs are monetized using the formula below, where the value of time is multiplied by the travel time loss per passenger and the number of air passengers who shift to rail in a given year, scenario and route.

$$TravelTimeLossCosts_t^{a,s,g}(r) = VOT * TravelTime_{loss} * AirPaxShifted_{actual,t}^{a,s,g}(r) \quad (29)$$

## 7.3 Step 6: Scenarios

To assess the future feasibility and impact of the proposed rail alternatives, two types of scenarios have been developed. The first set consists of growth scenarios, which explore different trajectories for passenger demand based on varying growth rates in both rail and air travel. These scenarios account for uncertainties in future travel behaviour, modal shift trends and broader mobility patterns.

The second set comprises policy scenarios, which reflect differing levels of institutional, regulatory and financial support for rail improvements. These scenarios are directly linked to the barriers identified in Chapter 6, which outlined the main challenges hindering the implementation of the alternatives. By combining growth assumptions with varying policy contexts, the scenario framework supports a more complete understanding of how external developments and governmental action or inaction may influence the success of each project alternative.

#### 7.3.1.1 Growth Scenarios

To account for future uncertainties in demand for international travel, this study applies three growth scenarios: a High, Base and Low scenario. Each scenario combines consistent growth assumptions for both air and rail travel. The high scenario reflects a future with strong economic growth, high consumer confidence and increasing demand for mobility across Europe. In this environment, both air and rail travel grow rapidly supported by favourable conditions such as technological progress, infrastructure investment and efficient operations. The base scenario assumes moderate and stable economic growth, with mobility demand increasing steadily in line with current trends and policy frameworks. Growth in both air and rail sectors continues at a balanced pace, reflecting gradual improvements and ongoing recovery. The low scenario corresponds to a more constrained future, where weaker economic performance, cost pressures and limited institutional support result in slower growth in overall travel demand. Under these conditions, both air traffic and rail passenger volumes increase only marginally. Forecasts for air traffic are based on EUROCONTROL's most recent long-term outlook (2024), while rail passenger forecasts are derived from scenario work conducted by STEER (2025).

EUROCONTROL's base scenario expects European air traffic to grow at an average annual rate of 1,6% between 2024 and 2050. Growth is projected to be strongest in the short term-averaging 2,5% annually between 2024 and 2030-due to post-COVID-19 recovery. Over the following decades, growth is expected to slow down, averaging 1,4% per year between 2030 and 2040 and 1,1% between 2040 and 2050. In the high growth scenario, air traffic increases more rapidly with an average annual growth rate of 2,2% over the full period. This more optimistic scenario assumes favourable economic and technological developments and includes short-term growth of 4,0% per year between 2024 and 2030. Conversely, the low growth scenario anticipates constraints such as rising fuel and $CO_2$ costs, limiting long-term growth to 0,7% per year. While EUROCONTROL does not provide detailed sub-period data for the low scenario, this study estimates short- and long-term growth rates by assuming 0,6% annual growth between 2024 and 2038 and a modest acceleration to 0,8% per year between 2038 and 2050, resulting in an overall average that matches the 0,7% forecast. Table 7-2 provides an overview of the growth percentages in the EU.

**Table 7-2:** EUROCONTROL Air Traffic Growth Rates by Scenario and Period for the EU

| Period | EU Base | EU High | EU Low |
|---|---|---|---|
| 2024-2030 | +2,5% | +4,0% | N/A |
| 2030-2040 | +1,4% | +1,8% | N/A |
| 2040-2050 | +1,1% | +1,4% | N/A |
| 2024-2050 | +1,6% | +2,2% | +0,7% |
| 2024-2038 | N/A | N/A | +0,6% |
| 2038-2050 | N/A | N/A | +0,8% |

Because EUROCONTROL only provides a base scenario for the Netherlands-estimating air traffic to grow at approximately 1,0% per year-this study applies proportional scaling to derive national-level high and low scenarios. Following the same ratios observed in the European forecasts, the high growth scenario for the Netherlands is estimated at 1,4% annually, while the low scenario is estimated at 0,4%. Sub-period growth rates for the Netherlands are also scaled accordingly: 1,6% between 2024 and 2030, 0,9% between 2030 and 2040, and 0,7% between 2040 and 2050 in the base case. For the high scenario, these become 2,5%, 1,1%, and 0,8%, respectively. For the low scenario, sub-period estimates are 0,4% in both the 2024-2038 and 2038-2050 periods. This approach ensures consistency with European-level trends while accounting for national variation in growth dynamics. Table 7-3 provides the growth rates for the Netherlands.

**Table 7-3:** Estimated Air Traffic Growth Rates for the Netherlands

| Period | NL Base | NL High | NL Low |
|---|---|---|---|
| 2024-2030 | +1,6% | +2,5% | N/A |
| 2030-2040 | +0,9% | +1,1% | N/A |
| 2040-2050 | +0,7% | +0,8% | N/A |
| 2024-2050 | +1,0% | +1,4% | +0,4% |
| 2024-2038 | N/A | N/A | +0,4% |
| 2038-2050 | N/A | N/A | +0,4% |

Rail passenger demand scenarios are drawn from STEER's (2025) European-level modelling, which outlines four potential trajectories. The most pessimistic of these (the "Sluggish" scenario) is excluded from this analysis, as recent data already demonstrate growth rates that far exceed its projections. For example, rail demand increased by 16% in 2023/24 and another 8% in the first months of 2024/25. As such, this study adopts three STEER scenarios to represent High, Base and Low rail growth scenarios.

The high growth scenario is based on the "Behaviour Change" scenario, which assumes strong modal shift and ambitious policy support for rail, with a compound annual growth rate (CAGR) of 3,0%. The base scenario, "Customer Offer," assumes gradual service improvements and infrastructure upgrades, resulting in a 2,3% CAGR. The low growth scenario is based on STEER's "Underlying Growth" projection, which reflects natural demand increases without significant additional investment or policy incentives and grows at 1,6% per year. Because recent rail passenger growth aligns more closely with the high-growth Behaviour Change scenario, this scenario is used to update the 2019 Amsterdam-Berlin baseline to 2023 volumes, making sure that subsequent projections start from a realistic and current reference point. Table 7-4 provides an overview of the rail growth rates.

**Table 7-4:** Rail Passenger Growth Scenarios and Compound Annual Growth Rates 2024-2050

| Period | Base | High | Low |
|---|---|---|---|
| 2024-2050 | +2,3% | +3,0% | +1,6% |

This dual-scenario framework combining EUROCONTROL's flight forecasts with STEER's rail demand projections enables a structured and consistent analysis of future demand under varying assumptions, laying the foundation for evaluating the feasibility and impacts of each project alternative.

#### 7.3.1.2 Policy Scenarios

To explore how the implementation of improved international rail services could unfold under different future conditions, this study applies three policy scenarios: an Optimistic, Neutral and Pessimistic scenario. These scenarios are not based on different demand growth rates, but instead reflect variations in how the institutional, regulatory and financial barriers (both alternative-specific and general) described in Chapter 6 might be addressed. Each scenario incorporates assumptions for both the Eurostar expansion and the dual service model.

**Optimistic Scenario**
In the optimistic scenario, all major institutional and financial barriers are effectively addressed. For the Eurostar Amsterdam-London route, this implies that staffing shortages at the KMar are resolved through a sustainable public-private funding arrangement and that cross-border coordination is substantially improved. This enables the originally planned expansion of two additional daily trains to take place in 2026, followed by the addition of a sixth train in 2027. To facilitate this higher frequency, one extra trainset in addition to the current plans is acquired. For the Amsterdam-Berlin corridor, improved political coordination facilitated by an intergovernmental task force and a significant increase in available funding due to NATO-related infrastructure investments allow the dual service model to be implemented two years earlier than originally planned, in 2028. Service frequency on the corridor increases to twelve daily trains, evenly split between fast and regular services, requiring the acquisition of one additional Talgo trainset compared to the base case. In this favourable policy environment, passengers are assumed to be more responsive to changes in service quality. Rail travel time elasticity is set to -1,90, while the elasticity for rail service frequency is 0,60. The cross-elasticity of air demand with respect to rail travel time reaches 1,98 and the cross-elasticity with respect to rail frequency is -1,02. These values reflect a context in which rail becomes structurally more competitive, supported by favourable regulatory and financial arrangements, and sustained political and financial backing.

**Neutral Scenario**
The neutral scenario describes a future in which current planning assumptions are realised without major delays or accelerations. For the Eurostar connection, this consists of the introduction of a fourth train in late 2026, followed by a fifth train in 2027 in line with the revised timeline. No extra rolling stock is needed beyond what has already been mentioned. For the Amsterdam-Berlin dual service, the original 2030 implementation target is met. By that year, the corridor operates ten daily trains (five fast and five regular). The five Talgo trainsets currently on order remain sufficient to operate this schedule. This scenario applies baseline elasticity values drawn from the literature: rail travel time elasticity is -1,58 and the frequency elasticity is 0,50. The cross-elasticities are set at 1,65 for rail travel time and -0,85 for rail frequency. The neutral scenario assumes a degree of political and institutional progress, but most barriers are only partially resolved and support remains moderate.

**Pessimistic Scenario**
In the pessimistic scenario, institutional, regulatory and financial barriers remain largely unresolved. On the Eurostar route, continuing disputes over border control staffing and funding persist. Shortages at the KMar continue to constrain operations, limiting the expansion to just one additional train in 2026, while the planned fifth train in 2027 is postponed indefinitely. Only one additional trainset is acquired. For the Amsterdam-Berlin connection, weak political coordination between the Netherlands and Germany, ongoing funding limitations and unresolved conflicts with domestic services in the Twente region delay implementation until 2032. When eventually launched, the dual service consists of only eight daily trains (four fast and four regular) requiring just four of the five Talgo trainsets originally planned. In this constrained policy environment, passengers are less responsive to service improvements. Rail travel time elasticity drops to -1,26, frequency elasticity to 0,40, cross-elasticity with respect to rail travel time to 1,32 and the rail frequency cross-elasticity drops to -0,68. This scenario reflects a stagnating policy climate where fragmented governance, limited EU coordination and persistent cost disadvantages compared to the aviation sector hinder the competitiveness of international rail services.

Together, these growth and policy scenarios establish the boundaries within which the societal impacts of each rail alternative can be assessed in Section 7.5.

## 7.4 Step 7: Discounting and Calculation of SCBA Indicators

To evaluate the financial performance of each alternative under the different future scenarios, this section assesses the expected costs and benefits using financial indicators. Since the timing of costs and benefits rarely aligns perfectly, it is necessary to discount future cash flows to their present value using a fixed discount rate. This allows for a meaningful and consistent comparison between different project alternatives, regardless of when individual costs or benefits are gained. The discounted values form the basis for the financial indicators used in this study, which include Capital Expenditures (CAPEX), Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR) and the cumulative discounted cash flow. These indicators help determine whether a project is socio-economically attractive and provide decision-makers with insights into its financial feasibility.

These indicators together provide a detailed understanding of the economic and financial performance of each proposed rail alternative under different scenario conditions. They form the foundation for comparing alternatives and for informing decisions about which investments are most promising.

#### 7.4.1.1 Discounted Cash Flows

To calculate the discounted cash flows used in this analysis, all future cash flows are adjusted using a constant real discount rate. This ensures that costs and benefits occurring in different years can be meaningfully compared by expressing them in present-day terms. The formula applied in this study divides each annual cash flow by the growth of the discount factor, raised to the power of the number of years between the cash flow year and the base year 2026.

In this study, a real discount rate of 3% is used to calculate the NPV, BCR and cumulative discounted cash flow. This rate follows the recommendation by EUROCONTROL (2025f) and reflects the social rate of time preference. Unlike private discount rates, which often include risk premiums and inflation, a social discount rate focuses on the long-term societal valuation of future costs and benefits. A 3% rate is commonly applied in European cost-benefit analyses for public infrastructure and environmental projects. By excluding inflation and private risk considerations, it makes sure that long-term societal costs and benefits are appropriately weighted in the economic appraisal.

$$DiscountedCashFlow\ ..._{t}^{a,s,g}\ (r) = \frac{CashFlow\ ..._{t}^{a,s,g}\ (r)}{(1 + DiscountRate)^{t-2026}} \qquad (30)$$

#### 7.4.1.2 Benefit-Cost Ratio

To assess the economic efficiency of each project alternative under different scenarios, the BCR is used. This ratio compares the total discounted benefits to the total discounted costs over the analysis period (2026-2050). A BCR greater than 1 indicates that the benefits of a project outweigh its costs, while a BCR below 1 suggests that the project is not economically viable. The following formulas describe how both the total and discounted costs and benefits are calculated.

Total Benefits are defined as the sum of all positive annual cash flows (e.g. time savings, reduced emissions) over the period from 2026 to 2050. Discounted Total Benefits are those same benefit flows, but adjusted to present value using a discount rate.

$$TotalBenefits^{a,s,g}(r) = \sum_{t=2026}^{2050} CashFlow\ ..._t^{a,s,g}\ (r)\ \text{, where } CashFlow\ ..._t^{a,s,g}\ (r) > 0 \tag{31}$$

$$TotalDiscountedBenefits^{a,s,g}(r) = \sum_{t=2026}^{2050} DiscountedCashFlow\ ..._t^{a,s,g}\ (r)\ \text{, where } DiscountedCashFlow\ ..._t^{a,s,g}\ (r) > 0 \tag{32}$$

Total Costs are the sum of all negative cash flows (e.g. investments, operating expenses) over the same time period. Discounted Total Costs similarly adjust these negative cash flows to present value.

$$TotalCosts^{a,s,g}(r) = \sum_{t=2026}^{2050} CashFlow\ ..._t^{a,s,g}\ (r)\ \text{, where } CashFlow\ ..._t^{a,s,g}\ (r) < 0 \tag{33}$$

$$TotalDiscountedCosts^{a,s,g}(r) = \sum_{t=2026}^{2050} DiscountedCashFlow\ ..._t^{a,s,g}\ (r)\ \text{, where } DiscountedCashFlow\ ..._t^{a,s,g}\ (r) < 0 \tag{34}$$

The BCR is then calculated as the ratio between the discounted benefits and discounted costs.

$$BCR^{a,s,g}(r) = \frac{TotalDiscountedBenefits^{a,s,g}(r)}{TotalDiscountedCosts^{a,s,g}(r)} \tag{35}$$

#### 7.4.1.3 Net Present Value

The NPV is one of the most commonly used financial indicators in project evaluation. It measures the difference between the present value of all benefits and the present value of all costs accumulated over the entire duration of the project. A positive NPV means that the project is expected to generate net value for society, indicating that the benefits outweigh the costs when discounted to present terms. Conversely, a negative NPV suggests that the discounted costs exceed the benefits, signalling that the project may not be economically viable. Therefore, NPV serves as a core metric for assessing the overall economic feasibility of a project (Dai et al., 2022).

The NPV is calculated by summing the discounted cash flows from the starting year (2026) to the end year (2050):

$$NPV_t^{a,s,g}(r) = \sum_{t=2026}^{2050} DiscountedCashFlow\ ..._t^{a,s,g}\ (r) \tag{36}$$

#### 7.4.1.4 Internal Rate of Return

The IRR is the discount rate at which the NPV of all cash flows from a project equals zero. In other words, it represents the break-even rate of return, where the present value of benefits exactly balances the present value of costs. If the IRR is higher than the discount rate used in the cost-benefit analysis, the project is considered financially attractive and worth investing in. Conversely, if the IRR is lower than the assumed discount rate, the project may not be viable. The IRR is a useful metric for comparing the profitability of different investment alternatives (Dai et al., 2022).

Mathematically, the IRR is the value of *r* that satisfies the following equation:

$$0 = \sum_{t=2026}^{2050} \frac{CashFlow \dots_t^{a,s,g}(r)}{(1+r)^t} \tag{37}$$

## 7.5 Step 8: Results

This section presents the quantitative results of the cost-benefit analysis for the evaluated project alternatives aimed at improving short-haul international rail connections from Schiphol. Each alternative is examined under a range of scenarios reflecting different assumptions regarding demand, costs and operational parameters. These scenarios are: base, high, low, optimistic and pessimistic.

Operational metrics such as flight frequencies, passenger volumes by mode and associated emission costs are reported to provide insights into modal shifts and environmental impacts. Financial metrics, including CAPEX, total benefits, total costs and economic indicators such as the BCR, NPV and IRR are presented to assess the economic viability of each alternative. Cumulative discounted cash flow profiles demonstrate the timing of investments and returns throughout the project horizon.

Discounted costs and benefits are further broken down by category, with graphical visualizations illustrating the relative contributions of each component. At last, the results of all alternatives and the base case will be compared, followed by a summary of the chapter and the main conclusions.

### 7.5.1 Results Base Case

To provide a baseline for comparison with the proposed project alternatives, this section presents the operational outcomes of the base case scenario, which assumes no major interventions in international rail services between Amsterdam and London or Berlin. The base case is evaluated under three different demand growth scenarios (Base, High and Low) while using the Neutral policy scenario.

Table 7-5 presents the operational metrics for both the Amsterdam-London and Amsterdam-Berlin corridors. Under the base demand scenario, the Amsterdam-London route sees y 304 thousand annual flights, serving 45,4 million air passengers. The Amsterdam-Berlin route accounts for 157 thousand flights and 26,7 million air passengers. Air-related $CO_2$ emission costs for the London and Berlin routes are estimated at €1,84 billion and €2,35 billion respectively. Rail use remains significant as well, with 38,2 million passengers on the London corridor and nearly 39,9 million on the Berlin corridor.

Under high growth assumptions, both routes see increases in flights and air passenger volumes, as well as higher emission costs. Conversely, in the low growth scenario, there is a modest decline in both air and rail use, reflecting reduced travel demand.

**Table 7-5:** Operational Metrics for Base Case by Route and Growth Scenario

| Route | AMS-LON | | | AMS-BER | | |
|---|---|---|---|---|---|---|
| **Operational Metric** | **Base** | **High** | **Low** | **Base** | **High** | **Low** |
| Flights (Thousand) | 304 | 328 | 271 | 157 | 169 | 139 |
| Air Passengers (Million) | 45,4 | 49,0 | 40,3 | 26,7 | 28,8 | 23,7 |
| Air Emission Costs (€ Billion) | 1,84 | 1,98 | 1,64 | 2,35 | 2,53 | 2,10 |
| Rail Passengers (Million) | 38,2 | 39,7 | 35,1 | 39,9 | 42,3 | 35,9 |

Table 7-6 aggregates the data for both routes to show the total system-wide impacts under each scenario. Combined, the two corridors account for 461 thousand flights and 72 million air passengers in the base scenario, with emissions costs reaching €4,19 billion. Total rail passengers amount to 78 million, demonstrating that even without additional interventions, international rail already makes up a good portion of the travel demand.

**Table 7-6:** Aggregate Operational Metrics for Base Case by Growth Scenario

| Route | Total | | |
|---|---|---|---|
| **Operational Metric** | **Base** | **High** | **Low** |
| Flights (Thousand) | 461 | 497 | 410 |
| Air Passengers (Million) | 72,1 | 77,7 | 64,1 |
| Air Emission Costs (€ Billion) | 4,19 | 4,50 | 3,73 |
| Rail Passengers (Million) | 78,1 | 81,9 | 71,1 |

These base case results underscore the scale of short-haul air traffic between Amsterdam and the two European destinations, as well as the environmental burden associated with it. This provides a benchmark for evaluating the effectiveness and impact of the proposed project alternatives in shifting demand from air to rail and reducing emissions.

### 7.5.2 Results Eurostar Expansion

The Eurostar Expansion consists of introducing one additional train on the Amsterdam-London route in 2026, followed by a second train in 2027 in the Neutral policy scenario. To support this capacity increase, two Siemens Velaro e320 trains will be procured.

First, the operational outcomes will be presented, followed by the financial metrics to evaluate the alternative's performance. After that, the cumulative discounted cash flow will be presented over time to determine when the alternative breaks even and how the cash flow develops. Finally, a brief summary of the alternative's results will be provided.

#### 7.5.2.1 Operational Outcomes of the Eurostar Expansion

Table 7-7 presents the operational outcomes of the Eurostar Expansion scenario across five different demand and policy scenarios: Base, High, Low, Optimistic and Pessimistic. The results show substantial modal shift from air to rail as two additional Eurostar trains are introduced between Amsterdam and London in 2026 and 2027. This shift leads to significant reductions in both flight frequency and air passenger volumes across all scenarios.

In the base scenario, the number of annual flights falls to 176 thousand, with over 19 million passengers shifting from air to rail, resulting in a reduction of air emissions costs to €1,06 billion. The optimistic scenario sees even stronger results, with over 30 million air passengers shifting, reducing flights to under 100 thousand and cutting air emission costs to €0,60 billion. In contrast, in the pessimistic case the shift is more modest, yet still results in a decrease of nearly 10 million air passengers and a drop in emission costs to €1,43 billion.

Rail ridership increases proportionally in all scenarios, with a peak of over 83 million rail passengers in the optimistic case. The difference between "demand shifted" and "actual shifted" reflects the residual air passengers due to limited rail capacity.

These results confirm that the Eurostar Expansion delivers strong modal shift effects even under less favourable assumptions, contributing meaningfully to emission reductions and more sustainable short-haul travel.

**Table 7-7:** Operational Metrics for Eurostar Expansion by Growth and Policy Scenario

| **Alternative** | **Eurostar Expansion** | | | | |
|---|---|---|---|---|---|
| **Operational Metric** | **Base** | **High** | **Low** | **Optimistic** | **Pessimistic** |
| Flights (Thousand) | 176 | 197 | 153 | 100 | 238 |
| Demand Flights Shifted (Thousand) | 135 | 146 | 118 | 228 | 69 |
| Actual Flights Shifted (Thousand) | 128 | 130 | 118 | 204 | 67 |
| Air Passengers (Million) | 26,3 | 29,6 | 22,8 | 15,0 | 35,5 |
| Demand Passengers Shifted (Million) | 20,1 | 21,9 | 17,6 | 34,0 | 10,3 |
| Actual Passengers Shifted (Million) | 19,1 | 19,4 | 17,6 | 30,4 | 9,9 |
| Air Emission Costs (€ Billion) | 1,06 | 1,19 | 0,93 | 0,60 | 1,43 |
| Rail Passengers (Million) | 66,7 | 68,2 | 62,8 | 83,7 | 52,6 |

#### 7.5.2.2 Financial Outcomes of the Eurostar Expansion

Table 7-8 presents the financial metrics for the Eurostar Expansion across different growth and policy scenarios. Costs and negative NPVs are highlighted in red to clearly distinguish expenditures and financial losses. The CAPEX vary notably between scenarios, reflecting the differing number of trains required: the Optimistic scenario consists of the acquisition of more trains, leading to a higher CAPEX (€263,7 million), while the Pessimistic scenario uses fewer trains and thus lower CAPEX (€87,9 million). The Base, High and Low scenarios maintain a consistent CAPEX of approximately €175,8 million.

Total benefits and discounted benefits follow the expected trend, with higher benefits in the Optimistic scenario due to increased ridership and modal shift and lower benefits in the Pessimistic case. Similarly, costs and discounted costs align with the scale of investment and operations in each scenario.

The BCR ranges from 0,92 in the Low scenario to 1,04 in the Pessimistic scenario, indicating that under most scenarios the expansion is close to or exceeds economic breakeven. The NPV is negative in all but the Pessimistic scenario, reflecting the considerable upfront investment required. The IRR is not applicable (N/A) in the Low and Optimistic scenarios due to the negative total cash flows, which do not yield an IRR within the project horizon.

Overall, these financial outcomes highlight that the Eurostar Expansion's economic viability is sensitive to demand growth and investment scale, with the Pessimistic scenario surprisingly yielding the highest BCR and positive NPV due to the lower investment costs involved.

**Table 7-8:** Financial Metrics for Eurostar Expansion by Growth and Policy Scenario

| **Alternative** | **Eurostar Expansion** | | | | |
|---|---|---|---|---|---|
| **Financial Metric** | **Base** | **High** | **Low** | **Optimistic** | **Pessimistic** |
| CAPEX (€ Million) | 175,8 | 175,8 | 175,8 | 263,7 | 87,9 |
| Benefits (€ Billion) | 2,19 | 2,17 | 1,92 | 3,08 | 1,16 |
| Discounted Benefits (€ Billion) | 1,48 | 1,54 | 1,36 | 2,20 | 0,82 |
| Costs (€ Billion) | 2,08 | 2,10 | 2,02 | 3,21 | 1,07 |
| Discounted Costs (€ Billion) | 1,53 | 1,54 | 1,48 | 2,37 | 0,79 |
| BCR | 0,96 | 1,00 | 0,92 | 0,93 | 1,04 |
| NPV (€ Million) | -54,0 | -2,6 | -124,9 | -165,3 | 32,4 |
| IRR (%) | 0,14 | 2,87 | N/A | N/A | 5,67 |

#### 7.5.2.3 Cumulative Cash Flows of Eurostar Expansion

Figure 7-1 presents the cumulative discounted cash flows for all Eurostar Expansion scenarios across the project timeline. Except the Pessimistic scenario, each scenario has two major negative cash flow peaks in the first two years, corresponding to the upfront investments in trainsets.

Following these initial investment years, all scenarios show a rising cumulative cash flow, indicating positive discounted returns that gradually offset the initial costs. However, the rate of increase varies: the Low and Optimistic scenarios have relatively flat cumulative cash flows and do not approach a positive balance within the analysed period. This is reflected in the shorter positive cash flow bars compared to the negative bars. The Base and High scenarios show stronger cumulative growth but still fall slightly short of breaking even during the timeline. The Pessimistic scenario is the only one where the cumulative cash flow turns positive around the 18th year (2044) and continues to improve thereafter.

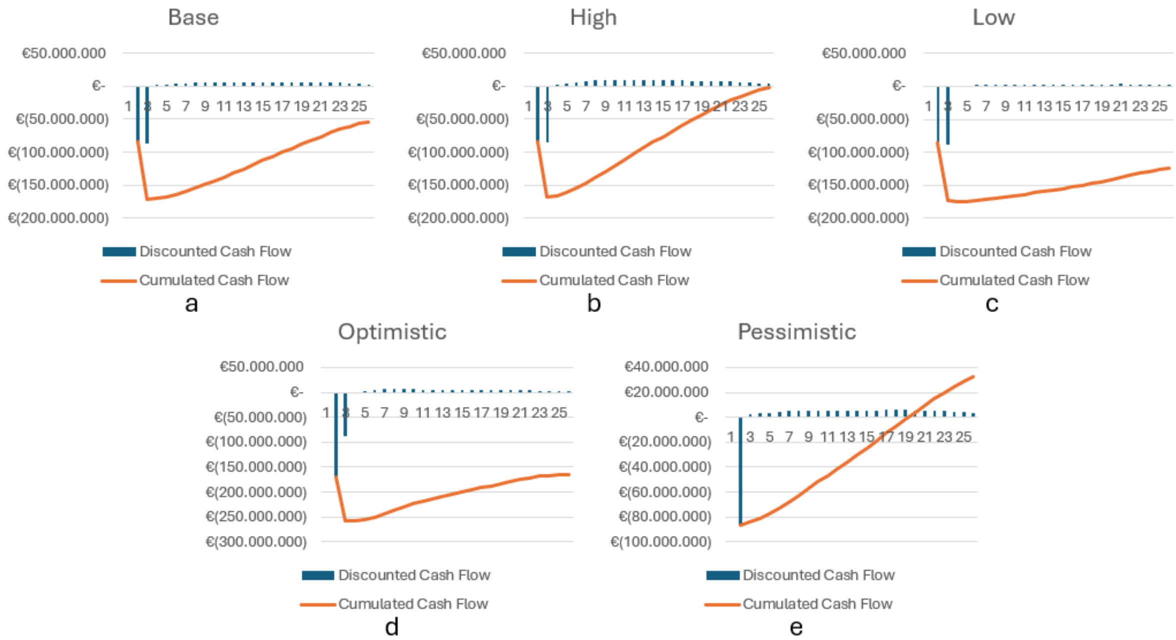


**Figure 7-1:** Cumulative Discounted Cash Flows of Eurostar Expansion across All Scenarios

#### 7.5.2.4 Summary of Eurostar Expansion

The operational results of the Eurostar Expansion demonstrate a substantial modal shift from air to rail, with significant reductions in flight frequency, air passengers and emission costs across all scenarios. Financially, the project requires substantial upfront investments, resulting in negative NPVs in most scenarios except the Pessimistic case, which benefits from lower CAPEX. Cumulative cash flows confirm these trends, with most scenarios approaching breakeven but only the Pessimistic scenario turning positive within the project horizon. Overall, the expansion is effective in promoting sustainable modal shift but its economic viability strongly depends on demand growth and investment scale.

### 7.5.3 Results Dual Service Model

The Dual Service Model introduces a new, faster train service alongside the existing regular service on the Amsterdam-Berlin route. This increases the total service frequency from 5 to 10 trains per day in the Neutral policy scenario, while reducing the average travel time from 5 hours and 51 minutes to 5 hours and 39 minutes. To enable this expansion, six new trainsets need to be acquired.

#### 7.5.3.1 Operational Outcomes of the Dual Service Model

Table 7-9 presents the operational outcomes of the Dual Service Model across the five different demand and policy scenarios. The results show a substantial modal shift from air to rail due to the doubling of the frequency.

In the base scenario, the number of flights falls to 40 thousand, with 20 million passengers shifting from air to rail. This leads to a reduction in air emission costs to €0,63 billion. The optimistic scenario shows even stronger shifts, with over 24 million passengers shifting, flights dropping to 15 thousand and emission costs decreasing to €0,24 billion. Conversely, the pessimistic scenario shows a more modest shift, but still 9,4 million passengers shift and emission costs reduce to €1,56 billion.

Rail ridership increases proportionally in all scenarios, peaking at 95,5 million passengers in the optimistic case. The difference between “demand shifted” and “actual shifted” is the highest in the high scenario, which reflects the limited rail capacity compared to the high passenger growth in that scenario. These results confirm that the Dual Service Model delivers a strong modal shift effect, contributing meaningfully to emission reductions and more sustainable short-haul travel.

**Table 7-9:** Operational Metrics for Dual Service Model by Growth and Policy Scenario

| **Alternative** | **Dual Service Model** | | | | |
|---|---|---|---|---|---|
| **Operational Metric** | **Base** | **High** | **Low** | **Optimistic** | **Pessimistic** |
| Flights (Thousand) | 40 | 52 | 33 | 16 | 103 |
| Demand Flights Shifted (Thousand) | 121 | 131 | 106 | 146 | 55 |
| Actual Flights Shifted (Thousand) | 116 | 117 | 106 | 141 | 54 |
| Air Passengers (Million) | 6,7 | 8,7 | 5,4 | 2,6 | 17,3 |
| Demand Passengers Shifted (Million) | 20,8 | 22,5 | 18,3 | 24,9 | 9,5 |
| Actual Passengers Shifted (Million) | 20,0 | 20,1 | 18,3 | 24,1 | 9,4 |
| Air Emission Costs (€ Billion) | 0,63 | 0,79 | 0,53 | 0,24 | 1,56 |
| Rail Passengers (Million) | 77,2 | 79,5 | 71,2 | 95,5 | 58,0 |

#### 7.5.3.2 Financial Outcomes of the Dual Service Model

Table 7-10 presents the financial metrics for the Dual Service Model across five growth and policy scenarios. Costs and negative NPVs are highlighted in red to clearly indicate expenditures and financial losses. CAPEX vary per scenario, depending on the number of trainsets acquired. The Optimistic scenario has the highest CAPEX (€189,5 million), while the Pessimistic scenario has the lowest CAPEX (€135,5 million), because of the difference in trainsets acquired. The Base, High and Low scenarios each acquire six trainsets, resulting in a CAPEX of €162,5 million. The construction costs of the fourth platform of €0,5 million are negligible compared to the CAPEX caused by the acquisition of the new trainsets.

Total and discounted benefits follow the expected trend: higher demand scenarios (Optimistic and High) generate greater benefits, while the Pessimistic scenario yields significantly lower returns. Correspondingly, total and discounted costs increase in scenarios with higher levels of operation and investment.

The BCR, calculated using discounted cash flows, ranges from 0,71 (Optimistic) to 0,83 (High). None of the scenarios exceed or come close to the threshold of 1,0, with the Base, High and Pessimistic scenarios coming closest. The NPV is negative in all scenarios, reflecting the substantial initial capital investment required. The Pessimistic scenario has the least negative

NPV (-€264,7 million), due to its lower investment requirements. The IRR is not applicable (in all five scenarios), as the total cash flows are negative.

In summary, the financial results show that the Dual Service Model requires significant investment and is sensitive to demand assumptions. The scenarios do not yield a positive NPV suggesting that this alternative does not provide net benefits for society. The Pessimistic and High scenarios have the least negative NPVs with the Optimistic scenario having an extremely negative NPV of over €1,1 billion.

**Table 7-10:** Financial Metrics for Dual Service Model by Growth and Policy Scenario

| **Alternative** | **Dual Service Model** | | | | |
|---|---|---|---|---|---|
| **Financial Metric** | **Base** | **High** | **Low** | **Optimistic** | **Pessimistic** |
| CAPEX (€ Million) | 162,5 | 162,5 | 162,5 | 189,5 | 135,5 |
| Benefits (€ Billion) | 3,17 | 3,23 | 2,88 | 3,99 | 1,70 |
| Discounted Benefits (€ Billion) | 2,13 | 2,19 | 1,94 | 2,76 | 1,10 |
| Costs (€ Billion) | 3,87 | 3,87 | 3,77 | 5,52 | 2,07 |
| Discounted Costs (€ Billion) | 2,63 | 2,64 | 2,56 | 3,87 | 1,37 |
| BCR | 0,81 | 0,83 | 0,75 | 0,71 | 0,81 |
| NPV (€ Million) | -500,6 | -449,4 | -628,0 | -1.105,1 | -264,7 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A |

#### 7.5.3.3 Cumulative Cash Flows for Dual Service Model

Figure 7-2 presents the cumulative discounted cash flows for all scenarios of the Dual Service Model over the 25-year project horizon. As shown, all scenarios start with negative cumulative cash flows that deepen over the first years due to high initial capital investments. These cash flows are mostly driven by the purchase of trainsets, while infrastructure costs remain minimal (€0,5 million) and have little influence on the trend.

All scenarios exhibit a similar slope in their cumulative cash flow curves, however the relative size of CAPEX compared to total discounted cash flow varies significantly across scenarios. The Base, High and Low scenarios share an identical CAPEX amount (€162,5 million), with the Low scenario having a slightly smaller relative investment due to lower overall cash flows. The Optimistic scenario has the highest CAPEX in absolute terms (€189,5 million), but relative to its total cash flow, this investment weighs less than in the Low scenario. The Pessimistic scenario, with the lowest CAPEX (€135,5 million), shows a disproportionately large share of investment compared to its total benefits, making the upfront costs a much larger part of the cumulative financial picture.

In all five scenarios, annual discounted cash flows remain negative throughout the entire project period. No single year results in a net positive discounted cash flow, meaning each year incurs more costs than discounted benefits.

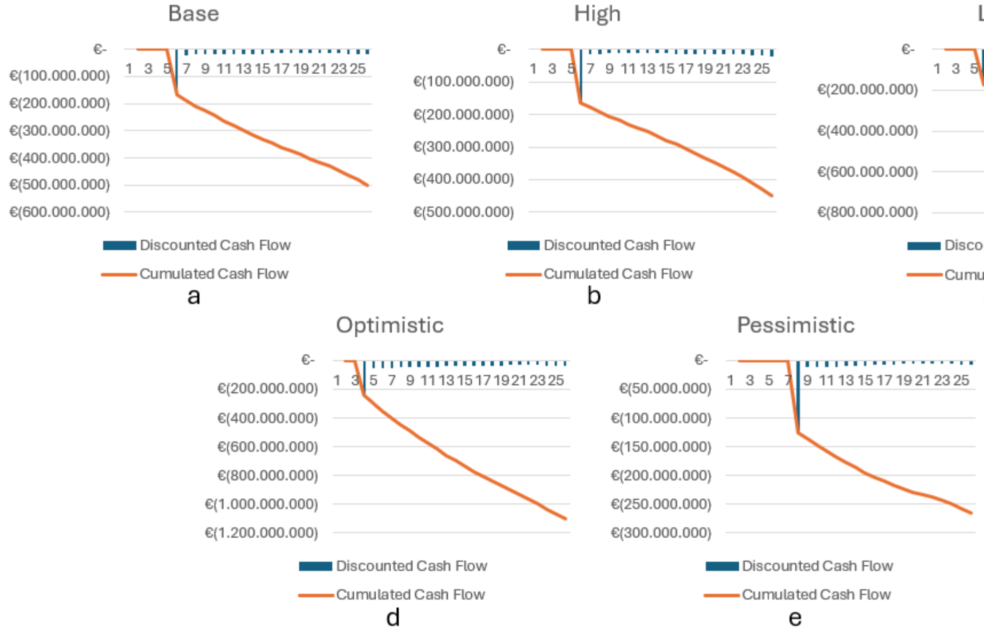


**Figure 7-2:** Cumulative Discounted Cash Flows of Dual Service Model across All Scenarios

#### 7.5.3.4 Summary of Dual Service Model

Across all scenarios, the dual service model demonstrates strong potential to shift passenger demand from air to rail, with between 9 and 25 million passengers switching modes over the 25-year period. As a result, the model contributes significantly to reductions in air travel emissions and supports the broader goals of sustainable mobility.

Financially, the model requires substantial upfront investment, particularly in rolling stock with CAPEX ranging from €135,5 to €189,5 million. While total and discounted benefits increase with higher demand, none of the five policy and growth scenarios achieve a positive NPV. The BCR ranges from 0,71 to 0,83, indicating that the investment falls short of economic feasibility, though the Pessimistic scenarios come closest to breaking even. The IRR is not applicable due to the negative total cash flows. Cumulative discounted cash flow analysis confirms that no scenario generates net positive yearly returns during the project period.

In summary, the Dual Service Model delivers meaningful environmental and modal shift benefits, but is not financial viable under the assumptions used. The Optimistic and Low scenarios have the most negative NPVs while the High and Pessimistic scenarios show the most promising financial results.

### 7.5.4 Results Both Alternatives Implemented

This section presents the results for the combined implementation of both project alternatives: the Eurostar Expansion on the Amsterdam-London route and the Dual Service Model on the Amsterdam-Berlin route.

#### 7.5.4.1 Operational Outcomes of Both Alternatives Implemented

Table 7-11 presents the operational outcomes of the combined implementation of both project alternatives - the Eurostar Expansion on the Amsterdam-London route and the Dual Service Model on the Amsterdam-Berlin route across the five demand and policy scenarios.

The combined effect results in a substantial modal shift from air to rail, driven by the introduction of faster and more frequent train services on both routes.

In the Base scenario, the number of flights decrease to 216 thousand, with over 39 million passengers shifting from air to rail, contributing to a reduction in air emission costs to €1,69 billion. The Optimistic scenario sees an even stronger shift, with nearly 55 million passengers shifting, flights dropping to 116 thousand, and emission costs falling to €0,84 billion. Conversely, the Pessimistic scenario shows a more modest modal shift, with about 19 million passengers shifting and emission costs reduced to €2,99 billion.

Rail ridership increases proportionally across all scenarios, reaching over 179 million passengers in the Optimistic case. The gap between "demand shifted" and "actual shifted" is the largest in the High and Optimistic scenarios demonstrating the effect of the high rail passenger demand on the limited capacity.

These results demonstrate that the combined implementation of both alternatives significantly strengthens the modal shift from air to rail, supporting greater emission reductions and promoting more sustainable short-haul travel.

**Table 7-11:** Operational Metrics for Both Alternatives Implemented by Growth and Policy Scenario

| **Alternative** | **Both Alternatives Implemented** | | | | |
|---|---|---|---|---|---|
| **Operational Metric** | **Base** | **High** | **Low** | **Optimistic** | **Pessimistic** |
| Flights (Thousand) | 216 | 249 | 186 | 116 | 340 |
| Demand Flights Shifted (Thousand) | 255 | 277 | 224 | 373 | 124 |
| Actual Flights Shifted (Thousand) | 245 | 247 | 224 | 346 | 121 |
| Air Passengers (Million) | 33,0 | 38,2 | 28,2 | 17,6 | 52,8 |
| Demand Passengers Shifted (Million) | 40,9 | 44,4 | 35,8 | 59,0 | 19,8 |
| Actual Passengers Shifted (Million) | 39,1 | 39,5 | 35,8 | 54,5 | 19,3 |
| Air Emission Costs (€ Billion) | 1,69 | 1,97 | 1,45 | 0,84 | 2,99 |
| Rail Passengers (Million) | 143,9 | 147,8 | 134,0 | 179,2 | 110,6 |

#### 7.5.4.2 Financial Outcomes of Both Alternatives Implemented

Table 7-12 presents the financial metrics for the combined implementation of both alternatives across the five growth and policy scenarios. Costs and negative NPVs are highlighted in red to clearly indicate expenditures and financial losses.

CAPEX vary by scenario, largely driven by the procurement of additional trainsets and infrastructure investments needed for both the Eurostar expansion and the Dual Service Model. The Optimistic scenario has the highest investment, resulting in a CAPEX of approximately €453,2 million. The Pessimistic scenario shows the lowest CAPEX at €223,4 million, reflecting scaled-back investments. The Base, High and Low scenarios each assume moderate investment levels with a CAPEX of about €338,3 million.

Total and discounted benefits follow the expected pattern: scenarios with higher demand and policy support (Optimistic and High) generate substantially greater benefits, while the Pessimistic scenario yields significantly lower returns. Similarly, total and discounted costs increase with higher operational levels and investments.

The BCR ranges from 0,80 (Optimistic) to 0,89 (High and Pessimistic). While none of the scenarios reach the threshold of 1,0, the Base, High and Pessimistic scenarios yield the most promising financial results.

NPV is negative across all scenarios, reflecting the considerable upfront capital required for rolling stock and infrastructure upgrades. The Pessimistic scenario shows the least negative NPV (-€232,2 million), due to its lower investment and operational scale. The IRR is not applicable in all scenarios.

In summary, the financial analysis reveals that implementing both alternatives together requires substantial investment and that financial feasibility is sensitive to demand and policy assumptions. Although no scenario yields a positive NPV, several scenarios come close to cost-effectiveness, particularly under moderate to conservative conditions.

**Table 7-12:** Financial Metrics for Both Alternatives Implemented by Growth and Policy Scenario

| Alternative | Both Alternatives Implemented | | | | |
|---|---|---|---|---|---|
| **Financial Metric** | **Base** | **High** | **Low** | **Optimistic** | **Pessimistic** |
| CAPEX (€ Million) | 338,3 | 338,3 | 338,3 | 453,2 | 223,4 |
| Benefits (€ Billion) | 5,26 | 5,40 | 4,81 | 7,08 | 2,86 |
| Discounted Benefits (€ Billion) | 3,60 | 3,73 | 3,29 | 4,97 | 1,92 |
| Costs (€ Billion) | 5,95 | 5,97 | 5,80 | 8,73 | 3,14 |
| Discounted Costs (€ Billion) | 4,16 | 4,18 | 4,05 | 6,24 | 2,16 |
| BCR | 0,87 | 0,89 | 0,81 | 0,80 | 0,89 |
| NPV (€ Million) | -554,6 | -452,0 | -752,9 | -1.270,4 | -232,2 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A |

#### 7.5.4.3 Cumulative Cash Flows for Both Alternatives Implemented

Figure 7-3 presents the cumulative discounted cash flows for all five growth and policy scenarios over the full 25-year evaluation horizon, covering the combined implementation of the Eurostar Expansion and the Dual Service Model.

As expected, all scenarios begin with a steep decline in cumulative discounted cash flow due to the high initial CAPEX. Following the initial investment phase, scenarios diverge. The High and Pessimistic scenarios show a few years of slightly positive annual discounted cash flows. The Base and Low scenarios hover around breakeven: the Base scenario shows marginally positive flows, while the Low scenario remains just below zero throughout. In contrast, the Optimistic scenario continues to generate negative annual discounted cash flows across the entire period, reflecting high operating costs that outweigh the discounted benefits even under high demand assumptions.

Notably, after the implementation of the Dual Service Model, all scenarios except the Pessimistic one maintain negative discounted cash flows for the remainder of the period. The Pessimistic scenario records slightly positive discounted cash flows between 2044 and 2046, a temporary recovery not observed in the other cases.

In relative terms, the Optimistic scenario has the largest absolute CAPEX, but due to its higher cumulative costs, this investment represents the smallest share of its total discounted cash flow. The Base, High and Low scenarios share comparable CAPEX levels, and their investment-to-cash-flow ratios are also quite similar. The Pessimistic scenario, despite having the lowest absolute CAPEX, exhibits the largest relative investment burden compared to its limited financial returns, making its cash flow profile particularly sensitive to upfront costs.

Overall, the results highlight the difficulty of recovering the initial investment through annual net benefits, particularly under more optimistic scenarios. In all five cases, no single year generates a net positive cumulative discounted cash flow, reinforcing that costs consistently outweigh discounted revenues throughout the evaluation period. This is primarily due to the persistent annual losses associated with the Dual Service Model alternative. While the Eurostar Expansion generates some positive flows in certain years, these are not sufficient to offset the sustained deficits of the Dual Service Model, especially in later years.

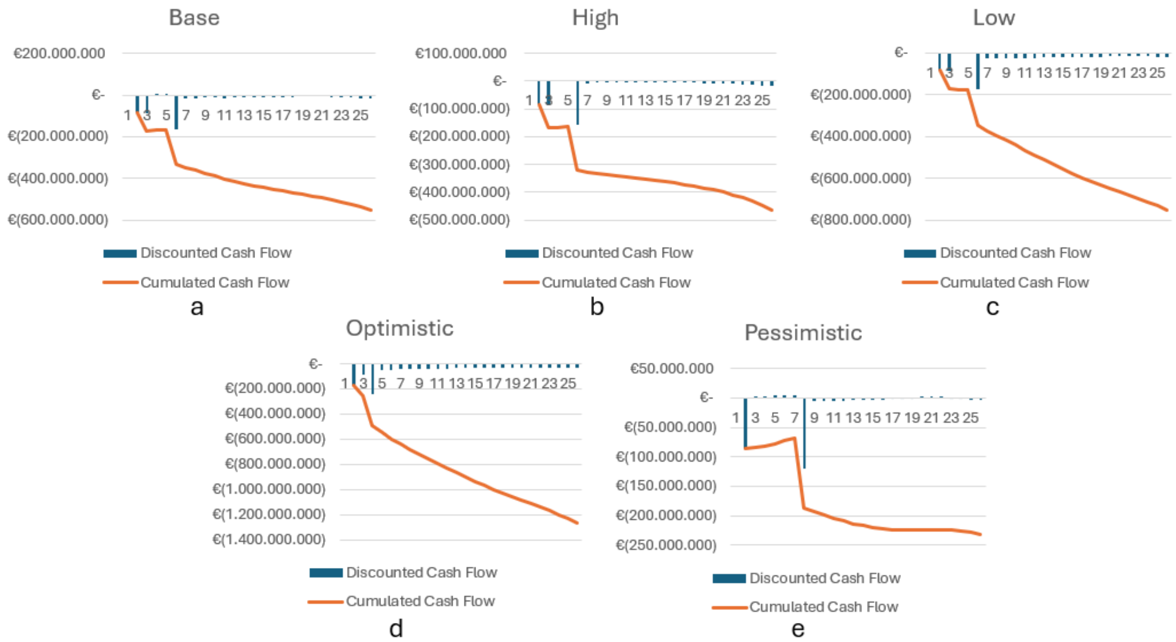


**Figure 7-3:** Cumulative Discounted Cash Flows of Both Alternatives Implemented across All Scenarios

#### 7.5.4.4 Summary of Both Alternatives Implemented

The combined implementation of the Eurostar Expansion on the Amsterdam-London route and the Dual Service Model on the Amsterdam-Berlin route results in a substantial increase in train frequency and capacity, alongside moderate travel time improvements. Together, these alternatives drive a significant modal shift from air to rail, with between approximately 19 and 55 million passengers shifting over 25 years depending on the scenario. This shift contributes notably to reducing air travel emissions, supporting sustainability objectives across all demand and policy settings.

From a financial perspective, the combined alternatives require considerable upfront capital investment, primarily for additional rolling stock and infrastructure upgrades, with CAPEX ranging from €223 million in pessimistic scenarios to €453 million in optimistic ones. Although total benefits rise with demand, none of the scenarios yield a positive NPV and BCR range narrowly between 0,80 and 0,89, indicating that the investment falls short of full economic viability. Cumulative discounted cash flow analysis further shows persistent negative returns throughout the 25-year horizon, with no scenario achieving a positive cumulative cash flow.

In summary, while the joint implementation of both alternatives offers meaningful environmental benefits and strengthens the modal shift from air to rail, its financial feasibility remains unviable. Nevertheless, the scenarios approaching break-even suggest that under moderate demand growth and policy support, the combined alternatives could be a valuable part of a strategic approach to reducing short-haul flights and promoting sustainable transport.

### 7.5.5 Breakdown of Benefits and Costs

This section provides a detailed breakdown of the total discounted benefits and costs associated with each project alternative. By disaggregating the results into specific categories the analysis offers insight into which factors contribute most to the economic performance of each intervention. Understanding these cost-benefit structures helps clarify the trade-offs involved and the relative strengths of each alternative.

#### 7.5.5.1 Breakdown of Benefits

Table 7-13 and Figure 7-4 illustrate the composition of total discounted benefits for each project alternative. The Eurostar Expansion shows a relatively balanced benefit distribution, with waiting time savings (45,8%) and air emission savings (38,0%) as the dominant contributors. In contrast, the Dual Service Model yields a much larger share of benefits from air emission savings (55,1%), highlighting its stronger impact on reducing short-haul flights between Amsterdam and Berlin. This alternative also includes a unique category-travel time savings (10,9%) reflecting the modest reduction in journey times on the upgraded Berlin service.

The air emission savings category captures the combined monetized benefits of reduced $CO_2$ emissions, air pollution, and noise, all of which decrease as air traffic is replaced by more sustainable rail alternatives.

When both alternatives are implemented together, total benefits reach €3,6 billion and the share of waiting time savings decreases to 30,3%, while air emission and operating cost savings together account for over 63% of total discounted benefits. The combined alternative thus delivers a more emission and efficiency-driven benefit profile.

**Table 7-13:** Breakdown of Discounted Benefits by Alternative and Benefit Category

| Alternative | Eurostar Expansion | | Dual Service Model | | Both Alternatives Implemented | |
|---|---|---|---|---|---|---|
| **Discounted Benefits** | **Value (€M)** | **Share (%)** | **Value (€M)** | **Share (%)** | **Value (€M)** | **Share (%)** |
| Air Emission Savings | 560,4 | 38,0 | 1.173,1 | 55,1 | 1.733,5 | 48,1 |
| Air Operating Savings | 238,9 | 16,2 | 307,1 | 14,4 | 546,0 | 15,1 |
| Waiting Time Savings | 676,1 | 45,8 | 416,1 | 19,5 | 1.092,2 | 30,3 |
| Travel Time Savings | - | - | 232,3 | 10,9 | 232,3 | 6,4 |
| Total Benefits | 1.475,3 | 100 | 2.128,6 | 100 | 3.603,9 | 100 |

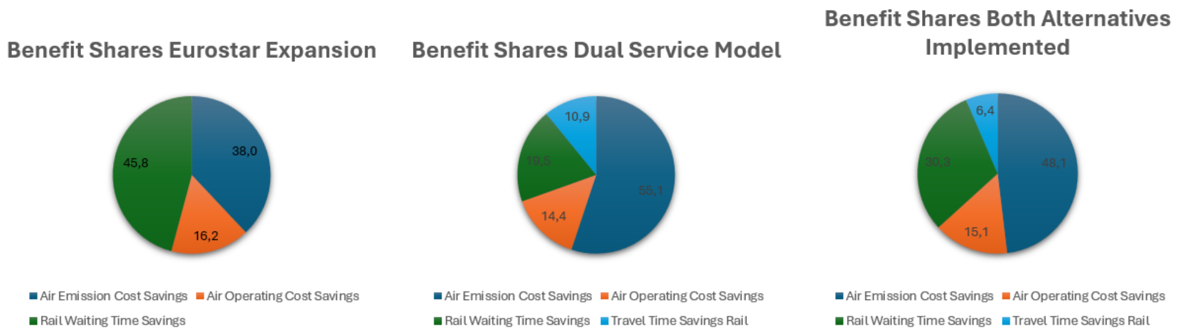


**Figure 7-4:** Breakdown of Discounted Benefits by Alternative and Share

#### 7.5.5.2 Breakdown of the Costs

Table 7-14 and Figure 7-5 present the composition of total discounted costs for each project alternative broken down by major cost categories. These include CAPEX, extra rail-related emissions, additional rail operating costs and net travel time costs for shifting air passengers.

Across all alternatives, operating costs represent the largest share of total discounted costs, accounting for 53% in the Eurostar Expansion, 66,5% in the Dual Service Model and 61,5% when both alternatives are implemented. Travel time costs for air passengers make up the second-largest component. These amount to 34% of costs in the Eurostar Expansion and 27,1% in the Dual Service Model. When both alternatives are implemented, they represent 29,7% of total costs.

CAPEX form a relatively small share of total costs with 11,3% for Eurostar Expansion and only 5,5% for the Dual Service Model. When combined, CAPEX amounts to 7,6% of total costs. Finally, rail emission costs are minimal in all cases, making up only 1-1,6% of total discounted costs. These are significantly outweighed by the emission savings on the air side (shown in the benefits table), reinforcing the environmental advantage of modal shift from air to rail. Overall, the cost structure highlights that the long-term viability of the alternatives depends more on operating costs than on upfront capital investments.

**Table 7-14:** Breakdown of Discounted Costs by Alternative and Benefit Category

| Alternative | Eurostar Expansion | | Dual Service Model | | Both Alternatives Implemented | |
|---|---|---|---|---|---|---|
| **Discounted Cost** | **Value (€M)** | **Share (%)** | **Value (€M)** | **Share (%)** | **Value (€M)** | **Share (%)** |
| CAPEX | 173,2 | 11,3 | 144,4 | 5,5 | 317,6 | 7,6 |
| Rail Emission Costs | 25,0 | 1,6 | 22,9 | 0,9 | 47,9 | 1,2 |
| Operating Costs | 810,6 | 53,0 | 1.748,9 | 66,5 | 2.559,4 | 61,5 |
| Travel Time Costs Air Pax | 520,6 | 34,0 | 713,0 | 27,1 | 1.233,6 | 29,7 |
| Total Costs | 1.529,4 | 100 | 2.629,2 | 100 | 4.158,6 | 100 |

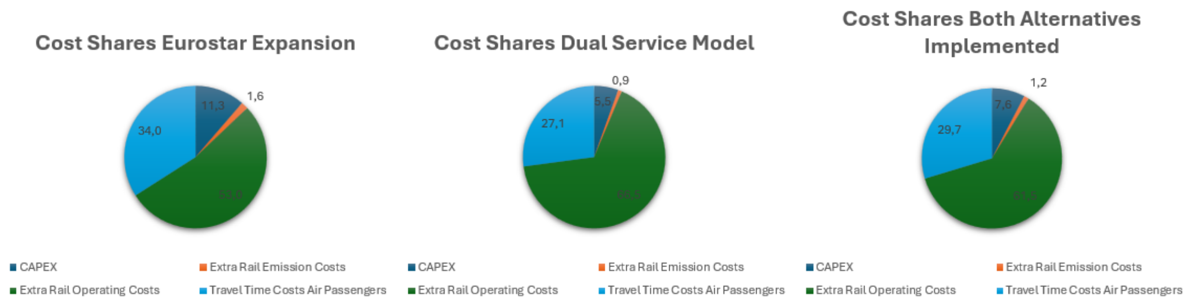


**Figure 7-5:** Breakdown of Discounted Costs by Alternative and Share

## 7.6 Sensitivity Analysis

To assess the robustness of the financial outcomes under uncertainty, a sensitivity analysis was conducted for all three project alternatives. For each alternative, the financial performance indicators NPV, BCR and IRR were evaluated under variations in several important input variables. These include ±20% changes in capital expenditures (CAPEX), value of time (VOT), rail operating costs (ROC), own elasticities (OE) and cross elasticities (CE). Additionally, three discount rate (DR) scenarios (1%, 3%, and 5%) were tested to assess sensitivity to long-term financial assumptions.

The sensitivity analysis was applied only to the growth scenarios and not to the policy scenario. This is because in the policy scenario, the own and cross elasticities have already been adjusted by ±20% to reflect behavioural responses to policy interventions. Applying additional sensitivity variation to these inputs would lead to redundancy. This approach makes sure that the sensitivity analysis isolates the impact of important financial and economic variables on investment performance while avoiding double-counting in the scenario assumptions.

### 7.6.1 Rationale for Chosen Parameters

CAPEX and ROC were selected for sensitivity testing because, as shown in the previous section, they constitute a substantial share of the total costs across all alternatives. Specifically, operating costs account for approximately 60% of the total costs, making them the most important drivers of financial outcomes. VOT was included as a parameter because it significantly affects the travel time costs for air passengers, which represent about 30% of total costs. Moreover, VOT influences both waiting time and travel time savings, which together contribute roughly 30-45% of the total benefits. This makes VOT a sensitive factor in determining the attractiveness and viability of the alternatives.

OE and CE were also tested since these parameters directly shape the projected changes in rail and air demand following implementation of the alternatives. Changes in demand impact nearly all costs and benefits, except for the fixed CAPEX and therefore have a strong influence on the overall financial performance. Finally, the discount rate was included because it reflects the time value of money and risk preferences over the long-term horizon of the projects. Variations in the discount rate can substantially alter the present value of future costs and benefits, thereby affecting the NPV and investment attractiveness.

### 7.6.2 Sensitivity Results Eurostar Expansion

Table 7-15 presents the results of the sensitivity analysis for the Eurostar Expansion alternative. To improve clarity, all scenario results with positive NPVs are highlighted in yellow.

When CAPEX decreases by 20%, the high scenario achieves a positive NPV and all scenarios show improved financial metrics, including less negative NPVs, better BCRs and IRRs even for the base scenario. Conversely, when CAPEX increases by 20%, financial metrics worsen across all scenarios. For changes in the VOT, a decrease leads to poorer financial outcomes, while an increase improves them resulting in a positive NPV for the high scenario and more favourable metrics across other scenarios.

ROC have the most significant impact. When ROC decreases by 20%, all scenarios exhibit positive NPVs and the strongest financial performance overall, with an average BCR of 1,32 which is substantially higher than the second-best metric of 1,02. When ROC increases, financial metrics deteriorate and scenarios become the least favourable. Variations in own elasticities cause only slight changes in financial metrics. A decrease leads to a small decline, and an increase leads to a slight improvement. Cross elasticities behave similarly, with the high scenario yielding a positive NPV. Changes in these elasticity parameters result in the smallest effects on financial outcomes. Regarding the discount rate, a lower rate improves financial metrics, allowing the high scenario to reach a positive NPV while a higher discount rate reduces profitability.

To conclude, ROC have the greatest influence on financial outcomes, while other parameters have relatively modest impacts. Among these, own and cross elasticities have the least effect. The high scenario achieves a positive NPV in at least one parameter change across all parameters, while the base and low scenarios only show positive NPVs when ROC decreases.

**Table 7-15:** Sensitivity Results for the Eurostar Expansion

| **Alternative** | | | | **Eurostar Expansion** | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Scenario** | **Base** | **High** | **Low** | **Base** | **High** | **Low** | **Base** | **High** | **Low** |
| **Financial Metric** | | **CAPEX -20%** | | | **CAPEX Base** | | | **CAPEX +20%** | |
| BCR | 0,99 | 1,02 | 0,94 | 0,96 | 1,00 | 0,92 | 0,94 | 0,98 | 0,89 |
| NPV (€ Million) | -19,4 | 32,0 | -90,2 | -54,0 | -2,6 | -124,9 | -88,7 | -37,3 | -159,5 |
| IRR (%) | 1,81 | 4,88 | N/A | 0,14 | 2,87 | N/A | N/A | 1,34 | N/A |
| **Financial Metric** | | **VOT -20%** | | | **VOT Base** | | | **VOT +20%** | |
| BCR | 0,94 | 0,97 | 0,89 | 0,96 | 1,00 | 0,92 | 0,99 | 1,02 | 0,94 |
| NPV (€ Million) | -85,1 | -37,3 | -155,4 | -54,0 | -2,6 | -124,9 | -22,9 | 32,1 | -94,4 |
| IRR (%) | N/A | 0,90 | N/A | 0,14 | 2,87 | N/A | 1,88 | 4,49 | N/A |
| **Financial Metric** | | **ROC -20%** | | | **ROC Base** | | | **ROC +20%** | |
| BCR | 1,32 | 1,36 | 1,27 | 0,96 | 1,00 | 0,92 | 0,76 | 0,79 | 0,72 |
| NPV (€ Million) | 358,2 | 409,6 | 287,4 | -54,0 | -2,6 | -124,9 | -466,3 | -414,9 | -537,1 |
| IRR (%) | 19,42 | 21,74 | 16,76 | 0,14 | 2,87 | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **OE -20%** | | | **OE Base** | | | **OE +20%** | |
| BCR | 0,96 | 0,99 | 0,91 | 0,96 | 1,00 | 0,92 | 0,97 | 1,00 | 0,93 |
| NPV (€ Million) | -63,0 | -8,3 | -140,2 | -54,0 | -2,6 | -124,9 | -46,6 | 1,7 | -110,8 |
| IRR (%) | N/A | 2,58 | N/A | 0,14 | 2,87 | N/A | 0,50 | 3,09 | N/A |
| **Financial Metric** | | **CE -20%** | | | **CE Base** | | | **CE +20%** | |
| BCR | 0,94 | 0,98 | 0,88 | 0,96 | 1,00 | 0,92 | 0,99 | 1,01 | 0,94 |
| NPV (€ Million) | -89,7 | -34,3 | -166,4 | -54,0 | -2,6 | -124,9 | -23,8 | 23,9 | -88,0 |
| IRR (%) | N/A | 1,32 | N/A | 0,14 | 2,87 | N/A | 1,70 | 4,25 | N/A |
| **Financial Metric** | | **DR 1%** | | | **DR 3%** | | | **DR 5%** | |
| BCR | 0,99 | 1,02 | 0,94 | 0,96 | 1,00 | 0,92 | 0,94 | 0,97 | 0,89 |
| NPV (€ Million) | -19,2 | 43,9 | -109,5 | -54,0 | -2,6 | -124,9 | -78,6 | -36,0 | -135,3 |
| IRR (%) | 0,14 | 2,87 | N/A | 0,14 | 2,87 | N/A | 0,14 | 2,87 | N/A |

## 7.6.3 Sensitivity Results Dual Service Model

For the Dual Service Model, the effects of CAPEX, ROC and CE follow a similar pattern as observed in the Eurostar Expansion. However, the responses of VOT, OE and DR differ. Specifically, higher VOT values lead to more negative NPVs, but paradoxically result in higher BCRs. For OE, increasing this parameter improves the NPV in the base and low scenarios, while in the high scenario, a higher OE actually worsens the NPV. Regarding the discount rate, contrary to typical expectations, a higher discount rate increases the NPV because the Dual Service Model generates negative total cash flows, which become less negative when discounted more heavily, thereby improving the NPV. Despite these variations, none of the sensitivity adjustments result in a positive NPV for the Dual Service Model across all scenarios, reaffirming its overall lack of profitability. The results are shown below in Table 7-16.

**Table 7-16:** Sensitivity Results for the Dual Service Model

| **Alternative** | | | | **Dual Service Model** | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Base** | **High** | **Low** | **Base** | **High** | **Low** | **Base** | **High** | **Low** |
| **Financial Metric** | | **CAPEX -20%** | | | **CAPEX Base** | | | **CAPEX +20%** | |
| BCR | 0,82 | 0,84 | 0,76 | 0,81 | 0,83 | 0,75 | 0,80 | 0,82 | 0,75 |

| Alternative | | | | Dual Service Model | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Base** | **High** | **Low** | **Base** | **High** | **Low** | **Base** | **High** | **Low** |
| NPV (€ million) | -471,8 | -420,6 | -599,2 | -500,6 | -449,4 | -628,0 | -529,4 | -478,2 | -656,8 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **VOT -20%** | | | **VOT Base** | | | **VOT +20%** | |
| BCR | 0,80 | 0,82 | 0,75 | 0,81 | 0,83 | 0,75 | 0,81 | 0,84 | 0,76 |
| NPV (€ million) | -487,7 | -441,6 | -616,5 | -500,6 | -449,4 | -628,0 | -513,6 | -457,2 | -639,5 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **ROC -20%** | | | **ROC Base** | | | **ROC +20%** | |
| BCR | 0,93 | 0,96 | 0,87 | 0,81 | 0,83 | 0,75 | 0,62 | 0,64 | 0,58 |
| NPV (€ million) | -150,8 | -99,6 | -278,3 | -500,6 | -449,4 | -628,0 | -1.295,1 | -1.243,9 | -1.422,5 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **OE -20%** | | | **OE Base** | | | **OE +20%** | |
| BCR | 0,81 | 0,83 | 0,75 | 0,81 | 0,83 | 0,75 | 0,81 | 0,82 | 0,76 |
| NPV (€ million) | -509,7 | -444,5 | -651,4 | -500,6 | -449,4 | -628,0 | -498,6 | -459,8 | -605,8 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **CE -20%** | | | **CE Base** | | | **CE +20%** | |
| BCR | 0,74 | 0,77 | 0,69 | 0,81 | 0,83 | 0,75 | 0,84 | 0,86 | 0,79 |
| NPV (€ million) | -636,8 | -575,7 | -765,0 | -500,6 | -449,4 | -628,0 | -429,9 | -385,0 | -551,7 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **DR 1%** | | | **DR 3%** | | | **DR 5%** | |
| BCR | 0,82 | 0,83 | 0,76 | 0,81 | 0,83 | 0,75 | 0,80 | 0,82 | 0,75 |
| NPV (€ million) | -623,7 | -564,4 | -788,6 | -500,6 | -449,4 | -628,0 | -410,7 | -366,4 | -510,7 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

### 7.6.4 Sensitivity Results Both Alternatives Implemented

For the scenario in which both alternatives are implemented the results are shown in Table 7-17. The sensitivity patterns for CAPEX, VOT, ROC, OE, CE and the discount rate follow exactly the same trends as observed in the Dual Service Model. Notably, only the high scenario under the low ROC sensitivity results in a positive NPV. This again highlights the limited financial viability of this combined alternative under the tested assumptions.

**Table 7-17:** Sensitivity Results for the Both Alternatives Implemented

| Alternative | | | | Both Alternatives Implemented | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Base** | **High** | **Low** | **Base** | **High** | **Low** | **Base** | **High** | **Low** |
| **Financial Metric** | | **CAPEX -20%** | | | **CAPEX Base** | | | **CAPEX +20%** | |
| BCR | 0,88 | 0,90 | 0,83 | 0,87 | 0,89 | 0,81 | 0,85 | 0,88 | 0,80 |
| NPV (€ million) | -491,2 | -401,8 | -689,5 | -554,6 | -465,2 | -752,9 | -618,1 | -528,7 | -816,4 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **VOT -20%** | | | **VOT Base** | | | **VOT +20%** | |
| BCR | 0,85 | 0,87 | 0,80 | 0,87 | 0,89 | 0,81 | 0,88 | 0,90 | 0,83 |
| NPV (€ million) | -572,8 | -492,1 | -771,9 | -554,6 | -465,2 | -752,9 | -536,5 | -438,3 | -733,9 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **ROC -20%** | | | **ROC Base** | | | **ROC +20%** | |
| BCR | 0,99 | 1,01 | 0,93 | 0,87 | 0,89 | 0,81 | 0,77 | 0,79 | 0,72 |
| NPV (€ million) | -42,8 | 46,7 | -241,0 | -554,6 | -465,2 | -752,9 | -1.066,5 | -977,1 | -1.264,8 |
| IRR (%) | 1,41 | 4,78 | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **OE -20%** | | | **OE Base** | | | **OE +20%** | |
| BCR | 0,86 | 0,89 | 0,80 | 0,87 | 0,89 | 0,81 | 0,87 | 0,89 | 0,82 |
| NPV (€ million) | -572,7 | -465,4 | -791,6 | -554,6 | -465,2 | -752,9 | -545,2 | -471,9 | -716,6 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **CE -20%** | | | **CE Base** | | | **CE +20%** | |
| BCR | 0,82 | 0,84 | 0,76 | 0,87 | 0,89 | 0,81 | 0,89 | 0,91 | 0,85 |

| Alternative | Both Alternatives Implemented | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Base** | **High** | **Low** | **Base** | **High** | **Low** | **Base** | **High** | **Low** |
| NPV (€ million) | -726,4 | -622,6 | -931,4 | -554,6 | -465,2 | -752,9 | -453,8 | -374,9 | -639,7 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Financial Metric** | | **DR 1%** | | | **DR 3%** | | | **DR 5%** | |
| BCR | 0,88 | 0,90 | 0,82 | 0,87 | 0,89 | 0,81 | 0,85 | 0,88 | 0,80 |
| NPV (€ million) | -642,9 | -538,3 | -898,0 | -554,6 | -465,2 | -752,9 | -489,3 | -412,4 | -646,0 |
| IRR (%) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

The sensitivity analysis demonstrates that the financial outcomes of the project alternatives are most influenced by variations in ROC and CAPEX, with ROC having the greatest impact on NPV and overall investment viability. Value of time and discount rates also affect financial metrics but to a lesser extent, while changes in own and cross elasticities have comparatively minor effects. The Eurostar Expansion alternative shows the highest resilience to parameter changes, occasionally achieving positive NPVs under favourable assumptions, whereas the Dual Service Model and the combined implementation scenario remain financially unviable across most tested variations. These results highlight that the rail operating costs are the most important costs for the alternative.

## 7.7 Summary and Conclusion

This chapter assessed the feasibility and impacts of two rail project alternatives aimed at reducing short-haul flights between Amsterdam-London and Amsterdam-Berlin over the project timeline from 2026 to 2050. The evaluation was conducted through a SCBA that assessed the societal impacts over multiple dimensions and scenarios to capture uncertainties and policy influences. The impacts in the SCBA where plotted for the base case with no improvements, the Eurostar Expansion on the Amsterdam-London route, the Dual Service Model on the Amsterdam-Berlin route and the simultaneous implementation of both alternatives. Policy scenarios accounted for different regulatory and political environments, ranging from neutral and optimistic to pessimistic outlooks. Demand growth projections were also included, covering base, high and low growth assumptions for air and rail. Finally, the impacts were calculated annually throughout the project horizon from 2026 to 2050, providing a detailed perspective on the outcomes.

Tables 7-18 and 7-19 present the comparative results of the two proposed alternatives relative to their respective base cases. For the operational analysis, the base scenario was used, as it represents the most probable and policy-relevant projection of demand and supply conditions. For the financial analysis, results are presented for both the base and pessimistic scenarios. The pessimistic scenario is included in particular because, despite its name, it yields the most favourable financial results for certain alternatives due to its lower costs.

**Table 7-18:** Overview of Operational Metrics across Alternatives for the Base Scenarios

| Operational Metric | Base Case (LON) | Eurostar Expansion | Change (%) | Base Case (BER) | Dual Service Model | Change (%) |
|---|---|---|---|---|---|---|
| Flights (Thousand) | 304 | 176 | -42,1 | 157 | 40 | -74,3 |
| Air Passengers (Million) | 45,4 | 26,3 | -42,1 | 26,7 | 6,7 | -75,0 |
| Air Emission (€ Billion) | 1,84 | 1,06 | -42,4 | 2,35 | 0,63 | -73,2 |
| Rail Passengers (Million) | 38,2 | 66,7 | +74,7 | 39,9 | 77,2 | +93,5 |

In operational terms, both the Eurostar Expansion and the Dual Service Model alternatives demonstrate a strong potential to shift passengers from air to rail, with significant reductions in flights, air passengers and emissions, alongside large increases in rail ridership. On the

Amsterdam-London corridor, the Eurostar Expansion reduces the number of flights from 304 to 176 thousand, which is a drop of 128 thousand flights or 42,1%. This is accompanied by an identical 42,1% decline in air passengers, a reduction of approximately 19,1 million travellers. This modal shift leads to a 42,4% reduction in air emission-related external costs, which decrease from €1,84 billion to €1,06 billion (a drop of €780 million). Simultaneously, rail passenger volumes on the corridor rise from 38,2 million to 66,7 million, marking an increase of 28,5 million passengers or 74,7%. These results illustrate the effectiveness of the Eurostar Expansion in offering a competitive rail alternative to short-haul air travel on one of Europe's busiest routes.

The impacts of the Dual Service Model on the Amsterdam-Berlin corridor are even more substantial. Annual flights decrease from 157 to 40 thousand which is a drop of 117 thousand flights or 74,3%. Air passengers fall by 75,0% from around 26,7 million to 6,7 million, equating to a reduction of 20 million passengers. Correspondingly, air emission costs are reduced by 73,2%, from €2,35 billion to €0,63 billion (€1,72 billion reduction). At the same time, rail usage nearly doubles, with passenger numbers increasing by 93,5%, from 39,9 million to 77,2 million per year which amounts to a gain of 37,3 million passengers. These outcomes underscore the potential of the Dual Service Model in supporting a modal shift.

**Table 7-19:** Overview of Financial Metrics across alternatives for the Base and Pessimistic Scenarios

| **Alternative** | **Eurostar Expansion** | | **Dual Service Model** | |
|---|---|---|---|---|
| **Financial Metric** | **Base** | **Pessimistic** | **Base** | **Pessimistic** |
| CAPEX (€ Million) | 175,8 | 87,9 | 162,5 | 135,5 |
| Benefits (€ Billion) | 2,09 | 1,16 | 3,17 | 1,70 |
| Discounted Benefits (€ Billion) | 1,48 | 0,82 | 2,13 | 1,10 |
| Costs (€ Billion) | 2,08 | 1,07 | 3,87 | 2,07 |
| Discounted Costs (€ Billion) | 1,53 | 0,79 | 2,63 | 1,37 |
| BCR | 0,96 | 1,04 | 0,81 | 0,81 |
| NPV (€ Million) | -54,0 | 32,4 | -500,6 | -264,7 |
| IRR (%) | 0,14 | 5,67 | N/A | N/A |

While both alternatives deliver clear operational and environmental benefits, their financial performance is more mixed. As shown in Table 7-19, neither the Eurostar Expansion nor the Dual Service Model achieves a positive NPV under the base scenario. The Eurostar Expansion alternative yields a slightly negative NPV of €54 million and a BCR of 0,96, indicating that its discounted benefits nearly but not fully cover the total investment and operational costs. In contrast, the Dual Service Model performs significantly worse with a highly negative NPV exceeding €500 million and a BCR of just 0,81. This weaker financial outcome reflects the higher capital and operational expenditures required to implement an hourly dual-service schedule stock along the Amsterdam-Berlin corridor.

However, when applying the pessimistic scenario the financial viability of the Eurostar Expansion improves notably. Under this scenario, lower CAPEX (€88 million versus €176 million in the base case) is combined with retained benefit levels, resulting in a positive NPV of over €32 million, a BCR of 1,04 and an IRR of 5,67%. These results suggest that the Eurostar Expansion can become financially feasible under more conservative investment assumptions. By contrast, the Dual Service Model remains financially unviable even in the pessimistic scenario. Although the losses are somewhat reduced, the NPV still stands at -€264 million and the BCR remains at 0,81, indicating that the discounted costs continue to outweigh the expected benefits. This persistent shortfall underscores the financial risks and high cost burden associated with the Dual Service Model, making it difficult to justify on economic grounds alone without additional public funding or cost-efficiency measures.

The Both Alternatives Implemented scenario yields the most substantial operational and environmental benefits in the base case. Together, the two rail projects reduce short-haul air traffic by 244 thousand flights annually and shift nearly 39 million air passengers to rail over the 25-year project period. These impacts reflect the combined effect of improved rail frequency on both the Amsterdam-London and Amsterdam-Berlin corridors. From a financial perspective, however, the base case results for this alternative remain unfavourable. Total CAPEX amounts to €338 million, which results in a negative NPV of -€554,6 million and a BCR of 0,87. These metrics indicate that the combined alternative does not achieve financial viability under the current assumptions, highlighting the need for cost reductions or additional public support if this scenario were to be pursued.

The sensitivity analysis shows that financial outcomes are most affected by rail operating costs and CAPEX, with operating costs having the greatest impact on NPV and investment viability. Value of time and discount rates have moderate effects, while demand elasticities matter less. The Eurostar Expansion is the most resilient, sometimes achieving positive NPVs under favourable assumptions. In contrast, the Dual Service Model and combined scenario remain financially unviable in most cases, underscoring the critical importance of controlling operating costs.

In conclusion, both alternatives deliver strong operational and environmental benefits by significantly reducing air traffic and emissions while increasing rail ridership. The Eurostar Expansion alternative shows more balanced performance across both operational and financial dimensions and becomes profitable under the pessimistic scenario due to its relatively low capital investment requirements and strong passenger demand base. The Dual Service Model, while highly impactful in terms of mode shift and environmental outcomes, faces greater financial challenges and would likely require additional public support, subsidy mechanisms or cost optimization strategies to be considered financially feasible. These findings underline the importance of considering both operational and financial dimensions when evaluating rail expansion strategies as alternatives to short-haul air travel.

# 8. Conclusion and Recommendations

This chapter brings together the main findings of the research and presents a structured conclusion to the study. The aim was to assess how short-haul flights between Schiphol Airport and six European destinations could be replaced by improved international rail connections, and what barriers need to be addressed to enable such a transition. This chapter represents Phase 3 of the research, in which the findings from the previous analytical chapters are synthesized. The chapter begins with a brief summary of the research objectives, main and sub-questions, and the methodology used (Section 8.1). It then systematically answers each sub-question (Section 8.2), before synthesizing these insights to address the main research question in Section 8.3. Based on these findings, Section 8.4 offers the policy recommendations for relevant stakeholders and outlines a practical way forward, highlighting the steps needed to implement the proposed rail improvements effectively. Finally, the chapter concludes with a reflection on the study's limitations (Section 8.5), suggestions for future research (Section 8.6) and a reflection on its societal relevance (Section 8.7).

## 8.1 Summary of Research Objectives and Methodology

This study investigates how short-haul flights from Amsterdam Schiphol Airport to the six European destinations: Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin can be replaced by improved international rail connections, thereby contributing to sustainability, multimodal accessibility and the more efficient use of airport capacity. As airports evolve into multimodal transport hubs, the integration between air and rail travel is becoming more important. Despite efforts such as the Multimodal Hub Schiphol, air-to-air transfers still dominate operations at Schiphol. Achieving a meaningful shift to rail is challenged by a range of infrastructural, operational, institutional, regulatory and financial barriers. Moreover, the broader societal impacts of replacing short-haul flights with rail remain insufficiently understood.

This leads to the main research question: ***What barriers need to be addressed to improve direct international rail connections from Schiphol Airport to the six destinations identified in the Actieagenda Trein en Luchtvaart, and what are the societal costs and benefits of replacing short-haul flights with these improved rail connections?***

Building on prior studies that assessed the potential for shifting short-haul flights to rail, this study identifies London and Berlin as the destinations with the greatest potential for replacement. The Dutch Mobility Knowledge Institute studied 13 European destinations where flights could be replaced by rail by 2030. Following this, the *Actieagenda Trein en Luchtvaart* focused on six destinations within 700 km: Brussels, Paris, London, Düsseldorf, Frankfurt and Berlin. London and Berlin are the most promising because they currently have the highest (London) and third-highest (Berlin) passenger volumes of the six destinations and are the only two destinations with short-term project alternatives in the Eurostar Expansion and the Dual Service Model.

To answer this, four sub-questions were explored. First, the study identified feasible project alternatives for improving direct international rail connections (SQ1). Then it assessed the infrastructure investments and operational changes required for implementation (SQ2). The third sub-question addressed the institutional, regulatory and financial barriers to these improvements, and how these obstacles might be overcome (SQ3). At last, the study evaluated the environmental, economic and social impacts of replacing short-haul flights with the proposed rail alternatives, comparing them to the costs of implementation (SQ4).

The research used a sequential exploratory mixed-methods design that integrates qualitative case study analysis with a SCBA. In Phase 1, expert interviews and document analysis were used to identify feasible rail alternatives and to explore implementation barriers. In Phase 2, the societal impacts of each alternative were quantified through a detailed SCBA. This analysis included operational and financial metrics and was performed under multiple demand and policy scenarios to reflect uncertainty. Now in Phase 3, the findings will be synthesized to draw conclusions and formulate recommendations. This mixed-methods approach ensured that the SCBA was informed by realistic constraints and reflects real-word conditions, increasing the relevance and applicability of the results to current policy and infrastructure debates.

## 8.2 Answering the Sub-Questions

This section systematically addresses the four sub-questions that guided this research. Each sub-question corresponds to one of the core analytical chapters (4, 5, 6 and 7) and focuses on a distinct aspect of improving direct international rail connections from Schiphol Airport. The answers presented here synthesize the key findings from those chapters to provide a clear and structured response to each sub-question.

### 8.2.1 Feasible Project Alternatives for Improving Rail Connections

**SQ1:** *What are feasible project alternatives for improving direct international rail connections between Schiphol and the six destinations?*

This subsection presents the feasible project alternatives for improving direct international rail connections between Amsterdam Schiphol Airport and six European destinations. While the KLM Air&Rail model was initially explored, it was excluded from the SCBA due to significant operational, institutional and financial barriers. Fragmented governance among stakeholders, limited integration of passenger and baggage handling, and strong financial incentives favouring feeder flights hinder its scalability and impact, as confirmed by expert interviews (Expert, June 2, 2025, Policy Officer 2, June 13, 2025).

The study evaluated alternatives from the perspectives of origin-and-destination focusing on travel time, frequency, capacity, and infrastructure compatibility, and transfer passengers, emphasizing smooth air-rail integration through direct airport access, IT system alignment and synchronized timetables. Analysis showed some routes already offer competitive options for O&D passengers, but transfer passengers face persistent challenges, particularly limited direct high-speed connections, with services still too infrequent or unreliable.

Two realistic and impactful alternatives emerged for improving international rail connections from Schiphol. The first, the Eurostar Expansion Amsterdam-London, is a near-term solution enabled by the recently opened UK terminal at Amsterdam Central. This alternative involves increasing Eurostar's service frequency from three to four daily trains in 2026, with a fifth train added in 2027, relying entirely on existing infrastructure and operational improvements rather than pending upgrades to the HSL-Zuid. Given the strong demand and high volume of short-haul flights on this corridor, the frequency increase alone has the potential to replace multiple short-haul flights, making it the most promising near-term rail alternative.

The second alternative, the Dual Service Model Amsterdam-Berlin, offers a promising mid-term upgrade planned for completion by 2030. This model features a new timetable with two coordinated ICE L train services: a faster limited-stop intercity running every two hours with a journey time of approximately 5 hours and 27 minutes and a regular intercity service stopping at most stations but with reduced dwell times, bringing travel time down to about 5 hours and 51 minutes. Together, these services provide an hourly frequency between Amsterdam and Berlin. This alternative leverages new ICE L trains capable of speeds up to 230 km/h and improves both travel time and frequency without requiring significant new infrastructure investments within the Netherlands.

The other destinations Brussels, Paris, Düsseldorf and Frankfurt, either face infrastructure bottlenecks or yield limited improvements and thus for these destinations no feasible alternatives were identified.

In conclusion, short-term international rail improvements are feasible only on corridors where existing infrastructure can support enhanced services without extensive new investments. The Amsterdam-London and Amsterdam-Berlin routes are the most promising for origin-and-destination passengers, which is why these alternatives were selected for further investigation.

### 8.2.2 Infrastructure and Operational Requirements

**SQ2:** *What infrastructure investments and operational improvements are required to implement the proposed alternatives?*

In this subsection, the research answers SQ2 by identifying the necessary infrastructure investments and operational improvements needed to implement the feasible alternatives introduced earlier.

The planned increase in Eurostar frequency from three to five daily departures can be achieved without additional infrastructure investments. The existing corridor capacity and the recently opened UK terminal at Amsterdam Centraal provide sufficient capacity to accommodate the planned growth. However, operational feasibility depends on acquiring two additional Siemens Velaro e320 trainsets and recruiting more crew members to operate the expanded services. A significant bottleneck remains the shortage of KMar personnel at Amsterdam Centraal, which delays border control procedures. This staffing shortage has directly affected the timetable, postponing the introduction of the fifth daily departure until 2027.

The Dual Service Model Amsterdam-Berlin relies on deploying new ICE L trainsets, expected to enter service by late 2025. These trains are fully interoperable across Dutch and German rail networks, removing the need for locomotive changes at the border and thereby improving operational reliability and passenger comfort. To support the planned service expansion, six additional ICE L trainsets must be allocated, along with proportional increases in operational and onboard staff. Thanks to the Schengen Agreement, no additional border control personnel are necessary, simplifying cross-border operations. While no major infrastructure upgrades are required, a minor station upgrade is planned at Deventer involving the construction of a fourth platform track to resolve capacity bottlenecks.

In conclusion, both project alternatives primarily rely on operational improvements and new rolling stock rather than significant infrastructure investments. The Eurostar Expansion requires resolving border control staffing challenges to fully implement frequency increases, while the Dual Service Model uses interoperable trains and minor station upgrades to improve travel times and service reliability. These targeted infrastructure and operational measures make the proposed alternatives feasible from a technical point of view.

### 8.2.3 Institutional, Regulatory and Financial Barriers

**SQ3:** *What institutional, regulatory and financial barriers affect the implementation of the proposed alternatives, and how can these barriers be addressed?*

This section explores the institutional, regulatory and financial barriers that hinder the implementation of the proposed alternatives, using the findings from Chapter 6. That chapter identified a total of four alternative-specific barriers and fourteen general barriers, grouped into five overarching categories to provide clarity: Market Structure and Competition, Planning, Capacity and Coordination, Cross-Border and EU Integration, Governance and Policy Fragmentation, and Political and Strategic Prioritization barriers.

For the Eurostar Expansion between Amsterdam and London, the primary barrier comes from the complex cross-border regulatory environment involving UK-Netherlands border controls. A key institutional challenge is the shortage of KMar personnel for customs and security checks, which has delayed service frequency increases. Additionally, financial disputes over who should fund these border control operations have further stalled progress. To overcome these barriers, improved coordination between border agencies, clear and dedicated funding mechanisms and streamlined regulatory procedures are essential to support the expansion of the Eurostar service.

The Dual Service Model for the Amsterdam-Berlin corridor faces different institutional and financial challenges. Operational conflicts with domestic rail services restrict capacity and scheduling flexibility, while a general lack of political urgency delays prioritization and dedicated funding. However, the corridor's growing strategic military significance presents a potential opportunity to secure additional EU and national resources. Addressing these barriers requires stronger stakeholder alignment, long-term investment commitments and political will to prioritize the corridor and roll out the dual service model.

Beyond these alternative-specific issues, a set of general barriers affects both proposed alternatives and limits international rail's ability to compete with short-haul flights. Market structures dominated by incumbent operators, regulatory asymmetries between aviation and rail and fragmented governance frameworks create uneven playing fields. Planning and capacity barriers such as short-term track access rights and institutional misalignment reduce investment certainty and complicate cross-border coordination. Political fragmentation and the absence of dedicated financial instruments further restrict sustainable rail development. Overcoming these general barriers demands systemic reforms including market liberalization, multi-year capacity contracts, stronger EU and bilateral cooperation, integrated cross-modal governance, and stable political and financial commitments aligned with sustainability goals.

In conclusion, the institutional, regulatory and financial barriers identified are complex and interrelated, extending beyond purely infrastructural or technical issues. The Eurostar Expansion and Dual Service Model face practical challenges that can be addressed through targeted reforms, improved coordination and strategic investment. Realizing international rail as a viable alternative to short-haul flights will require coordinated, systemic changes at both national and EU levels to create a supportive and competitive environment. In the short term, the most urgent priority is resolving the fragmented cross-border regulatory environment, particularly for Eurostar services where border control capacity constrains frequency. Without addressing these regulatory and staffing issues, expansion cannot proceed as intended. Over the longer term, the most difficult barrier is the regulatory and fiscal asymmetry between air and rail, which requires EU-wide reforms and political consensus.

### 8.2.4 Expected Societal Impacts of the Alternatives

**SQ4:** *What are the expected environmental, economic and social impacts of implementing the proposed alternatives to replace short-haul flights, and how do these impacts compare to the associated implementation costs?*

This subsection addresses SQ4 by evaluating the environmental, economic and social impacts expected from implementing the feasible rail alternatives. The analysis builds on the findings presented in Chapter 7, which assessed the feasibility and impacts of two rail project alternatives aimed at reducing short-haul flights between Amsterdam and London, and Amsterdam and Berlin over the period from 2026 to 2050. These alternatives were examined through a SCBA that considered multiple dimensions and scenarios to capture uncertainties related to policy developments and demand growth. The scenarios included variations in policies implemented, ranging from neutral to optimistic and pessimistic outlooks, as well as different growth assumptions for both air and rail demand.

Environmentally, both the Eurostar Expansion on the Amsterdam-London corridor and the Dual Service Model on the Amsterdam-Berlin corridor show strong potential to cut emissions by shifting passengers from air travel to rail. The Eurostar Expansion reduces annual flights by about 42%, cutting air passenger numbers by nearly 19 million and lowering air emission-related external costs by approximately €780 million. Rail ridership on this route increases substantially, by almost 29 million passengers, demonstrating rail's capacity to absorb the transferred demand. The Dual Service Model produces even greater effects, reducing flights by more than 74%, decreasing air passengers by 20 million per year and cutting air emission costs by €1,7 billion. Rail ridership nearly doubles, adding about 37 million passengers. These operational metrics clearly indicate that both alternatives contribute significantly to reducing environmental impacts by facilitating a modal shift from air to rail, leading to substantial emission reductions.

Economically, the financial outcomes for the two alternatives are mixed. In the base scenario, neither alternative achieves a positive NPV. The Eurostar Expansion results in a relatively small negative NPV of roughly €54 million and a BCR just below one, suggesting it is close to financial viability. In contrast, the Dual Service Model faces greater financial challenges, with an NPV loss exceeding €500 million and a BCR well below one, reflecting the higher capital and operational costs required to run an intensive hourly service. Under a pessimistic investment cost scenario, which assumes lower CAPEX due to only one additional train being added, the Eurostar Expansion turns financially viable with a positive NPV of about €32 million and a BCR slightly above one. This outcome indicates that a conservative cost assumptions and effective cost management can improve the project's feasibility. However, in practice large infrastructure and rolling stock projects often face cost overruns rather than savings, meaning that such a low-cost scenario should be viewed as an optimistic lower-bound rather than a likely projection. The Dual Service Model remains financially difficult even under this scenario.

When both alternatives are implemented together, their combined operational and environmental benefits are the most significant. Together, they reduce short-haul air traffic by nearly 244 thousand flights annually and shift almost 39 million air passengers to rail over the study period. Financially, however, the combined alternative is less favourable, requiring a total capital investment of approximately €338 million and resulting in a negative NPV exceeding €550 million with a BCR below one. This suggests that without substantial cost reductions the combined alternative is unlikely to be financially sustainable.

Looking at the benefits in detail, the Eurostar Expansion achieves a relatively balanced distribution between waiting time savings and air emission reductions. By contrast, the Dual

Service Model's benefits are more heavily weighted toward air emission savings, reflecting its stronger environmental impact. Travel time savings, while modest, play a notable role especially in the Amsterdam-Berlin corridor. Regarding costs, operating expenses account for the largest share of total discounted costs across all alternatives, followed by travel time costs associated with shifting air passengers. CAPEX make up a smaller portion of total costs, while rail-related emissions contribute negligibly. These findings emphasize that the long-term financial sustainability of the rail alternatives largely depends on controlling operating costs rather than solely minimizing initial investments.

In conclusion, the proposed rail alternatives are expected to generate considerable societal benefits by significantly reducing air traffic, lowering emissions and increasing rail usage, thus aligning well with broader sustainability and climate objectives. The Eurostar Expansion emerges as the more balanced option, offering meaningful environmental benefits alongside potential financial viability under a conservative version of the alternative. The Dual Service Model provides greater environmental gains but faces considerable financial challenges, underscoring the need for supportive policy frameworks and funding mechanisms.

## 8.3 Answer to the Main Research Question

**Main Research Question:** *What barriers need to be addressed to improve direct international rail connections from Schiphol Airport to the six destinations identified in the Actieagenda Trein en Luchtvaart, and what are the societal costs and benefits of replacing short-haul flights with these improved rail connections?*

This section synthesizes the most important findings from the previous analyses to evaluate the barriers that must be addressed to improve international rail connections and the societal effects of these improvements. It assesses how the proposed rail alternatives can reduce short-haul air travel by shifting passenger demand to rail. The analysis considers technical feasibility, implementation barriers and the societal costs and benefits identified throughout the study. By integrating these dimensions, this section provides a detailed answer to the main research question.

The study identified two feasible and promising rail alternatives: the Eurostar Expansion between Amsterdam and London and the Dual Service Model between Amsterdam and Berlin. These alternatives were selected due to their realistic implementation timelines and potential to reduce short-haul flights on busy corridors without requiring major new infrastructure investments within the Netherlands. The Eurostar Expansion leverages existing infrastructure and operational improvements, increasing service frequency from three to five daily departures by 2027. The Dual Service Model introduces new interoperable ICE L trainsets, offering doubling the frequency with improved travel times and reliability by 2030.

Operationally, both alternatives depend primarily on acquiring new rolling stock and expanding crew capacity. Infrastructure investments are limited but necessary, such as the construction of a fourth platform at Deventer station to resolve capacity bottlenecks on the Amsterdam-Berlin corridor. However, the Eurostar alternative faces notable operational constraints related to border control staffing shortages and financial responsibility disputes, delaying service expansion.

A complex web of institutional, regulatory and financial barriers hinders the realization of these rail alternatives. The Eurostar expansion is primarily constrained by cross-border regulatory complexities, including the shortage of customs and security personnel at Amsterdam Central and unclear funding for border control operations, making this the most critical barrier to address across all alternatives. Addressing it should be policymakers' top short-term priority to make these rail alternatives feasible. The Amsterdam-Berlin dual service faces challenges in aligning scheduling and capacity with domestic rail operators, compounded by a lack of political urgency and dedicated investment. More broadly, both alternatives are affected by systemic barriers such as dominant incumbent operators controlling market access, fragmented governance frameworks, regulatory asymmetries favouring aviation over rail and short-term track access rights that hinder long-term planning and investment certainty. Over the longer term, the most difficult general barrier to address is the regulatory and fiscal asymmetries between air and rail, which require EU-wide reforms and political consensus. Overcoming these barriers requires coordinated reforms including market liberalization, integrated cross-border governance, stable multi-year capacity contracts and political commitment aligned with sustainability goals.

From a societal perspective, both alternatives promise substantial environmental benefits by significantly reducing short-haul flights and associated carbon emissions. The Eurostar Expansion could cut air passenger numbers by nearly 19 million and reduce emission-related external costs by approximately €780 million. The Dual Service Model offers even greater environmental benefits, potentially reducing air passengers by 20 million and cutting emission costs by €1,7 billion annually. Together, these shifts would significantly reduce aviation's environmental footprint.

Economically, the Eurostar Expansion is close to financial viability, with a near break-even NPV under base assumptions and a positive outcome under a conservative version of the alternative. Conversely, the Dual Service Model faces substantial financial challenges with a negative NPV driven by high operating costs despite its environmental merits. When combined, the alternatives require significant capital investment and yield a negative financial return, highlighting the tension between environmental benefits and financial sustainability. Socially, the improved rail connections offer improved travel options for origin-and-destination passengers with increased frequencies and lower travel and waiting times.

In summary, the main research question reveals that improving direct international rail connections from Schiphol to the six European destinations is technically and operationally feasible on the Amsterdam-London and Amsterdam-Berlin corridors, but substantial institutional, regulatory and financial barriers must be addressed. The proposed rail alternatives offer significant societal benefits, particularly in reducing emissions and short-haul flight volumes, aligning with sustainable transport objectives. However, the alternatives generally lack strong financial viability, with only the Eurostar Expansion proving viable under a specific, conservative scenario. Notably, the pessimistic scenario performed the best out of all the different scenarios analysed, highlighting how small rail improvements can have the greatest potential for success. Balancing the substantial environmental benefits against the financial and operational challenges highlights the necessity of integrated policy frameworks and multi-level cooperation to effectively shift passenger demand from air to rail.

## 8.4 Policy Recommendations and Way Forward

This study concludes that improved international rail services from Schiphol Airport to London and Berlin can yield substantial environmental and social benefits, particularly by reducing short-haul flights and associated emissions. However, achieving this modal shift requires more than operational or technical improvements. It demands targeted policy interventions to overcome deeply rooted institutional, regulatory and financial barriers. The following recommendations aim to guide policymakers in creating the necessary conditions to make international rail a viable and competitive alternative to aviation. In addition to policy guidance, this study outlines a practical way forward for engineers and operators, highlighting the operational, infrastructural and scheduling steps that need to be taken to implement these rail improvements effectively.

### 8.4.1 Policy Recommendations

**Priority Recommendation: Resolve Cross-Border Regulatory and Staffing Constraints**
While multiple interventions are needed, the most urgent action for policymakers is to address the fragmented cross-border regulatory environment, particularly for routes like Amsterdam-London. This includes providing sufficient customs and security personnel at the stations, clarifying funding responsibilities for border operations and streamlining procedures across countries. Addressing this barrier first will create the necessary conditions for other international rail improvements to succeed.

**Integrate International Rail More Effectively Into Existing Networks**
Current Dutch and EU rail policies largely emphasize domestic connectivity, while international services remain underdeveloped and fragmented. To strengthen the overall network, policymakers should encourage better integration of international routes alongside national services. This can include setting clear targets for international modal shift where feasible, coordinating infrastructure planning to accommodate cross-border services and supporting funding mechanisms that support international trains to complement rather than compete with domestic travel.

**Promoting Multilateral Cooperation to Harmonize Cross-Border Standards**
Improving international rail connections depends on effective cross-border coordination. Governments (particularly those of the Netherlands, Germany, France, Belgium and the UK) must intensify bilateral and EU-level cooperation to harmonize technical, operational and regulatory standards. This involves aligning timetables, ticketing systems, safety protocols and border procedures to ensure smooth travel across countries. For routes like Amsterdam-London and Amsterdam-Berlin, cooperation should also focus on resolving institutional frictions such as border staffing and rail slot allocation.

**Address Structural Asymmetries Between Rail and Aviation**
Aviation currently enjoys substantial structural advantages over international rail, including lower taxes on fuel and tickets, more favourable regulatory frameworks and greater public investment. These imbalances must be corrected to create a level playing field. Policymakers should either remove aviation's competitive advantages by introducing kerosene taxes or mandating minimum ticket prices, or provide international rail with the same financial and regulatory support. This may include reduced track access charges, public service obligation contracts for international services or EU funding for rolling stock and infrastructure upgrades.

**Support Long-Term Investment Through Stable Capacity Contracts and Political Commitments**
Short-term track access rights and limited political prioritization discourage long-term planning and investment in international rail. The Dutch government should introduce multi-year capacity contracts for international operators, alongside stable and predictable investment frameworks. Aligning these efforts with broader European sustainability objectives such as the Green Deal and TEN-T policy, will strengthen political backing and unlock co-financing opportunities.

**Improve Institutional Coordination and Governance Structures**
Institutional fragmentation across countries and agencies hampers the coherent development of international rail services. Dedicated governance mechanisms, such as cross-border task forces or joint rail authorities, can improve coordination and implementation capacity. These structures should include representatives from national governments, infrastructure managers, operators and EU institutions, with a mandate to oversee service development, funding allocation and progress monitoring.

To realize the full societal benefits of international rail and reduce dependency on short-haul flights, a fundamental policy shift is required. One that treats international rail as a core component of Europe's sustainable transport network rather than a niche or secondary service. This shift must be underpinned by strong political will, multilateral cooperation and targeted reforms to remove the structural disadvantages that currently hinder international rail. Only then can the environmental potential of alternatives like the Eurostar Expansion and Dual Service Model be fully unlocked.

### 8.4.2 Way Forward

Based on the analysis of growth and policy scenarios, the most viable approach for implementing improved international rail services from Schiphol aligns with the pessimistic scenario, which assumes that institutional, regulatory and financial barriers remain largely unresolved. Despite these constraints, this scenario yields the most promising NPVs, suggesting a pragmatic approach that balances feasibility and impact.

For the Eurostar Expansion, implementation under this scenario means adding only one additional train in 2026, while the planned fifth train in 2027 is postponed indefinitely. One additional trainset is acquired and fully prepared for service, with staff training and depot readiness completed to support operational reliability.

For the Dual Service Model, launch is delayed until 2032. Upon implementation, the service consists of eight daily trains (four fast and four regular) rather than the originally planned ten, requiring four ICE L trainsets. Deventer Station receives its fourth platform, ensuring that the limited number of trainsets can operate reliably at the planned frequencies.

Even under these pessimistic conditions, operators should prioritize the readiness of rolling stock, including commissioning, certification and maintenance before service launch. Adequate crew assignment and timetable planning are needed to maximize reliability, while targeted infrastructure upgrades and performance monitoring will help optimize limited service capacity and assess passenger response for iterative improvements.

By following this approach, operators can realistically implement the most promising option within the constraints of current institutional, regulatory and financial barriers. While full-scale service expansion depends on broader policy interventions, this strategy makes sure that the Eurostar and Dual Service models deliver tangible benefits in reliability, ridership growth and environmental impact.

## 8.5 Limitations and Reflection

While this study provides important insights into the barriers and societal implications of improving international rail connections from Schiphol Airport, several limitations must be acknowledged that influence the scope, depth and interpretation of the findings.

**Limitations of the SCBA**

The SCBA conducted for this study provides a structured method to assess and compare societal costs and benefits of proposed rail alternatives. However, several constraints limit the accuracy and applicability of the results. A core assumption is that rail operating costs remain constant over time, despite their dynamic nature. These costs account for nearly 60% of total project costs and strongly determine the financial viability of each alternative. A more detailed breakdown or dynamic modelling of these cost components would have offered better insights into potential efficiencies, economies of scale or risks. This aspect should have been investigated much more extensively, as operating costs are crucial to understanding the long-term financial sustainability of international rail services.

Additionally, the SCBA modelled modal shift as an immediate and complete transition in the implementation year, with air passenger volumes and flights suddenly declining as rail services are improved. This assumption introduces abrupt year-on-year variations and likely overstates early impacts. In practice, such shifts occur gradually, as passengers respond to changes in service levels over time.

**Focus on Short-Term Alternatives**

This research deliberately focused on alternatives implementable by 2030, in line with near-term policy ambitions and infrastructure plans. However, this short-term lens excludes long-term or transformative options, such as new high-speed lines that could unlock a much greater modal shift from short-haul air to rail beyond 2040. While realistic in scope, this approach limits the strategic horizon of the findings and potentially underrepresents what international rail could achieve with more ambitious planning and investment.

**Data Limitations and Heavy Reliance on News Sources**

A further limitation is the heavy reliance on news articles and press releases as data sources. This was necessary due to the lack of detailed, corridor-specific public reporting from railway operators and infrastructure managers. While general plans and ambitions are often communicated publicly, concrete data such as cost breakdowns, service design details or evaluation studies are not always published. As a result, some assumptions had to be made from news articles, which may not always reflect the full complexity or internal uncertainties of the proposed rail developments.

**Limited Stakeholder Perspectives**

Although the study includes expert interviews, it did not include interviews with stakeholders from Schiphol Airport or from major airlines. These actors play a big role in the current air-rail dynamic and may have offered alternative perspectives on passenger behaviour, operational integration challenges and the commercial logic behind short-haul feeder flights. Their exclusion limits the scope of the institutional and operational analysis, especially regarding intermodal coordination and the role of aviation stakeholders in facilitating modal shift.

**SCBA Does Not Address Distributional Effects**

Finally, while the SCBA provides a useful macro-level assessment of net societal value, it does not explore the distributional effects of costs and benefits. That is, it does not indicate who gains and who loses. For example, intercontinental transfer passengers might face longer or more fragmented journeys, while others may benefit from improved ground transport connectivity. Similarly, cost burdens may fall disproportionately on certain governments, companies, passenger groups or airports. An analysis of these distributional effects would be valuable for policy development and stakeholder alignment.

In summary, this study makes a relevant contribution by evaluating near-term, feasible rail alternatives for replacing short-haul flights from Schiphol. However, its scope is limited by short planning horizons, data constraints, static modelling assumptions and gaps in stakeholder perspectives. These limitations show the need for future research that incorporates long-term strategies, dynamic behavioural modelling, more transparent operator data and inclusive stakeholder engagement to fully understand the potential and challenges of international rail as a substitute for short-haul aviation.

## 8.6 Future Research Directions

This study highlights several areas where future research can build on the current findings to more fully assess the long-term potential of international rail as a substitute for short-haul flights and to support more effective policymaking.

**Investigate Rail Operating Costs in Greater Detail**
The most important area for future investigation is the structure and development of international rail operating costs. In this study, these costs were kept constant across scenarios, despite their substantial impact. More detailed and dynamic modelling is needed to reflect how costs evolve over time due to changes in staffing, energy prices, train technology or economies of scale. In particular, exploring cost reduction strategies such as shared rolling stock pools, crew optimization or public service obligation models for international services could yield important insights for improving the financial case for rail.

**Simulate Policy Scenarios to Address Identified Barriers**
While this study identified numerous institutional, regulatory, and financial barriers, it did not explicitly model the effects of targeted policy reforms. Future research should develop and test alternative scenarios in which specific policy measures are implemented to overcome key obstacles. For example, introducing a frequent flyer levy to fund international rail investments, harmonizing border procedures, reducing track access charges, or liberalizing international train operations. By simulating the impact of such interventions on ridership, costs, and emissions, future studies can help quantify the potential benefits of political and regulatory action.

**Model Gradual Modal Shift Dynamics**
Another limitation of this study is the assumption of an immediate modal shift in the year of implementation. Realistically, passengers transition gradually to new rail services, responding to changing perceptions, service reliability and awareness over time. Future research should develop behavioural or agent-based models that simulate this gradual transition, potentially over a 5-10 year horizon. Such models would provide more realistic estimates of demand growth, carbon savings and revenue development, and could also explore how public campaigns, ticketing integration or aviation restrictions affect the pace of modal shift.

**Explore Long-Term and High-Impact Alternatives Beyond 2030**
This study focused on short-term alternatives with implementation potential before 2030. However, longer-term infrastructure projects could unlock much greater shifts from air to rail beyond 2040. Future research should assess the feasibility and impact of these more transformative projects, taking into account technological innovations, evolving passenger

preferences and changing climate targets. Scenario-based studies comparing incremental improvements to high-ambition strategies would help policymakers weigh the long-term trade-offs between cost, impact and feasibility.

**Improve Data Transparency and Stakeholder Inclusion**
To support more robust evaluations, future research should also address current data and stakeholder gaps. There is a clear need for more transparent and corridor-specific data from railway operators and infrastructure managers on service costs, design assumptions and performance targets. This would reduce reliance on news reports and press releases, which often lack detail and may not reflect underlying uncertainties. Additionally, more inclusive stakeholder engagement particularly with aviation actors could provide key insights into air-rail coordination challenges, transfer passenger behaviour and commercial dependencies. These perspectives are essential for developing workable intermodal strategies.

**Analyse Distributional Effects of Modal Shift Policies**
Finally, future studies should move beyond aggregate societal cost-benefit assessments to analyse how costs and benefits are distributed across different stakeholder groups. Modal shift policies may create winners and losers: regions more reliant on flights may face reduced accessibility, while others benefit from improved rail options. Understanding these distributional effects can support more effective policymaking, targeted compensation mechanisms and better stakeholder alignment.

## 8.7 Reflection on Societal Relevance

The societal relevance of this work lies in its contribution to sustainable transport objectives. By exploring feasible rail alternatives for short-haul flights from Schiphol Airport, the study addresses the challenge of reducing Europe's transportation-related carbon emissions. Implementing these alternatives could lead to a substantial decrease in aviation's environmental footprint, contributing to climate goals while also reducing noise pollution and other negative externalities associated with air travel. In addition to environmental benefits, the proposed rail solutions offer improved travel options for both origin-and-destination passengers and intercontinental transfer passengers. The study further highlights the economic and social trade-offs involved, demonstrating that although the alternatives may face financial and operational challenges, the shift from air to rail has significant benefits.

Moreover, this research provides actionable insights for policymakers, railway operators and airport authorities. It shows that addressing barriers such as regulatory fragmentation, cross-border staffing constraints and the structural advantages of aviation compared to rail is essential to unlocking the full potential of rail as a viable substitute for short-haul flights. By providing input for policy interventions, infrastructure investments and operational strategies, the study supports the broader integration of international rail into Europe's mobility network. Therefore, the findings are highly relevant not only to climate policy but also to economic planning, regional connectivity and the long-term goal of creating a more sustainable, resilient and socially valuable transport system.

# Declaration

This master thesis is my own work. During the preparation of this work, I used OpenAI's ChatGPT primarily to rewrite sentences, find synonyms for words and summarize sections I had previously written. After using these tools, I carefully reviewed, edited and refined the content to make sure it was accurate and in line with my own reasoning. Additionally, I used AI as a creative thinking partner, to bounce ideas off and gain inspiration for developing arguments and structuring sections. I take full responsibility for the content of this Master Thesis report.

Regarding the interviews, all participants were asked at the start whether they agreed with the provided informed consent form and whether they had questions about it. Some participants requested to be contacted to review my interpretation and use of their data in the results section. These participants were contacted and some adjustments were made based on their feedback. For other participants, no such preference was communicated. In accordance with TU Delft Human Research Ethics procedures (Data Management Plan, informed consent form and HRX checklist), all data have been processed ethically as agreed.

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# Appendix

## A. Literature Review Details

A structured search was conducted in ScienceDirect and Google Scholar on air-rail substitution, multimodal hubs, cost-benefit analysis and infrastructure investment. Boolean operators and filters prioritized recent (2010-2024) studies using keywords like "short-haul flight substitution" and "high-speed rail integration." Snowballing extended the selection with Reiter et al. (2022) leading to Rajendran & Popfinger (2022).

Inclusion criteria focused on quantitative studies using simulation, optimization, CBA or economic modeling to assess rail replacing short-haul flights. Studies on urban mobility, general aviation policies or qualitative-only analyses were excluded. Table A-1 summarizes the selected studies.

**Table A-1:** Overview of Selected Articles for Literature Review

| Article | Key Focus | Methodology | Scope | Findings |
|---|---|---|---|---|
| **Short-haul flight substitution by rail** (Reiter et al., 2022) | Feasibility of replacing short-haul flights with rail | Quantitative analysis | Germany | Rail substitution reduces $CO_2$ but increases travel time |
| **Evaluating air-rail substitutability** (Rajendran & Popfinger, 2022) | Simulation-based evaluation of HSR replacing short-haul flights | Discrete-event systems simulation (DESS), DMADV framework | Munich-Paris route | Rail capacity limitations, $CO_2$ reduction potential (56,8%), scheduling adjustments |
| **Sustainability benefits of air-rail substitution** (Avogadro et al., 2021) | Emission and accessibility impact of canceling short-haul flights | Large-scale data analysis of 1.700 routes | Intra-European network | Central regions benefit most in emission reductions, travel time concerns, |
| **High-speed rail and Lufthansa Express Rail** (Wandelt & Sun, 2022) | Airline-HSR cooperation in Germany | Comparative analysis of journey time and fares | Frankfurt Airport | Limited benefits in time/cost for extended network, luggage and schedule issues |
| **Airline-HSR cooperation and congestion** (Avenali et al., 2024) | Impact of airline-HSR agreements on congestion and airport strategy | Economic modeling | Hub airports | Cooperation does not reduce congestion, misaligned incentives |
| **Infrastructure investment in airport-rail systems** (Lu et al., 2024) | Optimization of air-HSR intermodal networks | Hierarchical optimization (MILP & PIQP) | 40-city network (China) | 22% emissions reduction, trade-offs passenger cost and environmental benefits |
| **High-speed rail impact on airport traffic** (Liu et al., 2019) | HSR development effects on airport traffic | Network-based analysis, regression | China & Japan | HSR reduces domestic traffic but feeds international flights |
| **Economic impacts of air-HSR competition** (Zhang et al., 2019) | Passenger mode choice, airline competition, economic effects | Literature review and empirical analysis | Global | HSR redistributes traffic but creates regional disparities |

| | | | | |
|---|---|---|---|---|
| **Cost-benefit analysis of HSR investments** (Adler et al., 2010) | Economic feasibility of HSR | Game-theoretic cost-benefit analysis | EU transport network | HSR investment can maximize welfare but may require subsidies |
| **Costs of HSR networks in Europe** (Branković & Kalem, 2021) | Cost analysis of HSR development | Comparative cost analysis | European countries | High costs vary by country, significant benefits in accessibility & sustainability |

## B. Trainset Requirements

Table B-1 shows the detailed daily operational schedule for the three Eurostar trainsets currently required to operate the Amsterdam-London high-speed service. Each row represents a specific activity (journey or turnaround) performed by a trainset. All times are shown in local time (CET/CEST for Amsterdam, GMT/BST for London). As indicated, two trainsets complete round trips starting from Amsterdam, while one completes a round trip starting from London. The schedule demonstrates that three trainsets are sufficient to operate the current three daily departures in each direction.

**Table B-1:** Indicative Daily Deployment of Three Eurostar Trainsets on the Amsterdam-London Corridor Based on the 2025 Timetable

| Trainset | Activity | Start Time (Local) | Duration (hh:mm) | End Time (Local) |
|---|---|---|---|---|
| Trainset 1 | AMS → LON | 06:40 | 04:17 | 09:57 |
| Trainset 1 | Turnaround | 09:57 | 01:00 | 10:57 |
| Trainset 1 | LON → AMS | 11:04 | 04:17 | 16:21 |
| Trainset 1 | Turnaround | 16:21 | 01:00 | 17:21 |
| Trainset 2 | AMS → LON | 13:40 | 04:17 | 16:57 |
| Trainset 2 | Turnaround | 16:57 | 01:00 | 17:57 |
| Trainset 2 | LON → AMS | 18:04 | 04:17 | 23:21 |
| Trainset 2 | Turnaround | 23:21 | 01:00 | 00:21 (Next Day) |
| Trainset 3 | LON → AMS | 06:16 | 04:17 | 11:33 |
| Trainset 3 | Turnaround | 11:33 | 01:00 | 12:33 |
| Trainset 3 | AMS → LON | 18:40 | 04:17 | 21:57 |
| Trainset 3 | Turnaround | 21:57 | 01:00 | 22:57 |

Table B-2 presents the proposed operational schedule for the Amsterdam-London Eurostar route with five daily departures in each direction. Compared to the previous schedule, one additional round trip departing from Amsterdam and one from London have been added, requiring two extra trainsets (Trainset 4 and Trainset 5). Additionally, Trainset 3's afternoon departure from Amsterdam has been moved earlier from 18:40 to 16:40 to reduce idle time and improve operational efficiency. Turnaround times remain approximately one hour at each terminal, maintaining sufficient time for boarding, cleaning and preparation between journeys.

**Table B-2:** Indicative Daily Deployment of Five Eurostar Trainsets on the Amsterdam-London Corridor Based on the Proposed 2026 Timetable

| Trainset | Activity | Start Time (Local) | Duration (hh:mm) | End Time (Local) |
|---|---|---|---|---|
| Trainset 1 | AMS → LON | 06:40 | 04:17 | 09:57 |
| Trainset 1 | Turnaround | 09:57 | 01:00 | 10:57 |
| Trainset 1 | LON → AMS | 11:04 | 04:17 | 16:21 |
| Trainset 1 | Turnaround | 16:21 | 01:00 | 17:21 |
| Trainset 2 | AMS → LON | 13:40 | 04:17 | 16:57 |
| Trainset 2 | Turnaround | 16:57 | 01:00 | 17:57 |
| Trainset 2 | LON → AMS | 18:04 | 04:17 | 23:21 |
| Trainset 2 | Turnaround | 23:21 | 01:00 | 00:21 (Next Day) |
| Trainset 3 | LON → AMS | 06:16 | 04:17 | 11:33 |
| Trainset 3 | Turnaround | 11:33 | 01:00 | 12:33 |
| Trainset 3 | AMS → LON | 16:40 | 04:17 | 19:57 |
| Trainset 3 | Turnaround | 19:57 | 01:00 | 20:57 |
| Trainset 4 | AMS → LON | 09:40 | 04:17 | 12:57 |
| Trainset 4 | Turnaround | 12:57 | 01:00 | 13:57 |
| Trainset 4 | LON → AMS | 14:04 | 04:17 | 19:21 |
| Trainset 4 | Turnaround | 19:21 | 01:00 | 20:21 |

| Trainset | Activity | Start Time (Local) | Duration (hh:mm) | End Time (Local) |
|---|---|---|---|---|
| Trainset 5 | LON → AMS | 09:04 | 04:17 | 14:21 |
| Trainset 5 | Turnaround | 14:21 | 01:00 | 15:21 |
| Trainset 5 | AMS → LON | 18:40 | 04:17 | 21:57 |
| Trainset 5 | Turnaround | 21:57 | 01:00 | 22:57 |

Table B-3 presents the detailed daily operational schedule for the Intercity services between Amsterdam and Berlin, illustrating how individual trainsets are deployed across specific journeys and turnaround activities. Each row represents either a scheduled trip or a turnaround operation, with all times expressed in Central European Time (CET/CEST), as both cities are in the same time zone. The schedule shows that round trips require approximately 12 hours and 12 minutes, including 15-minute turnarounds in both directions. The table includes three trainsets that perform complete round trips within a single operational day: two departing from Amsterdam in the morning and one from Berlin. Four additional trainsets are used for single-leg services, with two departing from Amsterdam and two departing from Berlin, where no matching return journey is scheduled within the same day. This distribution demonstrates that at least seven trainsets are required to operate the current set of daily Intercity services between Amsterdam and Berlin, assuming no overnight operations and sufficient buffer time for reliable performance.

**Table B-3:** Indicative Daily Deployment of Seven Intercity Trainsets on the Amsterdam-Berlin Corridor Based on the Current Timetable

| Trainset | Activity | Start Time (Local) | Duration (hh:mm) | End Time (Local) |
|---|---|---|---|---|
| Trainset 1 | AMS → BER | 08:00 | 05:51 | 13:51 |
| Trainset 1 | Turnaround | 13:51 | 00:15 | 14:06 |
| Trainset 1 | BER → AMS | 14:06 | 05:51 | 19:57 |
| Trainset 1 | Turnaround | 19:57 | 00:15 | 20:12 |
| Trainset 2 | AMS → BER | 10:00 | 05:51 | 15:51 |
| Trainset 2 | Turnaround | 15:51 | 00:15 | 16:06 |
| Trainset 2 | BER → AMS | 16:06 | 05:51 | 21:57 |
| Trainset 2 | Turnaround | 21:57 | 00:15 | 22:12 |
| Trainset 3 | BER → AMS | 08:06 | 05:51 | 13:57 |
| Trainset 3 | Turnaround | 13:57 | 00:15 | 14:12 |
| Trainset 3 | AMS → BER | 16:00 | 05:51 | 21:51 |
| Trainset 3 | Turnaround | 21:51 | 00:15 | 22:06 |
| Trainset 4 | AMS → BER | 12:00 | 05:51 | 17:51 |
| Trainset 4 | Turnaround | 17:51 | 00:15 | 18:06 |
| Trainset 5 | AMS → BER | 14:00 | 05:51 | 19:51 |
| Trainset 5 | Turnaround | 19:51 | 00:15 | 20:06 |
| Trainset 6 | BER → AMS | 10:06 | 05:51 | 15:57 |
| Trainset 6 | Turnaround | 15:57 | 00:15 | 16:12 |
| Trainset 7 | BER → AMS | 12:06 | 05:51 | 17:57 |
| Trainset 7 | Turnaround | 17:57 | 00:15 | 18:12 |

Table B-4 presents the operational schedule for all trainsets required to run the proposed hourly Amsterdam-Berlin service. In total, it includes 7 full round trips, with 4 starting in Amsterdam and 3 in Berlin and 6 single-leg trips: 3 originating from Amsterdam and 3 from Berlin. These single-leg trips are required to fill the remaining hourly gaps in the timetable and ensure a balanced distribution of departures from both cities. The combination of round trips and strategically placed single legs enables the operation of an efficient and reliable hourly service in both directions. A total of 13 trainsets are needed to operate the full schedule as proposed.

**Table B-4:** Indicative Daily Deployment of Thirteen Intercity Trainsets on the Amsterdam-Berlin Corridor under the Proposed Hourly Service

| Trainset | Activity | Start Time (Local) | Duration (hh:mm) | End Time (Local) |
|---|---|---|---|---|
| Trainset 1 | AMS → BER | 08:00 | 05:51 | 13:51 |
| Trainset 1 | Turnaround | 13:51 | 00:15 | 14:06 |
| Trainset 1 | BER → AMS | 14:06 | 05:51 | 19:57 |
| Trainset 1 | Turnaround | 19:57 | 00:15 | 20:12 |
| Trainset 2 | AMS → BER | 10:00 | 05:51 | 15:51 |
| Trainset 2 | Turnaround | 15:51 | 00:15 | 16:06 |
| Trainset 2 | BER → AMS | 16:06 | 05:51 | 21:57 |
| Trainset 2 | Turnaround | 21:57 | 00:15 | 22:12 |
| Trainset 3 | BER → AMS | 08:06 | 05:51 | 13:57 |
| Trainset 3 | Turnaround | 13:57 | 00:15 | 14:12 |
| Trainset 3 | AMS → BER | 16:00 | 05:51 | 21:51 |
| Trainset 3 | Turnaround | 21:51 | 00:15 | 22:06 |
| Trainset 4 | AMS → BER | 12:00 | 05:51 | 17:51 |
| Trainset 4 | Turnaround | 17:51 | 00:15 | 18:06 |
| Trainset 5 | AMS → BER | 14:00 | 05:51 | 19:51 |
| Trainset 5 | Turnaround | 19:51 | 00:15 | 20:06 |
| Trainset 6 | BER → AMS | 10:06 | 05:51 | 15:57 |
| Trainset 6 | Turnaround | 15:57 | 00:15 | 16:12 |
| Trainset 7 | BER → AMS | 12:06 | 05:51 | 17:57 |
| Trainset 7 | Turnaround | 17:57 | 00:15 | 18:12 |
| Trainset 8 | AMS → BER | 09:00 | 05:27 | 14:27 |
| Trainset 8 | Turnaround | 14:27 | 00:15 | 14:42 |
| Trainset 8 | BER → AMS | 15:06 | 05:27 | 20:33 |
| Trainset 8 | Turnaround | 20:33 | 00:15 | 20:48 |
| Trainset 9 | AMS → BER | 11:00 | 05:27 | 16:27 |
| Trainset 9 | Turnaround | 16:27 | 00:15 | 16:42 |
| Trainset 9 | BER → AMS | 17:06 | 05:27 | 22:33 |
| Trainset 9 | Turnaround | 22:33 | 00:15 | 22:48 |
| Trainset 10 | BER → AMS | 09:06 | 05:27 | 14:33 |
| Trainset 10 | Turnaround | 14:33 | 00:15 | 14:48 |
| Trainset 10 | AMS → BER | 15:00 | 05:27 | 20:27 |
| Trainset 10 | Turnaround | 20:27 | 00:15 | 20:42 |
| Trainset 11 | BER → AMS | 11:06 | 05:27 | 16:33 |
| Trainset 11 | Turnaround | 16:33 | 00:15 | 16:48 |
| Trainset 11 | AMS → BER | 17:00 | 05:27 | 22:27 |
| Trainset 11 | Turnaround | 22:27 | 00:15 | 22:42 |
| Trainset 12 | AMS → BER | 13:00 | 05:27 | 18:27 |
| Trainset 12 | Turnaround | 18:27 | 00:15 | 18:42 |
| Trainset 13 | BER → AMS | 13:06 | 05:27 | 18:33 |
| Trainset 13 | Turnaround | 18:33 | 00:15 | 18:48 |

# C. Interview Transcripts

## Interview 1: Expert from a National Passenger Organization and EPF Board Member

**Date:** *June 2, 2025*
**Reference:** (Expert, personal communication, June 2, 2025)

The expert is affiliated with national passenger organization Rover and serves on the board of the European Passengers' Federation (EPF). In this capacity, the expert is actively involved in national and European discussions on international rail services, sustainable mobility and alternatives to short-haul flights. The interviewee also participates in stakeholder consultations related to Amsterdam Airport Schiphol.

This interview transcript has been translated from Dutch and edited for conciseness and relevance to the research scope. Non-substantive exchanges and off-topic segments have been omitted.

**Interviewer:**
Which of the three project alternatives are you most familiar with? Let's start with that one.

**Expert:**
First, I'd like to say that I fully support this research and would like to offer some institutional context.

Right now, air travel remains highly competitive with rail in many respects. Your research rightly shows that international train services are insufficient and there is plenty of room for improvement. At the same time flying is still extremely cheap, making it difficult to offer a competitive rail alternative. A necessary condition for a significant modal shift is therefore to make air travel more expensive.

At the European level there are ambitious goals, such as doubling international train services by 2030 and replacing short- and medium-haul flights with rail. These are admireable policy objectives but progress is slow. This is partly due to the strong veto power held by the Council of Ministers, in which the European Commission, Parliament and Member States participate. That power is often exercised particularly by countries like France (via SNCF) and Germany (via DB) though this is slowly beginning to change.

Historically, public transport has been a lower priority than car or air travel in many European countries. Germany seems to be shifting this with major investments as outlined in its new coalition agreement. France is also taking steps, but mostly focused on domestic services and is less inclined to invest in international rail unless it is operated by SNCF.

Of the alternatives in your study, I consider the London connection the most urgent. There are approximately 60 to 70 flights per day between Amsterdam and London. The Channel Tunnel provides a solid foundation for a fully viable rail alternative.

ProRail recently studied, at the minister's request and following a parliamentary initiative by Volt how many train paths are available for international services to London. They concluded that 24 paths per day are technically possible, while Eurostar currently operates only three. The planned expansion of one additional train per day in 2026 and another in 2027, rather than the two originally proposed for 2026 illustrates the slow pace of growth. At the opening of the new Eurostar terminal at Amsterdam Central, Eurostar cited the lack of Royal Netherlands Marechaussee officers and the requirement to cover those costs themselves (unlike airlines at Schiphol) as major barriers.

Eurostar has limited resources. Although new trains have been ordered, it's unclear whether they will be deployed on the Amsterdam-London route. Operators often prefer to allocate rolling stock to newer, more profitable markets. Other companies are interested in entering the market but face access barriers.

In the UK, there is also growing pressure to better utilize Channel Tunnel capacity. There's even discussion about using more trains as an alternative to Heathrow expansion. As a result, some operators are ordering their own rolling stock. There is clear demand, but the shortage of available trains is a major bottleneck to the goal of doubling international rail traffic.

Still, rail holds strong potential. Train services can quickly become competitive especially when infrastructure and train paths are available. This is particularly true for business travelers, who account for a large share of flights and are open to night trains. For them, it's attractive to travel overnight and arrive directly in the city center.

The "Anders Reizen" coalition, a group of large employers, is actively promoting this shift. They've reduced air travel by 20-30% and emphasize the importance of frequency and departure times.

As for tourists, flying must become more expensive. However, many are already open to train travel as long as it's attractive and affordable. The direct city-center arrivals are a major advantage for them.

Unfortunately, Dutch government policy is a barrier to progress. New operators receive no certainty regarding train paths, nor multi-year commitments while such guarantees are essential for making investment viable.

Both young people and business travelers are open to night trains, this potential needs to be better utilized. That requires active intergovernmental cooperation: countries working together directly, not just via Brussels.

As for the third alternative in your study, I'm skeptical. The 'hub & spoke' model of airlines is sometimes proposed as a way to integrate train services, but in practice it rarely leads to significant changes. The model mainly serves to expand airlines' own networks and preserve market share.

Initiatives such as baggage check-in at stations like Swiss Air does in Switzerland have never really taken off in the Netherlands. It's a nice idea, but under the current system, where airlines try to channel as many connecting passengers as possible through their own hubs, it's unrealistic. KLM is a prime example. This results in many unnecessary short flights. Schiphol was long attractive and cheap, but investments have made its hub role more expensive.

Lufthansa uses similar strategies to compete with KLM, this system is ultimately not sustainable. At the same time, international agreements such as the Chicago Convention protect the aviation sector to such an extent that structural change is difficult to achieve.

France has now banned short domestic flights where a train journey of under 2.5 hours exists. The Netherlands has made little effort to follow suit despite public statements. In practice, it often remains symbolic policy.

**Interviewer:**
Could you indicate whether there are still major obstacles on the Amsterdam-Berlin connection? What exactly is the situation there?

**Expert:**
Yes, there definitely are. One of the main bottlenecks relates to the target year of 2030, while in fact, there are already opportunities to implement improvements now. The main infrastructure issue lies on the Utrecht-Arnhem corridor, where capacity competition arises between national and regional trains on the one hand and international trains on the other. International trains are often limited due to this competition.

An interesting and current perspective here is “Military Mobility.” This refers to the importance of enabling military vehicles, such as tanks to quickly travel from the Netherlands to Poland. This urgency has not previously applied to passenger trains. It brings in additional funding and likely also regulations that can speed up infrastructure projects. This offers hope for the long-anticipated project to double the tracks between Utrecht and Arnhem something that nearly happened 15 to 20 years ago.

It’s also important to consider broader European developments. Germany is investing heavily in high-speed connections toward Italy, including from Berlin. This creates opportunities to connect Dutch trains to those routes, provided the Utrecht-Arnhem bottleneck is addressed. Meanwhile, NS aims for a ten-minute intercity frequency to Arnhem, which influences available capacity. There is little flexibility to deviate from this ten-minute standard, even though passengers generally care more about reliability and punctuality than strict frequency. A 15-minute service could be sufficient in practice.

The situation on the line toward Berlin is complex. The international train often runs late due to having to yield to local trains, such as in the Twente region, reducing reliability. Although new, modern trains are being introduced, they offer less capacity. This is meant to be offset by increased frequency, but that still needs to be realized.

**Interviewer:**
Aside from institutional, regulatory and operational obstacles, are there also financial barriers that hinder the Amsterdam-London and Amsterdam-Berlin connections? For example, is there insufficient funding?

**Expert:**
Financially, the main obstacle is the extremely low price of air travel, which makes it difficult to develop a competitive rail alternative. In addition, there are significant track access charges in countries like the Netherlands, Germany, Belgium and the United Kingdom. The European Commission encourages lowering these charges, but ultimately this is a national policy decision.

Travel should not be free, because it places pressure on infrastructure and services. At the same time, we see that a relatively small portion of the population flies frequently: about 50 to 60% of Dutch people do not fly at all, while 5% account for more than half of all flights. This justifies a pricing mechanism.

From organizations like Rover and the European Passengers' Federation, we advocate for an air travel tax and a frequent flyer levy, a proposal also supported by research from Delft. Under this system, passengers only start paying extra if they fly more than a few times a year, with increasing rates for additional flights. According to CE Delft, this could lead to about a 25% reduction in flights especially intercontinental and approximately 20% less $CO_2$ emissions.

The revenues, potentially up to €80 billion per year, could be directed toward the expansion and improvement of the rail network. In the Netherlands, however, recent increases in air travel taxes are still being funneled into the general budget, which is less effective for facilitating this transition.

**Interviewer:**
Clear. Finally, which of the alternatives Amsterdam-London or Amsterdam-Berlin, do you consider most feasible in terms of expanding capacity?

**Expert:**
Amsterdam-London is the most feasible alternative and also the low-hanging fruit. It is the most frequently flown route between the Netherlands and the UK, with around 60 to 70 return flights daily. The infrastructure, including the Channel Tunnel, is already in place and capacity is available in principle.

While connections to Germany and Southern Europe are important, replacing air travel in those corridors is less urgent at this point. However, it will become increasingly relevant for leisure travel and partly for replacing car travel. The European Commission and member states aim for public transport to become the dominant mode of cross-border mobility by 2040, surpassing cars and planes. That is ambitious but an important policy goal.

Finally, coach travel also deserves more attention in this context, particularly for leisure transport, as it is often underestimated.

## Interview 2: Two Policy Officers from the Ministry of Infrastructure and Water Management.

**Date:** *June 13, 2025*
**References:** (Policy officer 1, personal communication, June 13, 2025), (Policy officer 2, personal communication, June 13, 2025)

One interviewee is a senior policy officer in aviation economics, and the other is affiliated with the Directorate for Public Transport and Rail at the Ministry of Infrastructure and Water Management. Both experts are involved in national policy development related to international rail services and aviation.

This interview transcript has been translated from Dutch and edited for conciseness and relevance to the research scope. Non-substantive exchanges and off-topic segments have been omitted.

**Policy Officer 1:**
The topics you're researching really fall within my directorate. I work in the Policy and Environment department. We focus on all long-term investments to improve public transport, including international matters, though mainly at a national level, which is also the emphasis of our policy. That sometimes makes things quite complex.

That's one of the barriers we might mention later. My role involves contributing to the Air-Rail action agenda, which I do in collaboration with Policy officer 2 from the Aviation Directorate. It's really about working together with the sector, looking at how we can jointly tackle the barriers you describe and deciding how far we want to go in that.

Within the Ministry of Infrastructure and Water Management, I coordinate several sustainability dossiers that come up. That's my background.

**Policy Officer 2:**
I can share a bit about my expertise. I'm a colleague of Policy officer 1 and also work at the Ministry of Infrastructure and Water Management. I work at the Aviation Directorate, specifically in the International Accessibility department, which handles the Air-Rail dossier within Aviation.

I have somewhat less knowledge of the rail-related questions you're asking, but I'm more familiar with how the aviation sector works, especially when it comes to replacing flights. For example, flights between Amsterdam and Brussels, which carry many transfer passengers. I know more about what's needed there and how to ensure smooth transfers for passengers at Schiphol.

Actually, that was my first thought about your questions: in our policy, we make a clear distinction between origin-destination passengers and transfer passengers.

We also notice big differences per corridor or destination regarding where the emphasis lies. For instance, replacing flights to London seems simpler than flights to Brussels because London mostly has O&D passengers traveling to and from the city, while the Amsterdam-Brussels route mainly carries transfer passengers, which makes replacement more complex.
That was my initial remark. I think you've somewhat defined this in your research, but it might be good to reflect on the types of passengers involved, and whether you focus on a specific passenger type or time periods. I believe that could be helpful.

**Interviewer:**
I specifically focused on O&D passengers. I initially included transfer passengers, but other interviews made it clear that it's much more complicated. For my research, and to keep it manageable, I decided to focus on O&D passengers.

**Policy Officer 1:**
I agree with that conclusion, especially for the destinations you chose. That matches our observations, those are indeed the routes where OD passengers are most promising and numerous. Good context to have, indeed. What exactly is your research question?

**Interviewer:**
My research question is: *What barriers need to be addressed to improve direct international rail connections from Schiphol Airport to six destinations, and what are the societal costs and benefits of replacing short-haul flights with these improved rail connections?*

I took the six destinations from the Air-Rail action agenda, but ultimately I focused on London and Berlin to explore what it would take to replace flights and what the social costs and benefits would be. I plan to conduct a cost-benefit analysis next to assess the effects of replacing these flights.

**Policy Officer 2:**
Since you mentioned cost-benefit analysis, are you familiar with what we call the substitution paradox? That is, the idea that replacing a short flight might simply be replaced by a long-haul flight instead?

**Interviewer:**
Yes, I've come across quite a bit of literature on that.

**Policy Officer 2:**
Sorry, I'm just sharing thoughts freely, but we can get back to your questions later.
This reminds me of a recent KiM study on the potential of bus transport as an alternative to flights. It was published last week and addresses alternatives for these flights. I don't know if bus transport is within your scope, but the study calls bus travel the "forgotten mode" of international passenger transport. Many people overlook it, but it has a lot of potential.

**Policy Officer 1:**
Both in terms of usage and positive environmental impact.

**Interviewer:**
Okay, that's good to know. I focus more on trains, but it's always useful to consider other options. Thanks for mentioning that.

**Policy Officer 1:**
Now we should consider what we can do to help you from our perspective. We focus more on the overarching policy picture. For example, the barriers you're investigating: there are barriers specific to one route, but there are also broader barriers that apply generally.m For instance, I could check if the Amsterdam-London route currently faces capacity problems, like limited staffing of the Royal Marechaussee at customs and security, which is a very specific issue.

But overall, the challenge we see is that there is very little integrated policy on international passenger transport. That's more in our domain, and your study is a good example of that. So maybe we can help you think through some of your questions.

**Interviewer:**
Yes, I'm currently very focused on these barriers. I've more or less finished the chapter on infrastructure and operational changes and am now looking at the barriers.
I've divided that chapter into alternative-specific barriers and more general barriers that apply to both alternatives.

I'm really curious: when you want to scale up the number of trains, whether to London or Berlin, what problems do you encounter? How are they solved? How is the policy process handled?

**Policy Officer 1:**
A very important point to mention is that it's not really a policy process. The international rail market is an open market, and we only have one international connection in the main rail concession, the Intercity to Brussels, because we consider it of such national importance. All other international connections are commercial decisions made by the companies involved. So we don't make policies like "we want five more trains" or set specific frequency targets ourselves.

While we recognize the importance of international rail and want to support its development, our influence is currently limited. We don't yet have a formal vision on international rail-it is still in development. If the ministry wants to see more trains or higher frequencies, we have to create the conditions that enable the market to respond, since the system is market-driven. That's a key starting point: our ability to directly steer these developments is constrained.

**Interviewer:**
Okay, understood. I've also read that it's hard for new operators to enter the market because they can't make multi-year agreements with governments.

**Policy Officer 1:**
Yes, with ProRail, the key issue is capacity. For Eurostar, as an established player, there are still challenges, but they benefit from legacy advantages and better access to financing for new trains. One major problem is that train manufacturers are overwhelmed, orders placed today might not be delivered until 2030-2035. New entrants face even greater difficulties, as they must build a business model without long-term guarantees to operate services. If you want to buy or lease trains, financiers typically require a clear picture of how you'll recoup that investment over a ten-year period.

However, ProRail currently only confirms train path capacity one year in advance. Although European directives and national policies are working toward enabling longer-term capacity guarantees, there is still ongoing debate within the sector about how to implement this effectively. It remains a significant barrier, and the market has yet to reach a consensus on the best way forward.

**Interviewer:**
Okay, so that's still under discussion.

**Policy Officer 1:**
Yes, this is absolutely recognized as a challenge. While financing may be available, the real problem lies in the instability of the business model. It's difficult to secure funding when there's uncertainty about whether you'll still be able to offer your product a year from now. That creates a lot of insecurity. It's especially hard for new entrants, since the rail market is largely dominated by established players. From the Ministry's perspective, we're used to working closely with ProRail and NS, but now other operators are entering the market, and they often have very different needs. For example, night trains require different types of infrastructure, such as layover yards, and some connections need turnaround facilities in specific locations. If you weren't involved when these systems were originally designed, it becomes much more difficult to operate effectively.

In addition to physical infrastructure, new entrants also face challenges with digital infrastructure. Established players are often reluctant to open up their systems. A recent example discussed in Parliament is that NS still doesn't sell tickets for other operators, even though it's a crucial sales channel for Dutch customers. They're aware of this power-and that's exactly why they don't share it. These are some of the barriers that make market entry challenging for new operators.

**Interviewer:**
Okay, clear. About that debate, was it about the roundtable debate, right?

**Policy Officer 1:**
That one too, yes. I couldn't follow it myself. But there was also a parliamentary committee debate about rail. And you referred to a roundtable discussion about international transport. Did you follow that?

**Interviewer:**
Yes, I mainly read the documents because I couldn't watch live. And news reports said, for example that according to someone from ProRail the rail capacity is two to three times higher than what the NS CEO claims.

So how do you explain that difference? Is it because they are different organizations with different goals? Or how can there be such a large difference?

**Policy Officer 1:**
I can only speculate, but from what I know, NS tends to reason from a product perspective: when do they want to run trains, and via which routes? ProRail, on the other hand, approaches it more from a system perspective, looking at where there is still capacity and whether the proposed service can be adapted to fit into that system. That's an important difference in perspective, and I think it often leads to tensions or mismatches between what is desired and what is operationally feasible. I'm not sure about that specific article, but I do see this dynamic come up frequently.

This distinction is highly relevant from a policy standpoint. When and how often a train can run directly affects whether it becomes a viable alternative to flying. We're not just aiming for any train service. We want regular, reliable service with sufficient capacity. A single daily train to London doesn't compare to ten trains a day when it comes to offering a realistic substitute for air travel. Frequency and reliability are key if we're serious about shifting passengers from planes to trains.

**Policy Officer 2:**
Yes, availability during the day is especially important, not only for transfer passengers but also for business travelers who want to make a day trip to London. Often, the first train arrives just a bit too late to attend early meetings. In the debate about banning short flights, a key criterion is whether the train schedule allows passengers to spend at least eight to ten hours at the destination, meaning the train must depart early enough in the morning and return late enough in the evening. If the available trains only allow, say, six hours at the destination, that route is typically exempted from the flight ban.

**Interviewer:**
Ah, that's a good point. Do you know much about the financial side? How current financial regulations make it harder for, say, Eurostar or NS to scale up these international train connections? Or is that a bit outside your scope? For example buying new trains.

**Policy Officer 1:**
Yes, that's definitely a barrier. It's essentially a business model issue. Companies can't borrow money without certainty, which creates a major obstacle. There will soon be a study published on night trains that maps out these barriers in detail, and its findings can be almost directly applied to all open access trains. If you'd like, remind me later, and once it's published, I can share the link. The study was commissioned by the Ministry of Infrastructure and Water Management (IenW) and is titled something like "Barriers and Obstacles for Good Night Trains."

**Policy Officer 2:**
Maybe I can add something about the difference with aviation and the level playing field. I don't know if it really fits your research scope, but there are maybe two important points. It's often said that aviation isn't priced properly but trains are, because train tickets have VAT and plane tickets don't. I think that's a bit more nuanced.

Aviation indeed has no VAT on kerosene or plane tickets, but it does have an aviation tax, which can be higher than the VAT percentage. Still, the full external costs aren't priced into aviation and not fully into rail either. But the perception exists that flying is too cheap and trains are too expensive, and that pricing could be adjusted.

Also, aviation is a largely globally regulated sector. For example, under ICAO (International Civil Aviation Organization), there are many rules that limit pricing measures. ICAO was established to promote civil aviation, historically seen as important for post-WWII exchange and meeting between peoples. Sustainability concerns only became prominent in recent decades. This makes it harder to price aviation properly, also because of rules about what you can and cannot charge VAT on. Europe and national governments are working on this, for example by differentiating the aviation tax by distance. So the comparison is complex because it's priced in a completely different way. That's important to know about financial barriers.

When it comes to air-rail integration, there's a crucial financial barrier: who bears the risk? If a train is canceled but it connects with a flight, who reimburses the ticket or arranges alternatives? The train company or the airline? That's a big obstacle.

And institutionally, there's siloing by mode. We collaborate a lot within the Ministry, but at the policy level, both European and national, policies are still made per mode, less in an integrated way. The same applies to the sector itself. Both sector and government are very divided by mode. That makes it hard to create integrated policies.

Our ability to steer varies. We have an open market for international rail but can build infrastructure or fix bottlenecks. For aviation, steering options are smaller. Within Europe, it's a free market: airlines generally cannot be banned from flying somewhere, with a few exceptions. That's an important barrier for us: it's hard to step outside your own mode.

**Interviewer:**
Yes, understood. And for example, about those aviation taxes, how do you think a frequent flyer tax could contribute to shifting from planes to trains?

**Policy Officer 2:**
My personal view is that a frequent flyer tax suggests the third flight pollutes more than the first, while in reality, every flight pollutes. An aviation tax covers that because every flight is taxed. Currently, it's a flat tax, but soon it will be distance-dependent, which I think is fairer because you price what people actually do. If you fly ten times, you pay the tax ten times. If you fly far, you pay more. But opinions differ.

What I find difficult about these issues is that sometimes flying is treated as a right. There are many opinions about this. It's worth noting that 90% of the world's population never flies. That really puts things in perspective. We're used to something that is actually quite unusual elsewhere in the world.

**Interviewer:**
Yes, very true. Thanks for that. Because I'm looking at barriers but also boundary conditions and external influences, this is definitely within my scope.

From previous interviews I learned Germany has a much more active policy on international train connections. Is that discussed with the German government? For example, if they want to improve a connection to the Netherlands, how does that work?

**Policy Officer 1:**
Yes, definitely. We do bilateral consultations with our German colleagues, focusing on cross-border connections like the train between Eindhoven and Düsseldorf. But these discussions also happen at a more strategic level. We've even done work visits to Germany to explore this phenomenon further. Lufthansa and Deutsche Bahn want to collaborate closely.

The important thing to note is that this is mostly a domestic matter for Germany. They have much more influence on their own system and can steer it more effectively. You see a similar situation in France, where domestic flights are being replaced by long-distance trains, supported by different regulations. In the Netherlands, however, all flights and long-distance trains are cross-border, which limits our ability to act similarly. That's why Germany can move faster than we can.

**Policy Officer 1:**
That also aligns with what I mentioned earlier: in the Netherlands, the focus is primarily on domestic public transport. This is also true in Germany, but there, domestic public transport competes with aviation. That's not the case here. We have very progressive policies on domestic public transport, but it doesn't really impact aviation. In Germany, domestic rail directly affects air travel substitution. Here, we need to develop an international rail product within a context that prioritizes national public transport.

Although, gradually at the European level, the importance of cross-border transport is being recognized more and more. The question is how this will trickle down into our national policies. But the primary focus remains accessibility for the average Dutch person commuting, exercising, or visiting family.

**Interviewer:**
Between the Amsterdam-London and Amsterdam-Berlin connections, which do you think has the most potential in the near future to make significant progress in replacing flights? Do you think they're more or less equal?

**Policy Officer 1:**
What came to mind is latent demand. We touched on the substitution paradox. What we do see with AirRail is that these are routes, London especially, but also Berlin, where an airline can economically decide: "Hey, I see that demand for flights is dropping because the rail product is improving, so I'll redeploy that aircraft elsewhere." There are a lot of flights to London, so competition and demand are both high. That creates an economic incentive that could lead to a modal shift.

I think the same applies to Berlin. The rail product there will become well suited for origin-destination travel. And on the volume side, Berlin might more quickly reach a level where it can make a significant dent in flights.

However, London poses many challenges: the tunnel capacity in London, border control by the Royal Marechaussee, and so on. You can still make substantial progress, but there are so many flights to replace that it's a huge task. Even after replacing some flights, until you implement extensive complementary policies, there will always be a baseline level of flights needed to cover demand that can't be met by rail, for example very early flights.

So, I think Berlin might reach this point sooner, because it already has fewer flights. The question also is: what do you consider good substitution? Is it every flight replaced, or the overall picture?

Do you aim for 100% substitution, or do you accept a baseline level of flights at certain times and the rest by train? That would already be a great achievement.

So, I think both have their chances. The key question is how airlines will commercialize this shift.

**Policy Officer 2:**
I had interpreted your question more as: where is the biggest potential gain? And I would say: London. Because there are so many flights to London. In principle, if you fill an entire Eurostar train, that replaces about five flights. So, with one additional train, you can potentially replace five flights. Of course, it's not that simple, because you can't fill the whole train in Amsterdam.

I also think the travel time to London is shorter. For many people and business travelers doing day trips, Berlin is just a bit too far by train. London has very high demand and, as far as I know, still some spare capacity on the rail network. Berlin may also have some potential, but intuitively, if you're going to invest anywhere, London will yield the most.

**Interviewer:**
Okay, understood. Regarding the aerial alternative, I initially included that in my scope but later interviews showed it wasn't really feasible or at least too complicated. One of the reasons given was the Chicago Convention, which apparently makes airlines focus on transfer flights because they are most profitable. I found that interesting. Is that driven by regulations, or how did that come about? Or do you not know exactly?

**Policy Officer 2:**
I can't answer that precisely. The Chicago Convention, which is ICAO, doesn't actually force airlines to carry transfer passengers. It mainly governs the agreements between countries on aviation rights: for example, whether an airline from China can overfly or stop in the Netherlands, or pick up passengers there. So, ICAO regulates these freedoms.

What is true is that transfer traffic is crucial for a strong network. If you only flew passengers based on local demand, Dutch people traveling abroad or foreigners traveling to the Netherlands, you'd have far fewer flights and worse global connectivity. Transfer allows, for example, KLM to pick up passengers in Scandinavia, the UK, Eastern and Southern Europe in the morning, and connect them onto a large aircraft departing from Schiphol to the US.

Without transfer traffic, you can't fill large planes, which affects range and profitability. Small planes can't cross oceans. So, profitability depends on having a certain volume. That's why a hub-and-spoke network is needed to offer more destinations more frequently.

But this is not really about regulation, it's more about the absence of restrictive regulation, which allows airlines to do this. Within Europe, there is essentially a free market: European airlines can fly freely within Europe. For third countries (non-EU), bilateral air service agreements are negotiated either by the EU or individual countries.

So, the answer isn't straightforward.

## Interview 3: Corridor Coordinator on the Amsterdam-Berlin Rail Corridor

**Date:** *June 25, 2025*
**Reference:** (Corridor coordinator, personal communication, June 25, 2025)

The interviewee is a Coordinating Policy Officer for Public Transport and Rail at the Dutch Ministry of Infrastructure and Water Management. She is specifically responsible for the Amsterdam-Berlin rail corridor and plays a role in the development of national policy for international rail services.

This interview transcript has been translated from Dutch and edited for clarity, conciseness, and relevance to the research scope. Non-substantive remarks and off-topic exchanges have been omitted.

**Corridor Coordinator:**
The first thing I want to mention is that there's a document you should really take a look at, a study from a few years ago on how to structure the Berlin service. I was involved in the Berlin project myself, though I also worked on other projects before that. Some elements of the current plans actually date back to that earlier period, and I believe that study might be quite relevant to your research. It's possible that the current approach is even based on it, though I'm not entirely sure about the details.

So, this concerns the Berlin service. It's quite a complex situation. Currently, the route has been adjusted. Since late 2024, the train has been running on a modified schedule. Unfortunately, this was done using a number of temporary measures. Right now, we're working on addressing that temporary setup.

We implemented a few measures:
A) To speed up the service
B) To ensure it could keep running at all, by maintaining alignment with the German timetable. Without that, the train would have had to stop operating.

So it's running now, but we do need to make sure the Berlin train is robustly integrated into the timetable. Right now, it's clashing with several domestic trains multiple times a day. So that's what we're working on now and that concerns the current route and speed, the current line and timetable.

At this moment, we are not actively pursuing other developments for the Berlin train on this particular route. Because the Berlin train is operated by NS and DB Fernverkehr. But other operators have also shown interest. A few have already indicated plans to start running on this route in the coming years.

So we're also looking at what's needed to allow for hourly service. For example, Deventer station would need to be upgraded. And if more trains start running, then we'll also need to examine level crossing safety and track stability. That's another factor.

Also, traction and energy supply: more trains require more power and the current grid may not support that. So those are some of the issues we're exploring. In summary: we're trying to properly implement the current speed improvement, while also assessing the feasibility of hourly international service on the corridor.

But we're currently not pursuing further speed increases or alternative routings like via Zwolle. And I'm not sure which "faster route" you're referring to. It might be the Arnhem route, do you know?

**Interviewer:**
No, it was the current route. But some news articles mentioned that it's mainly a German plan,

already quite advanced, while it's less prominent on the Dutch side. It originates from the Deutschlandtakt strategy, and it targets implementation by 2030. A part of the alternative I'm examining is the introduction of the ICE-L trains, which are now expected to enter service by the end of this year, although they've been delayed several times.

**Corridor Coordinator:**
Yes, I believe NS is still working on that. But I'm not sure of the exact status. That's also an NS-operated Berlin train. It now runs under open access conditions. So we're not as directly involved as we used to be, which I think is actually a healthy development.
Another relevant factor here is the freight traffic between Amsterdam and Oldenzaal. Freight trains can operate on that corridor two paths per hour, I believe. Those slots aren't fully used right now, as far as I know. But if you want more or faster passenger trains, it would help if those freight trains weren't there. Because otherwise, even a fast IC will just end up stuck behind a slower freight train.

So we're currently assessing whether freight traffic to Northeast Europe could be rerouted whether that's needed, feasible and so on. That study is ongoing, and it'll take another year. So any decision-making will take time. And only once it's clear whether those freight trains will remain on this line, which could be until 2040 or even 2050 if new infrastructure is needed then we can start seriously thinking about future options for the Berlin train. That's why we're not investing too much time in that yet.

**Interviewer:**
That's clear. I'm also researching policy-related barriers. What kind of barriers, financial or institutional, are you facing right now on this corridor, for example in implementing those temporary improvements?

**Corridor Coordinator:**
One of the biggest barriers is definitely financial. Are you familiar with the Mobility Fund?
It's basically depleted. Most of the money still in it plus the small annual additions, is already earmarked for overdue maintenance and long-delayed projects. There's very little room left for new investments.

Initially, €50 million was allocated for the Berlin train improvements. A few temporary measures were funded with that like relocating the platform in Oldenzaal and monitoring track stability. Around €30 million remains. But the study on how to robustly integrate the Berlin train, not temporary but permanent, shows it will cost far more than the €30 million we still have.
That's the first hurdle. If we start looking at long-term rerouting or increasing speeds, we're talking about hundreds of millions in extra investment which I really don't see happening anytime soon.

On top of that, due to NATO commitments, we need to allocate an extra 16 billion euros annually to defence. There's 1.5% set aside for infrastructure, so maybe some of that could be used to improve rail lines including this corridor to Northeast Europe. It's strategically important. But right now, it's very uncertain.

The Mobility Fund is empty, and I don't expect room for large-scale investments anytime soon. And we also have to ask ourselves, shouldn't we be prioritising the Arnhem corridor to the Ruhr area? Our economic interests there are much greater than in Berlin. Those are strategic considerations we must weigh.

So if NS or DB have some trick up their sleeves to make the train much faster without us having to invest billions, then great.

**Interviewer:**
According to that German plan, the journey time could be reduced by another 30 minutes, mainly by skipping some stops in Germany.

**Corridor Coordinator:**
Yes, that could definitely help. But we would need to carefully assess the impact. My guess is that the train would arrive at the Dutch border at a different time near Bentheim, for example. Then we'd need to ensure it can run straight through into the Netherlands and connect with our timetable. That's a tough puzzle, because Member States tend to schedule domestic trains first, and only later international ones. So yes, we're also talking about institutional barriers here.

**Interviewer:**
In other words, a matter of planning order?

**Corridor Coordinator:**
Exactly, a different sequencing. From an international perspective, I'd prefer to start with international trains. But in practice, given the large number of domestic passengers compared to international ones, national trains usually come first.

**Interviewer:**
Okay, clear. And regarding those new ICE L trains, did the Ministry have any involvement in that, or was it solely arranged by NS and DB?

**Corridor Coordinator:**
They arranged that themselves or at least, I believe so. I know that with the ICE trains, NS owns a few, three or four, I think. I'm not sure if that's also the case with these new trains, or if DB did most of the procurement. After all, the trains are operated by DB. But it's open access now, so we're no longer directly involved.

Actually, we never really were, because these kinds of major investments fall under the Ministry of Finance, which is the shareholder of NS. They decide whether such large-scale purchases can go through or not.

**Interviewer:**
I'm wondering, for the Amsterdam-Berlin corridor specifically, are there issues that make this route particularly difficult? Or are most of the barriers still the general ones, like the late scheduling of international trains?

**Corridor Coordinator:**
Yes, there is a lot of funding earmarked for this corridor. One thing still in play is that we now have bi-current rolling stock, so there's no longer a need to change locomotives at Bad Bentheim. However, I believe there's still a personnel change happening there.

We're really advocating for Germany to construct a voltage transition zone between Oldenzaal and Bad Bentheim, so that trains can continue running without interruption. That way, they wouldn't need to switch between different overhead voltage systems anymore.

I'm not sure if that's relevant for these particular trains. Since they stop at Bad Bentheim, they might already handle the voltage change there. Ideally, of course, you'd want all of Europe to use the same train control system and overhead voltage, but although progress is being made on the train protection side, that will still take a long time. So for now, bi-current trains are still necessary.

As for the voltage differences, that's unlikely to change European systems just aren't harmonized. So that will probably remain an issue. Another thing is personnel changes. In many cases, train staff must speak the language of the country they're operating in. International trains do have multilingual staff, but apparently staff changes are still happening. That's unfortunate and inefficient. It might also relate to the on-board service crew, such as train managers and bar staff, who are expected to speak the local language. I'm not sure if this applies to the train drivers specifically or more to the service crew.

The rest of the barriers are fairly general, ticketing for example. I believe NS International and Deutsche Bahn make these tickets easy to buy. So that's not a huge issue, although often you can only book them a few months in advance. That's just inconvenient and in itself a barrier.

**Interviewer:**
Right. And is the Ministry currently actively working on this corridor to investigate whether the air route between Schiphol and Berlin can be replaced by train travel? Or is that less relevant for your department at the moment?

**Corridor Coordinator:**
Well, that really depends on which government is in office. Right now, we're still in the aftermath of a business-oriented cabinet. So the focus is more on good connections and ensuring the Netherlands remains economically accessible, less so on sustainability. Two cabinets ago, under D66, we actually initiated the EU rail agenda. So back then, we were much more focused on sustainability. At the moment, within the corridor team, we're not really working on replacing flights.

We do see that the Berlin trains are already full in the summer, so there is definitely demand. And we know there are other operators who want to enter the market. So our focus is more on how to accommodate this growing demand and how to improve the connection overall, not necessarily on how many people we can shift from air to rail. We had also been working on a vision for international rail, where this theme does appear but that was under the previous cabinet, and it's now less emphasized under the current one.

**Interviewer:**
So right now, it's simply less of a political priority?

**Corridor Coordinator:**
Yes, and developing that vision is proving difficult. We're once again in a caretaker government, which means we can't really create long-term visions or make strategic commitments. Unfortunately, this happens nearly every year we begin working on a plan, and then we become demissionary again. So yes, we're looking into it, but as I said, it heavily depends on the political makeup of the cabinet. That largely determines the kinds of projects we pursue.

**Interviewer:**
Understood. And what about cooperation with the German ministries involved in this? Is there strong collaboration to improve and align this international train service, or is that process more difficult?

**Corridor Coordinator:**
So, we're just one of Germany's nine neighboring countries and unfortunately not the most important one. So for them, this corridor isn't a top priority. They're not in constant dialogue with us about all the connections we want to discuss. There was very good cooperation when that 2018 report was written to help accelerate improvements. But right now, the momentum has slowed.

Back then it was a higher priority. But as I mentioned, we also had a state secretary who was much more actively involved at the time. Especially in Germany, which has a very hierarchical system, instructions have to come from the top. If we don't approach the German state secretary or if they aren't convinced of the urgency, they won't pass it down to their staff and then nothing much happens.

Also, Germany is now much more focused on improving connections to Poland and Ukraine, as well as transporting coal and other goods, especially since Russian gas is no longer available. So geopolitical shifts have clearly influenced Germany's rail priorities.

**Corridor Coordinator:**
Although I say it's unfortunate for us, my colleagues in freight transport are getting more attention. Those coal shipments arrive first in the Port of Rotterdam. So freight is currently receiving a lot more focus, especially now that military vehicle transport is increasing as well.

**Interviewer:**
Yes, I read something about that, how the military budget includes funds for certain railway segments in the Netherlands, also near Rotterdam, to improve freight train operations, especially for transporting tanks and such.

**Corridor Coordinator:**
Yes, I don't know all the details, especially because part of it involves classified information. But from the perspective of the Directorate for Passenger Transport, we don't expect to receive much additional funding. However, there's still a possibility to tap into that 1.5% flexibility margin and we'll need to see if we can allocate some of that for our needs. But that's really just speculation at this point.

**Interviewer:**
Are there still many infrastructure or station modifications planned in the coming years to support these services? You mentioned something about Deventer and platform areas, are those changes already underway or is more research needed first?

**Corridor Coordinator:**
At our organization, we always go through three project phases: exploration, planning, and then implementation, the actual construction. Right now, we're completing the exploration phase for the robust integration of the Berlin train. This includes measures like the addition of a fourth platform at Deventer, speed upgrades between Amersfoort and Apeldoorn and between Hengelo and the German border.

We're also working on improving Oldenzaal station. We've installed a temporary side platform to separate the regional train from the policy train's path. However, that platform is located far from the main station area and isn't ideal for passenger transfers. So we're evaluating how to improve that setup.

But like I mentioned, I have €30 million available. What we can and will actually implement, depending on the outcomes of the feasibility studies, remains unclear at this point.
I expect we’ll have more clarity this autumn, though perhaps not given that we're currently in a caretaker government.

**Interviewer:**
Understood. We’ve already discussed institutional and financial barriers, but are there any legal or regulatory obstacles that impact this route or international train travel in general? Or is that not really a barrier in this case?

**Corridor Coordinator:**
No, not really. The framework itself is relatively clear, just very complex.
Even building a new rail line within the Netherlands is difficult, look at the challenges surrounding the Lelylijn or the Nedersaksenlijn. But achieving anything across a border is even harder. I’d say it’s three times more difficult because of all the coordination involved technically, operationally, timetable-wise, decision-making and figuring out who decides what and when.

The three phases we follow here are completely different from the processes used by DB Infra or the German federal planning bodies. So the challenge is: how do you stay aligned and ensure that one party doesn’t start investing while the other isn’t ready yet? And if one party later backs out, then the first has invested in vain. That’s the real difficulty, synchronization.

It’s not so much about laws getting in the way, but rather about very different procedures and technical standards. For example, we have our own guidelines and work procedures at ProRail, which are very different from those in Germany. So it’s not necessarily high-level legislation that causes problems, but more the deep-rooted procedural and operational differences.

## D. Supporting Calculations SCBA

### Flights Shifted from Air to Rail

The number of actual flights shifted from air to rail is calculated by dividing the actual number of passengers shifted by the average number of passengers per flight on that route in the given year. This is expressed as:

$$FlightsShifted_{actual,t}^{a,s,g}(r) = \frac{AirPaxShifted_{actual,t}^{a,s,g}(r)}{Pax_{flight,t}(r)} \tag{D1}$$

The average passengers per flight varies by route and changes over time, reflecting changes in aircraft capacity and load factor. However, it is assumed to be constant across all growth scenarios, policy scenarios and alternatives. In other words, it depends only on the route and the year. The average passengers per flight are calculated as the product of the aircraft capacity and the load factor for that route and year:

$$Pax_{flight,t}(r) = AircraftCapacity_t(r) * LoadFactor_t \tag{D2}$$

Both aircraft capacity and load factor are assumed to grow annually at a rate of 0.3% between 2023 and 2050, based on projections from *Destination 2050* (2025). The base year load factor for 2023 was obtained from Schiphol data (Schiphol, n.d.-d) and is 82.8%. The average aircraft capacity in 2023 was estimated by dividing the total number of passengers by the total number of flights for each route (Amsterdam-London and Amsterdam-Berlin), resulting in averages of 136 and 155 passengers per flight respectively. Dividing these by the 2023 load factor yielded aircraft capacities of 164 for AMS-LON and 187 for AMS-BER. The growth of aircraft capacity and load factor over time is modelled by:

$$AircraftCapacity_t(r) = AircraftCapacity_{2023}(r) * (1 + 0{,}3\%)^{t-2023} \tag{D3}$$

$$LoadFactor_t = LoadFactor_{2023} * (1 + 0{,}3\%)^{t-2023} \tag{D4}$$

### Air Passenger and Flight Demand

Before the service improvement takes place, air passenger demand remains constant and follows the values of the base case scenario. In the year of the improvement, however, air passenger demand is adjusted to reflect the impact of the improved rail service quality. These improvements influence air demand through cross-elasticities, which quantify how responsive air passengers are to changes in competing rail services. To estimate this modal shift from air to rail, cross-elasticities for travel time and frequency were derived by averaging values for business and leisure travellers, as reported by Behrens and Pels (2009). This results in an average cross-elasticity of approximately +1.65 for travel time and -0.85 for frequency. These values-originally estimated for the London-Paris corridor are applied to both the Amsterdam-Berlin and Amsterdam-London routes, under the assumption that passenger behaviour is comparable across these international city pairs. Accordingly, in the year of implementation, the base demand is multiplied by a factor that accounts for these service-driven changes. After the implementation year, air passenger demand is no longer driven by elasticity adjustments, but instead derived from the number of flights and the average number of passengers per flight. This reflects a shift from demand-side modelling to a capacity-based estimate in future years.

$$AirPaxDemand_t^{a,s,g}(r) = AirPaxDemand_t^{0,g}(r) \text{ for } t < t_{imp} \tag{D5}$$

$$AirPaxDemand_{t_{imp}}^{a,s,g}(r) = AirPaxDemand_{t_{imp}}^{0,g}(r) * (1 + \varepsilon_{c,freq} * \Delta Q_{freq}(r) + \varepsilon_{c,time} * \Delta Q_{time}(r)) \text{ for } t = t_{imp} \tag{D6}$$

$$AirPaxDemand_{t}^{a,s,g}(r) = Flights_{t}^{a,s,g}(r) * Pax_{flight,t}(r) \text{ for } t > t_{imp} \tag{D7}$$

Before the year in which the service improvement occurs, flight demand is assumed to remain equal to the flights in the  base case. In the improvement year itself, flight demand is recalculated by dividing the adjusted air passenger demand by the average number of passengers per flight. After the improvement year, flight demand is projected forward using compound annual growth factors.

$$FlightsDemand_{t}^{a,s,g}(r) = Flights_{t}^{0,g}(r) \text{ for } t < t_{imp} \tag{D8}$$

$$FlightsDemand_{t_{imp}}^{a,s,g}(r) = \frac{AirPaxDemand_{t_{imp}}^{a,s,g}(r)}{Pax_{flight,t_{imp}}(r)} \text{ for } t = t_{imp} \tag{D9}$$

$$FlightsDemand_{t}^{a,s,g}(r) = FlightsDemand_{t_{imp}}^{a,s,g}(r) * \prod_{i=1}^{n} \left(1 + \gamma_{i,g}\right)^{\Delta t_i} \text{ for } t > t_{imp} \tag{D10}$$

These formulas estimate the demand for modal shift from air to rail, based on passenger preferences. The first calculates the air-to-rail passenger demand, representing how many passengers would prefer to switch to rail due to improved service, by subtracting the adjusted air demand from the base case. The second reflects the corresponding reduction in flight demand, showing how many fewer flights would be needed based on this shift.

$$RailPaxDemand_{air,t}^{a,s,g}(r) = AirPax_{t}^{0,g}(r) - AirPaxDemand_{t}^{a,s,g}(r) \tag{D11}$$

$$FlightsDemandShifted_{t}^{a,s,g}(r) = Flights_{t}^{0,g}(r) - FlightsDemand_{t}^{a,s,g}(r) \tag{D12}$$

## Fuel Consumption (Fossil, Synthetic SAF and Non-Synthetic SAF)

Annual fuel consumption per flight is first calculated by adjusting the 2024 baseline using an annual fuel efficiency improvement factor. This accounts for ongoing technological advances that make aircraft more efficient and sustainable over time. The base fuel consumption values are 2.414 kg per flight for the Amsterdam-London route and 3.323 kg for the Amsterdam-Berlin route (ICAO, n.d.). An annual fuel efficiency improvement of 1,8 percent is applied, based on Destination 2050 (2025), reflecting the expected reduction in fuel use per flight each year:

$$FC_{flight,t}(r) = FC_{flight,2024}(r) * (1 + FE_{reduction})^{t-2024} \tag{D13}$$

The resulting annual fuel consumption per flight is then divided into three fuel types: fossil jet fuel, synthetic SAF and non-synthetic SAF. This is done by multiplying the total fuel consumption per flight by the projected fuel shares for each type in year *t*:

$$FC_{fossil,t}(r) = FC_{flight,t}(r) * Share_{fossil,t} \tag{D14}$$

$$FC_{syn,t}(r) = FC_{flight,t}(r) * Share_{syn,t} \tag{D15}$$

$$FC_{nonsyn,t}(r) = FC_{flight,t}(r) * Share_{nonsyn,t} \tag{D16}$$

These shares are based on Eurocontrol (2024) projections, which show a gradual increase in the share of SAF in the total fuel mix-from 2 percent in 2025 to 70 percent in 2050. The SAF share is further split into synthetic and non-synthetic SAF. For example, in 2030, a total of 6 percent SAF is projected, of which 1,2 percent is synthetic and 4,8 percent is non-synthetic. The remaining share in each year is assumed to be conventional fossil jet fuel. Shares are assumed to grow linearly between the years. These fuel shares are summarized in Table D1.

**Table D-1:** Shares of SAF throughout the Years

| Year | Total SAF Share (%) | Synthetic SAF Share (%) | Non-Synthetic SAF Share (%) |
|---|---|---|---|
| 2025 | 2 | 0 | 2 |
| 2030 | 6 | 1,2 | 4,8 |
| 2032 | 6 | 2 | 4 |
| 2035 | 20 | 5 | 15 |
| 2040 | 34 | 10 | 24 |
| 2045 | 42 | 15 | 27 |
| 2050 | 70 | 35 | 35 |

## Rail Passengers Demand and Maximum Rail Passengers Carried

The number of organic rail passengers carried is calculated by multiplying the share of organic demand by the total number of rail passengers actually carried. The share of organic demand is found by dividing the organic rail passenger demand by the total rail demand, which includes both organic passengers and those shifted from air travel. This approach assumes that the passengers carried on trains represent both groups proportionally. The total number of rail passengers carried is limited by the train capacity and load factor, so it is the minimum of the total rail demand or the maximum number of passengers that trains can carry.

$$RailPaxCarried_{organic,t}^{a,s,g}(r) = RailPaxCarried_{t}^{a,s,g}(r) * Share_{organic,t}^{a,s,g}(r) \quad \text{(D17)}$$

$$Share_{organic,t}^{a,s,g}(r) = \frac{RailPaxDemand_{organic,t}^{a,s,g}(r)}{RailPaxDemand_{t}^{a,s,g}\ (r)} \quad \text{(D18)}$$

The train capacity for the Amsterdam-Berlin route is 600 seats per train (Treinreiziger.nl, 2025a, Treinenweb, 2024), while the Amsterdam-London route uses Siemens Velaro e320 trainsets with over 900 seats each (Siemens, 2018). The maximum passenger capacity per year is then calculated by multiplying the number of trains by the train capacity and adjusting for the load factor, which reflects the average occupancy rate. The train carry capacity and the number of trains per year do not vary between growth scenarios therefore, the growth scenario indicator $g$ is omitted from the formulas.

$$RailPaxCarried_{max,t}^{a,s,g}(r) = TrainCarryCapacity_{t}^{a,s}(r) * \ LoadFactor_{t} \quad \text{(D19)}$$

$$TrainCarryCapacity_{t}^{a,s}(r) = Trains_{t}^{a,s}(r) * TrainCapacity(r) \quad \text{(D20)}$$

The number of passengers actually shifted from air to rail is calculated by multiplying the total number of rail passengers carried by the share of those passengers who previously would have flown. This share is determined by dividing the rail passenger demand coming from the air travel market by the total rail passenger demand, which includes both the demand from former air passengers and the organic demand from passengers who want to take the train. Since total rail demand may exceed the available capacity, the number of passengers actually carried is used rather than total demand. It is assumed that passengers from both the air travel market and the organic rail market are proportionally represented in the carried passengers according to their demand. This allows us to estimate the actual number of air passengers that shift to rail, while accounting for potential capacity constraints in the rail system, using the following formulas. In the base case, where no air-to-rail shift occurs, the total rail demand consists only of organic passengers, meaning organic demand is equal to the total rail demand in that case.

$$AirPaxShifted^{a,s,g}_{actual,t}(r) = RailPaxCarried^{a,s,g}_{t}(r) * Share^{a,s,g}_{air,t}(r) \quad \text{(D21)}$$

$$Share^{a,s,g}_{air,t}(r) = \frac{RailPaxDemand^{a,s,g}_{air,t}(r)}{RailPaxDemand^{a,s,g}_{t}(r)} \quad \text{(D22)}$$

$$RailPaxDemand^{a,s,g}_{t}(r) = RailPaxDemand^{a,s,g}_{organic,t}(r) + RailPaxDemand^{a,s,g}_{air,t}(r) \quad \text{(D23)}$$

The organic rail demand for the base case is calculated by multiplying the demand from year 2023 by the relevant annual growth factor. For the Amsterdam-London route, rail passenger numbers reached approximately 1.100.000 in 2023 (Eurostar, 2024), while demand on the Amsterdam-Berlin route was estimated at 1.000.000 in 2019 (Consultancy.nl, 2019). Given that recent growth aligns with the most optimistic scenario, a 3.0% annual growth rate is applied to forecast Berlin demand from 2019 to a 2023 baseline of approximately 1.125.500 passengers (Steer, 2025). This ensures consistency across routes and provides a realistic starting point for projecting future growth. The same growth factors are applied through 2050 and are further discussed in Section 7.3.

$$RailPaxDemand^{0,g}_{organic,t}(r) = RailPaxDemand^{0}_{organic,2023}(r) * \left(1+\delta_g\right)^{t-2023} \quad \text{(D24)}$$

The organic rail passenger demand changes depending on whether it is before, during or after the year of the service improvement, called the improvement year. For Amsterdam-London, the improvement years are 2026 and 2027, while for Amsterdam-Berlin it is 2030. Note that for Amsterdam-London there is no travel time improvement, so for travel time $\Delta Q$ is zero and does not add to new demand from that factor.

The symbol $\varepsilon$ stands for elasticity, which measures how sensitive rail passenger demand is to changes in service quality factors like travel time and service frequency. A negative elasticity for travel time means demand increases when travel time decreases and a positive elasticity for frequency means demand rises when the number of trains increases. Specifically, the rail travel time elasticity is -1.58 and the rail frequency elasticity is 0.5 (Victoria Transport Policy Institute, 2024).

The percentage quality improvements, called $\Delta Q$, are expressed as percent changes. For Amsterdam-London, frequency improvements are 33.3% in 2026 and 25% in 2027, with no travel time improvement. For Amsterdam-Berlin in 2030, the frequency improvement is 100% travel time improves by -3.0% meaning a 3% reduction in travel time. All the data and values provided here correspond to the Neutral policy scenario.

The organic rail passenger demand before the improvement year remains the same as the base scenario without improvements:

$$RailPaxDemand^{a,s,g}_{organic,t}(r) = RailPaxDemand^{0,g}_{organic,t}(r) \text{ for } t < t_{imp} \quad \text{(D25)}$$

During the improvement year, the demand is adjusted according to the elasticities and the quality improvements in travel time and frequency:

$$RailPaxDemand^{a,s,g}_{organic,t_{imp}}(r) = RailPaxDemand^{0,g}_{organic,t_{imp}}(r) * \left(1 + \varepsilon_{freq} * \Delta Q_{freq}(r) + \varepsilon_{time} * \Delta Q_{time}(r)\right) \text{ for } t = t_{imp} \quad \text{(D26)}$$

After the improvement year, the demand continues to grow based on the corresponding growth factor:

$$RailPaxDemand_{organic,t}^{a,s,g}(r) = RailPaxDemand_{organic,t_{imp}}^{a,s,g}(r) * \left(1+\delta_g\right)^{t-t_{imp}} \quad \text{(D27)}$$

for $t > t_{imp}$