The Impact of Rail Structural Reform on the Supply and Demand of Railway

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Acknowledgement

Starting a part-time PhD has truly been a long and memorable adventure - it took over eight years, after all! Looking back to just a year before I began, I would have thought anyone was crazy if they told me I'd dedicate so much time to this. This journey started with my curiosity about why different countries manage their rail systems in such diverse ways sparked from my job. I’m really lucky to have had the chance to explore this curiosity and find some answers; it's been incredibly meaningful to me.

Huge thanks are due to my supervisors, Prof. Andrew Smith, and Prof. Richard Batley from ITS, who saw my potential and let me engage with this research journey. I appreciate their patience and consistent support over these eight years—without them, I couldn't have completed this work. Sorry for sending them emails as a student for so many years!

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Over these years, I changed jobs twice, which meant working with many different colleagues who supported me in various ways. Special thanks to my current colleagues, like Ian Sewell, who helped expand my network for the interviews. Thanks to Mike Lampkin, who connected me with key industry contacts despite our short time (4 months) working together. I deeply appreciate all the industry experts who took the time to contribute to my qualitative research; their willingness to share their knowledge was crucial. I apologise for not being able to show their names here.

Finally, finishing this thesis is a huge personal success. There were countless times I questioned myself if I could have done better. Now, I can be comfortable saying “I did not!”, but that’s all I can give. Life isn’t always straightforward, and this PhD journey has taught me that the answers are rarely just "yes" or "no." ***Reconcile with oneself*** - this is a true reward for me.

- Sidi Sun

Abstract

This thesis explores the effects of rail structural reform on the cost efficiency and passenger demand in the railway sectors of Europe and East Asia. The study combines advanced econometric analysis with up-to-date data from 2017 and qualitative analysis with inputs from industry experts to provide a comprehensive analysis of how different vertical structures impact railway system cost and passenger rail mode share.

On the cost side, the research challenges the idea that Vertical Separation always leads to higher costs due to coordination issues. The empirical analysis indicates that while Vertical Separation is suitable for networks with lower train densities, the Holding Company regime is preferred as network utilisation increases, with the Vertical Integration regime becoming the most effective as train density continues to rise, requiring closer integration for optimal management. The thesis also suggests that higher investment intensity in Vertical Separation regimes facilitates cost reductions, highlighting the critical role of investment coordination in cost saving. The qualitative analysis offers a critical perspective, challenging the notion that these efficiencies derive solely from the Vertical Separation structure's inherent transparency and targeted investment strategies. Instead, it is more plausible that these cost reductions are driven by investments in advanced technological integrations like real-time management systems, which effectively reduce the misalignment costs in the Vertical Separation regime.

On the demand side, the empirical analysis establishes a clear link between industry structure and passenger response to pricing, safety, and infrastructure investment. The findings suggest that the Vertical Separation and Holding Company regimes correlate with heightened passenger responsiveness to service adjustments. In contrast, the Vertical Integration regime shows lesser sensitivity to pricing and service quality changes. Qualitative insights further enrich this understanding by illustrating how strategic fare reforms and investment strategies under different regimes shape passenger preferences and behaviours. For example, Vertical Separation, generally characterised by higher market liberalisation, employs strategies that target specific market segments, enhancing responsiveness to passenger needs through tailored fare adjustments and service enhancements. In contrast, Vertical Integration implements broader, less targeted changes across the entire network, which may result in lower responsiveness from passengers.

The qualitative aspect of this thesis enhances the comprehension of the impacts of reforms by emphasising the significance of a strong culture of collaboration, which helps to mitigate the coordination challenges posed by Vertical Separation. This underscores its importance across all regimes, based on insights from a select but diverse number of interviews with industry professionals.

The thesis concludes that while there is no one-size-fits-all solution for railway industry structures, success hinges on a balance of network characteristics, strategic investment

decisions, market liberalisation, and the promotion of a collaborative culture. These elements, when aligned, can optimise both cost efficiency and rail passenger mode share.

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Abbreviations and Acronyms

ABP	Annual Business Plan
ART	French Transport Regulator
CBA	Cost-Benefit Analysis
CER	Community of European Railway and Infrastructure Companies
DB AG	German Railway Corporation
DEA	Data Envelopment Analysis
DfT	Department for Transport
DMU	Decision-making Unit
EU	Europe
GB	Great Britain
GBR	Great British Railways
GC	Generalised Cost
GDP	Gross Domestic Product
GJT	Generalised Journey Time
HC	Holding Company
HS	Horizontal Separation
IM	Infrastructure Manager
IR	Irish Rail
ITF	International Transport Forum
JR	Japan Railways
MEA	Multi-directional Efficiency Analysis
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PDFH	Passenger Demand Forecasting Handbook
PFP	Partial Factor Productivity
RFF	French Railways Infrastructure Authority
ROC	Rail Operating Centres
RU	Railway Undertaking
SJ	Swedish Railways
SNCF	French National Railways
SOBC	Strategic Outline Business Case
STAG	Scottish Transport Appraisal Guidance
TfL	Transport for London

TFP	Total Factor Productivity
TOCs	Train Operating Companies
TVM	Transmission Voie-Machine
VI	Vertical Integration
VS	Vertical Separation

1. Introduction

This section will introduce the background of this thesis. First, the history of rail reform worldwide (i.e. Europe, Asia and North America) will be introduced. Then, it will briefly summarise the current status of the rail structural reform in different countries and how the reform affected the industry. The existing studies concerning the rail reform's influence will be briefly summarised to identify the gaps. More details of the literature will be introduced in Chapter 2. Then, the aim and contribution of this thesis will be explained, followed by the structure of this thesis at the end of this chapter.

1.1 Rail Reform

This section provides an introductory overview of the key themes and developments in global railway reforms. Detailed analysis and comprehensive discussions on these topics, including an extensive literature review, will be presented in Chapter 2, offering a deeper exploration of each aspect mentioned here.

Similar to all the other industries relevant to public services (e.g. electricity, natural gas, telecommunications, water), the railway was initially a vertically integrated monopoly owned by the public sector in most countries around the world except North America. This is because the initial investment cost for such services was extremely high. The decision to operate railways as a state-owned monopoly in most European countries was influenced not just by the high initial investment costs but also by the railways' being a natural monopoly. In such industries, competition is often impractical or inefficient because of the scale of the infrastructure required. Furthermore, many rail services, particularly those in less populated or less affluent areas, are inherently loss-making. This economic reality necessitated public ownership to ensure the provision of affordable, stable, and widespread rail services, balancing profitability with public utility and access. However, as time went on, a state-owned business's weaknesses began to emerge and eventually became a barrier to further improvement. Such negative influences incentivised the whole industry to reform.

First, a state-owned monopoly has few incentives for managers to meet market requirements. Confused management structures make things worse, leading to conflicting incentives from different branches of government. The ministers representing transport, finance, industry, labour, regional development and even defence may all have interests in the rail sector – generating conflicts that lead to lower efficiency and productivity (Drew et al., 2011). For example, in the United Kingdom before the rail privatisation in the 1990s, the state-owned railway company British Rail, faced criticism for its inefficiencies and bureaucratic management (Welsby and Nichols, 1999). Similar issues were noted in other European countries like France and Germany, where national railways were government-run until the liberalisation movements began in the 1990s.

The lack of internal competition in state-owned rail services often resulted in inefficiencies and a slow response to market demands (Pittman, 2007). This situation contrasted sharply with the dynamic road transport sector, particularly after the rapid motorway expansion from the 1960s'. As a result, a significant reduction in rail mode shares was recorded in Europe's passenger and freight markets over the 1970s and 1980s. For the EU15 countries, the mode share for rail passenger transport was 10.4% in 1970 and had reduced to 6.7% in 1990 (Bruinsma et al., 2008). Concerning freight transport, the decline was even more significant with rail having a 21.2% mode share in 1970 and 11.1% in 1990 (ECMT, 2003).

Last not but least, there have been financial difficulties for rail monopolies, which led to growing public funding requirements. A notable example is the GB Rail prior to its privatisation, which was loss-making and heavily reliant on government subsidies, particularly for regional services. Politicians have required railways to improve and expand railway infrastructure and services without necessarily wanting to pay for this. Faced with insufficient funds, yet unable to alter politically-determined service patterns and tariffs, railways have had little choice but to accumulate debt (Drew et al., 2011).

All of the above have incentivised the reform of railways across the world in recent decades. Actually, similar reforms, so-called New Public Management (NPM), have occurred in other sectors such as energy and water since the 1990s. The private sector managerial tools and principles were introduced to ensure macroeconomic stability, cutting deficit spending and reducing the scope and cost of government intervention (Ranghetti and Naciones, 2018).

The following sub-sections introduce the rail reform history of multiple countries in the world and discuss whether they have achieved the original intention of reform, i.e. resolving the issues brought by monopoly.

1.1.1 Rail Reform History

Europe

Since 1991, the railway reform process has been taken forward through EU legislation aiming to split up the railway industry. The introduction of competition between different operators and the tension at the 'wheel rail interface' aimed to reduce subsidies and address inefficiencies in many European countries. This process involved separating infrastructure management (the 'track') from the train operation (the 'wheel'), enabling different train operating companies to compete for services on the same track. This separation was intended to create a more competitive environment, encouraging operators to improve service quality and efficiency, thereby addressing the inefficiencies inherent in previously monopolistic systems (Drew et al., 2011).

The rail reforms in Europe have followed three steps: 1) separating the infrastructure from operations (at a minimum into separate divisions with their accounts), 2) establishing an independent regulator and 3) opening up the rail market (i.e. introducing competition). The rationale for the separation was that it would provide discrimination-free access to the infrastructure for transport operators and enhance competition within the railway industry.

More competition, in turn, would ideally increase the efficiency and demand for railway services and raise economic welfare (Commission of the European Communities, 1996).

The European Commission has published four legislative packages to guide the European countries to reform the rail system, aiming to gradually liberalise rail transport service markets, improve the efficiency of the management structure, and reduce the subsidies from the government. **Table 1** illustrates the key movement from each railway package to achieve the targets of rail reform (Commission of the European Communities, 2006). Each country within the European Commission was expected to follow these railway packages to reform the rail industry (European Commission, 2013). However, due to the different political, economic, geographic and cultural characteristics, every country implemented a different approach to follow the guidelines of rail reform (Nash, 2010). As a result, there exist different rail industry structures across the EU countries. Given the large number of European countries considered in this thesis, the reform history for each country will not be introduced specifically in this section. However, each country's current rail structural reform status will be explained in Section 2.1.2.

Table 1 – Target of each railway package from the European Commission[1]

	Target - Liberalisation	**Target – Better management**	**Target – Less subsidy**
First EU Railway Package (2001)	• Allocation of capacity independent of rail operators • Access rights for international freight services	• Organisational separation • Establishment of national regulatory bodies	• Account separation • Infrastructure charging
Second EU Railway Package (2004)	• Complete opening of the EU rail freight network (from 2006)	• Establishment of the European Railway Agency • Railway Safety Directive on a common approach to safety	
Third EU Railway Package (2007)	• Opening of international passenger rail services (from 2010) • Public Service Contracts Regulation	• Regulation on rail passenger rights and obligations • Certification of train drivers and crews	

[1] European Commission, Railway packages. [online] Available at: https://transport.ec.europa.eu/transport-modes/rail/railway-packages_en

Recast of the First Railway Package (2012)	• Recast of the First Railway Package	• Recast of the Interoperability Directive • Amended Railway Safety Directive	• Strengthening of Economic Regulation
Fourth EU Railway Package (2016)	• Competitive tendering for public service rail contracts • Full opening of the domestic passenger market	• Establishment of the European Union Agency for Railways	• Common rules for rail operators' accounts

Asia

Many rail reforms have been implemented outside of Europe as well. The privatisation of the **Japan** National Railway (JNR) started in 1987, leading to the creation of seven (one for freight and six for passenger) regional railway companies, with the organisational structure following the rules of horizontal (geographical) separation, functional distinction and vertical integration. The rail reform in Japan is considered to be one of the most challenging but also one of the most successful policies in Japan to date, given that it transformed a bankrupt company (JNR) into several railway companies with less cost and higher revenue. It's important to note, however, that part of this success was facilitated by the government's decision to write off a portion of JIM's debt, which played a significant role in the financial restructuring and eventual success of the reformed entities. On the other hand, the new railway structure utilises the advantages of regional divisions and successfully handles the long-term liabilities and measures for an underutilised workforce.

Rail reform in **South Korea** began in the late 1990s, as part of the government's efforts to promote competition and increase efficiency in the transport sector. The main goals of the reform were to separate infrastructure and operations, promote competition, and encourage private investment in the railway sector. The initial phase of the reform involved the separation of the Korean National Railroad (KNR) into multiple entities responsible for infrastructure and operations. The infrastructure manager, known as the Korea National Railway, was established in 2004 to manage and maintain the national rail network, while the operations entity, Korail, was reorganised as a public corporation responsible for passenger and freight railways. Currently, the railway industry in South Korea is dominated by Korail, which operates most passenger and freight services on the national rail network. However, several private companies operate freight services and some passenger services on specific routes.

Before 2013, the Chinese Ministry of Railways (MOR) had a dual role in government and enterprise: not only as a government department in charge of the railway industry's development strategy and policy but also responsible for managing the operations of the national railway transport enterprise. **China** started their rail reforms in 2013 with the dissolution of MOR by transforming MOR's original responsibilities into three groups of organisations. The former government function in network planning and policy formation was transferred to the Ministry of Transport (MOT). Its former government function in safety supervision and drafting of technical standards was undertaken by the newly-established National Railway Administration (NRA). Last but not least, the former enterprise function was taken over by the newly established China Railway Corporation (CRC). CRC owns 18 primary subsidiary companies (as independent legal entities) for passenger rail (transformed from the former 18 local rail authorities) and 3 subsidiary companies for freight rail. CRC retains some responsibilities from the former MOR, which include centralising and unifying train control for the whole national railway system, formulating the transport regulations obeyed by the subsidiary companies, organising the establishment of train diagrams and marshalling plans, and supervising the implementation of transport enterprises. Nevertheless, despite these reforms, the Chinese railway system retains an essentially vertically integrated organisational structure, with the majority of its entities remaining under state ownership, reflecting the continued significant influence of the government in the sector. Due to the late implementation of rail reform (insufficient observations), China is not involved in the empirical analysis of this thesis.

Other countries

Railways began in the **United States** early in 1825 and grew strongly through the end of the century and then started shrinking in response to rising competition from road transport. Unlike other countries in the world, the railway industry in the U.S. was primarily owned and operated by private companies. The only exception is Amtrak, which was created by the government in 1971 to provide intercity passenger rail services. The companies that owned and operated the railways were responsible for building and maintaining their own track infrastructure, as well as providing freight and passenger services[2]. The industry was heavily regulated by the government, particularly in terms of pricing and service offerings, and many railroads struggled financially due to high costs and a lack of pricing flexibility. The rail reform in the U.S. started in 1980 and focused more on deregulation instead of privatisation (given that the system was originally owned by private companies). The introduction of the Staggers Rail Act of 1980 deregulated the railroad industry, provided pricing flexibility, streamlined the abandonment process, reformed rate bureaus, and provided limited antitrust exemptions to railroads (Winston, 2005). The U.S. railroad industry is currently dominated by a handful of large Class I rail companies and primarily focused on freight transportation, with limited passenger services provided by Amtrak. The story of rail reform in **Canada** is very similar to the U.S., with the National Transportation Act of 1987 being introduced to deregulate the industry and abolish the previous regulatory body, intending to promote greater competition and efficiency in the industry.

In **Latin America**, all the major railways were originally state-owned and state-operated at the beginning of the 1990s. Rail reforms were implemented in Latin America during the 1990s, which mainly focused on privatising the railway infrastructure management and train

[2] Unlike freight railroads, Amtrak operated on infrastructure owned by these freight railroads (Class I) and other entities, paying fees to use the tracks for its passenger services.

operation. For example, in **Brazil**, **Mexico**, and **Argentina**, the privatisation process involved the transfer of state-owned railway companies to private ownership and management, primarily focusing on vertically integrated freight concessions. In Argentina and Brazil, this shift led to significant workforce reductions and reorientation of services, impacting both employment and the social dynamics of regions dependent on railway jobs. Mexico's privatisation similarly concentrated on freight services, with an emphasis on improving efficiency and serving major industrial customers, leading to a reduction in passenger services and changes in operational focus. These reforms underscored the complex interplay between privatisation, operational efficiency, and broader socio-economic impacts in the railway sector (Drew et al., 2011). In **Chile**, the government created a regulatory framework that aimed at enhancing competition among private railway companies. This framework was part of a broader strategy to improve railway performance in aspects like traffic growth, operational efficiency, and investment. The Chilean model focused on striking a balance between private sector participation and regulatory oversight to ensure a competitive and efficient railway sector. However, the privatisation process in these countries has been criticised for its slow pace and incomplete implementation. Besides, the railway industry still faces challenges such as a lack of investment in infrastructure and insufficient competition in some regions, which can probably explain the recent efforts spent to re-nationalise the industry in Argentina (Sharp, 2005).

Summary

Railway systems around the world have undergone significant reforms over the past few decades, with many countries restructuring their railway industries and introducing greater competition. There are three main approaches implemented in rail reform:

1. Structural separation - involves separating (completely separate or at least account separate) rail operations from infrastructure management and splitting passenger and freight rail operations. This approach has been commonly used in Europe to create a unified rail network and to promote efficiency and competition among private rail companies (Nash et al., 2013).
2. Privatisation - involves transferring state-owned railways to private ownership and management. This approach has been commonly used in Latin America and Asian countries like Japan to increase efficiency and investment in rail infrastructure.
3. Reforming the role of government in the rail industry, which can include separating rail operations and infrastructure management from government control (as in China) and strengthening independent regulation (as in Europe) or deregulation of the industry (as in North America).

Overall, railway reform has been driven by the need to increase efficiency, investment, and competition in the industry. While different approaches have been adopted in different regions, the ultimate goal is to provide safe, reliable, and affordable transportation for passengers and goods. Section 1.1.2 will introduce the current status of rail industry structures post-reform for the countries that are involved in the empirical analysis of this thesis.

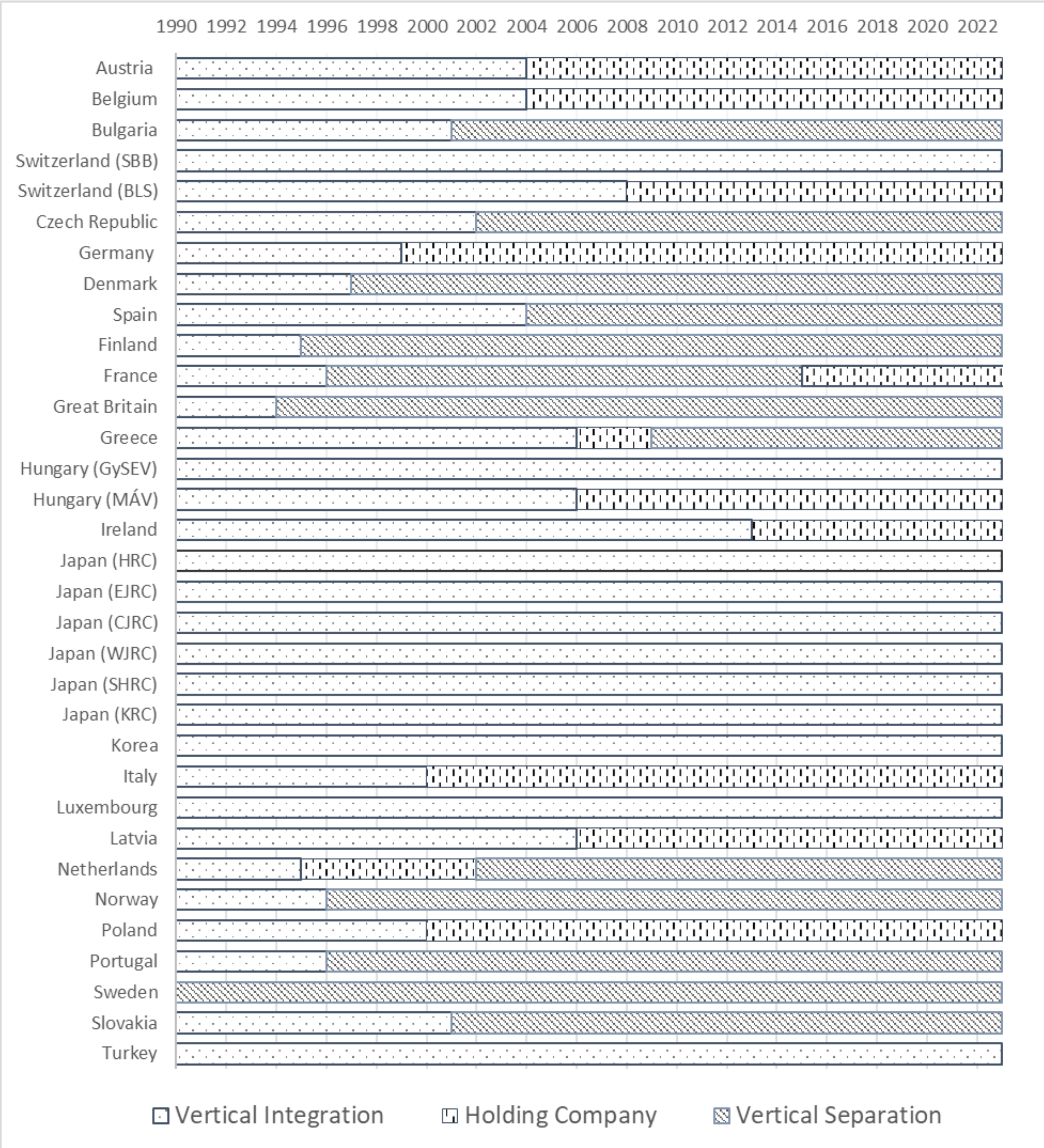
1.1.2 Latest Status of Rail Structural Reform

Typical post-reform rail structures include Vertical Integration (VI), Vertical Separation (VS), Holding Company (HC) and Horizontal Separation (HS). The first three of these refer to the relationship between Rail Undertaking (RU) and Infrastructure Management (IM), i.e., whether they are integrated into one company, (e.g. the VI regime), separated into two or more legally distinct companies (e.g. the VS regime) or only partially separated (e.g. the HC regime). In the HC regime, the Railway Undertaking (RU) and Infrastructure Manager (IM) are separated organisationally (i.e. with separated accounts) but remain within the same parent/holding company. The holding company is generally owned by the state, but it allows private companies involved in the business (i.e. as train operators).

Horizontal Separation, on the other hand, means that the freight and passenger operations are fully separated and operated by two or more companies, i.e. geographically or line-by-line. Horizontal and vertical separation represent two distinct strategies, which can coexist within the same regulatory framework. For example, in Great Britain, the rail system's significant restructuring in the 1990s led to the adoption of the VS regime, and while Horizontal Separation is not the primary model, the market is effectively segmented between passenger and freight services through different operators. Similarly, Sweden, known for pioneering rail reforms, has also implemented vertical separation and facilitates competition in both passenger and freight services, though it does not explicitly adopt an HS regime as defined by separating operations geographically or line-by-line. Regarding the HC regime, such as Deutsche Bahn (DB) in Germany, it embodies a blend of the HC and HS regimes too. DB operates both freight (DB Cargo) and passenger services (DB Fernverkehr for long-distance, DB Regio for regional) under separate subsidiaries, yet all are under the umbrella of the holding company DB. This structure allows for the coexistence of HC and HS principles, with operational and strategic separations. Japan, despite having a vertically integrated regime, also demonstrates the implementation of horizontal separation, showcasing the model's global applicability beyond European borders.

Figure 1 below illustrates the structural reform status (up to 2022) for the countries involved in this thesis. Among the 27 countries, twelve of them (44%) have vertically separated rail systems, nine countries (33%) use the HC regime, and the rest six (23%) are still using the VI regime. In the early 1990s, the passenger railways and infrastructures in all EU countries were operated/managed by the national railway company, which means they all use the vertically integrated system. For the countries changing from VI to VS regime, rail operation and infrastructure management from the national railway company were generally separated and undertaken by two parties. For example, the GB railway started its structural reform with railway privatisation in 1994. The rail franchise scheme was developed which allowed the rail infrastructure to be owned and managed by The IM (a public-owned company), while the rail services were franchised and operated by different Train Operating Companies (i.e. First Group, Abellio. Govia, etc.). The Office of Rail and Road plays a regulatory role as an independent institution to regulate The IM’s spending and track access allocation.

Figure 1 – Rail Structural Reform Progress for Selected Countries



For those countries changing from the VI to HC regime, rail operation and infrastructure management are separately undertaken by two companies within a holding company. For example, in Germany, the two former state railways were integrated in 1994 as Deutsche Bahn (DB) which was owned by the Federal Transport Ministry. To meet EU requirements, DB's infrastructure manager and rail operations are separate legal entities within the overall holding company of DB, each with its management boards. Several countries have undertaken structural reform more than once - the French Railway is a good example. French Railway was reformed in 1997 when RFF was formed as the owner and manager of the infrastructures taken from the original national railway, SNCF. SNCF was formed in 1938 with the nationalisation of France's main railway companies, and it continued to operate the passenger rail and most of the freight rail (around 70% market share) in France until 1997

(Berlioz, 1998). This reform was primarily focused on financial restructuring, with RFF taking over a substantial portion of SNCF's debt related to track funding, and aimed at improving operational efficiency and clarifying the roles between the state and SNCF. In 2015, RFF became SNCF Réseau and the operational assets of SNCF became SNCF Mobilités, both groups were placed under the control of SNCF. To sum up, the French railway market structure changed from the VI to VS[3] regime in 1997 and changed again to the HC regime in 2015.

[3] The RFF model represented a unique form of VS, primarily focusing on financial restructuring by transferring infrastructure ownership and debt from SNCF, yet leaving track maintenance responsibilities with SNCF.

1.1.3 Impact of Rail Reform

Rail reform has been implemented in various forms across the world, with varying degrees of success. In the EU, rail reform has largely been successful in achieving its original goals of reducing government subsidies, liberalising the rail market, and introducing competition to develop a single European railway area (Drew et al., 2011). The liberalisation of rail markets has allowed for greater choices for consumers and has led to improvements in efficiency and service quality in many countries. In the United Kingdom, for example, the privatisation of British Rail in the 1990s led to the introduction of competition and a more customer-focused railway system. Train operators were incentivised to improve service quality to attract customers, resulting in increased demand and revenue (Nash and Smith, 2007). Similarly, in Germany, the liberalisation of rail markets and the separation of infrastructure management from train operations has led to increased competition on the network. The introduction of competition in rail services has enhanced the quality and comfort for passengers, contributing to an increase in rail mode share (Brenck and Peter, 2007).

Rail reform has had varying degrees of success in some countries. In Japan, the privatisation of Japanese National Railways in the 1980s led to the creation of the Japan Railways Group, which has since become a profitable and efficient transportation company. In South Korea, the government-led restructuring of the national rail operator, Korail, has led to improved service quality and increased ridership (Briginshaw, 2008).

However, rail reform has not been without its challenges. In France, for example, the liberalisation of rail markets has been met with resistance from labour unions, who have gone on strike numerous times in protest of proposed reforms. The privatisation of state-owned rail companies in some countries has also faced criticism for leading to higher ticket prices and reduced service quality, particularly in those less profitable routes.

Both academics and policymakers have tried to compare and evaluate the rail reforms undertaken in different countries to determine if there is an optimal reform regime. Such evaluations generally include two core components, which are the characteristics of reform (i.e. separation regime) and the indicators used to identify the success or failure of different reforms. In past literature, the indicators generally focus on either the supply (i.e. cost and efficiency) or demand side of the rail system. On the supply side, there has been extensive quantitative literature studying the effect of different structural reforms on rail costs and efficiency; for a summary of this literature see Fitzova (2017). A key entry point for this thesis is the work of van de Velde et al. (2012) and Mizutani et al. (2015), which emphasised that the cost impact of VS as compared to VI depends on train density (intensity of usage of the network). Mizutani et al. took a transactional cost perspective – where the cost impact of train density could be explained by the higher cost of coordination between RU and IM in the case of higher train density, given that the costs associated with maintenance scheduling and maintaining safety under a busy train operation schedule are generally more expensive. Their work also highlighted the differential cost impacts of the VS regime as compared to the partial separation approach such as the HC regime. The relevant literature will be introduced in Chapter 2.

There is less evidence to show a significant influence of rail reform on the demand level from the previous literature. Figure 2 and Figure 3 below provide a high-level view by showing the trend of change in passenger rail mode share in different rail structures from 2000 to 2017. In Figure 2, it can be seen that the average rail mode share in the 24 selected European countries (the same countries as used in the econometric model in Chapter 4) experienced fluctuations over the past 17 years, with a slight increase in 2017 compared to 2000. Each type of rail structure[4] has a different trend of change in mode share. For example, the VI regime has experienced a higher increase in rail mode share compared with the VS regime. Meanwhile, the HC regime seems to have a decrease in rail mode share since 2013. Figure 3, on the other hand, compares the passenger rail mode share in the selected countries with different rail structures showing the time point of structural reform in each country. To ensure a balanced comparison and avoid an overly complex graph, three countries operating under the HC regime - Austria (AT), Hungary (HU), and Italy (IT) - and another three to represent the VS regime: Czech Republic (CZ), Spain (ES), and the Netherlands (NL), are selected. The VS regime in this graph seems to demonstrate a more positive change in mode share compared with the HC regime which has had a mode share reduction since around 2013. However, the above findings require quantitative analysis to prove whether the passenger rail mode share is influenced by rail structural reform. This is going to be discussed in Chapter 4.

Figure 2 – Passenger Rail Mode Share from 2000 to 2017 for Different Rail Industry Structures

[4] The average passenger rail mode share is calculated based on the structure type for each country. This means that if a country changed its railway structure in 2010 from VI to VS, the mode share data from 2010 onwards would be used to compute the average mode share for VS.

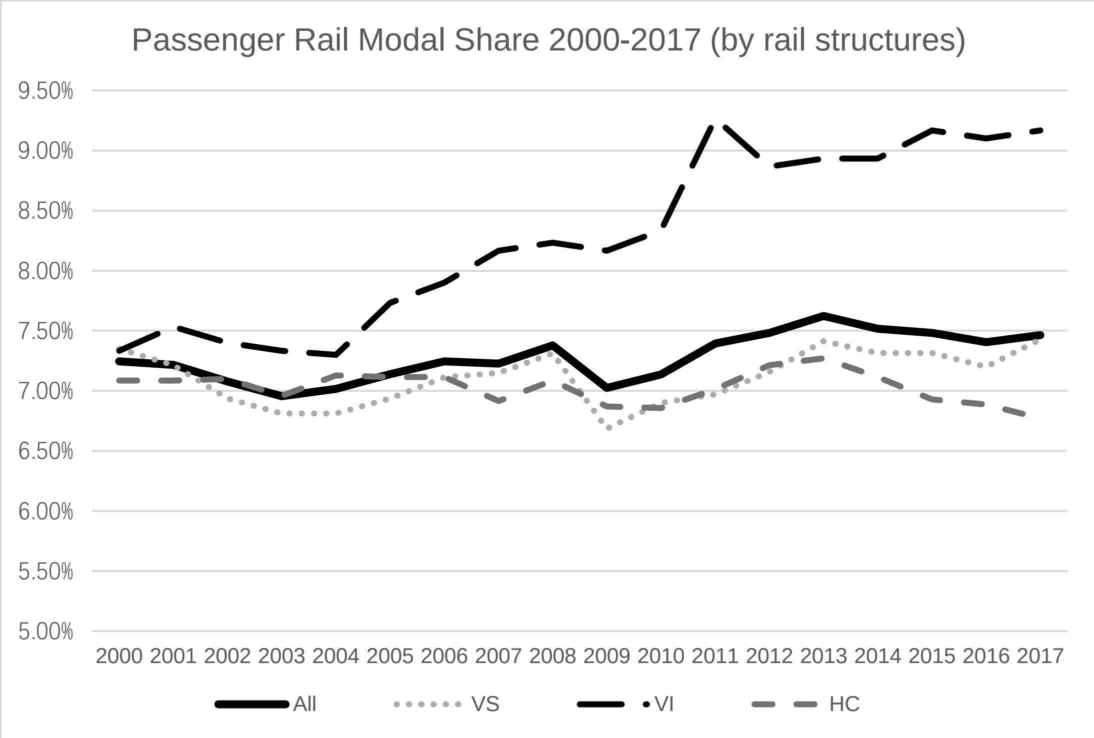
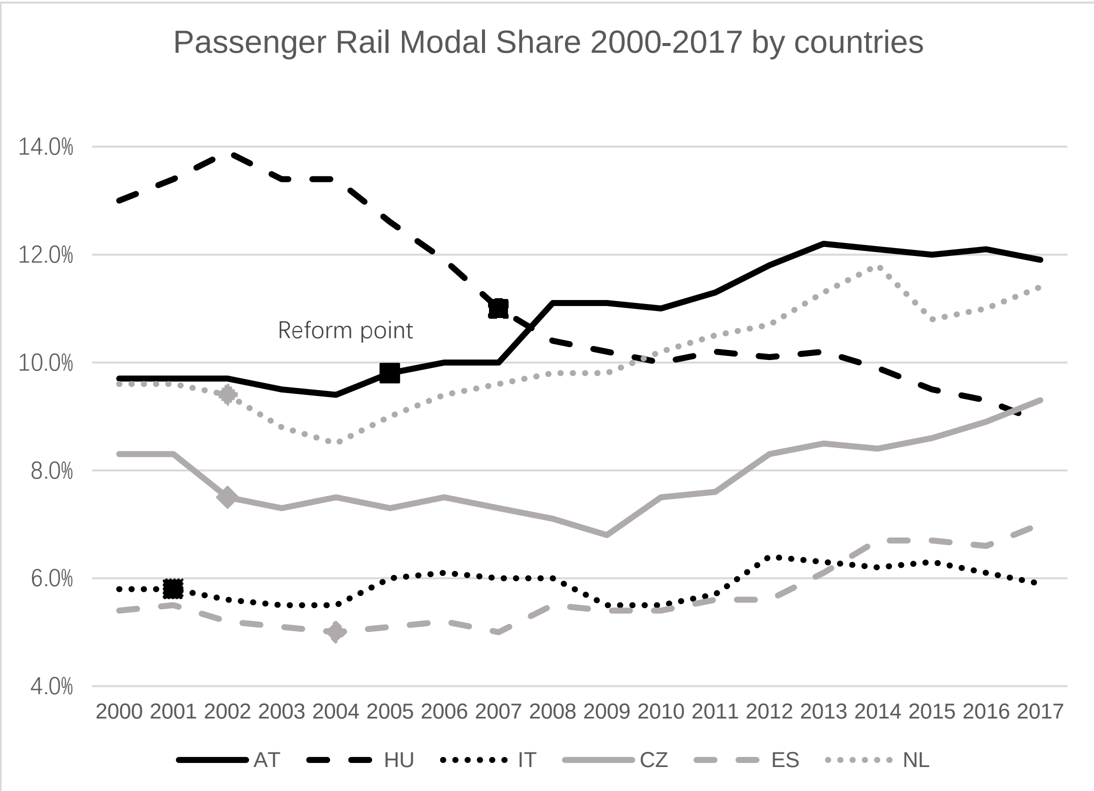


Figure 3 - Passenger Rail Mode Share from 2000 to 2017 for Selected Countries



1.2 Aim and Contribution of This Thesis

This thesis aims to fill gaps in the existing knowledge base and contribute to the literature on the cost and demand impacts of rail structural reform.

Concerning the **cost direction**, there has been extensive quantitative literature studying the effect of different structural reforms on rail costs and efficiency, as introduced in Chapter 1.1.3. However, there are two gaps in the relevant literature. First, there have been only a limited number of studies focused on investigating the factors leading to differences in cost efficiency between the two dominant forms of vertical structure in the EU – that is, VS and the HC regimes. Mizutani et al. (2015) and van de Velde et al. (2012) considered these two forms of vertical structure but found limited significance for the cost impact of the HC regime. Particularly, when examining the relationship between train density and costs within the HC framework, they did not identify statistically significant correlations, indicating that the influence of train density on costs in the HC regime remains inconclusive. This may be due to the limited years of data involved in the econometric model. The latest year is 2010 in their study, which may not be up-to-date to reflect the influence of rail reform in some countries that reformed their railways in the late 2000s. Thus, this thesis expands the dataset to 2017, which not only increases the sample size but also observes the lasting impact of the most recent reforms. Second, the previous literature, i.e. van de Velde et al. (2012) and Mizutani et. al. (2015), tried to explain the cost reduction due to lower train density in the VS regime by introducing misalignment cost in the short-term coordination between the RU and IM. This thesis aims to extend the econometric framework to incorporate investment coordination as a key source of potential cost and misalignment. To do this, the quality and impact of investment coordination under different organisational structures are investigated by introducing the intensity of the infrastructure investment into the cost function relationship.

The cost work does not consider other policy factors (e.g. public/private ownership) apart from vertical structures for the following reasons. First, this work **hypothesises** that vertical structure affects cost through misalignments generated from long-term coordination (i.e. investment coordination) between RUs and the IM. Private/public ownership is supposed to have a limited impact on coordination between RUs and the IM given that they are heavily regulated to avoid discrimination. Ownership may be correlated to some extent with competition on the network (in the sense that new competition is often linked with increased private sector participation), and thus this thesis introduces a competition variable. Second, it should be noted that the type of ownership in the sample is a complex mix for some countries (e.g. Japan's passenger rail is privatised but freight rail is still state-owned), thus making it hard to incorporate into the model.

The impact of rail reform on the **demand side**, particularly the pure demand impact, is limited in existing studies, often due to the challenges of isolating these effects from influential external factors like income, employment, and car ownership. This thesis **hypothesises** that structural reforms, while not directly altering mode choice, may affect internal aspects such as rail fares, performance and service quality, which indirectly shape passenger preferences. To capture the variabilities across different transport modes, the literature typically uses rail mode share as an indicator (i.e., the dependent variable in the econometric model). This method effectively isolates the unique impact of rail reforms from overarching economic and social factors - such as income and employment - that uniformly influence all modes of transport. This thesis employs rail mode share as the measure as well to evaluate how varying industry structures influence rail demand, aiming to capture the dynamics between structural reforms and their broader impact on transportation choices. By focusing on rail mode share, this thesis more accurately discerns the specific effects of industry structure changes on rail demand.

On the other hand, the findings from previous literature focusing on rail mode share have not been entirely consistent. Some studies, like Laabsch and Sanner (2012) and Mizutani and Uranishi (2020), found that vertical separation increases rail mode share. In contrast, other studies like van de Velde et al. (2012) and Tomeš (2017) did not find such a significant impact, suggesting that structural separation may not be the sole determining factor. Instead, factors such as rail fares, service quality, and car ownership rates are found to directly affect rail passenger demand - see (Paulley et al., 2006) and (Wardman, 2006). Moreover, it is essential to consider that these factors may also interact with the structural separation policy, further influencing rail demand. For example, passengers in regions with a specific separation policy may be more sensitive to changes in prices and service quality. In this context, the rail industry structure may influence passenger mode share indirectly through its interaction with other factors like rail performance, yield, and service quality. This disaggregated level of influence may help explain the inconsistent outcomes observed at the aggregated level of rail industry structure in previous literature. The complex interaction of various factors influencing rail demand highlights the need for a comprehensive approach when analysing the impact of rail reforms on passenger mode choice.

So, this thesis innovatively considers the interactions between the rail industry structure (structural separation) and other demand drivers in the mode share econometric model. Here it considers three types of demand drivers, namely travel cost, service quality and rail safety. The data available informs the use of average yield as a measure of travel cost, with train frequency and infrastructure investment serving as indicators of service quality, and rail accident data providing insight into rail safety. The hypothesis is based on rail industry knowledge and previous studies, which have found that yield and accident have negative impacts whilst train frequency and infrastructure investment have positive impacts on rail mode share in all types of rail industry structures.

Passenger rail mode share[5] is adopted as the dependent variable in this thesis since it is less straightforward to explain freight mode share by using the factors selected. Unlike passenger transport, freight rail demand is influenced dominantly by cost rather than other factors like service quality and safety, as highlighted by Beuthe et al. (2001) in their study on Belgian freight transportation demand elasticities. This thesis also considers the influence of some exogenous factors such as employment, GDP, car ownership and fuel price, which are

[5] Passenger rail mode share is defined as the market share (passenger kilometre) of rail mode within all the inland passenger transport modes (e.g., rail, car, bus and coach).

included as control variables in the model. Dummy variables are used to represent the VS, HC and VI[6] regimes employed across different European countries.

Overall, this thesis makes the following contributions. On the supply/cost side, it extends the econometric framework used in previous studies to incorporate investment coordination for the first time and discover the cost impact of infrastructure investment under different vertical structures. Besides, it expands the existing dataset to involve more recent years of rail reform data which allows us to find the cost-effective vertical structure under different levels of train density. It, therefore, demonstrates the appropriate (from a cost-saving perspective) vertical structure for different railway networks. On the demand side, this thesis introduces demand drivers - travel cost, service quality and rail safety - and their interactions with different industry structure variables in the quantitative analysis. This allows us to verify the hypothesis that structural reform can influence mode share indirectly through other factors like rail price, train frequency and safety. It also expands the limited literature quantitatively investigating the impact of structural reform on rail mode share and extends the dataset used to include more recent years (up to 2017). Last but not least, this thesis also reflects upon the approach used to model rail mode share, which could inform future research in this area.

On the other hand, this thesis significantly contributes through its qualitative analysis by investigating the real-world implications of rail reforms, particularly vertical separation, from the perspectives of industry professionals. This qualitative dimension, primarily comprising interviews and surveys with key players in the rail industry of several European countries, provides vital insights that complement and contextualise the quantitative findings. It explores the practical effects of rail reform on coordination between infrastructure managers and railway undertakings, offering a deep understanding of the reforms' impact on system-level efficiencies and operations. Additionally, this approach assesses the lived experiences of those directly affected by rail reforms, thus enriching the thesis with a more comprehensive evaluation of the changes that have occurred in the rail industry. The qualitative analysis not only validates the hypotheses drawn from quantitative analysis but reveals the nuances of the reform process, providing a more comprehensive view of the industry's development.

[6] The variable of vertical integration (*Dvi*) is omitted in the econometric model to avoid the dummy variable trap.

1.3 Thesis Structure

This thesis consists of six chapters, with this chapter - Chapter 1, as the introduction. Chapter 2 will review the previous literature on both the demand and supply (cost) area of rail reform's impact. Chapter 3 explains the empirical analysis that has been implemented on the cost side, including the data, methodology, results of the empirical analysis and following discussions on the results. Chapter 4 focuses on the empirical analysis of the demand side, with the same structure as Chapter 3. Chapter 5 introduces the qualitative analysis that has been undertaken to investigate deeply the econometric findings on both the cost and demand sides. The qualitative analysis contains desktop research, as well as several interviews that have been implemented to collect more detailed information within the rail industry. The last chapter derives the conclusions and policy implications which are based on the quantitative and qualitative analysis outputs.

2. Literature Review

As illustrated in the Introduction chapter, this thesis focuses on the impact of rail structural reform on both the rail supply and demand areas. This chapter will review the literature on both areas respectively and summarise at the end. Chapter 2.1 reviews the previous literature focusing on two main areas of rail supply: technical (production) efficiency and cost efficiency. Concerning cost efficiency (the main focus of railway supply), this chapter will cover deeper knowledge by introducing the theory background, functionality, rail characteristics, and target sample (i.e. countries) within the past literature. Chapter 2.2 aims to provide a concise literature review focusing on two main aspects: the impact of structural reform on rail demand and the identification of key drivers influencing rail transport choices.

2.1 Literature on Rail Supply

This section will first review the literature using different approaches to assess/investigate the technical and cost efficiency of the railway system. Then, it will introduce more specifically the cost efficiency literature which is the key entry point of this thesis (on the supply side). A summary table for relevant literature will be provided at the end of this sub-chapter.

Rail efficiency is one of the core areas to evaluate in the literature, given that efficiency can be used to identify which railway is more efficient (i.e. maximum outputs with minimum inputs) and which railway characteristics are most beneficial. There are several types of efficiency in the rail system depending on the definition of outputs and inputs for the rail system. For example, Tomikawa and Goto (2022) investigated the operational, cost efficiency, revenue-earning and profit-earning efficiency of Japanese Railway companies. This chapter focuses on introducing technical efficiency and cost efficiency given they are most relevant to this thesis and have a similar methodology as the analysis for other types of efficiency.

Many studies have aimed to quantitatively assess rail technical efficiency. Technical efficiency measures the degree to which the output is maximised for a given level of inputs or conversely, where the inputs are minimised for a given output. The three most popular measures for technical efficiency are partial factor productivity (PFP), total factor productivity (TFP), and efficiency based on Data Envelopment Analysis (DEA). PFP is expressed as the ratio of a single output to a single input, while TFP is measured by the ratio of multiple outputs to multiple inputs through a weighting system. PFP consists of a single input and output (e.g. passenger kilometre per number of staff), so it cannot be used to conclude the overall efficiency of the rail system. TFP, on the other hand, can consider all the core inputs and outputs, so it has been more widely used than PFP. The weights for the inputs and outputs in TFP are exogenously given by some standard, i.e. cost share of inputs. Although TFP does not have a restriction on the number of inputs and outputs considered, it has highly restrictive assumptions of constant returns to scale/density and marginal cost pricing. As a result, it is difficult to split the impact of technical change from the impact of scale or density change.

DEA is one of the most advanced approaches widely used in the literature, for example, to calculate the relative efficiency of a decision-making unit (DMU) with multiple inputs and outputs. DEA is an index number method for deriving productivity and efficiency measures in which the efficiency frontier is first computed using linear programming. Regression is normally applied as the second step to investigate the impact of the rail structure characteristics on efficiency. Oum and Yu (1994) used DEA to measure the overall efficiency of the railway systems of 18 European countries and Japan between 1978 and 1989 (predominantly the pre-reform period). The TOBIT model was run first to assess the correlation between the DEA efficiency index and the policy/uncontrollable variables (subsidies, electrification level and managerial autonomy). The TOBIT model is suitable for this analysis because it accommodates the bounded nature of efficiency scores, which cannot exceed certain limits (for example, 100%). This model offers more accurate estimates for situations where the dependent variable, like the DEA efficiency index, is subject to upper or lower bounds, thereby providing a clearer understanding of how these variables influence railway efficiency within these constraints. A set of residual efficiency indices were then derived based on the gross DEA index excluding the variables that influence the DEA index from the TOBIT model results. The conclusion indicates that the productive efficiency of the railway systems may be significantly enhanced by an institutional and regulatory framework that provides greater freedom when it comes to managerial decision-making. A similar two-step approach was applied by Cantos, Pastor et al. (2010). The Malmquist productivity index (Malmquist, 1953) was first used by Cantos et al. to measure productivity and to determine the changes in efficiency for railway companies in 16 European countries between 1985 and 2005. The Malmquist productivity index, based on the concept of production functions as described by Caves, Christensen, and Diewert (1982), assesses shifts in production technology and efficiency over time. This index is instrumental in rail efficiency research and decomposes productivity change into two components: efficiency change and technical progress. Efficiency change reflects how well a unit turns inputs into outputs, considering whether it's moving closer to or further from the best practice frontier over time. Technical progress, on the other hand, indicates shifts in the frontier itself, representing improvements in technology or methods. Together, these elements offer a comprehensive view of productivity changes, capturing both internal improvements within a unit and advancements in the broader industry or technological environment in the rail sector. The analysis was followed by TOBIT regression, with results indicating that countries with significant efficiency improvements were those that underwent vertical restructuring and allowed new train operator entries. In contrast with the findings above, Growitsch and Wetzel (2009) showed that vertically integrated companies have slightly higher efficiency. This conclusion was derived from the analysis of technical efficiency through DEA for 54 European railway companies from 2000 to 2004. Instead of using regression in the second step, Growitsch et al. split the rail companies into two groups, specifically integrated and virtually integrated firms, and then calculated the super-efficiency score for each group respectively.

Apart from the three popular approaches introduced above, Multi-directional Efficiency Analysis (MEA) is another non-parametric method capable of measuring the technical efficiency (or inefficiency) of each production factor. It is also capable of separately considering multiple inputs and outputs simultaneously. It is widely used to show the differences in efficiency patterns between select subgroups. Asmild et al. (2009) used MEA to investigate how the railway reform characteristics (accounting separation, complete separation, independent management, passenger service tendering and freight market opening) affect the inefficiencies of specific cost drivers. The results showed that the reforms from 1995 to 2001 in most EU countries had a positive impact on the efficiencies of both the material and staff costs, but more significantly with the former. Amongst the reform initiatives, accounting separation had the strongest effect on reducing costs.

On the other hand, the concept of cost efficiency has been adopted in many studies to measure the degree to which the costs are minimised for a given level of output. Cost efficiency can be explained as the combination of technical efficiency and allocative efficiency which considers not only the quantity but also the relative costs of the mix of inputs used to derive a given level of outputs (Smith and Nash, 2014). It is appropriate to investigate cost minimisation for a given level of output, given that the rail system outputs (i.e. train-kilometres) are generally determined (or, at least, regulated) by the government in the current rail system. The railway cost function considers elements such as cost (industry total cost), the level of outputs (train kilometres) and the input prices (labour price) for achieving cost minimisation in the operation process. The most widely employed cost function is the Translog cost function, which is a generalisation of the Cobb-Douglas form[7]. The Translog cost function is a top-down approach using empirical models. Compared to the bottom-up approach using mechanistic models, the top-down approach is more appropriate for establishing relationships with factors (e.g. the relationship between cost and output or between cost and input price) that may explain variations in costs (Odolinski and Wheat, 2021). The Translog cost function assumes all firms operate efficiently, focusing on the cost-output relationship rather than directly measuring efficiency. This function's characteristic is to implicitly infer the efficiency or inefficiency of firms or countries through dummy variables (i.e. variables representing different structures like HC and VS). These variables facilitate comparative analysis across groups, offering insights into relative efficiency based on cost structure variations. Thus, while not directly quantifying efficiency, the Translog cost function enables an indirect evaluation of efficiency impacts across diverse railway industry structures.

Smith and Nash (2014) compared the methodologies used for technical efficiency and cost function studies in rail, and they identified several relative advantages of the latter. First, given the varying degrees of subcontracting in the rail sector, the physical measures for some of the inputs (infrastructure and rolling stock inputs) are difficult to define and collect accurately as part of the technical efficiency analysis. Second, the measurement of technical efficiency (inputs and outputs) is complicated by the effects of joint costs and economies of scale and density. This means that a rise in productivity may be caused by diversification into new products or by an increased traffic density rather than due to being relevant to technical efficiency improvement. In addition, rail is not a perfectly competitive industry as both rail fares and timetables (as well as capacity) are often (heavily) regulated. For example, the Department for Transport (DfT) in the UK set up the Train Service Requirement in the rail contract to regulate the (minimum) number of trains running on the network. The DfT and regulator also regulate the fares for several services and ticket types on the network, called the “fare basket” with the maximum fare increase each year. Such restrictions and regulations limit the rail companies’ influence on the sector outputs (passenger kms). This means that sometimes the rail companies’ target is not to increase their productivity but to produce the target outputs at a minimal cost. Last but not least, the cost function uses an econometric model to provide estimates of the underlying structure of production/costs (i.e. elasticity for

[7] Cobb-Douglas production function can be shown as $Total\ production = Total\ factor\ productivity * Labour\ input^{\beta} * Capital\ input^{\alpha}$

different cost drivers). Such model outputs cannot be derived by other approaches like DEA unless DEA involves a second step with an econometric approach, in which case, the cost function is more transparent compared with a two-stage approach.

Based on the above considerations, the cost function approach was selected to assess the cost efficiency of the railway system in this thesis. Mizutani et. al. (2013), van de Velde, Nash et al. (2012), and Mizutani, Smith et al. (2015) are the key entry points of this thesis. In the work of Mizutani and Uranishi (2013) and Mizutani, Smith et al. (2015), Mizutani aimed to analyse the impact of structural separation policies, especially the impact of vertical (operation-infrastructure) and horizontal (passenger-freight service) separation on the industry cost. The total cost function was used for the data from 23 European and East Asian OECD countries between 1994 and 2010. The VI regime was found to have a higher cost compared to the HC regime, although the cost reduction effect of the HC regime is small. The train density within vertically separated railway organisations can also influence the total rail cost as in VS where a higher train density tends to increase the total cost.

van de Velde et al. (2012) conducted a study that built upon and expanded the dataset utilised by Mizutani and Uranishi (2013), offering qualitative and quantitative findings. This study introduced several analytical advancements. First, the inclusion of the United Kingdom in the sample was a significant improvement, as its exclusion had been a limitation in previous studies. In addition, a wide range of test variables were defined to account for different organisational approaches that can be adopted in railway systems, such as vertical integration, vertical and horizontal separation, holding company, and essential functions separation. These characteristics make this report inclusive in terms of the topics covered and the methodologies employed. Moreover, the study provides updated results on the effects of structural and liberalisation reforms. The findings indicate that vertical separation has positive effects on efficiency, particularly when train density is low and the proportion of revenue derived from freight traffic is small. On the other hand, horizontal unbundling and the holding company model are associated with cost reduction independent of other factors. Surprisingly, competition does not appear to have a significant impact on cost reduction, highlighting a potential limitation in the analysis related to the imprecision in attributing the effects of competition. Additionally, the advantages of horizontal separation are described, in part, as being derived from the sale of freight services, a benefit that is not strictly linked to the internal functioning of this structural reform. Another limitation of the study may arise from the computation of the national level of train density for each country, which may not accurately represent the actual variations in train density across different regions.

There have also been studies focused on cost changes in a small number of countries. Smith (2006) found there to be a significant cost impact due to the Hatfield accident post-2002 on British railways. Nash, Nilsson et al. (2013) compared the historical rail data in Britain, Sweden and Germany and also found that the complete VS regime (in Britain) may increase the cost and the requirements for government support compared to the accounting separation model in Germany. Similarly, Filippini et al. (2005) investigated the efficiency of Swiss railway companies, using stochastic frontier models to assess the impact of regulatory reforms on cost efficiency over 13 years. Smith and Wheat (2012) provided new evidence concerning the impact of passenger rail franchising on productivity and costs in Britain, which shows that although franchising in Britain increases cost, it may also improve the service quality and productivity as shown in more recent years (2006 - 2008). Extending this analysis, Preston and Robins (2013) evaluated the long-term welfare effects of Britain's passenger rail privatisation, finding a significant rise in costs, offset by consumer benefits from improved services. Cowie (2018) analysed long-term productivity gains in the privatised British passenger rail industry, revealing annual average productivity improvements of around 1% to 1.5% post-privatisation. Smith, Benedetto et al. (2018) used a translog total cost function to investigate the impact of regulation on rail industry costs. The results showed that regulation has a beneficial effect on cost, particularly when associated with VS (and when the train density levels are not too high) and when it is instrumental in creating competition (in passenger rail in particular).

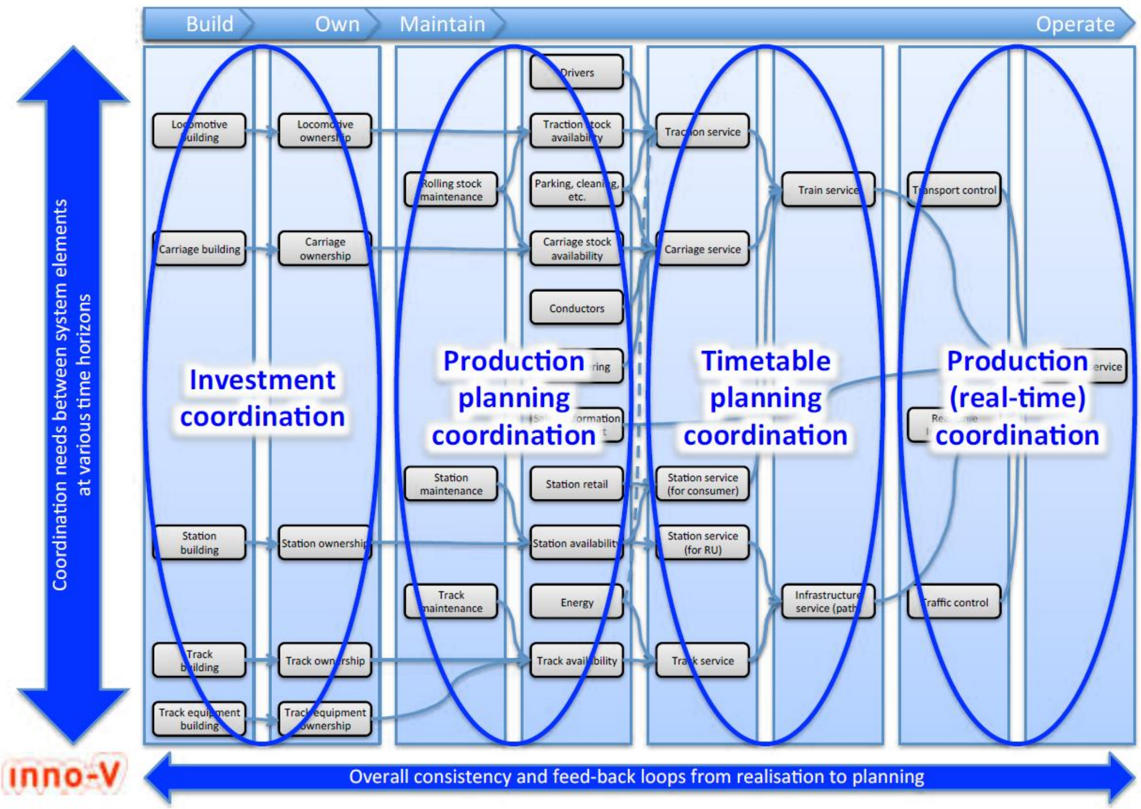
Transaction cost and misalignment issues are the two areas assumed as the key factors that can increase the associated costs by van de Velde, Nash et al. (2012), and Mizutani, Smith et al. (2015). Transaction cost is defined as the cost generated by the activities relevant to the contracts and rights in the rail industry. The transaction cost economics by Williamson (1985) and its application to the rail industry by Hori (1996) and Preston (2002) provide the theoretical arguments for vertical separation and integration. One challenge in the transaction cost analysis is defining and collecting the transaction costs separately from the total cost. Merkert (2007) tried to explain the rising costs in vertically separated rail companies using transaction costs in their studies, i.e. Merkert, Smith et al. (2012) and Merkert and Nash (2013). Merkert, Smith et al. (2012) applied a bottom-up model to investigate the transaction costs in Britain, Germany and Sweden. The vertically separated companies in Britain and Sweden were found to have higher transaction costs than the holding separation companies in Germany, although this only contributed to a very small proportion (3% - 4%) of the total cost.

Misalignment issues such as disruptions and maintenance rescheduling are not easy to measure directly as one variable in the econometric model due to the various industry structures and policies in different countries. van de Velde, Nash et al. (2012) provided a qualitative analysis of the potential misalignment issues between different rail organisations (i.e. RU and IM). Using a transaction-based approach, van de Velde et al. developed a generic model to describe the main production processes in the rail industry. The generic model includes the main sectors and functions in the rail industry which are grouped under four coordination headings: investment, production planning (traincrew levels), timetable planning and real-time coordination (see Figure 4). Table 2 shows the areas with potential misalignments within each coordination as discussed in the works of van de Velde, Nash et al. (2012) and Nash, Smith et al. (2014). The misalignments do not only exist in the VS regime but also in the HC and VI regimes. However, the integration model has been found to solve some of the misalignments more effectively than the VS regime. For example, the

Swiss case of the Rail2000 service improvement programme shows how large-scale investments can be coordinated within an integrated railway structure (van de Velde, Nash et al. 2012).

In the work of Mizutani and Uranishi (2013) and Mizutani, Smith et al. (2015), the conclusion of the train density's impact on cost in a vertically separated organisation seems to indicate that there are worse misalignment issues in the short-term coordination including disruption handling, timetable planning coordination and production (real-time) coordination. The disruptions are costly (both time and money) in the VS regime, which can explain the rise in cost according to one perspective (more time and money may be wasted with disputes between RU and IM). Based on this point, this thesis aims to extend the investigation to consider the potential misalignment issues in long-term coordination, specifically investment coordination. A new variable, infrastructure investment intensity, is introduced to examine the existence of such misalignment issues in investment coordination and to identify variations across different structural separation regimes.

Figure 4 - Generic Model of 4 Co-ordinations in a Railway System



Source: EVES report - Economic effects of Vertical Separation in the railway sector (van de Velde, Nash et al. 2012)

Table 2 - Areas of Misalignment Issues Across the Coordination Circles

Investment Coordination	Production Planning Coordination	Timetable Planning Coordination	Production (Real-time) Coordination
• Extension / decommissioning • Upgrading/downgrading	• Quality of resources and reliability • Small/medium scale investments	• Maintenance/renewal versus operations • Timetable robustness	• Disruption handling • Feedback loops

Source: EVES report - Economic effects of Vertical Separation in the railway sector (van de Velde, Nash et al. 2012)

As a summary, Table 3 below lists the relevant literature and the conclusions from each. There are a few gaps in the literature. First, there are only a few studies focused on investigating the factors leading to the differences in cost efficiency between the different regimes (either VS or HC). Second, 2010-11 is the most recent year of data covered in the literature which cannot therefore capture the effect of the latest reforms in many countries. The present thesis aims to fill in the above gaps by introducing an econometric model including more recent data and extending the framework of analysis to focus on investment coordination/misalignment costs and how these might vary across different vertical structures. The previous literature (e.g. Mizutani et. al. (2013), van de Velde, Nash et al. (2012) and Mizutani et. al., (2015)) have focussed their econometric estimation more on the production, timetabling and real-time coordination impacts, through exploring the relationship between the cost of different cost structures and train density specifically. The investigation is expanded by considering potential misalignment issues in long-term coordination, specifically investment coordination. To achieve this, a new variable, infrastructure investment intensity, is introduced to investigate whether such misalignment issues exist in investment coordination and whether there are variances across different structural separation regimes. If the extension and upgrading of the network introduce misalignment costs as assumed, then a higher intensity of infrastructure investment should lead to more of an increase in the total cost for the VS regime compared to the other regimes (HC and VI). Based on this hypothesis, the data and modelling approach adopted will be introduced in Chapter 3.

Table 3 - Summary of the literature

Literature	Efficiency	Reform characteristics	Methodology	Sample and period	Findings
Asmild, Holvad et al. (2009)	Technical (operating) efficiency	Accounting separation, complete separation, independent management, passenger competitive tendering, freight market opening	MEA	23 EU railway systems, 1995-2001	The EU Rail reforms improved the efficiencies of both the material and staff costs. Accounting separation had the strongest effect on reducing costs.
Cantos and Maudos (2001)	Cost and revenue efficiency	None, pure comparison between countries	SFA (half-normal model)	16 EU railway companies, 1970-1990	The revenue inefficiency was quantitatively greater than the cost inefficiency for most countries in the sample which may be explained by the strong policy of regulation and intervention reigning.
Cantos, Pastor et al. (2010)	Technical efficiency	Accounting separation, institutional separation, organisational separation, passenger competitive tendering, freight market opening	DEA, Malmquist Productivity Index and Tobit	16 EU railway systems, 1985-2005	Countries with the greatest improvements in efficiency are those that have restructured their networks vertically and also allowed for the entry of new operators.
Friebel, Ivaldi et al. (2010)	Technical efficiency	Separation of infrastructure from the operator, third-party access, independent regulatory entity	Regression (Linear Structural Relations and OLS)	11 EU railway systems, 1980-2003	The EU Rail reforms generally improve the rail technical efficiency in which deregulation is found to contribute to the improvement.
Growitsch and Wetzel (2009)	Technical efficiency	Integration, virtual integration and non-integration	DEA	54 EU railway companies, 2000-2004	Vertical integration yields better efficiency results in the mid-term due to the more efficient leveraging of economies of scale.
Lerida-Navarro, Nombela et al. (2019)	Technical efficiency	Rail liberalisation index	DEA, SFA and Tobit regression	27 EU countries, 2002-2011	All aspects of the rail sector liberalisation have positive impacts on rail efficiency in which competition is found to be the most important aspect.
Merkert, Smith et al. (2012)	Cost (transaction cost) efficiency	None	Bottom-up model for a transaction cost	42 rail companies in Germany, Sweden and Great Britain, 2006-2007	Transaction costs are equivalent to a maximum of around 3% of the total operating cost. Vertical separation introduces more transaction costs than the HC regime.

			measurement analysis		
Mizutani and Uranishi (2013)	Cost efficiency	Vertical separation, horizontal separation	Translog cost function	30 EU and East Asian rail companies, 1994-2007	Horizontal (passenger-freight) separation appears to reduce railway costs. Overall, the vertical separation effects paired with a lower train density tend to reduce the total railway cost.
Mizutani, Smith et al. (2015)	Cost efficiency	Vertical separation, horizontal separation, holding company, freight railway market opening, competition level in passenger railway	Translog cost function	33 EU and East Asian rail companies, 1994-2010	Focuses on the difference between full vertical separation and the holding company; finding that the holding company is cost-reducing compared to full vertical separation for busier railways (and vice versa for lightly used railways). A significant share of freight traffic generated additional costs in the case of full separation.
van de Velde, Nash et al. (2012)	Cost efficiency	Vertical separation, horizontal separation, holding company, freight railway market opening, competition level in passenger railway	Translog cost function	33 EU and East Asian rail companies, 1994-2010	Vertical separation works best for lower-density railways. At the same time, a higher proportion of freight running on the network leads to a smaller cost-reduction effect from vertical separation.
Oum and Yu (1994)	Technical efficiency	None, pure comparison between countries	DEA and Tobit	19 railway systems (EU and Japan), 1978-1989	Railway systems with low dependence on subsidies and a high degree of managerial autonomy from the regulatory authority tend to achieve higher levels of efficiency.
Smith (2006)	Cost efficiency	None, analysis for GB only	TFP and translog cost function	British Railway, 1963-2003	The Hatfield accident accounted for the cost rise among British railways. However, the higher cost did not lead to a better level of performance.
Smith, Benedetto et al. (2018)	Cost efficiency	VS, HC, horizontal separation, freight railway market opening, passenger railway competition, regulation index	Translog cost function	17 EU rail companies, 2002-2010	Strong regulation together with vertical separation can lead to cost reductions, even with higher train density levels than envisaged in the previous studies.
Tomikawa and Goto (2022)	Cost, Operational, Revenue-earning, and Profit-earning efficiency	None, analysis for Japan Railway only	DEA	JNR 1965 – 1986; Six Japan railway companies, 1987 - 2017	Revenue-earning efficiency had drastically increased before the privatisation but only slightly increased thereafter. Cost efficiency had drastically decreased before the privatisation, and became almost invariant after.

2.2 Literature on Rail Demand

This sub-chapter provides a review of the literature on rail demand, with a particular focus on the impact of structural reform on rail demand. Specifically, it begins by exploring the literature that examines the correlation between rail mode share and structural reform, which is most relevant to the research objective. Such literature utilises econometric models to estimate the effect of regulatory and institutional changes on the share of rail in the transport market. Section 2.2.1 will then review this literature and aim to provide a summary of the model approach and the key conclusions drawn from these studies. This will serve as a crucial starting point for the analysis of rail mode share, as it lays the foundation for understanding the impact of structural reforms on rail mode share and its implications for transport policy and planning. Another strand of research has focused on identifying the drivers of rail demand. These studies have investigated the various factors that influence passengers' choices to use rail transport, such as travel time, cost, convenience, and service quality. This section will draw on the insights gleaned from these studies to inform the econometric modelling of rail mode share.

On the other hand, despite the growing interest in rail mode share analysis, there is no consensus on the appropriate functional form of the models used. To address this issue, Chapter 2.2.2 examines the literature on demand and mode share analysis for other transport modes to understand: a) the demand drivers that are considered, and b) the previous functional form utilised to investigate the influences on transport mode share. By considering these approaches, this research aims to identify an appropriate functional form for the econometric model of rail mode share.

As the analysis focuses on econometric modelling, this chapter primarily concentrates on literature that employs this approach. Through this review, the aim is to provide a comprehensive understanding of the existing literature on rail mode share and demand, which will inform the ongoing research and contribute to the wider discussion on transport policy and planning.

2.2.1 Literature on the Impact of Structural Reform on Rail Mode Share

This section introduces previous studies focusing on the correlation between rail reform and mode share. Given the limited number of studies in this area, the review will cover the methodology used and the conclusions drawn from each piece of literature.

Most studies in this area have used rail mode share as the dependent variable, and have used econometric models to estimate the effect of regulatory and institutional changes on the share of rail in the transport market. However, the results of such studies have varied considerably. For example, Laabsch and Sanner (2012) analysed whether full ownership separation strengthens rail in comparison with other transport. In that study, data from nine European countries in the period 1994-2009 were analysed using regression techniques, with passenger and freight rail mode share specified as the dependent variables in separate models. The test variables included vertical structure variables, public budget contributions, GDP per capita, liberalisation, regulation and share of rail in total transport budgets. It was found that full separation was associated with significantly reduced mode share for passenger rail, whilst for freight rail, the regression derived ambiguous results. This finding suggests that vertical separation may not be an effective strategy for increasing rail mode share.

In contrast, the most recent study in this area, Mizutani and Uranishi (2020), found that vertical separation may increase passenger rail share. Mizutani and Uranishi used simultaneous equation models to analyse the impact of rail structure reform and regulation on rail mode share, which included panel data encompassing 29 OECD countries from 1995 to 2013. There are two contributions from this literature. Firstly, it is the first study to discuss the functional form of the rail mode share model and provide some theoretical evidence for choosing the log-log form model. The use of log-log transformations facilitates the estimation of elasticities directly, allowing for a more intuitive interpretation of the proportional change in the dependent variable in response to a proportional change in an independent variable. This provides theoretical support for the choice of functional form, which will be discussed specifically in Chapter 4. However, the decision to employ log-log transformations can depend on the nature of the data, the specific research question, and the underlying assumptions of the model. Additionally, by incorporating a diverse range of control variables such as rail price, network characteristics, and competition, this literature offers valuable insights into potential variables for consideration in the econometric model. Concerning the conclusions of this study, it found a positive impact of vertical separation on passenger rail mode share. Rail price and fuel price were found to have an association with rail mode share effectively. Gasoline and diesel prices were found to affect passenger rail mode share oppositely due to the wide usage of diesel trains in rail.

Not all studies have found a significant impact of structural reform on rail mode share. van de Velde et al. (2012) developed a fixed-effect econometric model to analyse rail mode shares in both passenger and freight transport. The fixed effects approach is appropriate when individual or entity-specific time-invariant characteristics might bias the predictor or outcome variables. The fixed effects model effectively controls for these potential biases. On the other hand, the random effects model is suitable if individual/entity-specific effects are uncorrelated with the regressors, often used when entities are considered random samples from a larger population. Based on data covering 26 OECD countries over the years from 1994 to 2010, the econometric model in van de Velde et al. (2012) used rail mode share as the dependent variable and rail structure (VS, HC and omitted VI) as the test variables. No evidence was found that the VS regime is superior to the HC regime, in terms of the impact on rail's mode share in freight or passenger transport. Similarly, Tomeš (2017) used a fixed-effect regression model with data from 27 European countries from 1995 to 2013 and found no evidence of vertical separation's impact on rail mode share. However, Tomeš (2017) did find horizontal separation to be a more promising strategy to increase rail mode share, especially when followed by the privatisation of freight operations. This is perhaps because privatisation bestows greater managerial and financial independence to freight divisions and eliminates internal cross-subsidies between freight and passenger divisions. These reform measures can be especially beneficial for rail freight.

In addition to structural reform, some other policies have also been found to influence rail mode share. Esposito et al. (2020) assessed the impact of rail liberalisation policy reforms in the EU by using a Prais-Winsten regression model. The Prais-Winsten model is a statistical technique designed to correct for autocorrelation in panel data. Autocorrelation issues in freight data are due to their close ties with economic activities and industrial production cycles. This analysis covered 21 EU countries from 1993 to 2013, revealing that reduced regulatory constraints in the EU railway sector were associated with an increase in freight rail mode share.

To summarise, studies that have used econometric models to analyse the effect of regulatory and institutional changes on rail mode share have produced varying results. For example, Laabsch and Sanner (2012) found that full separation reduces passenger rail mode share, while Mizutani and Uranishi (2020) found a positive impact of vertical separation on passenger rail mode share. Furthermore, there is evidence to suggest that horizontal separation may be a more promising strategy to increase rail mode share, particularly when followed by the privatisation of freight operations. This is because privatisation can provide greater managerial and financial independence to freight divisions and eliminate internal cross-subsidies between freight and passenger divisions. Other policies have also been found to influence rail mode share, such as rail liberalisation policy reforms. Studies have found that a lower level of regulatory provision in the EU railway sector led to an increase in freight rail mode share. In addition to structural reforms, the price of rail and fuel has also been found to have a significant association with rail mode share in Mizutani and Uranishi (2020). Concerning the approach used in the literature, econometric models with panel regression have generally been used to analyse the impact of rail structure reform and regulation on rail mode share. Mizutani and Uranishi (2020) provided some theoretical evidence for choosing the log-log form model. Control factors such as rail price, network characteristics, and competition have been incorporated into the econometric model. **Table 4** below provides a summary of the model approach and findings from the literature.

Overall, the literature indicates that there is no one-size-fits-all solution to increase rail mode share. The success of structural reform measures in increasing rail mode share depends on a variety of factors, including the type of structural reform and the specific characteristics of the transport market. Policymakers must consider these factors when designing and implementing structural reform measures to increase rail mode share.

Table 4 - Rail Mode Share Literature Summary

Literature	Approach & data	Findings
Laabsch and Sanner (2012)	Random effect panel regression; Dataset included nine countries from 1995 to 2009	Full separation significantly reduced passenger rail mode share, while the regressions derive ambiguous results in the freight segment
van de Velde et al. (2012)	Fixed effect panel regression; Dataset included 26 OECD countries from 1994 to 2010	No evidence was found that vertical separation is superior to holding company in the impact on rail's mode share in freight or passenger transport
Tomeš (2017)	Fixed effect panel regression; Dataset included 27 European countries from 1995 to 2013	Separate freight from passenger rail was found to be a more promising strategy to increase rail mode share, especially when followed by the privatisation of freight operations.
Mizutani and Uranishi (2020)	Three-stage least squares, with a log-log model in each stage's regression; the Dataset included 29 OECD countries from 1995 to 2013	The vertical separation had a positive impact on passenger rail mode share. Rail price affected passenger rail mode share negatively.
Esposito et al. (2020)	Prais-Winsten regression model with panel data of 21 EU countries from 1993 to 2013	A lower level of regulatory provisions in the EU railway sector led to an increase in freight rail mode share

2.2.2 Relevant Literature on the Demand Analysis of Rail and Other Transport Modes

As the primary objective of this thesis is to examine the interplay between rail demand drivers and separation regimes and their potential impact on rail mode share, this sub-chapter presents a review of prior research that explores the demand drivers specific to railways as well as other modes of transportation. By delving into the existing literature, this thesis enhances the understanding of the key factors influencing rail demand and their relationship to various separation regimes. Additionally, by introducing literature on alternative transport modes, insights into the demand drivers and quantitative methodologies employed for mode share analysis in previous studies can be gained. This literature will provide the thesis with theoretical evidence about the examination of mode share/choice, thereby addressing the shortage of existing literature on the approach employed for rail mode share analysis.

The literature reveals that rail demand drivers can be divided into two categories: exogenous and endogenous drivers. In Great Britain, the Passenger Demand Forecasting Handbook (PDFH) employs a consistent set of categories to represent the demand drivers (ATOC, 1997). PDFH stands out among railway administrations globally as it has been offering a comprehensive framework and recommended parameters (i.e. elasticities for demand drivers) for rail demand forecasting since 1986 (RDG, 2018). Moreover, PDFH is regularly updated to incorporate emerging evidence. Exogenous drivers are factors that affect rail demand but are not in the command of the railways, such as GDP, employment, population, fuel price, and car ownership. Previous studies have demonstrated the significant influence of these economic factors on rail demand. For instance, Wardman (2006) identified GDP as the primary driver of rail demand in Great Britain, while population growth also had a notable impact. Additionally, the specific effects of employment and population on different ticket types were observed in Wardman et al. (2019).

Economic factors can also influence rail mode share; however, their influence may sometimes be contrary. Bresson et al. (2003), Bresson et al. (2004), and Toro-González et al. (2020) all found a negative correlation between income and public transport demand. This suggests that public transport, including rail, can be considered an inferior good. Fuel price and car ownership represent competitive modes of transport compared to rail and are typically considered in rail demand and public transport demand analyses. Wardman (2006) discovered that both fuel costs and car ownership significantly impacted rail demand, a finding corroborated by Delsaut (2014), Bresson et al. (2004) and Wardman et al. (2019). Moreover, Wardman’s econometric and survey-based approaches revealed the limited influence of additional costs associated with motoring, such as parking and tolls, on motoring behaviour (i.e. car journeys). This indicates that factors like parking and tolls beyond fuel costs have a minimal effect on rail demand levels.

Endogenous drivers, on the other hand, are internal factors that relate to the cost and time of a rail journey, including fares, journey time, and service quality. Previous studies have found that rail fare was a somewhat complex driver of demand. Firstly, it is important to recognise that the impact of rail fares on demand can vary across different geographic areas as well as ticket types (Wardman, 2006; Wardman et al., 2019). For instance, Wardman (2006) conducted an examination of rail fare elasticities in different geographic areas of Great Britain, namely London, Non-London, and South East. This aligns with the categorisation employed in the Passenger Demand Forecasting Handbook (PDFH) as well (RDG, 2018). Competition between ticket types has also been shown to have an impact on rail demand levels in Great Britain by Toner et al. (2020). Toner et al. combine analysis of ticket sales data with market research to provide a comprehensive understanding of consumer behaviour, with a particular focus on the estimation of ticket-specific own-elasticities and cross-elasticities. Research has also shown that the complexity of fare structures and ticket types can affect rail demand (Anciaes et al., 2019), as it increases search cost and risk, which may lead to a negative effect on demand.

Understanding the impact of fare changes on the other types of public transport demand is crucial for analysing rail mode share dynamics. While the primary focus of this thesis is on rail transport, insights from other public transport modes offer valuable context. For example, Toro-González et al. (2020) and Bresson et al. (2003) also found a notable impact of fare changes on public transport demand in Colombia and Europe respectively. Toro-González et al. utilised aggregated choice models based on random utility theory and relied on data from the Urban Transport Passenger Survey conducted by the Colombian National Statistics Bureau. The analysis includes information on different transport modes, including BRT, and incorporates variables such as speed, frequency, and fares to examine demand determinants. Based on the panels of English counties and French urban areas, Bresson et al. (2003) considered bus service only in the data for England, while for France other modes are also included (e.g. regional train in Paris, metro in Paris, Lyon and Marseille, the light rail system in Lille, tramways in Lille, Nantes, Strasbourg, Grenoble, Saint-Etienne and Rouen). Notably, Bresson et al. also discovered that improvements in service quality and availability could counterbalance fare increases without adversely affecting patronage. In other words, enhancing public transport services can potentially mitigate the negative effects of fare adjustments. This finding suggests the existence of potential cross-impacts among external demand drivers.

Journey time and service quality are crucial demand drivers that have been investigated in the literature. For example, the impact of transfer time (waiting time between connecting services) on demand was investigated by Román and Martín (2014) and Wardman (2001), whilst Wardman and Tyler (2000) focused on the access and egress time’s influence. Sometimes, they are discussed together because travel time is the appropriate factor to quantify service quality (i.e. convert service quality to equivalent journey time). A good example of this approach is the usage of Generalised Journey Time (GJT). GJT is a unique concept within the British railway industry. It has been employed since the early days of forecasting applications in the 1970s to encapsulate the overall quality of a train service about its timetable. GJT encompasses several components, including the time taken for travel between stations, any additional time required for interchange, a penalty to account for the inconvenience of not being able to travel at the desired time (frequency penalty), and a penalty for each train change during a journey. The development of GJT was driven by recognition of the need to capture the overall attractiveness of diverse train services. This includes services with a mix of limited through connections, various speeds and numbers of required connections for connecting services, and highly irregular intervals between departures. While service patterns have become more standardised over time, with greater uniformity in journey time, interchange, and departure times, GJT remains an essential representative measure. GJT serves as a comprehensive metric to evaluate the overall service quality of train journeys, accounting for multiple factors that influence passenger experience. By aggregating various components of the travel experience, GJT offers a holistic view of journey time and service quality. Wardman (2006) particularly discussed the demand impact (elasticities) of GJT in Great Britain. Meanwhile, Wheat and Wardman (2017) used a more simplified formulation of combining GJT and fare into a single index called Generalised Cost (GC). The underlying assumption behind GC is the assignment of a value to time, enabling the conversion of journey time into an equivalent monetary cost. By condensing two critical factors influencing passenger travel decisions—time and cost—into one comprehensive metric, it facilitated a more straightforward assessment of the trade-offs between time and money that passengers implicitly make when choosing rail services. The choice between GJT and GC is mainly based on the model fit of the econometric model, which may be influenced by the dataset (i.e. geographic area, ticket type considered, etc.). On the other hand, institutional factors frequently guide this decision. These factors can encompass data availability, policy objectives, and the preferences of decision-makers and stakeholders, making one metric more favourable over the other in certain contexts.

The existing GJT index does not take into account the impact of service attributes, such as crowding, rolling stock quality, and travel time reliability, on demand. This limitation arises from the fact that these attributes are mainly derived/analysed from station-to-station movement data. This presents challenges such as the absence of historical data, insufficient level of detail, and measurement difficulties (Wheat and Wardman, 2017). These challenges necessitate treating reliability and punctuality as independent demand drivers in previous studies, as detailed historical and granular data that might allow for their direct inclusion in broader indexes like GJT or GC are frequently lacking. Abate et al. (2013) found that punctuality could have a positive impact on productivity in passenger rail, such as increasing the total passenger demand or passenger-kilometres, in several European countries. However, Wardman and Batley (2021) and Batley et al. (2011) arrived at a different conclusion, stating that performance improvements may have a limited impact on patronage.

Policy factors like competition within the passenger rail market can also be considered endogenous demand drivers, although it is typically influenced by other intermediate factors such as rail fares and service quality. For example, the competition within the passenger rail market in the Czech Republic has led to a price war between train operators (Tomeš et al., 2014) and an increase in total passenger rail demand. Similarly, open access competition has been found to affect rail prices in Milan, Italy (Beria et al., 2016), by reducing the incumbent's fares in response to the entry of a competitor. By examining these previous studies, it becomes clear that many complex and interrelated factors contribute to rail demand. This thesis will build upon this knowledge to investigate the interaction between demand drivers and separation regimes.

The literature extensively utilises panel data regression and choice models to analyse rail demand, drawing on their ability to incorporate both cross-sectional and time-series data, a feature highlighted in studies by Bresson et al. (2004), Wheat and Wardman (2017), and Toner et al. (2020). Panel data regression is particularly valued for its versatility in capturing the dynamics of rail demand over time and across different geographic locations, offering a robust framework for understanding the effects of policy changes and market conditions on rail usage, as demonstrated by Batley et al. (2011) and Wardman et al. (2019). The use of logarithmic transformation in panel regression analyses simplifies the interpretation and comparison of results across various contexts by producing constant demand elasticities. This methodological approach not only enhances the clarity of policy implications but also enables researchers and policymakers to draw reliable conclusions about the factors influencing rail demand. Moreover, the inclusion of choice models complements this analysis by providing a deeper understanding of individual decision-making processes related to rail travel, emphasising the importance of these methodologies in constructing a comprehensive picture of rail demand.

Choice modelling is extensively used in transportation research to understand passenger mode choice, particularly for valuing attributes such as lateness and reliability. While the primary application of discrete choice methods has been to quantify passengers' valuations of these attributes - thus offering insights into their preferences - these models also indirectly support forecasting by revealing how changes in service quality could influence future travel behaviour. Discrete choice methods effectively quantify passengers' preferences, as highlighted by Batley et al. (2007, 2008a) and Batley and Ibáñez (2009), demonstrating that season ticket holders significantly value punctuality more than occasional travellers. Among logit models, the Binary Logit is utilised for binary outcomes ('Yes' or 'No'), while the Multinomial Logit (MNL) addresses choices among multiple modes, such as car, bus, and train. The Mixed Logit (ML) model extends MNL to account for unobserved heterogeneity, recognising that individuals might make choices based on factors not explicitly included in the model. This suite of models provides a toolkit for analysing and forecasting travel behaviour, underlining the versatility and depth of choice modelling in understanding and predicting the nuances of passenger preferences and mode selection.

Choice modelling seems to be popular in the other transport modes too. Toro-González et al. (2020) analysed Urban Transport Passenger Survey data to examine demand determinants for various transport modes, including BRT, using variables like speed, frequency, and fares. Neal and Koo (2020) used a freight choice model to investigate users’ mode choices for cargo airships. Suzuki et al. (2001) compared three types of models, namely linear regression, Cobb-Douglas, and linearised logit models, against the chosen model type, namely the asymmetric-response model. The latter model was similar to the linearised logit model but specified the difference (gain and loss) between each airline's service quality/price and the market reference point (median point of the market) as separate variables in the model. Another study conducted by Babić et al. (2014) estimated the airline market share at a specific airport using multiple linear regression and fuzzy logic. Compared to the Logit model, fuzzy logic allowed the dependent variable to have multiple values instead of just zero and one. Thus, the dependent variable was defined as different levels of market share (i.e., high, medium, and low) in the fuzzy logic used in this study.

2.2.3 Summary

The literature on rail mode share analysis is limited and generally employs econometric modelling, such as panel regression, to investigate the influence of various factors on demand. Control variables, including GDP and employment, are commonly included, along with the investigation of the impact of structural reform. However, the conclusions drawn from this literature are not always consistent, particularly in terms of whether vertical separation affects rail mode share. Some studies have found that vertical separation (full ownership separation) is associated with reduced mode share for passenger rail, while others have found ambiguous results for freight rail. Nonetheless, a recent study, Mizutani and Uranishi (2020), indicates that vertical separation may increase passenger rail mode share. On the other hand, Tomeš (2017) found horizontal separation (i.e., separation of operations, such as freight and passenger) combined with freight operation privatisation has shown promise for enhancing rail mode share. Other policies, such as rail liberalisation reforms, have also been found to influence rail mode share positively. The review highlights that there is no consensus on the appropriate functional form of the models used in these studies.

In the review of demand analysis for rail and other transport modes, exogenous drivers include economic factors like GDP, employment, population, fuel price, and car ownership, which have been demonstrated to significantly affect rail demand in prior research. The relationship between income and rail demand is complex and can vary by context. While some studies suggest a negative correlation in specific scenarios, indicating rail as an inferior good, this is not a universal finding. In some urban and high-income areas, such as London, rail travel can be seen as a desirable mode of transportation, with demand increasing alongside income. This is exemplified by the significantly higher rail commuters (both numbers and mode share) in London compared to other cities (Department for Transport, 2023).

In the analysis of rail demand, fuel prices and car ownership are considered significant factors, reflecting alternative transport options that compete directly with rail. Endogenous drivers encompass factors related to the cost and duration of a rail journey, such as fares, journey time, and service quality. The variability of rail fare's influence on demand is distinct across different geographic areas and ticket types, where the complexity of rail fare structures and the competitive dynamics between various ticket options can also affect rail demand patterns. Journey time and service quality are also significant demand drivers. Some studies employ GJT and GC to assess the overall service quality and attractiveness of train journeys.

Regarding methodology, panel regression with fixed or random effects has been used to specify the econometric model in the literature. Conversely, discrete choice methods (e.g., various logit models) have been employed in rail and other transport mode studies, as evidenced by Batley et al. (2007, 2008a), Batley and Ibáñez (2009), Toro-González et al. (2020), and Suzuki et al. (2001). Discrete choice methods are generally employed to value how individual-level factors such as lateness and reliability influence travel behaviour, focusing on understanding and quantifying passengers' preferences and willingness to pay, rather than predicting overall market trends or demand forecasts.

This thesis selects several factors based on data availability and previous literature. Additionally, it introduces the interaction between some of these variables and structural reform variables to investigate their multivariate effects on passenger rail mode share. This represents a creative contribution to the literature and enables us to distinguish the specific impact of structural reform on rail mode share. Considering the findings of previous literature that punctuality had a limited impact on rail demand (see Batley et al., 2011) and the limited availability of punctuality data from European rail companies, punctuality was excluded from this thesis.

It is worth noting that the specification of econometric models has varied across studies. In particular, some studies have utilised fixed effects while others have used random effects. Additionally, there is no consensus regarding the use of log-log transformed variables. However, these models provide a useful framework for analysing rail demand, particularly when considering the impact of structural reform. It is also important to consider the limitations of data availability (i.e. limited punctuality data) when selecting variables to include in the model. This thesis aims to contribute to the literature by investigating the multivariate effects of various factors on rail demand, particularly in the light of structural reform.

3. Empirical Analysis – Cost Effect of Rail Structural Reform

This chapter explores the costs associated with introducing structural reforms in the rail sector. The analysis is based on the dataset that covers railway organisations in Europe and East Asia OECD countries from 1994 to 2017. The aim is to understand the effects of unbundling methods, such as vertical and horizontal separation, on total rail costs. The dataset was originally compiled by Mizutani and Uranishi (2013), and then further enhanced by Mizutani et al. (2015) and van de Velde et al. (2012). The chapter aims to examine the relationship between organisational structures and their cost efficiency, with a particular focus on the impact of rail infrastructure investment under different organisational frameworks. The **hypothesis** is that vertical structure increases total cost through misalignments generated from long-term coordination (i.e. investment coordination) between RUs and the IM. This research utilised the translog cost function, a flexible econometric model that facilitates the examination of the relationships between costs, outputs, and input prices, to comprehensively assess the cost effects of rail structural reform.

3.1 Data

The data analysed in this chapter uses, as a starting point, a dataset developed originally by Mizutani and Uranishi (2013) and then enhanced by Mizutani et al. (2015) and van de Velde et al. (2012). Mizutani and Uranishi (2013) aimed to assess the impact of different unbundling methods, specifically vertical separation and horizontal (passenger-freight) separation, on cost differences under relatively similar conditions. To ensure a comparable sample, they focused on railway organisations in European and East Asian OECD countries between 1994 and 2007. Initially, all OECD countries within this timeframe were considered. However, the United States, Canada, and Australia were excluded due to their distinctive network conditions, such as long line hauls, and the significant presence of freight services in their railway industries. Additionally, Mexico and the UK were excluded due to the lack of data available from the International Union of Railways (UIC) database. In the case of Japan, Mizutani and Uranishi treated each Japanese rail company separately to avoid estimation bias that could arise from combining them into one large rail organisation. This approach is followed in this thesis. To enhance the dataset from Mizutani and Uranishi (2013), van de Velde et al. (2012) incorporated British data into the sample, considering the substantial vertical and horizontal separation that occurred in Britain. Furthermore, van de Velde et al. updated the dataset beyond 2007, extending it up to 2010 whenever possible. To achieve this, van de Velde et al. sent a questionnaire to all CER (Community of European Railway and Infrastructure Companies) members, gathering new data and validating the existing data. In this thesis, the dataset is expanded to 2017, which not only increases the sample size but also observes the lasting impact of the most recent reforms (e.g., see the French Rail example below). The rail companies and years involved in the dataset are shown in Table 5.

The definition of structural reform in this chapter aligns with Mizutani and Uranishi (2013) and is based on the classification of railway organisations by the UIC (International Union of Railways). The UIC categorises railway organisations into five groups: (1) integrated company, (2) railway undertaking (i.e., passenger and freight operators), (3) passenger operator, (4) freight operator, and (5) infrastructure manager (i.e. organisation responsible for providing infrastructure). According to the UIC classification, a vertically integrated firm refers to a company that provides rail operations while also managing its infrastructure. Conversely, a vertically separated firm consists of a railway undertaking and an infrastructure manager as distinct entities.

In this chapter, a rail operating company is classified as vertically separated depending on whether it is institutionally separated from the infrastructure company – this aligns with the approach in Mizutani and Uranishi (2013). However, it is important to note that vertical separation can manifest in various forms, which can create challenges in data collection related to competition/regulatory environments or the extent of governmental influence. Thus, this chapter acknowledges cases where a rail operating company has a separate accounting system from the infrastructure company, even if they belong to the same institution. This scenario is referred to as the Holding Company regime. In such cases, despite being part of the same institution, the rail operating company and the infrastructure company have separate financial objectives and incentives. These cases are included in the analysis to capture the diverse nature of vertical separation arrangements within the railway industry.

An example illustrating how this thesis considers structural reform is the case of RFF (Réseau ferré de France) in France. In 1997, RFF was established as the entity responsible for owning and maintaining the French national railway network. However, on January 1, 2015, RFF was restructured to SNCF Réseau. Similarly, the operational assets of SNCF were reorganised into SNCF Mobilités. Both entities were then placed under the control of SNCF. In the dataset, SNCF is classified as vertically separated during the period from 1997 to 2014, corresponding to the time when RFF was functioning as the infrastructure manager. However, from 2015 to 2017, SNCF is categorised as operating under a holding company regime. This reflects the reorganisation that took place, with SNCF Réseau and SNCF Mobilités operating as separate entities under the overarching control of SNCF. This classification allows for accounting for the changes in vertical separation arrangements during different periods within the SNCF group.

In addition to vertical separation variables, a dummy variable was introduced to account for horizontal separation. Horizontal separation refers to the scenario where passenger operations and freight operations are conducted by separate companies, maintaining institutional independence from each other. This variable allowed for the assessment of the impact of horizontal separation on the outcomes under investigation. To examine the effects of competition, passenger and freight market competition dummy variables were included respectively. Following the approach from van de Velde et al. (2012), these two variables facilitated an understanding of the influence of competition in the passenger market on the outcomes of interest. By incorporating this dummy variable, the impact of passenger/freight market competition on cost could be assessed.

Regarding the coverage of cost data, the objective is to obtain a measure of total costs for the railway system in each country. This specifically entails incorporating the total infrastructure costs of the main infrastructure manager (in Switzerland, there are two) along with the costs incurred by all passenger and freight operators operating on that main system. For Switzerland, it is recognised that although the two main operators, SBB and BLS, utilise each other's infrastructure, treating them as separate vertically integrated companies does not distort the number of train kilometres assumed to be operated on each system. Small vertically integrated systems, which are numerous, particularly in Switzerland and Germany, are not included. While the study by Mizutani and Uranishi (2012) is based on a sample of companies rather than countries and typically excludes small new entrants (train operators), adjustments are made to address this issue based on the available data. This data-processing approach follows the methodology employed by van de Velde et al. (2012).

Importantly, new variables were added to enable the study of the cost effects of investment under different organisational structures and also to substantially update the dataset in time, which, as noted, is important in studying the impact of reforms given the timing of their introduction in different countries.

Table 5 - Railway Operators and Periods Included in this Chapter

Country	Company	Year
AT – Austria	OBB	1994 - 2017
BE – Belgium	SNCB/NMBS	1994 - 2009
BG – Bulgaria	BDZ	2002 - 2010
CH – Switzerland	BLS	1994 - 2010
CH – Switzerland	SBB CFF FFS	1994 - 2010
CZ – Czech Republic	CD	1994 - 2017
DE – Germany	DB AG	1994 - 2017
DK – Denmark	DSB	1994 - 2009
ES – Spain	RENFE	1994 - 2012
FI – Finland	VR	1994 - 2017
FR – France	SNCF	1994 - 2014
GB – Great Britain	ATOC	1994 - 2017
GR – Greece	OSE	1994 - 2007
HU – Hungary	GySEV/ROEE	1994 - 2013
HU – Hungary	MAV	1994 - 2017
IE – Ireland	CIE	1994 - 2010
IT – Italy	FS	1994 - 2016

JP – Japan	HRC	1994 - 2016
JP – Japan	EJRC	1994 - 2016
JP – Japan	CJRC	1994 - 2016
JP – Japan	WJRC	1994 - 2016
JP – Japan	SHRC	1994 - 2016
JP – Japan	KRC	1994 - 2016
KR – South Korea	KORAIL	1994 - 2017
LU – Luxembourg	CFL	1994 - 2012
LV – Latvia	LDz	2008 - 2010
NL – Netherlands	NS	1994 - 2017
NO – Norway	NSB	1994 - 2009
PL – Poland	PKP	1994 - 2016
PT – Portugal	CP	1994 - 2011[8]
SE – Sweden	SJ	1994 - 2017
SK – Slovakia	ZSSK	1994 - 2007
TR – Turkey	TCDD	1994 - 2016
Total Number of observations		650

Table 6 below explains the key variables Following Mizutani et al. (2015), the cost data was collected from UIC International Railisa Statistics supplemented to some extent by other sources such as individual company accounts. For example, the operating and financial costs data for SJ (Sweden) were collected from SJ's annual report. Additionally, the rail outputs (e.g. passenger-km and tonne-km) data from Eurostat and OECD datasets were compared and calibrated[9] if required. The energy price and consumption data were collected from IEA[10], Eurostat, and company accounts (i.e. JR companies and KORAIL) as they were not available in the UIC dataset after 1990. In some cases, e.g. Japan, the data comprises multiple, regional vertically integrated companies. In other countries, where there has been some form of vertical separation, a single total cost of the rail industry is computed, defined as the sum of the different train operating companies' costs (after subtracting infrastructure charges paid as they are just a transfer payment) and the cost of the infrastructure-providing company (i.e., infrastructure manager). This follows the approach taken by Mizutani et. al. (2015) and the literature in general and reflects the fact that for vertically separated industries it would involve an arbitrary allocation to allocate rail infrastructure costs to the different train operating companies running on the network. That said, it should be noted that some of the vertically integrated companies in Japan are larger than some of the smaller countries in the sample.

[8] The values of infrastructure investment for 2012-2017 were out of line with the values for all other years for Portugal, so the dataset only updates Portugal data to 2011.

[9] For example, some missing or odd data were calibrated by the data from other data sources.

10 "Energy Prices and Taxes" by International Energy Agency (IEA)

All of the cost-relevant data was converted to 2005 prices in euro based on the exchange rate and GDP deflator from Eurostat and OECD. Total cost in this thesis is defined as the sum of costs for labour, energy, material and capital. Total industry costs were collected as infrastructure costs plus train operating company costs, as noted. While calculating the price (i.e., labour price), the average price for the whole industry/company was also considered. Labour cost covers wages and salaries plus social security costs. Material cost includes all the purchases of commodities and external services used as inputs in the production process. Energy cost covers both electricity and fuel costs. Capital cost includes depreciation, financial expenses and the total cost of the infrastructure manager (with infrastructure charges[11] deducted). Since total industry costs are computed as infrastructure costs plus train operating company costs, capital costs for infrastructure are included irrespective of whether the railway is vertically separated or not. However, in the case of vertically separated railways, there is a need to strip out transfer payments (track access charges) to avoid double counting. This follows the same approach as in Mizutani et. al. (2015). Further details on the definitions can be found in Mizutani et. al. (2015). Note that the investment variables on the right-hand side of the model do not directly translate into the cost measure used as the dependent variable since the investment variables are annual cash expenditure measures, whereas the dependent variable includes operating and maintenance costs, and any capital costs are reflected through a depreciation measure of capital costs. The investment variables were also normalised (i.e. divided by, for example, train-km) and interacted with structure dummy variables (see below). Therefore, these methods are considered appropriate means of studying potential misalignment costs resulting from how investment is handled/coordinated under different railway vertical structures.

Although the aim is to model the whole rail system costs for each country, there are some small vertically integrated systems not covered by the dataset (e.g., in Switzerland). Additionally, where there was a lack of data on new entrants' costs, the data were scaled up based on the incumbent companies’ costs and their corresponding passenger and freight market share, with the model then including total industry train-km, rather than only incumbent train-km. This approach follows that of Mizutani et al. (2015). Concerning data calibration, the data from different sources (i.e., Eurostat and individual company accounts like the IM in GB Railway) were compared, and any missing or problematic data were adjusted and calibrated. In situations where data for certain years were missing, extrapolation or interpolation techniques were employed to estimate the values for those missing years. When historical data was available, the trend or pattern observed in the available data was used to make an informed projection for the missing years. Similarly, when data for the following years were available, that information was used to estimate the missing values based on the observed trend. These extrapolation and interpolation methods allowed for approximating the missing data points and ensuring a more comprehensive dataset for the analysis. The refined data represents only a very small proportion of the overall dataset, but it should be acknowledged

[11] Infrastructure charges means the fees charged by the infrastructure manager from the rail companies, such as track access charge. They are excluded from the capital costs to avoid double counting.

that these techniques introduce some level of uncertainty and should be interpreted with caution.

Variables representing technological change over time, the share of freight rail revenue, and rail internal competition (in passenger and freight rail, respectively) were captured as the control variables. In line with the literature, inter-modal competition is not captured. Any effects, if they exist, would be indirect and not possible to measure in a variable with data compiled at the national level, as competition effects would be highly route-dependent. Wider factors such as economic recessions were captured via the output measures in the cost function.

In line with Mizutani and Uranishi (2013), the importance of train density as a significant factor influencing the cost effects of vertical separation was recognised. Therefore, train density was included as a key variable in this thesis as well, which was calculated by dividing the total number of train-kilometres by the total route length of a railway. To ensure consistency, train density was measured on a per-day basis by dividing the annual train-kilometres by 365 days. This approach accounts for variations in train operations throughout the year and obtains a more accurate representation of the density of train activity. The train density variable interacted with the rail structural reform variables.

Importantly, new variables were added that enable the study of the cost effects of rail infrastructure investment under different organisational structures. The rail infrastructure investment intensity was captured by three new variables, *I(a)*, *I(b),* and *I(c),* to measure the intensity of the investment activities (these being important to consider investment coordination under different vertical structures). Here, either train-km, route length (kms), or population was used as the denominator. The infrastructure investment data covered both infrastructure enhancement and renewal (those were not separately identified in the OECD dataset of Transport Infrastructure Investment and Maintenance). As defined in the dataset, it contains the capital expenditure on new railway infrastructure[12] or extension of existing railways (including high-speed rail), including reconstruction, renewal (major substitution work on the existing infrastructure which does not change its overall performance) and upgrades (major modification work improving the original performance or capacity of the infrastructure). For the countries with multiple rail companies (e.g. Switzerland, Hungary and Japan), the total investments in each country were split/allocated to each company in the country based on their revenue size. Given the much smaller size of the new entrants in Switzerland and Hungary (compared to their original incumbents), Japan is the only country affected by this approach. Considering revenue as the primary source for infrastructure investment, especially in contexts like Japan where passenger services predominantly support the railway infrastructure rather than freight rail, adopting revenue-based allocation for infrastructure investment is deemed appropriate. Additionally, an alternative allocation method based on

[12] Here, the word "Infrastructure" includes land, permanent way constructions, buildings, bridges and tunnels, as well as immovable fixtures, fittings and installations connected with them signalisation, telecommunications, catenaries, electricity sub-stations, etc.) as opposed to rolling stock.

train-km was explored, yielding results closely aligned with the initial approach. The specific definition of *I(a/b/c)* is as follows.

- *I(a)* is equal to the total infrastructure investment divided by the total train-km,
- *I(b)* is equal to the total infrastructure investment divided by the total route-km, and
- *I(c)* is equal to the total infrastructure investment divided by the total number of inhabitants (which is the same for all the companies within one country).

In regulated sectors such as the railway industry, output levels, quality targets, and prices are typically determined by economic regulators or governments. These regulatory bodies establish a framework that sets specific targets for outputs and quality, often accompanied by regulated prices. This approach is commonly observed in regulated sectors, as discussed in studies like Coelli et al. (2005) and Friebel et al. (2010). In this context, the exogeneity of train density (measured as train-km/route-km per day) is commonly assumed in the general rail cost literature. This assumption implies that train density is determined externally and independently of the factors being analysed. The exogeneity assumption allows for the identification of the causal effects of other variables on rail costs without concerns about reverse causality. Tests for the exogeneity of the investment intensity variable included the use of lagged infrastructure investment intensity variables. The results showed that the findings were not sensitive to using either contemporaneous or lagged versions of the variable. This suggests that the investment intensity variable remains exogenous in relation to the other factors under consideration. Additionally, it is worth noting that in the railway industry, governments typically play a prominent role in setting funding envelopes for investment. They have the authority to exogenously determine the level of investment in infrastructure. This further supports the exogeneity assumption of the investment intensity variable, as its determination is primarily driven by external factors rather than endogenous considerations within the model.

Multicollinearity check

A check for collinearity among the variables included in the model was conducted. The analysis revealed multicollinearity between *Qp* (passenger rail output), *Qf* (freight rail output), *N* (route length), *R* (revenue share of freight rail), and *I* (investment intensity). While the presence of multicollinearity can potentially distort regression results, in this case, the multicollinearity was not significant enough to warrant immediate concern.

Due to the presence of multicollinearity and the decision-making criteria outlined in Chapter 3.3.1, variable *R* was excluded from the preferred case modelling dataset. The detailed implications of this exclusion, along with further multicollinearity considerations, will be thoroughly examined in Section 3.3.1.

Table 6 - Definition of the Variables Used for the Estimation of the Cost Function

Variable	Description	Unit	Mean	Standard Deviation	Minimum	Max
TC	Sum of labour, energy, material and capital costs	€ million	4,922	6,417	107	34,198
cL	Labour cost	€ million	1,563	1,963	28	9,932
cE	Energy cost	€ million	210	260	2	1,413
cM	Material cost	€ million	1,292	1,718	33	10,134
cK	Capital cost	€ million	1,499	2,071	7	14,421
wL	Labour costs per employee	Euro	44,007	22,039	3,215	99,994
wE	Energy price per 1000 TOE	Euro	722,005	266,813	269,886	1,818,221
wM	Material costs per rolling stock	Euro	103,880	111,883	2,169	620,612
wK	Capital costs per route length	Euro	231,798	332,268	5,349	2,408,668
Qp	Passenger-km	1000 km	22,262	30,012	75	135,098
Qf	Freight tonne-km	1000 km	12,937	18,391	62	115,652
R	Freight revenues to total revenues	%	0.799	0.123	0.062	0.990
N	Total route km	Km	7,815	8,599	220	41,718
V	Train-km per route length per day	-	64	37.165	8.160	172.349
T	Percentage of electrified line	%	54	24.876	0	100
Dvs	Vertical separation dummy	-	0.277	0.448	0	1
Dhc	Holding company dummy	-	0.141	0.348	0	1
CMP	Passenger competition	-	0.686	1.113	0	4
Dcf	Freight competition dummy	-	0.375	0.484	0	1
Dhs	Horizontal separation dummy	-	0.340	0.474	0	1
S(L)	Share of labour input expenditure	-	0.364	0.122	0.081	0.685
S(E)	Share of energy	-	0.052	0.030	0.011	0.210

	expenditure					
S(M)	Share of material expenditure	-	0.284	0.110	0.017	0.701
S(K)	Share of capital expenditure	-	0.299	0.159	0.035	0.769
I(a)	Rail Infra Investment (euro per train-km)	€/ km	10,079	10,597	196	109,323
I(b)	Rail Infra Investment, (euro per line-km)	€/ km	234,393	270,417	1,542	1,701,087
I(c)	Rail Infra Investment (USD) per inhabitant[13]	$/inhabitant	109	103.78	1.03	751.39

[13] The unit of this variable has not been converted to Euro, given that we think the impact of exchange rate is minor and the same across most of the countries. So, it would not affect the model results.

3.2 Methodology

In this thesis, the Translog cost function (Christensen and Greene, 1998) was used to investigate the cost impact of infrastructure investment intensity associated with rail structural reform. The translog cost function is derived from the production function by considering the cost side of the production process. It provides a mathematical representation of the relationship between the costs of inputs and the levels of output produced. In the traditional framework, the production function is assumed to have a specific functional form, such as the Cobb-Douglas or the constant elasticity of substitution (CES) production functions. The Cobb-Douglas production function models the relationship between production output and production inputs (factors). It is used to calculate ratios of inputs to one another for efficient production and to estimate technological change in production methods. The general form of a Cobb-Douglas production function for a set of n inputs is

$$Y = f\ (x_1, x_2, \dots\ x_n) =\ \gamma \prod_{i=1}^{n} {x_i}^{\alpha_i}$$

In this formula, Y stands for production's output, and $x_i$for production's input. Meanwhile γ and α_i are the parameters determining the overall efficiency of production and how output responds to changes in the input quantities. The application of this functional form in measuring production is owed to the mathematician Charles Cobb and the economist Paul Douglas. Cobb and Douglas restricted the output-elasticity parameters α_1 and α_2 to the range $\alpha_i\ \in (0,1)$ and to sum to one, which implies constant returns to scale. So, the function with labour and capital as input factors looks as

$$Y = \gamma {x_1}^{\alpha_1} {x_2}^{1-\alpha_1}$$

In order to transfer the above equation to a linear equation (i.e. to facilitate econometric estimation), the natural logarithm is applied to both sides. So, based on the data on output, labour and capital, the parameters γ and α_1 can be estimated using Ordinary Least Squares

$$lnY = ln\gamma +\ \alpha_1 lnx_1 + (1 - \alpha_1) lnx_2$$

However, these functional forms impose certain restrictions on the relationship between inputs and outputs, such as constant returns to scale or fixed elasticity of substitution. The cost function relaxes these assumptions and allows for more flexibility in modelling the cost-output relationship. It is based on the idea that the cost of production is influenced by not only the levels of outputs but also the input prices. It captures the economies of scale, input substitutability, and input complementarity in a more general way. The cost function is derived by assuming cost minimisation in a production process, see the equation below. It shows how costs (*C*) are related to the level of outputs (*Y*) and input prices (*P*). If data is available over time, it can also show how costs change over time (*t*) due to technical changes.

$$C_{it} = C(Y_{it}, P_{it}, t)$$

The translog cost function is most commonly used in the rail cost and rail reform literature (see e.g. the early work of Caves et al. (1985), and also Coelli et al. (2005), Mizutani and Uranishi (2013)) due to its flexible form. Mathematically, the translog cost function is specified as a logarithmic function of input prices (w) and output levels (y), as shown in the equation below. It includes cross-product terms and allows for the estimation of various cost elasticities and cost share parameters. Although railway industries are regulated and/or publicly owned, cost models in most studies are assumed to reflect cost-minimising behaviour. Given the focus on understanding how different railway industry structures impact system costs on average, this study does not use stochastic frontier analysis, as it primarily aims to examine cost implications across structures rather than assessing relative efficiency performance for specific countries within each framework.

$$\ln\mathrm{C} = \alpha_0 + \sum_i \beta_i lny_i + \sum_i \gamma_i lnw_i + {}^{1}/_{2} \sum i \sum j\, \beta_{ij}(lny_i)(lny_j) + {}^{1}/_{2} \sum i \sum j\, \gamma_{ij}(lnw_i)(lnw_j) + \sum i \sum j\, \delta_{ij}(lny_i)(lnw_j)$$

The model follows a standard cost function specification where (in logs) cost is a function of multiple outputs (passenger and freight), network size (in order to distinguish between economies of scale and density), electrification to represent technical change and a set of input prices. This is a standard approach to modelling total rail industry costs (which is the aim) in the general rail cost literature (see e.g. the early work of Caves et. al. 1985 and also in the rail reform literature (see e.g. Mizutani et. al. 2015). The translog cost function used in this thesis is a multiple-output model in which the output measures are passenger-km and tonne-km respectively. The inputs of the cost function include the price of the labour[14], energy, material and capital inputs. The specification for the econometric model is shown below:

$$\ln\mathrm{TC} = \alpha_0 + \sum_m \alpha_m lnQ_m + \sum_j \beta_j lnw_j + \gamma_N lnN + \tau_T lnT + {}^{1}/_{2} \sum n \sum m\, \alpha_{mn}(lnQ_m)(lnQ_n) + \sum j \sum m\, \alpha_{mj}(lnQ_m)(lnw_j) + \sum m\, \alpha_{mN}(lnQ_m)(lnN) + \sum m\, \alpha_{mT}(lnQ_m)(lnT) + {}^{1}/_{2} \sum k \sum j\, \beta_{jk}(lnw_j)(lnw_k) + \sum j\, \beta_{jN}(lnw_j)(lnN) + \sum j\, \beta_{jT}(lnw_j)(lnT) + {}^{1}/_{2}\gamma_{NN}(\ln\mathrm{N})^2 + \gamma_{NT}(lnN)(lnT) + {}^{1}/_{2}\tau_{TT}(\ln\mathrm{T})^2 + (d_{VS1} + d_{VS2}lnV + d_{VS3}lnR + d_{VS4}lnI)D_{vs} + (d_{HC1} + d_{HC2}lnV + d_{HC3}lnR + d_{HC4}lnI)D_{hc} + D_{hs} + D_{cf} + CMP$$

Where: *TC* = total cost; *Qp* = quantity of passenger rail output; *Qf* = quantity of freight output; *wL* = labour input price; *wE* = energy input price; *wM* = materials input price; *wK* = capital price *N* = total route length; *T* = technology (% of electrified route length); *V* = train density; *R* = proportion of revenue made up by freight; *I* = rail infrastructure investment level; *Dvs, Dhc,*

[14] The types of input factor prices used depend on data availability, and are consistent with those that have been used in Mizutani, F. and S. Uranishi (2013).

Dhs, Dcf, CMP are the dummy variables that have been explained earlier. The parameters of d_{VS1}, d_{HC1} are the parameters for the dummy variables to be estimated. Restrictions on the input factor prices are introduced to satisfy the homogeneity conditions (such as the linear homogeneity of degree one) in the cost function:

$$\sum_j \beta_j = 1, \sum_k \beta_{jk} = 0, \sum_j \beta_{jN} = 0, \sum_j \beta_{jT} = 0, \sum_j \beta_{jT} = 0, \sum_j \alpha_{Yj} = 0, \sum_j \alpha_{mj} = 0, \beta_{jk} = \beta_{kj}\ , \beta_{jN} = \beta_{Nj}, \beta_{jT} = \beta_{Tj}, \alpha_{Yj} = \alpha_{jY}, \alpha_{YN} = \alpha_{NY}, \alpha_{YT} = \alpha_{TY}, \alpha_{mn} = \alpha_{nm}, \alpha_{mj} = \alpha_{jm}, \alpha_{mN} = \alpha_{Nm}, \alpha_{mT} = \alpha_{Tm}, \gamma_{NT} = \gamma_{TN}$$

In the literature, the cost function is jointly estimated with input share functions by applying Shephard's lemma (Shephard, 1953). Shephard's lemma states that the partial derivative of the cost function with respect to the price of an input is equal to the partial derivative of the production function with respect to that input. In the context of the translog cost function, Shephard's lemma is used to examine the cost shares and input demand elasticities. The cost shares represent the proportion of total cost accounted for by each input, while the input demand elasticities measure the responsiveness of input quantities to changes in input prices. Shephard's lemma and its application to the translog cost function help economists analyse the cost and production relationships, understand the input demand behaviour, and assess the impact of input price changes on cost allocation. Varian, 1992 (pp. 74-75) further explains this concept, providing a theoretical foundation for understanding how Shephard's lemma underpins the analysis of input demand and cost relationships in economics. This approach has been used widely in the literature such as Mizutani and Uranishi (2013) and Smith, Benedetto et al. (2018).

When Shephard's Lemma was applied to the cost function, it obtained the input share equation as follows:

$$\mathrm{S}_j = \beta_j + \sum_m \alpha_{mj} lnQ_m + \sum_k \beta_{jk}(lnw_k) + \beta_{jN}(lnN) + \beta_{jT}(lnT)$$

Where *Sj*: input j's share of the total cost.

This analysis includes traffic density, measured by train-kilometres per route-kilometre, as a key test variable. It further explores the interaction of this variable with structural dummies to assess if the ideal industry structure varies across systems with different usage intensities. This approach follows the previous literature, i.e. Mizutani and Uranishi (2013). The rationale behind this approach is that highly utilised railway systems often face a greater number of instances where the interests of operators and infrastructure managers may misalign. Consequently, the most appropriate industry structure for densely used systems might differ from that for less densely used systems. It was noted that this analysis treated the traffic density measure as a simplified approximation of a more complex reality. For example, systems predominantly composed of double tracks are likely to have fewer capacity conflicts compared to systems primarily consisting of single tracks. Similarly, systems with diverse train speeds, such as high-speed passenger trains sharing tracks with regional passenger and freight trains, may encounter more path conflicts than systems with a homogeneous train fleet operating at similar speeds. Furthermore, systems with numerous junctions might face more path conflicts than those with simpler route structures. Nonetheless, the focus here is not mainly on transaction costs, but rather on the costs resulting from incentive misalignment when resolving conflicts between different types of track usage.

Additionally, this analysis evaluates the inclusion of freight traffic revenue as a control variable, interacting it with structural regime indicators. This proportion considers both the volumes of passenger and freight traffic and their respective revenues, reflecting the complexity and service quality requirements of high-value freight traffic. However, the analysis identified multicollinearity between the variable representing the proportion of revenue from freight traffic and infrastructure investment intensity. Thus, this variable was omitted from the cost function for the preferred case (Case 3), which will be explained specifically in Section 3.3.1.

The following test variables were involved in the cost function (see also Table 4):

- VS dummy (*Dvs*): takes the value of 1 in the case of full VS of operations and infrastructure for a given observation in each year; zero otherwise.
- HC dummy (*Dhc*): In each year, takes the value of 1 in the case where an HC structure is present for a given observation in each year; zero otherwise.
- VI dummy (*Dvi*): this variable is omitted to avoid perfect collinearity. All cost effects are therefore measured relative to the VI structure.
- In addition to the above dummy policy variables, interaction terms were also included. The interaction term between the industry structure forms (*Dvs* and *Dhc)* and infrastructure investment intensity *(I(a,b,c))* aims to investigate how the effect of industry structure on cost varies according to the infrastructure investment intensity. This analysis introduces the interaction term between the industry structure forms (*Dvs* and *Dhc*) and train density (*V*) to test whether the most cost-effective solution is different on more and less dense systems. The interaction term between the industry structure forms (*Dvs* and *Dhc*) and revenue freight proportion (*R*) was also involved to see how the effects of these industry structures are affected by the relative level of freight running on the network[15]. The interaction of dummies focuses on the test variables of interest, namely train density and infrastructure investment intensity (*V* and *I*) in order to test the hypotheses explained in the paper – i.e. how the cost impact associated with vertical separation changes with the intensity of infrastructure investment.

[15] Although this interaction is omitted in the later stage due to multilinearity, which will be explained in the next section with more details.

- Horizontal (passenger-freight) separation dummy (*Dhs*): takes the value of 1 where horizontal separation took place (i.e. freight and passenger rail operation are separated); zero otherwise.
- Passenger competition measure (*CMP*): this variable is used to measure the level of competition in passenger railways, with: 0 = no competition at all; 1 = competition is possible; 2 = competition has happened but is minor compared to the whole network (i.e. 10%); 3 = competition has happened and is major compared to the whole network (i.e. 25%+); and 4 = all services are submitted to competition (as it is in Britain). This approach follows that of Mizutani et. al. (2015).
- Freight competition dummy (*Dcf*): this variable takes the value of 1 when freight competition took place (i.e. actual freight entry); zero otherwise.

It's crucial to differentiate between capital costs and infrastructure investment intensity in the model function. The former represents ongoing depreciation and financing costs within the operational budget, while the latter is treated as an intensity measure, capturing the strategic allocation of resources towards infrastructure enhancement distinct from routine capital expenses. This distinction acknowledges the lag effect of infrastructure investments, where the benefits and associated costs materialise over time, diverging from immediate capital outlays. The inclusion of both variables, supported by a multicollinearity test, confirms their independence within the model, ensuring there's no double counting and highlighting the impact of strategic investments on the railway system's cost structure.

Estimation can then proceed using Zellner’s (1962) Seemingly Unrelated Regression (SUR) which is more efficient (in terms of estimation) than single equation ordinary least squares. The SUR approach is particularly useful in economic models like translog cost functions, where unobservable factors might simultaneously influence several dependent variables (Greene, 2012). Its ability to account for correlations across different equations makes it a more efficient estimation method compared to OLS in many scenarios. Prior to estimation, all of the observations of each variable were divided by the sample mean, except for the dummy variables. All of the models were estimated using the STATA software.

3.3 Econometric Results

The preferred model specification is shown below, building on the past literature and in particular the model structure estimated by Mizutani et. al. (2015). Additionally, the preferred model function represents the important departure point from previous literature - the interaction of investment intensity and rail structure variables.

Five main cases and three sensitivity tests were introduced in this thesis. The five main cases consider the key changes in the dataset and variables, such as the extension of the original dataset used by Mizutani, introducing the new investment variables, and excluding the variable *R* (revenue share of freight rail). To be specific, Case 1 aims to update the models found in previous literature. Thus, Case 1 included all the variables from the previous study, Mizutani et. al. (2015), including variable *R*. In Case 2, a new variable *I(a)* (investment intensity) is introduced, revealing multicollinearities between *I(a)* and *R*. These multicollinearities affect the robustness of the model outputs. Consequently, to ensure the model remains reliable and the results are not distorted by multicollinearity, variable *R* is excluded in the preferred case, Case 3.

The three sensitivity tests mainly focus on testing whether some changes in variables, i.e. introducing lags to investment variables, would introduce big differences to the outputs. Thus, eight models estimated are:

- Case 1 - Extend the dataset in Mizutani et. al. (2015) to the year 2017
- Case 2 - Case 1 + new variable *I(a)*[16]
- Case 3 - Case 1 + new variable *I(a),* but exclude variable *R* from the model (**Preferred Case**)
- Case 4 - Case 1 + new variable *I(b),* but exclude variable *R* from the model
- Case 5 - Case 1 + new variable *I(c),* but exclude variable *R* from the model
- Sensitivity Test 1 – Case 4 with an alternative way to allocate *I(b)* to different rail companies within Switzerland, Hungary and Japan
- Sensitivity Test 2 – Case 2, but exclude variables *V* and *R*
- Sensitivity Test 3 – Case 3, but consider 3 years of lag for variable *I(a)*

Table 7 shows the estimation results. The coefficients on the key variables such as the output measures, input factor prices and network variables show reasonable signs across all the cases. The goodness-of-fit in the regressions is acceptably high for the models (pseudo R2 is over 0.97). The restrictions imposed on the cost model ensure that the symmetry and

[16] Variables I(a/b/c) were logged in the model.

homogeneity conditions of the input factor prices are automatically satisfied. Monotonicity conditions play a crucial role in cost function analysis. The cost function needs to reflect economic realities, where it typically expects costs to increase with both higher output and higher input prices. This expected behaviour underscores the principles of diminishing marginal productivity and increasing returns to scale, ensuring that the cost function accurately models the cost dynamics of production. The analysis includes evaluating the partial derivatives of the cost function concerning output and input factor prices to verify compliance with economic expectations. These derivatives show positive values for all the cases (i.e. coefficient for *Qp, Qf* and *wj*), indicating that the cost function does not decrease as output or input prices increase. By satisfying these monotonicity conditions, the cost function aligns with economic assumptions such as increasing returns to scale and diminishing marginal productivity.

The concavity condition in a cost function pertains to the shape and curvature of the function's surface. It signifies that the average cost of producing a given level of output lies below the straight line connecting any two input combinations. This implies that as the production scale increases, average costs decrease. The Hessian matrix was utilised in Stata to verify the concavity of input prices. The condition was satisfied in 12% of the observations, which aligns reasonably with previous findings by Mizutani and Uranishi (2013)[17] and Baum and Linz (2009) that note a lack of concavity in a substantial portion of the sample. In addition, imposing global concavity is not straightforward and can compromise the flexibility of the translog model, as highlighted on page 229 of Coelli et al. (2005). For additional insights, refer to the work of Ryan and Wales (2000).

Compared to Mizutani et. al. (2015), the interaction term between vertical structure and freight traffic proportion was dropped in Cases 3 to 5 and in sensitivity test cases. Because the model's outcomes varied significantly when comparing the share of revenue from freight traffic to the share of train-kilometres, leading to the conclusion that including this relationship weakens the model's argument.

[17] The concavity condition in Mizutani and Uranishi (2013) was 30%-43%.

Table 7 - Estimation Results of the Total Cost Function (Case 1 – 5)

Variables	*Case 1*		*Case 2*		*Case 3*		*Case 4*		*Case 5*	
Qp	0.1067	***	0.1101	***	0.1106	***	0.1106	***	0.1029	***
	(0.0130)		(0.0130)		(0.0131)		(0.0131)		(0.0130)	
Qf	0.3254	***	0.3214	***	0.3187	***	0.3188	***	0.3230	***
	(0.0236)		(0.0237)		(0.0212)		(0.0212)		(0.0208)	
wL	0.3173	***	0.3169	***	0.3170	***	0.3170	***	0.3175	***
	(0.0052)		(0.0052)		(0.0051)		(0.0051)		(0.0051)	
wE	0.0377	***	0.0379	***	0.0379	***	0.0379	***	0.0378	***
	(0.0028)		(0.0026)		(0.0026)		(0.0026)		(0.0025)	
wM	0.3220	***	0.3224	***	0.3223	***	0.3223	***	0.3224	***
	(0.0063)		(0.0062)		(0.0062)		(0.0062)		(0.0061)	
wK	0.3230	***	0.3228	***	0.3228	***	0.3228	***	0.3223	***
	(0.0048)		(0.0048)		(0.0048)		(0.0048)		(0.0048)	
N	0.5959	***	0.5995	***	0.5992	***	0.5991	***	0.6019	***
	(0.0276)		(0.0276)		(0.0261)		(0.0261)		(0.0263)	
T	0.0685	*	0.0578		0.0491		0.0487		0.0479	
	(0.0317)		(0.0319)		(0.0301)		(0.0301)		(0.0300)	
*Qp*Qf*	-0.0385	*	-0.0429	**	-0.0467	**	-0.0468	**	-0.0530	***
	(0.0155)		(0.0155)		(0.0153)		(0.0153)		(0.0154)	
Qp Qp*	0.0724	***	0.0688	***	0.0700	***	0.0701	***	0.0768	***
	(0.0155)		(0.0156)		(0.0156)		(0.0156)		(0.0156)	
Qf Qf*	0.0121		0.0166		0.0135		0.0135		0.0079	
	(0.0178)		(0.0180)		(0.0179)		(0.0179)		(0.0180)	
*Qp*wL*	0.0367	***	0.0369	***	0.0373	***	0.0373	***	0.0373	***
	(0.0044)		(0.0044)		(0.0044)		(0.0044)		(0.0044)	
*Qp*wE*	0.0143	***	0.0142	***	0.0141	***	0.0141	***	0.0145	***
	(0.0024)		(0.0022)		(0.0022)		(0.0022)		(0.0022)	
*Qp*wM*	0.0088		0.0079		0.0078		0.0078		0.0070	
	(0.0048)		(0.0048)		(0.0048)		(0.0048)		(0.0047)	
*Qp*wK*	-0.0598	***	-0.0591	***	-0.0593	***	-0.0593	***	-0.0587	***
	(0.0040)		(0.0040)		(0.0040)		(0.0040)		(0.0040)	
*Qf*wL*	0.0333	***	0.0329	***	0.0329	***	0.0329	***	0.0331	***
	(0.0056)		(0.0056)		(0.0056)		(0.0056)		(0.0056)	
*Qf*wE*	0.0001		-0.0001		-0.0001		-0.0001		0.0006	
	(0.0029)		(0.0027)		(0.0027)		(0.0027)		(0.0026)	
*Qf*wM*	0.0375	***	0.0384	***	0.0380	***	0.0380	***	0.0358	***
	(0.0064)		(0.0063)		(0.0063)		(0.0063)		(0.0062)	
*Qf*wK*	-0.0710	***	-0.0712	***	-0.0709	***	-0.0709	***	-0.0694	***
	(0.0055)		(0.0055)		(0.0055)		(0.0055)		(0.0055)	
*Qp*N*	-0.0611	**	-0.0526	**	-0.0516	*	-0.0515	*	-0.0570	**
	(0.0201)		(0.0203)		(0.0202)		(0.0202)		(0.0203)	
*Qf*N*	0.1437	***	0.1405	***	0.1483	***	0.1485	***	0.1628	***

	(0.0316)		(0.0319)		(0.0313)		(0.0313)		(0.0312)	
*Qp*T*	-0.0540	*	-0.0505	*	-0.0523	*	-0.0524	*	-0.0615	**
	(0.0217)		(0.0219)		(0.0219)		(0.0219)		(0.0220)	
*Qf*T*	0.0006		0.0020		0.0056		0.0057		0.0120	
	(0.0179)		(0.0180)		(0.0178)		(0.0178)		(0.0177)	
wL wL*	0.1385	***	0.1393	***	0.1399	***	0.1399	***	0.1394	***
	(0.0075)		(0.0075)		(0.0075)		(0.0075)		(0.0075)	
wE wE*	0.0508	***	0.0495	***	0.0495	***	0.0495	***	0.0490	***
	(0.0026)		(0.0024)		(0.0024)		(0.0024)		(0.0024)	
*wM*wM*	0.1093	***	0.1110	***	0.1113	***	0.1112	***	0.1101	***
	(0.0061)		(0.0060)		(0.0060)		(0.0060)		(0.0059)	
wK wK*	0.1672	***	0.1667	***	0.1669	***	0.1669	***	0.1660	***
	(0.0049)		(0.0050)		(0.0050)		(0.0050)		(0.0050)	
*wL*wE*	-0.0045		-0.0045		-0.0047		-0.0047		-0.0046	
	(0.0030)		(0.0028)		(0.0028)		(0.0028)		(0.0028)	
*wL*wM*	-0.0440	***	-0.0450	***	-0.0451	***	-0.0451	***	-0.0449	***
	(0.0050)		(0.0050)		(0.0050)		(0.0050)		(0.0050)	
*wL*wK*	-0.0900	***	-0.0898	***	-0.0901	***	-0.0901	***	-0.0898	***
	(0.0050)		(0.0051)		(0.0051)		(0.0051)		(0.0051)	
*wE*wM*	-0.0172	***	-0.0170	***	-0.0171	***	-0.0171	***	-0.0167	***
	(0.0027)		(0.0025)		(0.0025)		(0.0025)		(0.0024)	
*wE*wK*	-0.0291	***	-0.0279	***	-0.0278	***	-0.0278	***	-0.0277	***
	(0.0024)		(0.0023)		(0.0023)		(0.0023)		(0.0023)	
*wM*wK*	-0.0481	***	-0.0490	***	-0.0491	***	-0.0491	***	-0.0485	***
	(0.0041)		(0.0041)		(0.0041)		(0.0041)		(0.0041)	
*wL*N*	-0.0997	***	-0.0996	***	-0.0998	***	-0.0998	***	-0.0998	***
	(0.0088)		(0.0088)		(0.0088)		(0.0088)		(0.0088)	
*wE*N*	-0.0193	***	-0.0185	***	-0.0185	***	-0.0185	***	-0.0192	***
	(0.0044)		(0.0041)		(0.0041)		(0.0041)		(0.0040)	
*wM*N*	-0.0242	*	-0.0244	**	-0.0241	*	-0.0241	*	-0.0215	*
	(0.0096)		(0.0095)		(0.0094)		(0.0094)		(0.0093)	
*wK*N*	0.1433	***	0.1425	***	0.1423	***	0.1423	***	0.1405	***
	(0.0080)		(0.0081)		(0.0081)		(0.0081)		(0.0081)	
*wL*T*	-0.0276	***	-0.0272	***	-0.0271	***	-0.0271	***	-0.0268	***
	(0.0062)		(0.0062)		(0.0062)		(0.0062)		(0.0062)	
*wE*T*	0.0042		0.0037		0.0036		0.0036		0.0026	
	(0.0031)		(0.0029)		(0.0029)		(0.0029)		(0.0029)	
*wM*T*	-0.0045		-0.0048		-0.0044		-0.0044		-0.0016	
	(0.0069)		(0.0068)		(0.0068)		(0.0068)		(0.0067)	
*wK*T*	0.0280	***	0.0283	***	0.0279	***	0.0279	***	0.0258	***
	(0.0056)		(0.0057)		(0.0057)		(0.0057)		(0.0057)	
*N*N*	-0.1612	**	-0.1635	**	-0.1733	**	-0.1737	**	-0.1799	**
	(0.0568)		(0.0567)		(0.0552)		(0.0552)		(0.0549)	
*T*T*	0.1845	***	0.1768	***	0.1742	***	0.1742	***	0.1794	***

	(0.0321)		(0.0321)		(0.0322)		(0.0322)		(0.0322)	
*N*T*	-0.0293		-0.0386		-0.0456		-0.0457		-0.0417	
	(0.0344)		(0.0344)		(0.0332)		(0.0332)		(0.0333)	
Dvs	0.0032		-0.0649		-0.0900	***	-0.0908	***	-0.0864	**
	(0.0331)		(0.0370)		(0.0271)		(0.0271)		(0.0269)	
*V*Dvs*	0.3983	***	0.3561	***	0.3187	***	0.4161	***	0.3204	***
	(0.0489)		(0.0504)		(0.0373)		(0.0442)		(0.0375)	
*R*Dvs*	0.0919	***	0.0359							
	(0.0273)		(0.0313)							
*I(i)*Dvs*			-0.0841	***	-0.0990	***	-0.0983	***	-0.1060	***
			(0.0227)		(0.0197)		(0.0197)		(0.0200)	
Dhc	-0.0489		-0.0539		-0.0486		-0.0485		-0.0595	*
	(0.0287)		(0.0315)		(0.0312)		(0.0313)		(0.0292)	
*V*Dhc*	0.1383	***	0.1332	**	0.1397	***	0.1320	*	0.1671	***
	(0.0417)		(0.0420)		(0.0400)		(0.0514)		(0.0462)	
*R*Dhc*	-0.0256		-0.0246							
	(0.0356)		(0.0392)							
*I(i)*Dhc*			-0.0016		0.0075		0.0076		-0.0093	
			(0.0246)		(0.0223)		(0.0223)		(0.0224)	
Dhs	-0.2814	***	-0.2915	***	-0.2964	***	-0.2964	***	-0.2862	***
	(0.0250)		(0.0251)		(0.0246)		(0.0246)		(0.0244)	
CMP	-0.0069		-0.0014		0.0007		0.0008		-0.0022	
	(0.0101)		(0.0103)		(0.0102)		(0.0102)		(0.0101)	
Dcf	0.0558	**	0.0486	*	0.0467	*	0.0467	*	0.0611	**
	(0.0211)		(0.0212)		(0.0212)		(0.0212)		(0.0214)	
_cons	0.3922	***	0.3999	***	0.4003	***	0.4002	***	0.3929	***
	(0.0166)		(0.0166)		(0.0167)		(0.0167)		(0.0166)	
Log of likelihood	3357.567		3374.614		3375.922		3375.692		3388.46	
Pseudo R2	0.978		0.979		0.978		0.978		0.978	
Observations	650		650		650		650		650	

*** Significant at 1%, ** 5%, * 10%

Table 8 - Estimation Results of the Total Cost Function (**Sensitivity Tests**)

Variables	*Sensitivity Test 1*		*Sensitivity Test 2*		*Sensitivity Test 3*	
Qp	0.1113	***	0.1566	***	0.1039	***
	(0.0130)		(0.0123)		(0.0138)	
Qf	0.3174	***	0.3433	***	0.2930	***
	(0.0212)		(0.0216)		(0.0236)	
wL	0.3170	***	0.3162	***	0.3114	***
	(0.0051)		(0.0050)		(0.0055)	
wE	0.0379	***	0.0389	***	0.0392	***
	(0.0026)		(0.0026)		(0.0027)	
wM	0.3223	***	0.3208	***	0.3212	***
	(0.0062)		(0.0058)		(0.0068)	
wK	0.3228	***	0.3241	***	0.3282	***
	(0.0048)		(0.0048)		(0.0053)	
N	0.5994	***	0.5104	***	0.6447	***
	(0.0261)		(0.0246)		(0.0288)	
T	0.0497		-0.0381		0.0831	*
	(0.0301)		(0.0297)		(0.0328)	
*Qp*Qf*	-0.0464	**	-0.0625	***	-0.0117	
	(0.0153)		(0.0160)		(0.0181)	
Qp Qp*	0.0697	***	0.0223		0.0751	***
	(0.0156)		(0.0146)		(0.0191)	
Qf Qf*	0.0141		-0.0114		-0.0131	
	(0.0179)		(0.0188)		(0.0245)	
*Qp*wL*	0.0373	***	0.0390	***	0.0361	***
	(0.0044)		(0.0043)		(0.0048)	
*Qp*wE*	0.0142	***	0.0147	***	0.0132	***
	(0.0022)		(0.0022)		(0.0024)	
*Qp*wM*	0.0078		0.0038		0.0152	**
	(0.0048)		(0.0045)		(0.0054)	
*Qp*wK*	-0.0592	***	-0.0575	***	-0.0644	***
	(0.0040)		(0.0040)		(0.0045)	
*Qf*wL*	0.0329	***	0.0335	***	0.0298	***
	(0.0056)		(0.0055)		(0.0064)	
*Qf*wE*	0.0000		0.0006		0.0012	
	(0.0027)		(0.0027)		(0.0029)	
*Qf*wM*	0.0379	***	0.0375	***	0.0336	***
	(0.0063)		(0.0060)		(0.0073)	
*Qf*wK*	-0.0708	***	-0.0716	***	-0.0647	***
	(0.0055)		(0.0056)		(0.0064)	
*Qp*N*	-0.0508	*	0.0206		-0.1018	***
	(0.0202)		(0.0187)		(0.0220)	

*Qf*N*	0.1464	***	0.2068	***	0.1422	***
	(0.0314)		(0.0328)		(0.0359)	
*Qp*T*	-0.0515	*	-0.0169		-0.0910	***
	(0.0219)		(0.0226)		(0.0262)	
*Qf*T*	0.0051		0.0242		0.0176	
	(0.0178)		(0.0188)		(0.0239)	
wL wL*	0.1398	***	0.1420	***	0.1273	***
	(0.0075)		(0.0073)		(0.0082)	
wE wE*	0.0495	***	0.0481	***	0.0474	***
	(0.0024)		(0.0025)		(0.0026)	
*wM*wM*	0.1112	***	0.1088	***	0.1090	***
	(0.0060)		(0.0057)		(0.0066)	
wK wK*	0.1669	***	0.1703	***	0.1659	***
	(0.0050)		(0.0050)		(0.0056)	
*wL*wE*	-0.0047		-0.0044		-0.0022	
	(0.0028)		(0.0029)		(0.0030)	
*wL*wM*	-0.0451	***	-0.0445	***	-0.0393	***
	(0.0050)		(0.0048)		(0.0055)	
*wL*wK*	-0.0901	***	-0.0931	***	-0.0858	***
	(0.0051)		(0.0050)		(0.0056)	
*wE*wM*	-0.0171	***	-0.0154	***	-0.0174	***
	(0.0025)		(0.0025)		(0.0026)	
*wE*wK*	-0.0278	***	-0.0283	***	-0.0278	***
	(0.0023)		(0.0024)		(0.0025)	
*wM*wK*	-0.0490	***	-0.0489	***	-0.0523	***
	(0.0041)		(0.0040)		(0.0046)	
*wL*N*	-0.0996	***	-0.0987	***	-0.0963	***
	(0.0088)		(0.0086)		(0.0097)	
*wE*N*	-0.0186	***	-0.0178	***	-0.0190	***
	(0.0041)		(0.0042)		(0.0044)	
*wM*N*	-0.0240	*	-0.0258	**	-0.0240	*
	(0.0094)		(0.0090)		(0.0105)	
*wK*N*	0.1421	***	0.1423	***	0.1392	***
	(0.0081)		(0.0081)		(0.0090)	
*wL*T*	-0.0270	***	-0.0290	***	-0.0254	***
	(0.0062)		(0.0060)		(0.0071)	
*wE*T*	0.0036		0.0026		0.0028	
	(0.0029)		(0.0030)		(0.0032)	
*wM*T*	-0.0044		-0.0006		-0.0006	
	(0.0068)		(0.0065)		(0.0079)	
*wK*T*	0.0278	***	0.0269	***	0.0231	***
	(0.0057)		(0.0058)		(0.0065)	
*N*N*	-0.1721	**	-0.3384	***	-0.0955	
	(0.0552)		(0.0541)		(0.0589)	

*T*T*	0.1735	***	0.1366	***	0.2017	***
	(0.0322)		(0.0339)		(0.0363)	
*N*T*	-0.0450		-0.1430	***	-0.0199	
	(0.0332)		(0.0321)		(0.0377)	
Dvs	-0.0936	***	-0.1940	***	-0.0772	**
	(0.0272)		(0.0245)		(0.0282)	
*V*Dvs*	0.4164	***			0.3556	***
	(0.0442)				(0.0404)	
*R*Dvs*						
*I(i)*Dvs*	-0.0988	***	-0.0724	***	-0.0928	***
	(0.0197)		(0.0208)		(0.0196)	
Dhc	-0.0531		-0.0879	**	-0.0141	
	(0.0310)		(0.0328)		(0.0313)	
*V*Dhc*	0.1448	**			0.1834	***
	(0.0523)				(0.0415)	
*R*Dhc*						
*I(i)*Dhc*	-0.0006		0.0115		0.0138	
	(0.0224)		(0.0225)		(0.0202)	
Dhs	-0.2975	***	-0.2689	***	-0.2782	***
	(0.0245)		(0.0260)		(0.0264)	
CMP	0.0012		0.0239	*	-0.0093	
	(0.0102)		(0.0105)		(0.0107)	
Dcf	0.0473	*	0.0903	***	0.0511	*
	(0.0212)		(0.0215)		(0.0218)	
_cons	0.4006	***	0.3980	***	0.3678	***
	(0.0166)		(0.0173)		(0.0197)	
Log of likelihood	3375.148		3398.506		2860.911	
Pseudo R2	0.978		0.975		0.98	
Observations	650		650		554	

*** Significant at 1%, ** 5%, * 10%

3.3.1 Comparison between Cases

The initial step is to outline and compare the various Cases in this section to identify the preferred case for an in-depth discussion.

Case 1 serves as the base case and includes the extended dataset by updating the data from van de Velde et al. (2012) and Mizutani et al. (2015) to the year 2017. The coefficients obtained for each variable in the model produce reasonable results. Notable findings include:

- The output and price variables (*Qp, Qf,* and *wj*) exhibit positive signs with statistical significance at 1%, aligning with previous literature and economic assumptions of diminishing marginal productivity and increasing returns to scale.

- The control variables, total route length (*N*) and technology index (*T*), also demonstrate a positive impact on costs. The positive finding for *T* contrasts with the literature; however, given the lower confidence level (90%), it is not a significant issue compared to the low confidence level of the result in van de Velde et al. (2012).

- The coefficients of the horizontal (passenger-freight) separation dummy variable (*Dhs*) show a negative sign with statistical significance at 1%, indicating that companies can reduce costs through horizontal separation of passenger and freight services. This finding is consistent with van de Velde et al. (2012) and Mizutani et al. (2015). The explanation behind this finding can be found in Kim (1987), who states that there are diseconomies of scope between passenger and freight services. Furthermore, the cost reduction benefits from HS may be enhanced by privatising these separated services. Private ownership might drive further efficiency improvements and cost savings, leveraging market incentives to optimise operations beyond the gains achieved through separation alone. Additionally, Mizutani and Uranishi (2013) hypothesised that the hidden costs of passenger services would be eliminated because passenger services are often subsidised while freight services are not. Thus, this finding suggests that separating passenger and freight services is beneficial from a cost reduction perspective.

- The freight competition dummy variables (*Dcf*), which indicate actual entry into the freight market, demonstrate a negative impact on costs, revealing a new finding. This implies that introducing competition to the freight market reduces costs to some extent. Previous literature, such as Cantos (2013), also found positive efficiency effects from competition in the rail market. In contrast, the passenger rail competition variable (*CMP*) does not show a statistically significant impact on costs.

- Similar to van de Velde et al. (2012) and Mizutani et al. (2015), Case 1 shows a positive cost impact of train density (*V*) when interacting with the vertical separation variable. Additionally, the analysis derived a beneficial effect of train density when combined with the holding company structure. This indicates that higher train density can lead to cost increases in both the VS and HC regimes. Comparing the coefficients, it is evident that the cost effect of train density (i.e., elasticity) is higher in the VS regime than in the HC regime. This is a novel finding that was not tested previously. This result was derived from the expanded dataset with more years of rail data post-reform.

- The revenue share of freight rail (*R*) has a positive impact on costs, although the elasticity is relatively small (below 0.1). Once again, this finding is consistent with the results from van de Velde et al. (2012) and Mizutani et al. (2015).

Case 2 introduces a new variable, infrastructure investment intensity *I(a),* to Case 1. Compared to the results of Case 1, the coefficient for *R* becomes insignificant due to light multicollinearity between variables *R* and *I(a)*. To further investigate this relationship, this analysis conducted a test using a slightly different definition of *R* (share of train-km for freight rail), which resulted in a significant change in the coefficient. This finding weakens the case for including this relationship in the model, leading us to remove the variable *R* from the subsequent cases (Cases 3 to 5). Besides, the removal of variable *R* has minimal effect on the key findings concerning infrastructural investment intensity in Cases 3 to 5.

Cases 3 to 5 involve the inclusion of variables *I(a), I(b),* and *I(c)* respectively, based on Case 1, while excluding variable *R*. These cases aim to identify the most appropriate definition of infrastructure investment intensity. The coefficients for *I(i)*Dvs* in all three cases show a negative cost effect with a statistical significance of 1%. Additionally, the model fit for Cases 3 to 5 exhibits a high degree of similarity.

To ensure the accuracy of the analysis, especially in countries with multiple rail companies like Switzerland, Hungary, and Japan, a revenue-based allocation method for total investments was chosen due to its direct impact on infrastructure investment decisions. This method is particularly relevant for Japan, where the significant emphasis of railway operations on passenger services exists. This allocation approach is considered reasonable since revenue is a primary source of infrastructure investment, particularly in Japan's railway system focused on passenger services. In **Sensitivity Test 1**, infrastructure investment was allocated based on train-kms for multiple companies within a country and compared with Case 4, showing only minor differences.

Sensitivity Test 2 removed variables V and R from Case 3, showing minor differences in the results, confirming the infrastructure investment intensity narrative's consistency. In **Sensitivity Test 3**, a 3-year lag on the infrastructure investment variable was introduced, showing minimal impact on results, which remained true for a 5-year lag, underscoring the lag's negligible effect on findings.

3.3.2 Preferred Case

Cases 3 to 5 consistently demonstrate a negative cost impact when considering the interaction between the investment measures (*I(a), I(b),* and *I(c)*) and the VS dummy variable. The coefficients for *I(a/b/c)*Dvs* exhibit negative values with a statistical significance of 1%. Section 3.4 provides a more comprehensive discussion of this result, highlighting it as the preferred model. In terms of the sizes, signs, and statistical significance of the parameters of interest, as well as the log-likelihoods, there is little difference between the three versions of the investment variable in Cases 3 to 5.

However, when comparing Cases 3, 4, and 5, **Case 3** has a more reasonable definition of infrastructure investment intensity. This is because it considers train kilometres as the denominator to calculate the intensity, reflecting the aim of infrastructure investment to enhance the efficiency of rail operations, influenced by both the track and trains. Investment per train-km is thus a more suitable measure to capture the intensity of infrastructure investment in a railway system. Consequently, Case 3 emerges as the optimal choice for illustrating the cost impact in different rail industry structures. It is worth noting that the results are not sensitive to the choice of measure. **Case 3** is upheld after considering the outcomes of the sensitivity analyses, as detailed in **Table 7**, highlighting its robustness against methodological variations.

Figure 5 - Cost Reduction Effect of the Different Models (VS and HC)

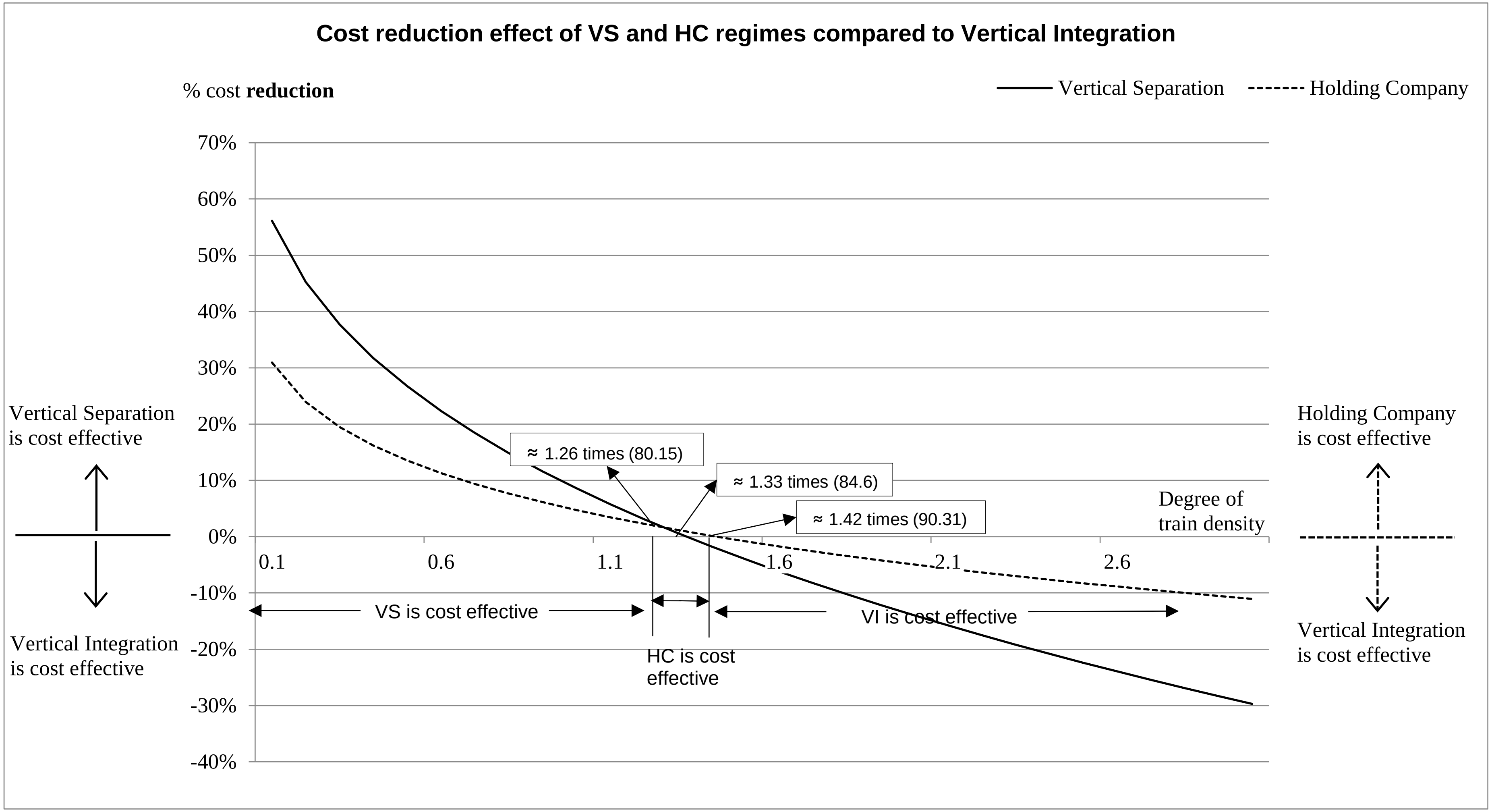
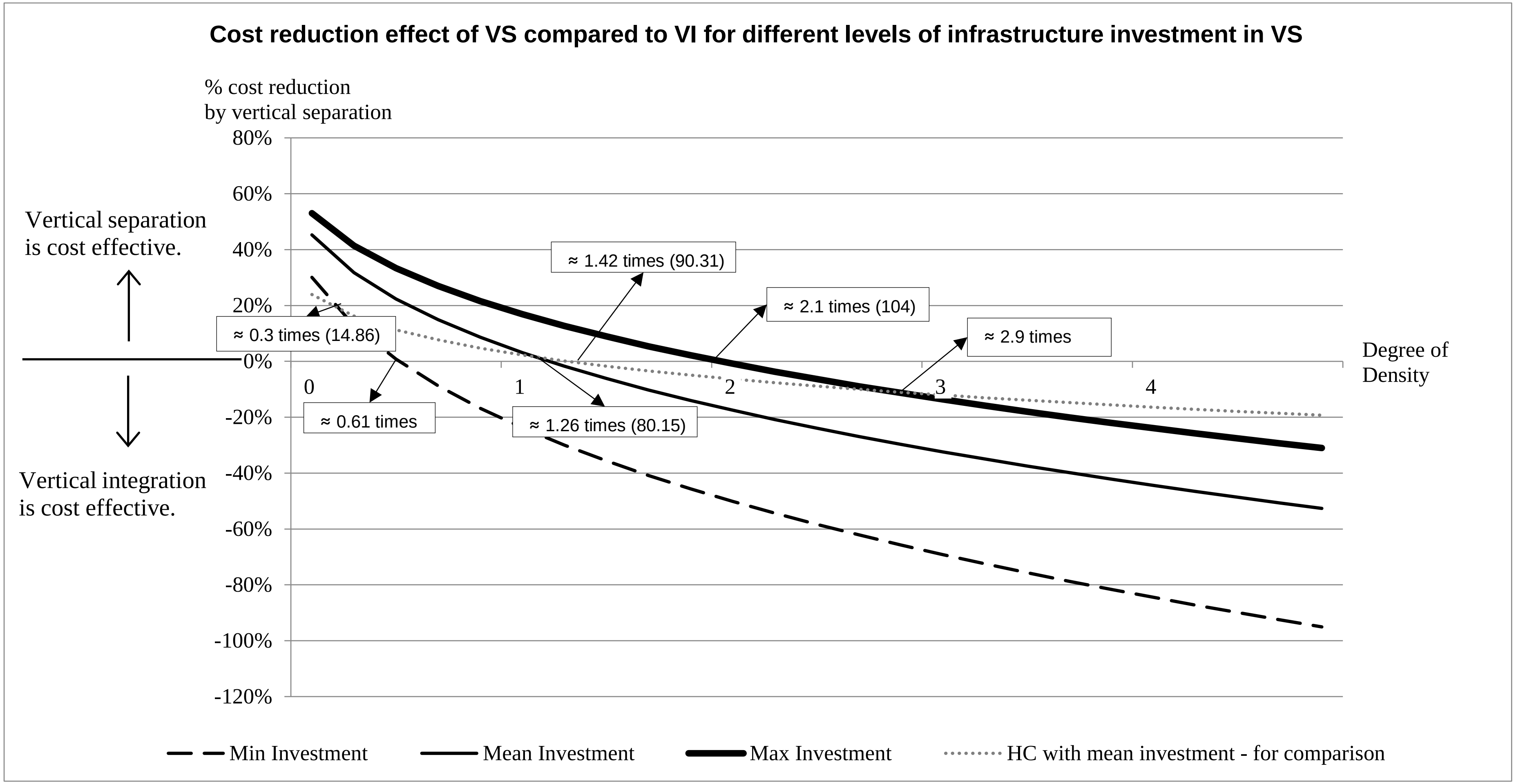


Figure 6 - Cost Reduction Effect of VS with the Minimum, Mean and Maximum Infrastructure Investment Levels



3.4 Discussion on the Preferred Case

This section begins with a comparative analysis between current findings and past literature, highlighting the significant updates made to the dataset for a more comprehensive understanding of railway reforms' impacts. The discussion then shifts focus to exploring the details of investment coordination or misalignment costs and their variation across different vertical structures.

3.4.1 Compared with Previous Literature

As noted earlier, this analysis includes a substantial update to the data used in the past railway cost function literature, extending datasets as far as 2017. This both increases the sample size and gives a more up-to-date view on the impact of rail reforms given that in some countries the reforms were implemented in the late noughties and beyond.

This analysis provides support for some of the key findings from the past literature (van de Velde et al. (2012); Mizutani et. al., (2015)). In particular, a strong (and statistically significant) cost-reducing impact of horizontal separation (passenger and freight separation) was found. This could be explained by several cases in which cost reductions took place because freight divisions were sold to new owners rather than as a direct consequence of horizontal separation. This analysis also provides insight into the freight competition. The freight competition dummy variables (*Dcf*), representing actual entry into the freight market, have been found to exert a negative impact on costs. This discovery underscores that the introduction of competition into the freight sector can lead to cost reductions, aligning with findings from previous literature such as Cantos (2013) which observed positive efficiency effects from rail market competition. Interestingly, this cost-reducing effect of competition appears to be specific to the freight market, as the competition variable for passenger rail (CMP) did not exhibit a statistically significant impact on costs – which is consistent with the findings in van de Velde et al. (2012).

A strong theme from the past literature has been the cost impact of vertical separation as compared to vertical integration, as well as different forms of vertical separation (namely the HC regime versus full, legal vertical separation), and also how train density can affect this comparison (see Mizutani and Uranishi (2013); van de Velde et al. (2012); Mizutani et. al., (2015)). The cost impact of the vertical structure was assumed to be driven by the difference in coordination mechanisms between the RU and IM. The coordination mechanism may generate transaction costs, which are the costs incurred in making an economic exchange, such as the costs of reaching an agreement with the selling party and the costs related to enforcing the realisation of the transaction, making sure the seller sticks to the contract. Applied to the railway world, this theory allows for developing a deeper understanding of the factors that may indicate which form of organisation is more suited to minimise transaction costs. This theory was discussed in van de Velde et al. (2012) and inspired by the Transaction Cost Economics theory developed by Williamson (1975; 2000), which pays explicit attention to transaction costs besides the actual production costs of a good or service. van de Velde et al. (2012) particularly highlight the misalignment of incentives that can occur in coordination in vertically separated environments. To specify such areas of transaction costs generated, the variables of train density and infrastructure investment intensity will be focused on.

Two figures, Figure 5 and Figure 6, are produced and shown below to illustrate the econometric model results. The components of vertical separation ($(d_{VS1} + d_{VS2} lnV + + d_{VS4} lnI)D_{vs}$) and holding company ($(d_{HC1} + d_{HC2} lnV + d_{HC4} lnI)D_{hc}$) are discussed separately. The cost reduction effect of one structure compared to the other is then computed by taking the exponential form of each component and deducting it from one. Figure 5 focuses on the relationship between train density and costs under average investment intensity (i.e. $lnI = 0$), highlighting past literature. Figure 6 expands this comparison to show how vertical separation's cost-effectiveness against vertical integration varies with train density, depicted through lines for high, mean, and low investment intensity levels. For the HC regime a single line is shown as the cost effect of this form was not found to depend on investment intensity. The findings from each figure are discussed in turn below.

Figure 5 shows, first of all, how the two forms of vertical separation compare to vertical integration in terms of costs at different train densities (for now, holding infrastructure investment intensity per train-km at the sample mean). Where the VS (and HC) lines are above the origin this means that the VS and HC structures offer cost reductions (i.e. are less costly than vertical integration) for a given level of density. Figure 5 shows that the VS regime becomes a more expensive form of vertical structure than VI for busier railways, though does reduce costs for more lightly-used railways. This result of VS is directionally the same as in van de Velde et al. (2012) and Mizutani et al. (2015). According to the transaction cost theory, this finding can be explained by the increasing transaction costs on a busier network. For example, the entailing costs for tasks such as maintenance scheduling and maintaining safety under a busy train operation schedule are more expensive for vertically separated structures.

The train density break-even point between the VS and VI regimes is 84.6 (1.33* sample mean of 63.6) – where the VS curve crosses the horizontal axis. This result means that the VS regime (for now, with an average intensity of infrastructure investment per train-km) is more cost-efficient compared to the VI regime if train density is under 84.6 (train-km/route-km per day); after which VS starts to increase costs. This break-even point differs from past work (previously 0.99* sample mean[18]). The model suggests that the VS regime can be cost-effective for a broader range of railway networks, especially those with higher traffic volumes.

Another key difference in the model compared to past work is that the cost impact of the HC regime, relative to VI or VS, is also found to vary with train density - as shown by the HC curve in Figure 5. However, the slope of the line for VS is steeper than that for HC. This means that cost is affected to a greater degree by train density in the VS regime than in the HC regime. As compared to VS, the HC regime is more expensive for lightly used railways but intersects the VS curve at 1.26 times the sample mean (80.15 train-km/route-km per day). As

[18] The sample mean in Mizutani et. al. (2015) is very similar.

train density increases above this level the HC is a more effective structural form than VS. Assuming train density is a key driver for the misalignment costs between RU and IM where higher density increases conflict resolution costs, the HC regime appears more effective than the VS regime in mitigating these costs.

This discovery notably advances the discourse beyond the insights provided by van de Velde et al. (2012), by demonstrating that the HC regime addresses misalignment issues between RU and IM more effectively than the VS regime, a distinction not previously delineated. The higher cost break-even point identified for the HC regime underlines this finding, marking a significant contribution to the understanding of rail industry structure efficiencies.

This comparison between the two different forms of vertical separation (holding company and full legal vertical separation) is important in the context of EU rail reforms because the European Commission has permitted both methods as a valid means of delivering a form of VS in line with EU legislation. It does suggest though that the choice of form of VS is important. Beyond a train density cut-off point of 80.15 (1.26 times 63.6), the HC regime would be the cheapest means of delivering vertical separation, whilst full legal separation might be preferred (from a purely cost-reducing perspective) for less well-utilised railways to the left of this cut-off point (see Figure 5). With train density higher than 90.31 (1.42 times 63.6), vertical integration seems to be the most cost-efficient regime compared to both the VS and HC forms of separation.

3.4.2 Investment Coordination and Vertical Structure

Figure 6 considers the relationship between the choice of vertical structure and different intensities of infrastructure investment (as measured by investment per train-km). The cost effect of infrastructure investment is complex. As one element of cost, infrastructure investment contributes to total cost; but essential infrastructure investment may help to save operational costs. For example, rail electrification normally has high implementation costs, but it can reduce energy costs and operational costs given that electric engines have higher energy efficiency and less need for maintenance. The locomotion costs associated with operating an electric train can be four times lower than a diesel train (International Transport Forum, 2020).

van de Velde et al. (2012) provided a hypothesis that where a railway is undertaking significant investment, this would lead to higher costs in the VS regime than in the HC or VI regimes due to the extra misalignment costs (investment coordination problems) generated – with the HC and VI regimes deemed to be better at coordinating investment. However, this hypothesis was not tested empirically in their work. This chapter reveals a distinct difference in managing higher investments' cost impacts between the VS and HC/VI regimes. However, the finding is the opposite of that expected by van de Velde et. al. (2012). The model results show a negative impact of the interaction between investment intensity (*I(a))* and *Dvs (*with 1% statistical significance). On the other hand, the coefficient on the interaction term *I(a)*HC* (holding company) is close to zero and not statistically significant. This means that a higher intensity of infrastructure investment in the VS regime leads to a reduction in overall system costs, whereas there is no such cost-reducing effect in the case of the HC regime, compared with vertically integrated railways. A test was undertaken to include the interaction of investment intensity (*I(a)*) with the dummy variables *Dvs, Dhc,* and also *Dvi*. This test, specifically designed to explore the investment impacts on the VI regime, omitted the train density variable to focus solely on the investment dynamics. The results from this test analysis underscore the primary findings, revealing a statistically significant (1%) cost-reduction effect of infrastructure investment in the VS regime, while the interactions of *I(a)* with *Dhc* and *Dvi* did not exhibit a statistically significant impact on costs. This further clarifies that the cost-reducing advantage of higher infrastructure investment is uniquely observed within the VS regime, with no such effect detected in the HC and VI regimes.

Figure 6 illustrates how the cost relationship with vertical structure and train density alters under varying levels of infrastructure investment intensity in VS and HC regimes. By comparing VS to VI, **Figure 6** illustrates that a higher infrastructure investment intensity can shift the break-even point for train density in the VS regime to the right (higher). Compared to the minimum investment intensity, the break-even point under the maximum infrastructure intensity is more than three times higher (2.1* sample mean versus 0.61* sample mean)[19].

[19] Note that the interaction term between D_{HC} and investment was not statistically significant, and as such the holding company break-even point does not vary with investment intensity as noted above

This indicates that when infrastructure investment intensity is high, the VS regime can operate the railway system more cost-efficiently than the HC and VI regimes with the same train density.

Note that there is only one line for the HC regime in **Figure 6** since there was found to be no significant relationship between HC cost impacts and the level of investment intensity. Importantly the break-even point of 2.1* sample mean is even higher than the cost break-even point for the HC regime with an average investment intensity. It, therefore, appears that the cost advantage that the VS regime appears to hold in terms of higher investment outweighs its short-term coordination disadvantages associated with high train density (noted in the past literature and discussed above).

Table 9 below provides a comprehensive analysis of the cost effects of train density and investment intensity, highlighting the cost-effective range of train density for each vertical structure. The table considers mean, high, and low levels of infrastructure investment intensity.

Table 9 - The Indicative Cost-effective Range of Train Density (train-km/route-km per day) for Each Vertical Structure with Different Levels of Infrastructure Investment

Infrastructure Investment Intensity (annual)	Vertical Separation	Holding Company	Vertical Integration
Mean (≈ 9,500 €/train-km)	Less than 80.15	80.15 ~ 90.31	More than 90.31
High (≈ 44,700 €/train-km)	Less than 104	none	More than 104
Low (≈ 800 €/train-km)	Less than 14.86	14.86 ~ 90.31	More than 90.31

The results show that the break-even point for train density in the vertical separation regime can be significantly influenced by investment intensity. For instance, with a medium level of infrastructure investment intensity (sample mean), the vertical separation appears to be less cost-effective under high train density (>80.15 train km per route length per day). Conversely, vertical integration is better suited for handling higher train densities (>90.31 train km per route length per day) in terms of cost savings. However, when the infrastructure investment intensity is high, the vertical separation regime can be more cost-effective than the vertical integration regime, even with train densities as high as 104 train km per route length per day.

Another notable finding is the position of the HC regime, which falls between the vertical separation and vertical integration regimes. From a cost perspective, the HC regime acts as a substitute for full vertical separation. With a lower level of infrastructure investment intensity, the HC regime performs better than vertical separation when there is intensive train usage on the network. However, it is not as effective as the vertical integration regime when train density exceeds a certain threshold (i.e., >90.31 train km per route length per day). As the infrastructure investment intensity increases to a certain level, the HC regime loses its role as a substitute for the vertical separation regime. At this point, the most cost-effective regime becomes a competition between the vertical separation and vertical integration regimes, with a break-even point of 104 train km per route length per day.

These findings highlight the complicated relationship between train density, investment intensity, and the cost-effectiveness of different vertical structures in the railway industry. It underscores the importance of considering both factors in determining the optimal organisational form for minimising costs.

Table 10 presents examples of indicative cost-effective vertical structures under different combinations of infrastructure investment intensity and train density levels. It provides insights into the appropriate vertical structure from a cost-saving perspective for various railway networks. The table demonstrates that VS is more suitable for networks with low train density and/or high infrastructure investment intensity. In such cases, by having separate entities for rail operations and infrastructure management, VS can minimise transaction costs and improve operational efficiency.

On the other hand, the VI regime is more suitable for networks with high train density and/or low infrastructure investment intensity. In such cases, integrating the operations of passenger and freight services can lead to cost savings. The synergies and economies of scale achieved through vertical integration can help optimise resource allocation and improve overall efficiency.

The HC regime, positioned between VS and VI, serves as an intermediate option. It can be considered as a compromise between the two extremes, offering a balance between cost savings and operational efficiency. The HC regime performs well in networks with moderate train density and infrastructure investment intensity, providing a viable alternative to both VS and VI.

Table 10 - The Indicative Cost-effective Vertical Structure under Different Levels of Infrastructure Investment and Train Density

Infrastructure Investment Intensity (annual)	High Train Density (100)	Medium Train Density (60)	Low Train Density (20)
High (≈ 44,700 €/train-km)	VS	VS	VS
Mean (≈ 9,500 €/train-km)	VI	VS	VS
Low (≈ 800 €/train-km)	VI	HC	HC

These findings indicate the complex dynamics between train density, infrastructure investment, and the different vertical structures in the railway industry. There could be two perspectives to explain these findings.

Perspective A, which emphasises the role of infrastructure investment in mitigating misalignment costs, provides insights into the complicated relationship between train density, investment, and cost efficiency. Mizutani et al. (2015) suggest that higher train density levels in the VS regime may lead to increased costs due to greater misalignment costs arising from disruptions. Disruptions can arise from various factors, such as delays, congestion, and maintenance issues, which can impede the smooth operation of train services. The misalignment costs associated with these disruptions include the costs of resolving the disruptions, managing customer dissatisfaction, and maintaining the overall efficiency of the railway system. To address these misalignment costs, investment in infrastructure becomes crucial. By investing in infrastructure, railway operators can enhance the reliability, capacity, and performance of the rail network, thereby reducing the likelihood and impact of disruptions. This is exemplified by the introduction of the European Rail Traffic Management System (ERTMS), which has standardised and harmonised train control systems across Europe. The implementation of ERTMS has resulted in higher reliability rates and increased capacity, enabling railways to operate more efficiently and effectively (ERTMS, 2014). Consequently, disruptions are minimised, leading to cost savings in terms of resolving disruptions and ensuring uninterrupted train services. The VS regime, characterised by the separation of rail operations and infrastructure management, is particularly sensitive to misalignment costs due to its reliance on effective coordination between multiple entities. In this context, higher levels of infrastructure investment can significantly alleviate misalignment costs by improving real-time management, enhancing the capacity of the rail network, and streamlining operational processes. The benefits of infrastructure investment are more pronounced in the VS regime compared to other vertical structures, as the VS regime is more vulnerable to disruptions and misalignments arising from higher train density.

An alternative explanation, **Perspective B**, focuses on the cost efficiency of investment in different operational regimes. Van de Velde et al. (2012) argue that misalignment in investment coordination arises from mismatches between market needs and infrastructure investment, as well as between infrastructure and rolling stock investments. In the railway industry, ensuring the optimal allocation of investment resources is crucial for cost-effective operations. Coordinated structures, such as the HC regime, are expected to exhibit better investment coordination by aligning infrastructure and rolling stock investments with market demands. However, on the other hand, with a clear separation of rail operations and infrastructure management, vertical separation may promote stricter planning and evaluation within the investment coordination process. Additionally, regulatory oversight in vertically separated environments imposes a higher level of scrutiny on the infrastructure manager, fostering a more disciplined approach to investment decision-making. This regulation ensures that investments are assessed based on their cost-effectiveness and alignment with market needs, minimising wasteful expenditures. The VS regime, despite its challenges in coordination, may benefit from this focused and regulated investment approach, resulting in higher cost efficiency compared to more integrated regimes.

3.4.3 Summary

In conclusion, the econometric modelling results provide comprehensive insights into the cost dynamics of different vertical structures in the railway industry. The finding that higher infrastructure investment has a greater cost-reducing effect in the VS regime than in more integrated regimes challenges conventional expectations. Previous research, such as that by van de Velde, Nash et al. (2012), has suggested that more integrated solutions, such as the HC or VI, would be more efficient in managing infrastructure investment. However, the results of this Chapter indicate that the VS regime, when supported by higher infrastructure investment intensity, is better equipped to utilise this investment effectively and achieve cost reductions in the overall rail system.

The analysis explores the impact of train density and infrastructure investment intensity on cost efficiency from two perspectives. One explanation offered from the perspective of infrastructure investment's role in reducing disruptions and the cost efficiency of investment coordination provides a specific understanding of the relationship between train density, investment, and the different vertical structures in the railway industry. Another possible explanation for this unexpected finding is the increased transparency and focus of the VS railway system. In vertically separated environments, the clear division between rail operations and infrastructure management facilitates greater clarity in decision-making processes and accountability. This transparency allows for a more targeted and efficient allocation of investment resources, resulting in cost savings. These insights can inform policymakers and industry stakeholders in making informed decisions regarding the optimal vertical structure and investment strategies to achieve cost savings and improve the overall performance of railway systems.

While this chapter has provided valuable hypotheses (perspectives) regarding the cost effects of rail structural reforms, the narrative is not completed without robust qualitative insights. Chapter 5 of this thesis will examine the real-world effects of rail structural reforms, integrating quantitative findings with qualitative insights. This approach combines interviews, surveys, and extensive desktop research to validate hypotheses generated in the current chapter. By engaging with stakeholders' experiences and strategic responses, this next phase aims to offer a deeper understanding of the rail industry. This qualitative exploration will not only enhance the understanding of the dynamics between train density, investment, and rail industry structures but also offer a more comprehensive view of how such reforms are perceived and implemented within the industry.

4. Empirical Analysis – Demand Effect of Rail Structural Reform

This chapter delves into an empirical analysis that seeks to investigate the effects of rail structural reform on passenger rail mode share. The study employs data from 24 European countries spanning from 2000 to 2017. The study places significant emphasis on the pivotal role of rail price, safety, service quality, and economic factors. The analysis also includes a discussion about model functions that encompass linear regression, Tobit regression, and log-log models.

The study not only validates hypotheses about interactions between the rail industry structure (structural separation) and other demand drivers but also pioneers new insights into the demand implications of various rail industry structures. Section 4.1 lays the foundation by detailing the data selection model specifications tailored to capture the relationships under investigation.

In Section 4.2, the methodological framework is introduced, discussing the selection of passenger mode share within the complex landscape of European rail transport. Sections 4.3 and 4.4 critically evaluate the econometric results and discuss their broader implications. The results highlight new findings and offer policy recommendations. This approach underscores the chapter's contribution to the discourse on rail reform, providing a detailed understanding of its impact on the process that is underscored by the rationale behind focusing on passenger rail mode share. Overall, this chapter adds to the existing body of literature on rail reform, providing valuable insights that can inform policy decisions in the European context.

4.1 Data

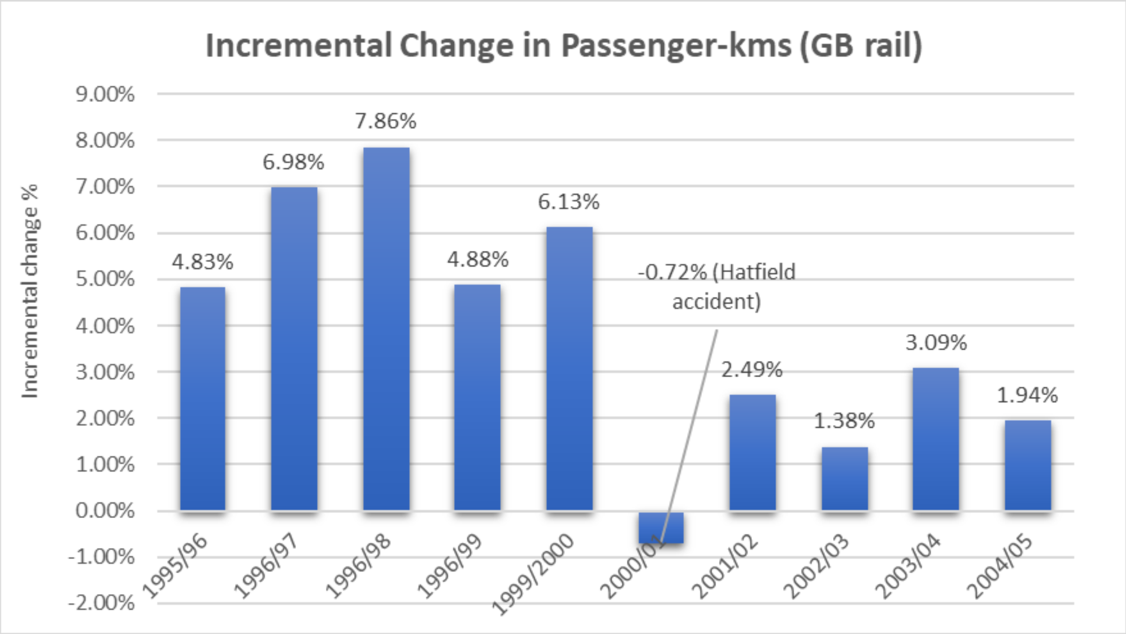
This analysis selected 24 European countries from 2000 to 2017 to analyse the passenger rail mode share in Europe, as shown in **Table 11**. The selection of European countries is due to the data availability for some key variables, e.g. passenger rail mode share and car ownership. Some countries' data are less complete than others – due to missing data for one or more variables, which means the dataset is unbalanced. For example, rail accident data for Denmark before the year 2004 cannot be collected from either of the key data sources (neither Eurostat nor UIC).

In this analysis, the primary focus is on the mode share of passenger rail. This is because passengers are typically more responsive to changes in the variables being tested in this analysis. Factors such as rail safety, service quality, and rail prices tend to have a more pronounced impact on passenger decision-making and their choice of transportation mode. For instance, passengers place a significant emphasis on safety when choosing their mode of travel. The perceived safety of rail transportation, including factors such as accident rates, incidents, and overall security measures, can greatly influence passenger preferences. While specific incidents, such as the Hatfield accident in the GB in 2000, serve as examples of how safety concerns can directly impact rail demand, the broader implication is that general safety perceptions play a crucial role in transportation choices. The Hatfield incident, caused by metal fatigue-induced derailment resulting in casualties and injuries, underscored the immediate and long-term impacts on passenger rail demand. Studies by Smith (2006) and Preston et al. (2009) collectively examine the far-reaching impacts of this incident. These two studies reveal not only the efficiency challenges post-accident but also the effects on delays and overall passenger rail performance. This suggests that passenger responses to rail safety are not merely reactions to isolated incidents but are influenced by the cumulative understanding and perception of rail safety standards. The examination of such impacts, including the efficiency challenges and delays that follow adverse safety events, highlights the broader relationship between safety perceptions and public transportation choices. **Figure 7** illustrates the incremental change in total passenger-kilometres in GB rail, with a noticeable demand reduction in the year of the Hatfield accident followed by a slower recovery. Exploring the share of passengers using rail offers insights into the influence of safety improvements and confidence-boosting measures in rail transport.

In contrast, the freight rail segment, an essential part of the rail industry, is primarily driven by price competitiveness and logistical considerations. As detailed by Beuthe et al. (2001), freight rail mode share is significantly influenced by economic and competitive factors rather than by aspects like service quality and safety that are pivotal in passenger decisions. Therefore, this thesis concentrates on passenger rail mode share to explore how structural reforms and associated variables, particularly safety, impact passenger preferences and decisions. This focus allows for a deeper investigation into the factors that directly affect passenger rail usage, offering insights into strategies for enhancing rail's attractiveness as a safe, reliable mode of transport.

In the initial phase of the analysis, an examination of the collinearity between variables present in the dataset was conducted. Collinearity refers to the interdependence or correlation between two or more predictor variables, and it can sometimes be a challenge in statistical modelling. The investigation indicated mild multicollinearity between car ownership and GDP per capita (*GDP pc*). Both of these factors are relevant to understanding rail mode share and are essential in shaping passenger transportation choices. Despite the potential correlation, both factors are fundamental to understanding the complexities of passenger rail mode share and provide valuable insights into the factors driving transportation choices. Thus, both variables were retained in this analysis.

Figure 7 – Year on Year Incremental Change (%) in Passenger-kilometres in GB Rail



Source: ORR Passenger rail usage (Table 1230)

Table 11 – Selected Countries and Periods

No.	Country	Year
1	Austria	2000 - 2017
2	Belgium	2000 - 2009
3	Bulgaria	2006 - 2010
4	Switzerland	2008 - 2017
5	Czech Republic	2000 - 2017
6	Germany	2000 - 2017
7	Denmark	2004 - 2009
8	Spain	2000 - 2017
9	Finland	2004 - 2017
10	France	2004 - 2017
11	United Kingdom	2002 - 2017
12	Greece	2004 - 2007
13	Hungary	2001 - 2017
14	Ireland	2000 - 2017
15	Italy	2000 - 2016
16	Luxembourg	2004 - 2012
17	Latvia	2008 - 2017
18	Netherlands	2004 - 2017

19	Norway	2004 - 2009
20	Poland	2004 - 2017
21	Portugal	2000 - 2017
22	Sweden	2003 - 2017
23	Slovakia	2004 - 2007
24	Turkey	2000 - 2016
Total observations		310

This chapter considers the following types of variables in the quantitative analysis.

Dependent variable:

- The dependent variable in the model is the rail passenger mode share (*MS*), which indicates the proportion of rail passenger kilometres in relation to passenger transportation by car and bus.
- It is important to note that this analysis excludes other transportation modes such as air, inland waterways, and short-sea shipping. The rationale for this exclusion is primarily driven by data availability limitations, as the data source used (Eurostat) focuses on rail passenger mode share in this particular manner.
- Acknowledging the relevance of modes like air, inland waterways, and short sea shipping in specific contexts, it's noted they typically hold less significance in domestic markets, particularly for passenger travel. Thus, omitting these variables from this analysis is not expected to introduce bias to the results unless they exhibit strong correlations with the variables of interest.

Economic variables:

- GDP per capita (*GDP*) was collected from the World Bank and transferred to the 2005 price base. Note that this variable was converted to the logarithmic form in the linear regression, given that a large value of GDP per capita may lead to a very small coefficient in the model results.
- Employment rate (*emp*) was collected from the World Bank, which indicated the employment-to-population ratio.

Competitor variables:

- Gasoline price (*fuel*) was selected to capture the fuel price of the competitor (i.e. car and bus). It was collected from IEA (Energy Prices and Taxes for OECD Countries Statistics Report in 2020), then exchanged to euro and deflated to the 2005 price base.
- Car ownership (*car*) was collected from Eurostat and converted to the ratio of passenger cars per inhabitant.

- The share of rail route length within the total route length of rail and road (*rlshare*) is used as an indicator of the comparative presence of the competing modes. The network length for the railway was collected from UIC, while the length of the road was collected from Eurostat.

Dummy (binary) variables:

- VS dummy (*dvs*): takes the value of 1 in the case of full VS of operations and infrastructure for a given observation in each year; zero otherwise.
- HC dummy (*dhc*): In each year, takes the value of 1 in the case where an HC structure is present for a given observation in each year; zero otherwise.
- VI dummy (*dvi*): this variable is omitted to avoid perfect collinearity; all demand effects are therefore measured relative to the VI structure. However, the interactions between *dvi* and other explanatory variables are retained.

Test variables:

- Train frequency (*freq*) was defined as the average number of trains per kilometre of route per day, thus:

  $$freq = \frac{Total\ annual\ train\ kilometer/365}{rail\ line\ kilometer}$$

  Based on this, *freqR* was derived to represent the train availability on the network, by multiplying *freq* with *rlshare*. This specification would better represent the availability of train services, as it indicates the collective influences of both train frequency and route length.
- The ratio of rail accidents to road accidents (*accd*) indicates the relative safety of the railway system. To account for variations in rail network length across different countries, the number of accidents per passenger-km was used to calculate the ratio of rail and road accidents. The rail accident numbers were collected from Eurostat, including all types of rail accidents (i.e. collision, derailment, level crossing, etc.), while the road accident numbers came from OECD including all types of road injury accidents.
- Passenger rail yield (*yield*) was used to indicate the rail price. It was defined as the total passenger rail revenue (from UIC) divided by passenger km (from OECD).
- UIC defined punctuality as the percentage of passenger trains with delay mins less than 5 mins. Initially considering punctuality (*punc*) as a measure of rail service quality, challenges arose due to limited data availability. Consequently, rail infrastructure investment (*inv*) was chosen as a substitute in the main analysis, reflecting a pragmatic approach to analysing service quality in the context of data constraints. This decision is supported by research indicating that infrastructure investments in railways, such as enhancements and renewal in electrification and signalling systems, directly contribute to service quality improvements, including increased train speed and reduced delays. For example, The International Transport

Forum (ITF) underscores the pivotal role of infrastructure investment in elevating rail system efficiency and service quality, including punctuality (ITF, 2019). In this case, punctuality was kept in a test modelling scenario (see Case 0 in Chapter 4.3).

Rail infrastructure investment (*inv*) was defined as the proportion of rail infrastructure investment within the total investment in both rail and road infrastructure. This variable served as an indicator of the service quality provided by the rail system. The rationale behind this choice is that higher infrastructure investment usually leads to improved train management, which in turn enhances the punctuality and reliability of train operations.

- Competition level (*Cmp*) within passenger rail is another factor included in this chapter. This is a judgement-based 0 – 4 scale, where 0 means no competition and 4 means full competition. This variable is an index developed by van de Velde et al. (2012) to indicate the extent of entry (tendering and open access) in passenger rail, and the same approach was followed here[20]. Given that the level of competition is naturally correlated with alternative rail industry structures (e.g. vertical integration is generally associated with lower levels of competition), this variable has not interacted with industrial structures.

Several adjustments were made to the panel data to ensure its completeness and consistency. Specifically, for rail accident data from 2000 to 2003, Eurostat was supplemented with information from UIC due to missing data. However, discrepancies between UIC and Eurostat reports required a robust approach by extrapolating Eurostat's 2000 data using trends observed in UIC data from 2000 to 2004. This method aimed at maintaining the reliability and consistency of the dataset. For the 2017 road accident data missing for Denmark, Ireland, and Luxembourg, the approach taken was to assume the figures remained unchanged from 2016, ensuring dataset consistency despite missing points. To compensate for missing rail infrastructure investment data in Ireland, the Netherlands, Portugal, and Switzerland for certain years, the decision was made to fill these gaps with investment levels from the most recent year available for each country. This method of adjusting the panel data was employed to maintain the integrity and accuracy of the analysis, addressing the issue of data availability and ensuring consistency across different sources and years.

Table 12 below documents the variables used in the model and provides the data source and summary statistics.

[20] The corresponding threshold of market entry ratio of competitive tendering for *Cmp* (1 to 4) are around 0-10%, 10%-25%, 25%-50% and 50% to 100% respectively.

Table 12 – Summarised Statistics of Selected Variables

Variable	Description	Data Source	Mean	Standard Deviation	Minimum	Maximum
MS	The share of pass-km for passenger rail, within rail, car and bus mode.	Eurostat	0.0715	0.0346	0.0140	0.1980
Emp	Employment to population ratio	World Bank	53.4252	5.9554	40.7850	65.9450
GDP	Main GDP aggregates per capita (euro, 2005 price)	World Bank	41,918	27,189	5,135	145,586
Car	Car ownership per inhabitant	Eurostat	0.4469	0.1208	0.0680	0.6660
Fuel	Gasoline price (euro, 2005 price)	IEA	1.1651	0.2393	0.6333	3.1611
rlshare	Share of rail route length within the total rail and road length	UIC and Eurostat	0.0580	0.0395	0.0144	0.1900
Freq	Average trains per day (Total train-km per route line km per day)	UIC	51.0357	32.8068	8.1603	156.1808
freqR	Freq * rlshare	Calculations	2.9476	2.6437	0.2001	14.9365
Inv	Share of rail infrastructure investment within rail and road infrastructure investment	OECD	36.1859	19.4939	2.9903	88.9192
Yield	Passenger rail revenue per passenger km (euro, 2005 price)	UIC & OECD	0.0920	0.0867	0.0028	0.5735
Accd	The ratio of accidents per passenger km between rail and road	Eurostat & UIC / OECD	0.0665	0.1321	0.0001	1.2593
Dvs	Dummy variable - if the rail structure is vertically separated (0-No, 1-Yes)	Cost analysis	0.4419	0.4974	0	1
Dhc	Dummy variable - if the rail structure is holding company (0-No, 1-Yes)	Cost analysis	0.2935	0.4561	0	1
Dvi	Dummy variable - if the rail structure is vertical integration (0-No, 1-Yes). This variable is omitted, but the interactions with other variables are included.	Cost analysis	0.2645	0.4418	0	1

Cmp	Competition level (0 ~ 4) in passenger rail	Previous study (EVES)	1.1323	1.2458	0	4
*Punctuality**	Percentage of passenger trains with delay time less than 5 minutes	UIC	90.9028	4.7012	78.0	98.9

* punctuality data is just used for the test run, as in Case 0 in the econometric result table.

4.2 Methodology

Given the limited literature in this area and the use of different model approaches to investigate the impact of structural reform on rail mode share, three different model specifications were introduced across seven distinct cases. These models, namely linear regression, logarithmic transformation of linear regression (referred to as the log-log model), and Tobit regression, have been widely employed in similar studies.

The next step involved selecting a preferred model based on a detailed comparison of model specifications and outcomes. This process aimed to pinpoint the most effective model for capturing the relationships between different rail industry structures and passenger rail mode share. Evaluating various model specifications, along with their strengths and weaknesses, allowed for a thorough and reliable assessment of structural reform's impact on rail mode share. The preferred model was selected to provide a solid basis for drawing insightful conclusions about how different industry structures influence passenger rail mode share.

4.2.1 Model Functions

Linear regression is a widely used method in predictive analysis. It serves as a linear approach for modelling the relationship between a criterion or scalar response and multiple predictors or explanatory variables. In the context of a linear regression model, the underlying assumption is that a one-unit change in the independent variable *X* results in a *b-unit* change in the dependent variable *Y*. The fundamental goal of linear regression is to establish a linear equation that best fits the data, allowing us to predict the value of the dependent variable based on the values of the independent variables. In this thesis, the linear model can be described as per the equation below:

$$MS_{it} = a_1 + a_2 GDP_{it} + a_3 emp_{it} + a_4 car_{it} + a_5 freqR_{it} + a_6 dvs_{it} + a_7 dhc_{it} + a_8 inv * dvs_{it} + a_9 inv * dhc_{it} + a_{10} inv * dvi_{it} + a_{11} yield * dvs_{it} + a_{12} yield * dhc_{it} + a_{13} yield * dvi_{it} + a_{14} accd * dvs_{it} + a_{15} accd * dhc_{it} + a_{16} accd * dvi_{it} + a_{17} cmp + \varepsilon_{it} \quad (1)$$

Where[21]: *GDP* = main GDP aggregates per capita; *emp* = employment to population ratio, *car* = car ownership per inhabitant, *Fuel* = Gasoline price, *freqR* = Freq * rlshare, *inv* = Share of rail infrastructure investment within rail and road infrastructure investment, *dvs* = Vertical Separation, *dhc* = Holding Company, *dvi* = Vertical Integration, *yield* = Passenger rail revenue per passenger km, *accd* = The ratio of accidents per passenger km between rail and road, *cmp* = Competition level (0 ~ 4) in passenger rail;

Tobit regression is a regression method that shares similarities with linear regression, but it is specifically designed to handle censored or limited dependent variables. In cases where the dependent variable is restricted within a specific range, Tobit regression becomes a suitable choice to model such data effectively. In this thesis, the dependent variable is passenger rail mode share, which is bound between 0 and 1, representing the proportion of rail passenger-

[21] See more details of variable definition in Table 12.

kilometres relative to car and bus passenger transportation. Since the mode share cannot exceed 1 or be less than 0, it is considered censored within this range. Tobit regression addresses this censoring issue by estimating two parts of the model simultaneously. First, it models the likelihood of observing censored values below or above the bounds (in the case of 0 and 1), using a binary response model. Second, it models the continuous part of the dependent variable using linear regression for the observations that lie within the range. This approach allows Tobit regression to account for the limitations of the dependent variable while still capturing the relationships between the explanatory variables and the outcome of interest. The model function for Tobit regression is as follows:

$$MS_{it} = a_1 + a_2 GDP_{it} + a_3 emp_{it} + a_4 car_{it} + a_5 freqR_{it} + a_6 dvs_{it} + a_7 dhc_{it} + a_8 inv * dvs_{it} + a_9 inv * dhc_{it} + a_{10} inv * dvi_{it} + a_{11} yield * dvs_{it} + a_{12} yield * dhc_{it} + a_{13} yield * dvi_{it} + a_{14} accd * dvs_{it} + a_{15} accd * dhc_{it} + a_{16} accd * dvi_{it} + a_{17} cmp + \varepsilon_{it}$$

$$MS_{it} > 0$$

$$MS_{it} < 1 \quad (2)$$

Log-log regression is a variant of linear regression where both the dependent variable (*Y*) and the explanatory variables (*X*) are transformed into their natural logarithms before performing the regression analysis. This transformation helps in capturing the constant percentage change or elasticity relationship between the variables, as opposed to the constant additive relationship assumed in traditional linear regression. In the log-log model, a 1 percent change in an independent variable (*X*) is associated with a *b* percent change in the dependent variable (*Y*). This implies that the impact of *X* on *Y* is proportional or multiplicative, rather than additive, as seen in linear regression. This makes the log-log model particularly suitable when expecting the relationship between variables to be better represented in terms of relative changes or elasticities. The log-log model also allows for a more flexible representation of the data by considering the constant elasticity relationship between the transformed variables. This is particularly relevant in situations where the variables may not exhibit constant additive relationships and where the focus is on understanding proportional impacts.

Additionally, in the log-log model, the variables are standardised by taking the natural logarithm of each variable and subtracting the mean of that variable from each observation. This standardisation process allows the coefficients in the log-log model to directly represent the elasticities of the variables with respect to the average values in the dataset.

In this thesis, the log-log model can be described in terms of the equation below:

$$MS_{it} = a_1 + a_2 Ln(GDP_{it}) + a_3 Ln(emp_{it}) + a_4 Ln(car_{it}) + a_5 Ln(freqR_{it}) + a_6 dvs_{it} + a_7 dhc_{it} + a_8 Ln(inv) * dvs_{it} + a_9 Ln(inv) * dhc_{it} + a_{10} Ln(inv) * dvi_{it} + a_{11} Ln(yield) * dvs_{it} + a_{12} Ln(yield) * dhc_{it} + a_{13} Ln(yield) * dvi_{it} + a_{14} Ln(accd) * dvs_{it} + a_{15} Ln(accd) * dhc_{it} + a_{16} Ln(accd) * dvi_{it} + a_{17} cmp + \varepsilon_{it} \quad (3)$$

The dummy variables (e.g. *dvs*, *dhc* and *dvi*) in this model have not been converted to logarithm form, given that these variables embody zero values which cannot be logged.

Additionally, both the Likelihood ratio test and AIC test show that *freqR* omitting dummy variable interactions is more appropriate than including such interactions.

4.2.2 Comparison between Model Functions

Table 16 presents the results obtained from testing each of the model specifications, namely linear regression, Tobit regression, and log-log regression. These models were assessed based on various perspectives, including model specification, theoretical underpinnings, model fit, and the reasonability of the obtained results.

After careful evaluation, it was concluded that the log-log regression provided the most appropriate functional form for the analysis. This choice was driven from four perspectives:

1. **Model Specification**

   The linear regression model specification suggests that a one-unit increase in the independent variable (i.e., yield) leads to an *X-unit* increase in passenger rail mode share. This interpretation aligns with the straightforward linear relationship assumed in the model, where the change in the independent variable has a direct and proportional impact on the dependent variable.

   The Tobit model, on the other hand, provides a more suitable model specification for cases where the dependent variable has a limited range, as is the case with passenger rail mode share, which must fall between 0 and 1. By considering the censored nature of the dependent variable, the Tobit model effectively restricts the predictions within this bounded range, ensuring that the estimated passenger rail mode share remains within the valid limits. This characteristic enhances the accuracy and validity of the model's predictions, especially in scenarios where the dependent variable exhibits constrained values.

   The log-log model specification takes a different approach. In this model, a 1% increase in the independent variable (i.e., yield) results in an *X*% increase in passenger rail mode share. The log-log model is designed to capture the relative percentage changes or elasticities between variables, providing a more detailed understanding of their interconnected dynamics.

   The model specifications for both the Tobit model and the log-log model hold plausible economic explanations that are consistent with the underlying principles of rail mode share dynamics. The Tobit model's straightforward interpretation is well-suited for scenarios where the primary focus lies in understanding absolute changes in variables and their direct impact on the dependent variable, which, in this case, is passenger rail mode share. On the other hand, the log-log model takes a different approach by emphasising proportional changes and elasticities between variables. This model specification proves to be particularly valuable when investigating how relatively small shifts in factors can influence passenger rail mode share on a percentage basis. By examining the relative percentage changes, the log-log model provides a good understanding of the interconnected dynamics between variables. The log-log model's ability to capture elasticities and proportional effects makes it well-suited for the objective of delving deeper into the relative impacts of structural reform on rail mode share.

2. Theoretical Background

The comparison of the theoretical backgrounds underlying each model function highlights the relative merits and appropriateness of the log-log model for analysing railway mode share. While the linear regression and Tobit model do not have specific theoretical foundations tailored to the context of analysing railway mode share, the log-log model benefits from a theoretical explanation drawn from the literature.

The log-log model's theoretical foundation can be traced back to Winston's pioneering work in 1983, where cost functions and Shephard's lemma were employed to derive a mode share model for freight rail. Building upon this foundation, Mizutani and Uranishi (2020) extended the log-log approach to develop a mode share model specifically for passenger rail. This theoretical rationale provides a solid basis for utilising the log-log model in the context of railway mode share analysis.

In contrast, the linear regression and Tobit model do not directly incorporate such proportional relationships, and while the Tobit model addresses the issue of censoring in the dependent variable, it does not have a specific theoretical background concerning the railway mode share analysis.

From this perspective, the log-log model emerges as a more robust choice for the research objectives. It provides a stronger theoretical explanation that aligns with the complexities of mode share dynamics in the context of rail transportation.

3. Statistical Model Fit

In comparing the fit of linear, Tobit and log-log models, it is essential to consider that the dependent variables differ between the two models. While the linear and Tobit models use the raw mode share as the dependent variable, the log-log model employs the logarithm of the mode share. As a result, the traditional R-squared measure, which quantifies the proportion of variance explained by the model, may not be suitable for direct comparison. To address this challenge and determine the most appropriate model fit, the Box-Cox test was utilised. The Box-Cox test is specifically designed to compare a linear model with its logarithmic transformation, making it a relevant and reliable measure in the context. This test assesses the goodness-of-fit for both the linear and log-log models, allowing us to determine which model better captures the underlying patterns in the data. Conducting the Box-Cox test using STATA quantitatively evaluates the performance of each model and investigates which one aligns more closely with the actual data. The result of the Box-Cox test is shown in **Table 13**.

Table 13 - Box-Cox Test Result

Test H0:	Restricted log-likelihood	LR statistic chi2	P-value Prob > chi2
Lambda = -1	-151.29578	107.26	0.000
Lambda = 0	-98.431321	1.53	0.216

Lambda = 1	-132.87058	70.41	0.000

The analysis utilised the Box-Cox test results to determine the optimal model transformation. The test statistic, lambda, assessed the most suitable transformation for the analysis, guiding the choice between different model specifications to best fit the data. The lambda values hold important implications, each corresponding to a specific transformation of the dependent variable (mode share) and allowing for the comparison of the linear, log-log, and inverse specifications.

- A lambda value of 1 indicates the equivalent of a regression in which both the dependent and independent variables remain untransformed. The null hypothesis associated with this value is that the linear specification is the best-fitting model.
- A lambda value of 0 corresponds to the equivalent of a regression in which the dependent variable Y^* is defined as the logarithm of Y ($Y^* = \log(Y)$). The null hypothesis for this transformation is that the log-log specification is the best-fitting model.
- A lambda value of -1 corresponds to a regression in which $Y^* = 1/Y$. The investigation under the null hypothesis evaluates if using the inverse of mode share offers a more fitting model than linear or logarithmic approaches, examining alternative ways to better fit the data.

The p-value associated with the "lambda = 0" test is higher than 0.05, indicating that the null hypothesis, the log-log specification is the best-fitting model, cannot be rejected. Therefore, based on the Box-Cox test, it concludes that the log-log function is preferred for this analysis. The significance of this result lies in the theoretical basis of the log-log model, which aligns well with the underlying principles of rail mode share dynamics.

4. Model Results

The analysis involved a simplification of the model to focus on key variables excluding dummies, aiming to understand economic explanations behind model results more clearly. The objective was to determine whether each model function could derive reasonable results, such as positive or negative mode share impacts, for each variable.

The comparison of elasticities for some key variables between the three model functions is presented in **Table 14**, and these results can also be found in Tables 17 - 19. This comparison aimed to demonstrate the plausibility of the model results based on their elasticities. The examination observed that the model results for linear regression were very similar to those for the Tobit model. This finding is not surprising, given that both model functions assume a linear correlation between the dependent and independent variables. As a result, the comparison of elasticities would be primarily conducted between the linear and Tobit models versus the log-log model.

When comparing linear regression with log-log regression, it shows that the log-log regression produced more sensible results. For instance, the variables of car ownership and rail accident ratio are expected to have negative impacts on rail mode share, which aligns with the theoretical expectations. However, the linear regression showed positive coefficients for both variables, which contradicts the underlying logic of their influence on rail mode share.

Table 14 - Model Results (coefficient) Comparison between Linear, Log-log, and Tobit Model

Variable	Linear model (case 1)	Log-log model (case 4)	Tobit model (case 7)
Emp	-0.2441	0.2263	-0.1835
Ln(GDP)	-0.0082	-0.0653 *	-0.0202
Car	0.2166 *	-0.3397 ***	0.0205
Fuel	0.2194 ***	0.4309 ***	0.1499 ***
freqR	0.1448 ***	0.0690	0.0701 *
Yield	-0.0175	-0.0677	-0.0774 ***
Accd	0.0150 *	-0.0003	0.0022
Inv	0.0741 **	0.0035	-0.0008
Cmp	-0.0303	0.0241	0.0046
_cons	0.6433 **	4.3968 ***	0.8880 ***
R2	0.9577	0.9594	n/a

Table 15 employs a scoring system to compare the three model functions across the four evaluation areas. Each model is scored on a scale from 0 to 1 for each criterion, where 1 point means a model's clear advantage or strong suitability in that specific aspect, reflecting its effectiveness in capturing the dynamics of rail passenger mode share. A score of 0 indicates a relative disadvantage or lesser appropriateness for the research context. This scoring system is designed to provide a straightforward, cumulative assessment of each model's overall performance and suitability for analysing the demand effect of rail structural reform. The assignment of points across all categories reflects an evaluation of the models' specifications, theoretical underpinnings, fit to the data, and the coherence and relevance of their results, guiding the selection of the most appropriate model for this analysis.

In conclusion, the log-log model consistently provided more reasonable and theoretically sound results compared to the linear/Tobit model, with the highest score of 4 in the comparative analysis. Its emphasis on proportional relationships and elasticities makes it a more suitable choice for the research objectives, allowing us to gain a deeper understanding of the intricate interactions within the rail mode share system. As a result, the log-log model was preferred and selected as the most appropriate model specification for the analysis.

Table 15 – Summary of Comparison between Linear, Log-log and Tobit Model Functions

	Linear Model	Log-Log Model	Tobit Model
Model Specification	1	1	1
Theoretical Background	0	1	1
Model Fit	0	1	0
Model result	0	1	0
Score	**1**	**4**	**2**

4.3 Econometric Results

This chapter first investigates the impact of punctuality on rail passenger mode share using a test scenario named Case 0, which includes a limited number of observations (100) due to the availability of punctuality data from UIC. To analyse this scenario, equation (2) is employed, as the log-log model had been identified as the most suitable model function.

Concerning panel regression, a fixed effects specification is appropriate when individual or entity-specific time-invariant characteristics might bias the predictor or outcome variables. The fixed effects model effectively controls for these potential biases. On the other hand, random effects models are suitable if they assume that the individual/entity-specific effects are uncorrelated with the regressors, often used when entities are considered random samples from a larger population. To determine whether fixed effects or random effects would be more appropriate for the panel regression in Cases 0 to 6 as well, the Hausman test was conducted for each case respectively. The results of the Hausman test for Case 1 to Case 6 consistently favoured the random effects model, indicating that assuming random effects was more suitable for the panel regression analysis. Case 0 shows a *p-value* of 0.3609 (higher than 0.05), which means Fixed Effects is more suitable. As displayed in **Table 16**, the findings from Case 0 with the limited punctuality data did not derive statistically significant evidence of punctuality's impact on rail passenger mode share. While the test scenario did not reveal a statistically significant relationship between punctuality and rail passenger mode share, it is important to recognise the constraints of the data and the limited number of observations available for this specific variable.

Table 16 – Model Result (Test run with punctuality)

	Test run with punctuality data (100 observations)
Variable	**Case 0 (FE)**
Emp	-1.1511 ***
GDP	0.1049 *
Passvol	1.0855 ***
Rlshare	0.0701
Yield	-0.0413
Accd	-0.0179
Punc	0.0465
Inv	0.0209
_cons	0.0471 *
R2	0.7124

The subsequent analysis applied regression models for nine different cases using the main dataset, excluding the punctuality variable. Cases 1 to 3 utilised the linear regression model described in equation (1), with the model results shown in **Table 17**. Additionally, Cases 7 to 9 applied the Tobit model according to equation (3), see the results in **Table 18**. Cases 4 to 6 (with preferred case) employed the log-log model based on equation (2), with the model results shown in **Table 19**. Each model was tested with a range of variables to explore their impact on rail mode share.

To create a base scenario and investigate the direct impact of structural reform on rail mode share, the analysis included single variables and omitted interactions (e.g., *yield*dvs*) in Cases 1, 4, and 7. This comparison between Cases 1, 4, and 7 aims to assess the effect of structural reform on rail mode share, and the results in Case 4 (with the preferred model function, log-log model) were found to be consistent with previous findings, i.e. van de Velde et al. (2012), and supported the hypothesis that structural reform influences rail mode share indirectly through other factors (as observed in Case 6), see in Table 20.

As mentioned earlier in this chapter, the Hausman test conducted for Cases 1 to 6 determined that random effects were more suitable for the panel regression for all the cases. In Cases 2 and 3 (as well as Cases 5 and 6, Cases 8 and 9), different formulations of the variable *freqR were tested*. Specifically, they explored whether introducing interactions between *freqR* and dummy variables (*dvi, dvs, dhc*) would yield more appropriate results.

Among the considered cases, Case 6 emerged as the preferred model for further analysis. The log-log model demonstrated the best functional form for the data, making Case 6 the most suitable for the research objectives. Although Cases 5 and 6 produced similar coefficients for most generic variables, the results from the Likelihood Ratio and AIC tests indicated that *freqR* without interactions was the more appropriate formulation. Consequently, **Case 6 was selected as the preferred model**, providing valuable insights into the impact of structural reform on rail mode share and supporting the use of the log-log model for this analysis.

Table 17 – Model Result for Linear Regression

Variable	**Case 1**	**Case 2**	**Case 3**
emp	-0.2441	-0.3460 *	-0.3442 *
Ln(GDP)	-0.0082	-0.0243	-0.0213
car	0.2166 *	0.1974 *	0.2021 *
fuel	0.2194 ***	0.2028 ***	0.1912 ***
freqR	0.1448 ***		0.1026 **
yield	-0.0175		
accd	0.0150 *		
inv	0.0741 **		
dvs	-0.0291	-0.1733	-0.0162
dhc	-0.0195	-0.2351 **	-0.1565 *
*freqR*dvs*		0.1867 **	

*freqR*dhc*		0.1154 **	
*freqR*dvi*		0.0416	
*inv*dvs*		0.0844	0.0805
*inv*dhc*		0.0470	0.0494
*inv*dvi*		0.0915	0.1016 *
*yield*dvs*		-0.0361	-0.0413
*yield*dhc*		0.1268 *	0.1431 **
*yield*dvi*		-0.1966 ***	-0.1809 ***
*accd*dvs*		-0.0017	-0.0016
*accd*dhc*		-0.0466 *	-0.0513 *
*accd*dvi*		0.0212 *	0.0251 **
cmp	-0.0303	-0.0429	-0.0409
_cons	0.6433 **	0.9835 ***	0.9107 ***
R2	0.9577	0.9661	0.9659

Table 18 – Model Result for Tobit Model

Variable	**Case 7**	**Case 8**	**Case 9**
emp	-0.1835	-0.3165 **	-0.2703 *
Ln(GDP)	-0.0202	0.0081	0.0074
car	0.0205	0.0532	0.0664
fuel	0.1499 ***	0.0669 *	0.0753 *
freqR	0.0701 *		0.0792 **
yield	-0.0774 ***		
accd	0.0022		
inv	-0.0008		
dvs	0.0620 *	0.1864	0.1884 *
dhc	0.0753 *	0.1220	0.0710
*freqR*dvs*		0.1074 *	
*freqR*dhc*		0.0341	
*freqR*dvi*		0.0918	
*inv*dvs*		-0.0283	-0.0346
*inv*dhc*		0.0086	0.0088
*inv*dvi*		0.0483	0.0429
*yield*dvs*		-0.1295 *	-0.1099
*yield*dhc*		-0.0223	-0.0225
*yield*dvi*		-0.1008 ***	-0.0975 **
*accd*dvs*		-0.0059	-0.0056

*accd*dhc*		-0.0074	-0.0045
*accd*dvi*		0.0516 ***	0.0492 ***
cmp	0.0046	-0.0015	-0.0034
_cons	0.8880 ***	0.9989 ***	0.9749 ***
R2	n/a	n/a	n/a

Table 19 – Model Result for Log-log Model (with Preferred Case)

Variable	**Case 4**	**Case 5**	**Case 6 (Preferred Case)**
emp	0.2263	0.1338	0.1146
GDP	-0.0653 *	-0.0670 *	-0.0678 *
car	-0.3397 ***	-0.3260 ***	-0.3224 ***
fuel	0.4309 ***	0.3264 ***	0.3174 ***
freqR	0.0690		0.0835 *
yield	-0.0677		
accd	-0.0003		
inv	0.0035		
dvs	0.0528	-0.0653	-0.1051
dhc	0.0519	-0.0606	-0.0833
*freqR*dvs*		0.1800 *	
*freqR*dhc*		0.0945 *	
*freqR*dvi*		0.0414	
*inv*dvs*		0.0658	0.0635
*inv*dhc*		0.0707 *	0.0747 *
*inv*dvi*		-0.0716 *	-0.0702 *
*yield*dvs*		-0.1265 **	-0.1380 **
*yield*dhc*		-0.0747	-0.0552
*yield*dvi*		-0.0231	-0.0101
*accd*dvs*		-0.0902 ***	-0.0886 ***
*accd*dhc*		-0.0621 **	-0.0704 **
*accd*dvi*		0.0067	0.0079
cmp	0.0241	0.0118	0.0130
_cons	4.3968 ***	4.4572 ***	4.4811 ***
R2	0.9594	0.9659	0.9657

Table 20 – Effect of variables on passenger rail mode share

	van de Velde et al. (2012)	**Tomeš (2017)**	**Mizutani and Uranishi (2020)**	**This thesis (Case 6)**
GDP	--	---	0 to +++	-
Employment	++	0 to ++	NI	0
Car ownership	NI	NI	NI	---
Fuel price	NI	0	+ to +++	+++
Train availability	NI	NI	0	+
Competition (internal)	0	0	0	0
Vertical separation	0 to -	-	+++	0
Holding company	0	NI	0	0
Rail infrastructure investment	NI	NI	NI	0 in VS; + in HC; - in VI
Rail price	NI	---	- to ---	-- in VS; 0 in HC; 0 in VI
Rail insecurity (accident)	NI	NI	NI	--- in VS; -- in HC; 0 in VI

Note: the signs in the table indicate the following:

- Positive effect: +++ (strong significance), ++ (medium significance), + (weak significance). Strong with significant at 1% level, medium at 5% level, weak at 10% level
- Negative effect: --- (strong significance), -- (medium significance), - (weak significance). Strong with significant at 1% level, medium at 5% level, weak at 10% level
- Non effect: 0
- Not included: NI

First and foremost, the analysis indicated that the results for the majority of the control variables aligned with expectations, demonstrating reasonable relationships with passenger rail mode share and consistency with findings from the previous literature, as detailed in **Table 20**. An exception to this pattern was the employment rate, whose impact on rail mode share appeared insignificant in the study. This differs slightly from previous literature, where van de Velde et al. (2012) identified a positive impact of employment rate, and Tomeš (2017) presented mixed findings, with some cases showing positive effects and others indicating no significant relationship. This variation could be attributed to differing datasets and changes in employment patterns over time captured in the model.

Notably, GDP per capita (*GDP pc*) exhibited a negative impact on rail mode share, a finding consistent with past literature, including studies by van de Velde et al. (2012) and Tomeš (2017). This phenomenon can be attributed to several factors associated with higher GDP per capita, which collectively incentivise passengers to opt for car travel over rail transportation. First, an increase in GDP per capita typically reflects higher average incomes, leading to greater affordability of car ownership (as the weak multicollinearity between GDP per capita and car ownership variables observed and discussed earlier in this chapter). With more disposable income, individuals are more likely to purchase and use private vehicles for convenience and flexibility not always matched by rail travel. Furthermore, higher GDP per capita is often correlated with a higher value of time among individuals. In contexts where rail infrastructure may not provide direct or rapid services, the perceived time-saving benefits of car travel become a significant factor. Moreover, the increased value of time leads to a higher demand for travel modes that offer greater control over departure times, routes, and privacy, qualities that cars typically provide over public rail transport. The aggregate effect of these factors—enhanced affordability, time sensitivity, and the perceived advantages of convenience and status—explains the trend where higher GDP per capita levels are associated with reduced rail mode share. This is not to say that rail travel cannot compete; rather, it highlights the importance of rail systems evolving to meet the changing preferences and demands of a wealthier population, through improvements in service speed, frequency, reliability, and connectivity.

This analysis has shown that car ownership has a significant negative impact on passenger rail mode share. This highlights the competition between private and public modes of transportation. The more personal vehicles there are, the less people tend to use rail services. It's worth noting that previous empirical analyses conducted by van de Velde et al. (2012), Tomeš (2017), and Mizutani and Uranishi (2020) did not consider car ownership as a variable. Mizutani and Uranishi's study omitted car ownership from their empirical analysis due to its high correlation with other key variables, presumably GDP per capita. the investigation also identified a weak correlation between car ownership and GDP per capita (as mentioned earlier in this chapter); however, given its marginal impact on the model's outcomes, both variables were retained to delve into their distinct effects on rail mode share. This allows to enrich the existing literature by demonstrating how important car ownership is in determining transportation mode selection.

In relation to fuel prices, recent research has shown that higher fuel prices can encourage people to use rail travel instead of cars. These findings support the results from Mizutani and Uranishi (2020) but differ from Tomeš (2017), which found no significant correlation. This suggests that economic measures, such as adjusting fuel taxes, can be effective in promoting public transport use. However, the relationship between car ownership and fuel prices can have a complex impact on rail mode share, as changes in these variables may offset each other's effects.

This analysis demonstrates a positive impact of train availability on rail mode share, highlighting the essential role that service frequency plays in enhancing the attractiveness and convenience of rail travel. Specifically, rail frequency (*freqR*) was utilised to measure the availability of train services, which combines average trains per day with the share of rail route length relative to the total rail and road length. This finding contrasts with Mizutani and Uranishi's (2020) study, which did not find a significant impact of train availability on rail mode share, using rail route-km per road km as their variable. The discrepancy between the findings and the results of Mizutani and Uranishi may be attributed to the measure of train availability. the measure considers not only the route length but also train frequency, which provides a more accurate reflection of how accessible and convenient the service is for passengers. This insight into the positive correlation between rail frequency and mode share underscores the importance of enhancing train frequency.

The analysis indicated that the impact of competition within the passenger rail sector on mode share was uncertain, as evidenced by the non-statistically significant coefficient for the competition variable (*cmp*). This finding is consistent with the previous literature and may need a deeper examination of the rail market competition. This variable serves as a policy-oriented measure, assessing market entry levels through a qualitative scoring system, reflecting the regulatory landscape's impact on competition rather than quantifying it directly. The variability in the significance and direction of competition's impact across different contexts suggests that its effects are highly contingent on the specific regulatory, operational, and market conditions in individual regions or countries. For instance, the extent of market liberalisation, the regulatory framework governing competition, and the competitive dynamics between rail operators can potentially influence how competition affects mode share. On the other hand, the introduction of competition is often aimed at improving service quality and efficiency, but competition can also hinder the benefits if it causes service fragmentation or passenger confusion.

In conclusion, the control variables in the model demonstrated reasonable relationships with passenger rail mode share, providing confidence in the validity of the analysis. The negative impact of car ownership and the positive impact of fuel prices highlight the influence of cost and convenience factors on mode choice. Moreover, the positive relationship between rail frequency and mode share underlines the importance of service quality and frequency in attracting passengers to rail travel. Nevertheless, the impact of competition within the passenger rail sector remains inconclusive and requires further examination to ascertain its significance on rail mode share dynamics.

4.4 Discussion

This chapter's primary objective is to examine the interaction between rail structural reform and various test variables to understand their collective impact on rail passenger mode share. The exploration focuses on understanding the interplay between various factors to uncover insights into the dynamics affecting rail mode share and the response of different industry structures to changes in key variables. By investigating the coordination between rail structural reform and the test variables, this analysis aims to provide valuable guidance for policymakers and stakeholders in making informed decisions to influence rail demand. There are several findings derived from the econometric model results.

Specifically, the analysis of the rail price variable, which is derived from the ratio of total passenger rail revenue to passenger-kilometres, indicated a negative impact on passenger rail mode share under the VS regime. This outcome suggests that, within the context of VS, passengers might exhibit higher sensitivity to changes in fare levels or perceived pricing structures. It's important to note, however, that the yield variable represents an aggregate measure of revenue per unit of rail service consumed, rather than direct ticket prices faced by consumers. Thus, while a negative association under the VS regime implies price sensitivity, it considers broader revenue dynamics including fare policies, service value, and perhaps even other revenue (e.g. rent, car park, etc.). Similarly, the absence of statistically significant coefficients under the HC and VI regimes doesn't necessarily mean that price changes have no effect on mode share. This lack of significance could also be due to variations in fare strategies or differences in service offerings, which might weaken the direct impact of fare adjustments on mode share. This interpretation aligns with findings from Mizutani and Uranishi (2020), who noted that the direct effect of rail fares on passenger mode share was not significantly discernible under the VI regime. The distinction between revenue-based yield and specific pricing strategies underscores the complexity of assessing fare sensitivity and requires careful consideration of the broader economic and operational context within which rail services operate.

Regarding the relative accident ratio, it exhibited negative impacts on rail mode share under both the VS and HC regimes, with the influence being stronger under the VS regime. However, the corresponding coefficient for the VI regime was not statistically significant, suggesting an absence of a clear relationship between rail safety and passenger mode share under the VI structure. It's important to note that the absence of a clear statistical relationship under the VI regime does not necessarily indicate that safety is irrelevant to passengers. Instead, it may reflect that the integrated management of rail services and infrastructure under VI potentially allows for more effective mitigation of safety concerns, or perhaps that safety perceptions are influenced by factors not captured solely through accident rates. A relevant example of the impact of rail safety on demand can be observed in the UK, a country employing the VS regime during the time of the Hatfield accident in 2000/01. This event not only led to a significant decline in rail demand but also underscored the broader implications of rail accidents on passenger rail performance, productivity, and infrastructure investment strategies (Smith and Wheat, 2009). Although, extrapolating from this single incident to broader trends requires caution. The specific circumstances of the Hatfield accident, including its severity and the subsequent media attention, might have amplified its impact on public perception and demand, beyond what might be expected from accident rates alone.

The analysis shows different effects of rail infrastructure investment on passenger rail mode share, depending on the industry structure. In the case of the HC regime, infrastructure investment is positively correlated with an increase in rail mode share, indicating that such investments make rail transport more attractive. However, in the VI regime, infrastructure investment seems to have a negative impact on mode share. This initial finding, which suggests that investment to improve network connectivity and service quality could reduce mode share, requires further exploration.

To explain this apparent contradiction, a hypothesis is developed from examining factors such as price and safety. The hypothesis assumes that the benefit of infrastructure investment in the VI regime is comparatively lower than in other regimes (such as VS and HC), which is offset by the disbenefits of infrastructure investment. This hypothesis is supported by the examination of service availability (as measured by train frequency timing and the relative length of rail track, known as *FreqR*) and safety impacts on mode share in Cases 5 and 6. The analysis reveals that in the VI regime, the use of different modes of transportation remains relatively unchanged in response to improvements in service availability and safety enhancements resulting from infrastructure investment. Additionally, the potential disruptions arising from such investments, such as those from renewal projects, may discourage passengers, thereby outweighing the intended advantages of the investments. In essence, while infrastructure investment is generally aimed at boosting rail appeal through better connectivity and service quality, its impact is adjusted by the industry structure under which it occurs. In the VI regime, the expected positive outcomes might be mitigated by the adverse effects of investment-related disruptions on passenger demand. This understanding underscores the complex interplay between infrastructure investment and rail mode share.

This may also explain the lack of significant influence of infrastructure investment on mode share in the VS regime. While van de Velde et al. (2012) pointed out that VS might introduce additional coordination costs and potential disruptions from infrastructure investments, the adverse impacts on passenger demand are potentially counterbalanced by the benefits these investments bring. Enhanced connectivity, service quality, and safety improvements can significantly contribute to the attractiveness of rail travel, negating the temporary inconveniences caused by construction and upgrades. This delicate balance between the drawbacks and advantages of infrastructure investment might explain its non-significant effect on mode share within the VS context, underscoring the complexity of its influence on rail transportation dynamics.

The policy implications derived from this research are of significant importance for policymakers and rail operators alike. The findings highlight the varying degrees of influence that different structural regimes have on passenger mode choice, suggesting tailored strategies for enhancing passenger demand and improving overall rail performance.

First, it suggests that rail companies operating under the VI regime may have limited ability to influence passengers' mode choices by adjusting rail prices or enhancing rail safety measures, as these factors seem to have minimal impact on passenger demand. On the other hand, in the VS and HC regimes, passengers appear to be more sensitive to changes in rail safety, price, and infrastructure investment, with varying levels of sensitivity between the VS and HC regimes. This indicates that rail companies operating in the VS and HC regimes have multiple avenues to stimulate passenger demand by optimising safety measures, offering competitive pricing, and making strategic infrastructure investments.

Furthermore, the findings indicate the importance of rail liberalisation in influencing passenger demand. Countries with the VI regime, such as Ireland and Luxembourg, were found to have lower rail liberalisation indices within the EU (IBM Global Services and Kirchner C., 2011). A lower level of rail liberalisation implies fewer external rail operators involved in the rail system, potentially limiting passengers' alternative choices on the network. This could explain why passengers under the VI regime appear less responsive to changes in price and safety, as they might have fewer viable options available to them.

The implications of these findings underscore the significance of adopting effective rail structural reform and liberalisation policies. For countries considering rail reform, the choice of structural regime can significantly impact the strategies available to boost passenger demand and enhance rail system performance. By understanding the varying sensitivities of passengers to different factors in each regime, policymakers and rail operators can tailor their approaches to optimise mode share.

Overall, this chapter has provided valuable insights into the relationship between rail structural reform and passenger mode share, showing how different variables interplay within various structural regimes to influence transportation choices. It is crucial to validate these insights against the real-world experiences and perceptions of industry professionals. Thus, the **Chapter 5** of this thesis aims to bridge this gap by delving into qualitative analysis, where surveys and interviews with key stakeholders will explore whether the theoretical implications drawn from the empirical findings align with the practical realities of the rail industry. This approach, combining quantitative and qualitative insights, will provide a more comprehensive understanding, enabling policymakers and industry stakeholders to develop strategies that optimise rail performance and enhance passenger satisfaction, thereby contributing to the overall advancement of the rail sector.

5. Qualitative Analysis

5.1 Introduction

The previous chapters of this thesis have employed quantitative analysis to investigate the patterns and correlations in the rail industry's cost and demand frameworks. While these findings have laid a foundation for understanding the economic impact of reforms on the industry, the narrative behind the data remains incomplete. This chapter bridges that gap by introducing a qualitative analysis that examines the numerical data through the practical insights from senior rail industry professionals. Combining the econometric discussion with qualitative depth, this chapter aims to provide a more comprehensive examination of the reforms' multifaceted implications.

To achieve a comprehensive understanding of the impact of rail reform, it is necessary to combine quantitative and qualitative methodologies. The econometric analysis carried out thus far provides a basic structure of correlations, which will be further explained through the qualitative analysis. This is a crucial step towards interpreting the causal relationships indicated by the quantitative data, differentiating between the variables as either causes or consequences within the narrative of the rail industry's reform. This methodological partnership aims to address the quantitative findings' "why" and "how," enriching the econometric conclusions with detailed interpretations.

The qualitative exploration is driven by three interconnected objectives. First, it seeks to find evidence that supports or challenges the hypotheses and conclusions formulated from the quantitative analysis, providing explanations for the observed patterns in cost and demand impact of rail reform. Second, it aims to assess how rail structural reforms have been experienced in practice, with a particular focus on maximising system-level benefits across different rail frameworks. Lastly, the qualitative inquiry aims to investigate the actual effects of rail reform on the coordination between IM and RU.

These areas of focus are not chosen arbitrarily; they emerge from the unresolved debates within current academic and industry discussions, particularly regarding the consequences of vertical separation. For example, Van de Velde et al. (2012) outline critical debates surrounding the freedom for EU Member States to choose between vertical separation and holding company structures, reflecting the broader industry discussion on the optimal configuration for efficiency and non-discriminatory access. Furthermore, the discussion extends to the specific needs of dense networks and the appropriate structural regime to ensure close coordination and optimal performance, underlining the complexity and lack of consensus on the optimal rail industry structures to meet the goals of European transport policy.

The discourse on rail reform, specifically vertical separation, serves as a vital background for this chapter. Literature and policy debates focused on the theoretical impact of such restructuring, with many voicing concerns over potential coordination difficulties and compromised system-level efficiencies. However, theoretical perspectives alone cannot give substance to the real-world implications of these reforms. Hence, including qualitative research in this chapter provides essential support to assess these claims, offering a critical evaluation of whether the hypothesised downsides of vertical separation exist in reality.

To derive robust qualitative insights, this research employs a multifaceted methodology in survey and interview techniques, complemented by comprehensive desktop research. Desktop research acts as a vital mechanism, converting part of survey responses into detailed **case studies** that highlight specific aspects of the rail industry's responses to reform. Through the examination of reports, industry websites, and other relevant data sources, these case studies bring to life the theoretical underpinnings and real-world impacts of rail structural changes.

Selected senior professionals in the rail industry across distinct European countries were surveyed and interviewed to represent various rail reform regimes. The choice of these countries, namely the UK, Ireland, and France, captures the essence of different structural reforms from vertical separation to integration. The UK follows the VS regime where infrastructure management and train operations are distinctly separated, to increase competition and efficiency within the rail sector. On the other hand, Ireland, despite its recent reclassification as an HC regime in 2013, still operates in a manner closely resembling vertical integration, where Irish Rail oversees both infrastructure management and train operations. The 'HC' designation primarily aligns with EU regulatory frameworks rather than indicating a functional separation of duties. France offers a unique viewpoint, as it has transitioned from the VS to the HC regime. This transition reflects France's attempt to balance EU directives with national strategic objectives, providing valuable insights into the adaptability and outcomes of such reforms.

The interview participant selection strategy is equally comprehensive, ensuring representation from both IMs and RUs. In the UK, the engagement extends beyond industry operatives to include government perspectives, with departments like the Department for Transport (DfT) adding a policy dimension to the qualitative feedback. By receiving input from these various levels, the research includes a wide array of views, covering the operational, strategic, and regulatory angles of rail reform.

To accommodate the constraints and preferences of participants and to enable a more flexible and inclusive approach, the majority of interviews are conducted using Microsoft Teams. This online platform has proven instrumental in transcending geographical barriers and facilitating the inclusion of international stakeholders in the research. Additionally, some participants preferred to return completed surveys, enriching the dataset with their written insights. This mixed-mode engagement ensures a wide range of input while respecting the time and logistical challenges faced by busy professionals. The process is dynamic and iterative, with the transition from data collection to case study formulation being critical for understanding the specific contexts and implications of each reform regime.

This chapter commences with the methodology of the qualitative research, demonstrating the logic behind the question design and the customisation of survey versions to accommodate the unique rail structures across countries. The narrative then moves to discuss the strategies for data collection and the ensuing analysis, ensuring a transparent description of both processes. Last but not least, the findings will be discussed by thematic categories in Chapters 5.3 and 5.4, integrating qualitative insights with quantitative analysis to conclude the thesis comprehensively.

The inherent limitations of qualitative research are recognised and indicated in Chapter 5.5. Potential biases, the subjective nature of responses, and the scope of participant selection all present challenges to the validity and reliability of the conclusions. Such reflections are critical, as they underscore the need for multiple data sources and methods to verify the findings.

To sum up, this chapter provides an overview of the key findings from the qualitative analysis and contextualises these insights within the broader framework of rail industry reforms. By doing so, it adds to the understanding of the theoretical and empirical debates that are shaping the future of rail transport policy and practice. Through this approach, the research makes a valuable contribution to the ongoing discussion on the direction and design of rail reforms and advances a more informed debate on this important topic.

5.2 Methodology

When evaluating reforms in the rail industry, it is crucial to consider how strategic decision-making intersects with operational execution. This aspect plays a vital role in determining cost efficiency, demand management, and service delivery. While quantitative analysis can provide a high-level view of patterns and correlations, it is limited in capturing the specific reasoning and complex decision-making processes that are behind the statistical results. To gain a deeper understanding of these processes, a methodological approach that goes beyond numerical representation is necessary. Thus, a qualitative methodology, particularly through interviews based on surveys with open-ended questions, was used in this analysis.

In qualitative research, particularly when using interviews, it's essential to ground the approach in a solid theoretical framework. This study's methodology is based on conducting interviews guided by a survey with open-ended questions and grounded theory methodologies (Strauss and Corbin, 1998). These frameworks emphasise understanding phenomena from participants' perspectives and allow for the emergence of themes and concepts from the data (Glaser and Strauss, 1967). The process involves purposive sampling (Patton, 2002), where participants are selected based on their relevance to the research question, and a detailed analysis involving coding and thematic exploration (Braun and Clarke, 2008).

Open-ended survey questions can be highly effective in gathering valuable feedback. They provide survey respondents with the freedom to express their experiences and perspectives in their own words. This allows for a more comprehensive view that goes beyond just the ‘what’ of the situation, and instead delves into the ‘how’ and ‘why’ behind people’s actions. With open-ended survey questions, respondents can elaborate on their answers, leading to in-depth explanations and discussions on complex topics (Kvale, 1996). Such questions can also reveal the deep and pragmatic effects of industry reform that may not be immediately apparent. For instance, when exploring the impact of structural reforms on operational coordination, a yes/no question would be insufficient. The depth of insight required to understand the shifts in coordination patterns post-reform consists of the respondent’s knowledge of the nature of these shifts, the challenges encountered, and the strategies to overcome them. Open dialogue prompted by open-ended questions is the optimal method for capturing the intricacies of industry reforms. This narrative can only be pieced together through discussion with rail industry insiders.

Interviews with senior rail professionals using a structured survey guide enable the collection of detailed insights, offering a richer narrative on industry dynamics, strategic decisions, and operational challenges. The selected interviewees are diverse, covering a broad range of the rail industry, including IM, RU, and governmental bodies. This comprehensive coverage ensures insights from all critical perspectives of rail reform. Furthermore, their deep involvement and extensive experience within the industry enable them to provide valuable, informed opinions on the intricacies of structural changes, their implementation, and their impacts, aligning closely with the themes explored in this study. Section 5.2.2 explains the detailed principles of selecting participants for interviews. Desktop research may uncover general guidelines and policy documents but often lacks the details necessary to understand the internal workings of the industry, the reasoning behind specific strategic shifts, and the practical challenges of daily operations. This approach bridges the gap left by quantitative data and desktop research, providing a detailed understanding of reform impacts.

5.2.1 Design of the Survey Questions

Surveys were developed that aligned with the central objectives of the research. This qualitative phase of the survey aimed to explore beyond the surface findings of the quantitative analysis. The survey helped us to corroborate or refute the hypotheses that had emerged. It facilitated a deeper examination of the cost and demand impacts observed from rail reforms. The survey design was linked to three core research objectives, each reflecting significant areas of investigation within the context of rail industry reforms.

The first objective was to collect evidence that supported or refuted the patterns identified in the quantitative findings, thereby offering a comprehensive explanation of the factors influencing cost and demand in the rail sector. Secondly, to investigate the operational reality of rail reform and its impact on the coordination between infrastructure managers and railway undertakings. This was important because the efficiency of coordination was believed to vary under different structural frameworks, which could affect overall industry performance. Thirdly, to understand the practical experience of these structural reforms and to determine how different models impacted the system-level optimisation of benefits. The survey questions were designed to draw out insights relevant to these themes.

To organise the investigation, **Table 21** below shows this logic chain, outlining the knowledge areas covered by the survey, the intention behind each question, and the exact phrasing used to obtain the desired information. The logic chain was not only a procedural tool but also a strategic guide that outlined the purposeful exploration of the intricate web of rail reform impacts, ensuring that each question contributed positively to the overall thesis.

Table 21 – Logic Chain of Survey Questions

Areas	Objective & Contribution	Key components within the survey
1 – Infrastructure investment strategy	• Identify the elements that influence the cost efficiency of infrastructure investments across different separation regimes. • Enhance the thesis's comprehensiveness by providing a deeper understanding of the quantitative analysis results, particularly examining hypotheses such as the cost efficiency of infrastructure investments under the VS regime.	• Factors in the planning stage, such as cost-benefit analysis within project appraisal, that impact the cost efficiency of infrastructure investments. • Comparative analysis of investment strategies in various structural regimes.

		• Factors influencing the cost efficiency during the implementation phase of infrastructure projects.
2 – Impact of structural reform on passenger demand	• Capture industry professionals' insights on how rail reform might influence passenger demand, including the identification of direct and indirect effects (i.e. through affecting the demand drivers). • Gain a detailed understanding of the quantitative evidence of reform's impact on passenger rail mode share, exploring the relationship between structural changes and adjustments in demand drivers like fares and service quality.	• Exploration of passenger sensitivity to changes in demand drivers (such as price, service quality, reliability, and safety) within unbundled structures. • Assessment of travel behaviour in response to rail policies, including price regulations, emerging from structural reforms.
3 – System-level benefits optimisation	• Enhance understanding of the methods employed by various rail structure regimes to maximise system-level benefits from infrastructure investment. • Address the literature gap regarding challenges faced by the VS regime in achieving optimal system-level benefits, especially in the context of coordination and communication between RUs and IMs.	• Identification of mechanisms used to optimise system-level benefits in different rail regimes. • Examination of specific challenges in the VS regime related to coordination and communication that may impede the realisation of system-level benefits.
4 – Coordination between RU and IM	• Investigate the nature of coordination between companies under different structural regimes and the impact of these regimes on inter-company coordination. • Address the coordination challenges identified in the literature for unbundled structures and assess the effectiveness of mechanisms implemented to mitigate these issues.	• Inquiry into the tangible changes in daily train operations as a result of structural reform. • Evaluation of strategies employed to address coordination challenges between RUs and IMs.

Following the logic chain table, the survey structure and questions were developed as below:

- The first chapter of the survey is an introduction, which includes the background and purpose of this survey.

- The survey consists of four main questions with a few sub-questions in each. However, these questions may differ slightly in the surveys conducted for railway companies in different countries based on their unique characteristics. The specific survey questionnaires for each rail company with responses can be found in **Appendix A** Survey
- Question 1 – corresponding to **Area 1** of the logic table: This main question is about the planning stage before implementing an infrastructure investment. There are three sub-questions involved in this main question, which are shown as follows.
    a. How important is the role of cost-benefit analysis within the strategic planning stage of the infrastructure investment projects? What elements do you think are as important as cost & benefit to consider in different types of investment (i.e. renewal and enhancement)?
    b. Do you think the operators' feedback plays a vital role in helping the IM inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Does the feedback contribute to IM's strategic planning of infrastructure investment?
    c. Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?
- Question 2 – corresponding to **Area 2** of the logic table: This question concerns the potential demand impact of rail structural reform. There are three sub-questions involved in this main question, which are:
    a. Do you think rail passengers are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?
    b. Do you think any of the above factors changed significantly due to the previous rail structural reform in the country?
    c. Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. change their demand response to the factors above?
- Question 3 – corresponding to **Area 3** of the logic table: This main question aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment, and it includes two sub-questions.
    a. Do you think that regulation is the most useful approach to ensure the system-level benefit is considered in the planning stage of the investment? Are there any

mechanisms (i.e. consultation) that help to deliver system-level benefits in the investment implementation stage?

   b. If the investment brings a higher cost than benefit to the IM or RU, how to incentivise (or, maybe obligate) the IM or RU to coordinate with other organisations/companies to deliver the investment? Is there any circumstance where such schemes don't work well?

- Question 4 – corresponding to **Area 4** of the logic table: This main question aims to investigate the difference in coordination between the RU and IM in different separation policies. There are two sub-questions:

   a. In the daily operation, how does the IM ensure efficient coordination with the RU in daily train operations especially when a disruption on the network occurs?

   b. As I understand, the key incentives for the coordination between RU and IM (which are not in the same team) on a daily basis include joint management (reporting to a unique manager) and financial incentives. Are there any other ways that you think may improve the coordination?

5.2.2 Survey Versions, Instructions and Participants

Within the qualitative analysis, multiple versions of the survey were developed to accommodate the diverse separation regimes present in the rail industry across different countries. This approach was essential to ensure that the questions were relevant and specific to each context. Furthermore, to add specificity and depth, company names (either RU or IM) were included in the surveys. In certain instances, country-specific sub-questions were integrated to address unique circumstances, such as ongoing rail reforms in the UK and their impact on coordination between RUs and IMs. Each version of the survey can be found in **Appendix A** Survey [22] at the end of this thesis.

Before undertaking the interview, an initial communication with potential participants was conducted, which involved an introduction to my research background and the overarching goals of this survey. This was intended to provide a holistic understanding of the research context and its significance. Within the survey (as a supplement to the interview), a brief introductory section was included, too. Care was taken to avoid disclosing the quantitative findings beforehand, to prevent any preconceived notions or biases from influencing the responses. The focus was to collect unbiased insights that could independently validate or challenge the quantitative analysis.

[22] Questions 2 and 3 was switched to maintain continuity of thought. For instance, Questions 1 and 3 in this section focused on railway costs and benefits, which would be better to be discussed next to each other. This change was made to improve the flow of the survey questions.

Designed to last one hour, interviews often extended based on the depth of discussions, primarily conducted via Microsoft Teams and recorded for accuracy. A pilot interview was conducted face-to-face, allowing for an in-depth session that included feedback on survey questions, leading to their refinement. Post-interview, transcripts were reviewed and summarised per survey question, then sent to interviewees for validation and clarification. This iterative process ensured unbiased insights to validate or challenge quantitative analysis findings, leading to finalised responses reflective of review and interviewee input.

The ideal survey participants were professionals with extensive experience in the rail Industry, preferably occupying senior positions capable of providing high-level industry insights. A balanced selection of participants from both infrastructure managers and railway undertakings was sought. Due to the multi-country scope of the research, the process of finding suitable participants presented networking challenges, as the contacts did not extend to all relevant parties in each country. Nonetheless, efforts were made to identify and engage with appropriate individuals. The survey questions were designed to gather as unbiased responses as possible, often supported by evidence such as case studies, which could then be investigated further through desktop research. Thus, the emphasis was on the quality of responses rather than the number of participants, with a single knowledgeable respondent from a significant position often offering enough valuable insight.

Participant Introduction

The participant selection strategically focused on senior professionals across the rail industry, emphasising an extensive diversity of perspectives. Interviewees, ranging from directors to mid-level managers, including former CEOs, were chosen for their comprehensive industry experience and insights. Their positions allowed them to offer detailed views on reforms, balancing strategic oversight with operational complexity. The COVID-19 pandemic posed challenges to traditional face-to-face interviews, leading to a shift towards virtual platforms like Microsoft Teams. This adjustment, while impacting the ease of scheduling due to increased remote work dynamics and health-related absences, did not influence the quality of insights gathered. The strategic mix of participants ensured a thorough exploration of the survey's thematic areas, like cost-benefit analysis, reflecting a deep, multi-faceted understanding of rail industry challenges and reforms. **Table 22** below illustrates the diversity of participants, reflecting the range of organisations and roles across different countries:

Table 22 – Survey Participant Introduction

Country	Organisation	Position/Title
Great Britain	Infrastructure Manager (department in England)	Strategy & Planning Director (Integrated Rail Plan)
Great Britain	Infrastructure Manager (department in Scotland)	Former Strategy & Planning Director
Great Britain	Railway Undertaking	Operations Director
Great Britain	Government	Member of DfT’s Franchise Advisory Panel
Ireland	IM and RU	Former Chief Executive Officer

Ireland	IM and RU	Head of Transport Planning
Ireland	IM and RU	Operations Planning Manager
France	Infrastructure Manager	Head of Cost Analysis Unit
France	Railway Undertaking	Project manager for traffic forecasting and economics

However, the potential variance in the depth and quality of responses across different countries was still regarded as the key limitation of the approach. While the interview sought to mitigate subjectivity through its design, the reliance on a smaller pool of participants might have influenced the diversity of perspectives captured. Additionally, the need to tailor surveys to specific countries and companies meant that comparing responses across different regimes required careful consideration of the contextual differences. Despite these challenges, the interview method was considered as the most effective tool for extracting detailed, context-specific insights that are essential for a comprehensive understanding of rail industry reforms.

5.2.3 Data Collection and Analysis

Data Collection Process

The data collection process for this thesis was planned and executed with attention to detail, taking into account the complex nature of the rail industry. Professionals were interviewed as the main data collection method, which was carried out in three different ways: face-to-face interviews, video meetings via Teams, and written responses. These methods were chosen based on the location and convenience of the interviewees. This varied approach ensured that the interview was flexible and respondent-friendly, accommodating the diverse circumstances of each participant.

Face-to-face interviews, conducted when the respondents were accessible within London, allowed for an interactive discussion, enriching the quality of the data gathered. These sessions provided an opportunity to delve deeper into the details of rail reform beyond the structured survey questions. For those residing in other cities or countries, Teams video meetings offered a platform for comprehensive discussions, sometimes involving multiple stakeholders, thereby enriching the dialogue with varied perspectives. In cases where language barriers existed or if the interviewee preferred written communication, email was utilised, allowing respondents to express their thoughts.

After the interviews were conducted, there was a process of summarising the discussions. Every conversation was documented in order to record meaningful responses to the survey questions. Afterwards, the recorded information was thoroughly examined, and the participants had the opportunity to confirm its correctness. This repetitive procedure not only increased the dependability of the data but also permitted the addition of case studies. Additionally, further research was conducted on particular cases or examples mentioned during the interviews to provide a more comprehensive conclusion.

Analysis of Qualitative Data

The qualitative data analysis aimed to create a narrative that addresses the thesis's research questions. The first step was to summarise the individual responses to each survey question for comparative analysis. This approach highlighted the differences in strategies across various separation regimes, allowing for a discussion of the pros and cons of each separation regime.

The analysis then progressed to connect each response with the broader objectives of the qualitative analysis, crafting a narrative that not only explains the 'how' and 'why' behind the impacts of rail reform but also integrates these findings into the big picture of the thesis. This narrative construction was central to the thesis and aimed at providing a comprehensive understanding of the rail reform landscape from the perspectives of those directly involved in its implementation and management.

The methodology focused on extracting meaningful insights and evidence from the qualitative data instead of searching for statistical patterns. This approach ensured that the analysis remained grounded in the real-world experiences and professional judgments of the rail industry experts, thereby enriching the overall findings of the thesis with depth and context.

5.3 Findings from Interview Responses

5.3.1 Overview of Interview Responses

Summary of Response Rate

To gather diverse and insightful perspectives for this research, invitations to participate in the survey were sent to professionals across various segments of the rail industry in Ireland, Great Britain, and France. These invitations targeted specific organisations known for their influence and operational significance in the rail sector. In Ireland, invitations were sent to three individuals at Irish Rail, all of whom responded positively. During one interview, two individuals were involved, resulting in a single survey response that reflects their views.

In Great Britain, the approach was more varied, encompassing different organisations / companies of the rail industry: three invitations were extended to civil servants at the Department for Transport (DfT), yielding one response. Significant challenges were raised when engaging with the DfT due to their strict internal policies on information sharing and potential conflicts of interest. Their work is highly regulated and in the public spotlight, which makes it difficult for them to participate in external surveys. To overcome this challenge, a former DfT employee who currently works as a member of the DfT's Franchise Advisory Panel was reached out, thus avoiding the restrictions faced by current employees. Concerning the Train Operator, one interviewee from a train company responded, and at the IM, both individuals approached provided responses. The interview outreach in France, targeting the Infrastructure Manager and a key operator (under SNCF holding company) in the market, was met with a full response rate, with both invitations receiving responses.

The results obtained from the primary research conducted across different European countries and organisations in the rail industry are diverse and complex. The response rate reflects the willingness and ability of industry experts to participate in academic research, which can be affected by various factors including organisational policies, individual workloads, and the relevance of the research topic to their professional interests.

Survey Response Overview

The survey responses of Irish Rail professionals indicate a detailed approach to infrastructure investment planning. They highlight the importance of cost-benefit analysis while also considering broader aspects such as political influences, environmental sustainability, and social equality. The feedback from operator is deemed essential, as it plays a significant role in identifying current network issues and shaping strategic planning. This approach underscores the complexity of balancing economic efficiency with other crucial considerations in the infrastructure investment process.

The responses from various entities in GB Rail such as the IM, the DfT, and the operator indicate the importance of balancing economic, operational, and political aspects in infrastructure planning. These responses reflect the diverse perspectives within the rail system. Particularly from The IM's standpoint, there is an emphasis on the need for greater involvement of TOCs in discussions about infrastructure schemes and service changes. This perspective suggests that the feedback from operators, while valued, needs to be more significantly integrated into strategic planning processes of the infrastructure investments. These responses also highlight the complexities of coordinating between IM and RU, underscoring the complicated nature of the British rail system.

The survey responses from France, encompassing views from both The IM and RU, illustrate a comprehensive and detailed planning approach to rail infrastructure investment. The responses indicate an emphasis not just on cost-benefit analysis but also on environmental sustainability, social equity, and regional economic development. The French rail system's multifaceted decision-making process, facilitated by the HC structure, effectively balances various strategic, operational, and environmental factors. This highlights the HC's vital role in ensuring that the diverse objectives of The IM and RU align with national rail goals, showcasing the benefits of close coordination within the HC model.

The diversity in perspectives within each country, and among different companies within the same rail system, suggests a strong correlation with the current industry structure and the stage of railway reform each country is in. For instance, both Ireland and France currently apply a Holding Company regime, yet differences in coordination between the RU and IM are evident. In Ireland, better coordination is observed, possibly due to the recent and incomplete separation[23] in 2013 and shared physical workspaces. These varied insights underscore the impact of organisational structures and reform stages on the functioning and planning within the rail industry.

Chapter 5.3.2 provides detailed explanations and discussions following each single question in the survey. The comparative analysis will identify the differences between different rail systems and industry structures.

5.3.2 Thematic Analysis of Findings

This section takes a closer look at the survey data and analyses the responses to uncover the main themes that have emerged. the analysis is structured around four key themes, each of which corresponds to a main question from the survey. By comparing and contrasting the responses from different rail companies across various countries, this section aims to draw meaningful conclusions about their perspectives and practices. This comparative approach not only highlights similarities and differences across the rail sector in different countries but also provides insights into how specific industry structures and reforms influence these entities. This thematic analysis is a crucial step in understanding the complexity of the rail industry and the implications of structural reforms within it.

[23] there is a functional distinction between the roles of infrastructure management and service operation, but both functions are still housed within the same organisational entity, rather than being completely separated into independent companies under a holding company structure.

Theme 1 - Infrastructure investment strategy

This theme (area) corresponds to Question 1 within the survey questionnaire. There are three sub-questions within this theme.

Question 1a. How important is the role of cost-benefit analysis within the strategic planning stage of the infrastructure investment projects? What elements do you think are as important as cost and benefit to consider in different types of investment (i.e. renewal and enhancement)?

GB Rail's response indicates that:

- **The IM** has adopted a collaborative approach to strategic planning and investment. This approach emphasises the importance of CBA while integrating socio-economic factors, political influences, and broader transformational goals. The IM in **England** region highlights the necessity of considering clear passenger benefits, wider economic and social impacts, and policy alignment in investment decisions.

  Similarly, the IM in **Scotland** region details a collaborative planning process involving ScotRail and Transport Scotland, following the Scottish Transport Appraisal Guidance (STAG) for investment appraisals. This unified strategy across regions showcases The IM's commitment to balancing traditional CBA with long-term strategic objectives. This ensures that railway investments not only contribute to operational improvements but also to societal progress and economic development. Political expediency, economic appraisal, and strategy play significant roles in Scotland's infrastructure investment decisions.

  The interviewee also underscores the need for better alignment of renewals, enhancements, and maintenance with long-term business goals, emphasising the importance of maintaining assets effectively and considering enhancements as part of an overall strategic vision. To expand upon the distinction between enhancements and renewals within the GB rail system, it's important to understand that renewals focus on maintaining the existing network's efficiency and safety, whereas enhancements aim to improve and expand the network to meet long-term business and stakeholder goals. The case of **Carstairs Junction** exemplifies the complexities in aligning these aspects with broader strategic objectives. This junction, crucial for cross-border passenger and freight services, faced challenges due to ageing infrastructure, highlighting the difficulty in balancing renewal needs with enhancement ambitions to benefit the wider rail system. For more details, please refer to the original survey response in Appendix A (page 185).

- **The DfT** in the UK offers a critical view of the role of CBA in government rail infrastructure investment. The DfT points out that while CBA is a standard component in the planning stages, its practical influence is often limited. There is a tendency to focus more on monetary aspects like capital and operational expenditures, rather than on the broader benefits that projects might bring. Furthermore, CBA is frequently used post-facto, **serving to confirm decisions already made for political reasons rather than actively driving them**. This approach can lead to an underestimation of operational costs and a lack of consideration for the strategic long-term impact of infrastructure projects. The DfT's observations also highlight that train operators, often seen as management contractors with limited long-term risk, are given less influence in the CBA process. This situation could result in a skewed investment focus towards already busy areas, neglecting regions that might benefit more from new investments. Political and strategic considerations, such as regional balance, are emphasised as being equally or more important than CBA in the decision-making process. The Strategic Outline Business Case (SOBC), performing as the stage before business case appraisal and focusing on qualitative aspects rather than just quantitative metrics, is identified as a crucial element of project evaluation. The DfT also underscores the limitations of current forecasting methods and suggests the need for a more systematic approach to cost and revenue forecasting, advocating for a more balanced approach that incorporates political, strategic, and qualitative factors alongside CBA in infrastructure investment decision-making.

- The interviewee from the **Operator** underscores the importance of Cost-Benefit Analysis in large infrastructure projects, such as the Midland Mainline electrification, focusing on achieving cost efficiency and environmental benefits. He notes the significant role of TOCs in evaluating operational efficiency and costs, particularly in the transition of rolling stock from diesel to electric operation. Challenges exist in aligning the planning and real-world operational implementation of these projects, often leading to deviations from anticipated CBA outcomes.

Irish Rail's response emphasised that:

- **Overview of Cost-Benefit Analysis in Irish Rail's Strategic Planning**. Irish Rail (IR) recognises the importance of CBA in the strategic planning of infrastructure investment, but it is not the sole deciding factor, especially in the early stages. According to interviewees from Irish Rail, initial project outlines, similar to the UK's SOBC, provide an overview of the project's alignment with policy, objectives, and a cost range. A detailed CBA becomes more pertinent during later stages, such as the preliminary design phase. This approach reflects a phased consideration of cost and benefits, where early-stage planning focuses more on aligning with broader policy objectives and setting the direction for more detailed financial analysis later on.

- **Importance of Non-Monetised Benefits and Political Influence.** Irish Rail is increasingly acknowledging non-monetised benefits, particularly in the context of environmental sustainability and meeting net-zero targets. This shift towards green business cases indicates a broader perspective in project evaluation, transcending traditional financial metrics. However, even with the inclusion of non-monetised benefits, some projects might not be deemed cost-effective and end up being influenced by political decisions. This scenario is illustrated by Spain's expansion of its high-speed rail network, guided more by policy decisions than strict CBA. In Ireland, projects often have funding ceilings, with planners aiming to maximise output within these financial limits, suggesting a pragmatic approach to infrastructure development constrained by budgetary realities.
- **Role of Government Policy and Safety Considerations.** IR highlights that while CBA is critical for substantial investments, it is not the only factor in decision-making. Strategic planning for significant projects is subject to other key elements like rail safety and regulatory compliance. Safety improvements, often mandated by EU/UK railway safety regulations, are considered another area of benefit in investment decision-making. Moreover**, policy influences from the government or local authorities**, such as environmental targets and population considerations, **play a significant role**. This is particularly evident in the case study of the **Western Rail Corridor** scheme, where the government's political desire to invest in the West of Ireland overrode traditional cost-benefit priorities – see more details in Appendix A (page 172). In contrast, renewals are more influenced by the network's condition, indicating a prioritisation of operational reliability in investment decisions.

French Rail's response shows that:

- From the perspective of the IM, the legal mandate for CBA in strategic planning for infrastructure investments exceeds 23 million euros. This requirement, rooted in French law, highlights the formalised and rigorous approach to infrastructure decision-making within the IM. The CBA is not just a financial tool but a comprehensive evaluation mechanism, mandated to evaluate the utility and added value of investments. It ensures that projects are financially viable and align with broader policy goals, sustainability, social needs, and the long-term vision of the rail network. This holistic approach to investment planning considers environmental sustainability, social equity, regional economic development, interoperability, and customer experience. It reflects the IM's commitment to transcending economic considerations, aiming for investments that contribute holistically to public transportation.

- The **RU** outlines a more financially focused approach. The RU participates in socioeconomic studies for the IM's projects but mainly concentrates on financial analysis. This distinction suggests a more operational, immediate financial perspective in contrast to the IM's broader, long-term strategic planning. The structural separation between the RU and IM, **with different accounting systems and financial objectives, further complicates the exchange and alignment of information regarding CBA.** This separation might lead to different perspectives on the same investment, indicating a potential area for improved coordination and information sharing. the RU 's insight into the selective sharing of information by the IM points to a need for more integrated analysis, particularly in enhancing socio-economic analysis with actual charges and pricing information.

Question 1b. Do you think the operators' feedback plays a vital role in helping the IM inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Does the feedback contribute to IM's strategic planning of infrastructure investment?

GB Rail's response indicates that:

- **DfT** acknowledges a limited consideration of train operators' (TOCs) feedback in rail infrastructure investment decisions. This is primarily attributed to the short duration of running contracts for TOCs, which typically last around seven years. **This short-term contract structure disincentivises TOCs from engaging deeply in long-term investment decisions, as they may not see the benefits within their contract period**. Additionally, while there is recognition of the potential value of smaller-scale investments like track renewals and installation of switches and crossings, which could enhance the efficiency and speed of train movements, these often get overlooked or deprioritised. The DfT's focus tends to be on larger, more visible projects, influenced by political considerations. This approach indicates a gap in integrating the practical, on-the-ground insights of operators into the strategic planning process, potentially overlooking investments that offer immediate operational benefits in favour of more politically salient projects.

- **The IM** acknowledges the value of operator feedback in infrastructure management but emphasises a more structured, expert-driven approach. In England, strategic planning for renewals and asset management is led by IM's internal experts, such as asset managers and engineers, with regulatory and governmental bodies also playing key roles. While operator feedback on ground-level issues is useful, **decision-making processes mainly revolve around long-term asset maintenance and**

enhancement strategies guided by IM's professionals and regulatory requirements. In Scotland, despite a similar reliance on internal expertise, there is a stronger emphasis on collaborative dialogue, partly due to ScotRail's ownership by Transport Scotland and its direct accountability to Scottish Ministers. This structure fosters a more integrated approach, balancing operator insights with the political and regulatory framework. However, tensions arise between political objectives and regulatory determinations, reflecting the complexity of aligning strategic planning with diverse stakeholder interests in the Scottish rail network.

- For **the Operator**, operator feedback is integral to both immediate operational management and long-term strategic planning with the IM. The operator employs a joint head of performance, who is accountable for performance from both IM and the operator's perspectives. This role creates a cohesive feedback loop, directly influencing operational decisions and informing infrastructure investment strategies.

  However, it is important to note the **varying collaboration methods among different operators with the IM**. While TOC's joint performance management approach significantly guides IM's investment decisions, aligning priorities between IM and operators remains a challenge due to differing operational horizons and business planning cycles. This situation highlights the complexities in considering diverse priorities and operational timelines in railway infrastructure planning and investment.

Irish Rail's response emphasises that:

- Operator feedback is a crucial element in IR's infrastructure management, as highlighted by all the interviewees from IR. The RU is often the first to report infrastructure issues to IM, making their input essential for identifying and addressing potential network disruptions promptly. This feedback is particularly important for renewal prioritisation and understanding the benefits of enhancements, such as station expansions or line electrifications.
- Post the 2013 Forth railway package, Irish Rail transitioned into separate IM and RU entities, yet maintained a highly collaborative approach. Regular performance analyses and meetings between IM and RU focus on addressing network issues like speed restrictions and congestion, ensuring efficient and smooth operations. This contrasts with the UK's approach, where IM has more autonomy, potentially leading to conflicts with operational needs.
- A case study from GB Rail's **West Coast Mainline**, provided by one interviewee who has worked in the DfT of the UK, illustrates the complexities and inefficiencies in managing train diversions, contrasting with the more streamlined operations in Ireland

– see more details of this case study in Appendix A (page 165). The involvement of multiple stakeholders in the UK often results in bureaucratic delays and conflicts, highlighting the smoother, more integrated approach of Irish Rail.

French Rail's response emphasises that:

- The IM places significant emphasis on operator feedback as a pivotal element of their strategic decision-making for infrastructure management. This feedback, primarily from entities like SNCF Voyageurs and Fret SNCF, is essential for identifying potential network disruptions and shaping maintenance and investment strategies. A dedicated committee, comprising representatives from all operating entities, systematically collects and analyses this feedback. This process is complemented by broader public consultations, involving a range of stakeholders, to ensure comprehensive consideration of societal, environmental, and economic factors in infrastructure planning. Thus, the IM's approach is characterised by a blend of direct operator insights and wider stakeholder engagement, fostering a robust and responsive infrastructure management system.
- From the perspective of the RU, the railway undertaking under SNCF, operator feedback is instrumental in aiding infrastructure inspection and issue identification, especially regarding operational disruptions. In events of network disturbances, the RU actively participates in specialised committees to analyse the causes and impacts, contributing to immediate problem-solving and long-term strategic planning. This collaboration between The IM and RU exemplifies a proactive approach, where operator experiences not only address current operational challenges but also influence future infrastructure resilience and efficiency strategies.
- The SNCF holding company developed the collaborative framework where the RU actively contribute to the IM's operational assessments and investment decisions. This collaboration is institutionalised through a dedicated committee, ensuring systematic collection and analysis of operator insights alongside broader stakeholder consultations.

Question 1c. Do you think cost-benefit analysis contributes significantly to cost efficiency and value for money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?

GB Rail's response indicates that:

- **DfT** believes that the **CBA Does Not significantly contribute** to the cost efficiency and value for money in UK rail infrastructure projects. The UK railway's regulator

(ORR) focus on regulating public sector companies without commercial risk has sometimes been perceived as less engaged with infrastructure enhancements. This perception may influence the relevance of their views in the broader context of UK rail infrastructure projects. The introduction of Great British Railways (GBR) has not fundamentally resolved these issues, highlighting a need for more effective regulatory frameworks to enhance cost efficiency and value in rail infrastructure projects.

- From **IM's** perspective, CBA is a **decision-making tool rather than a primary driver** for infrastructure investment projects. Instead, the importance of culture, processes, and behavioural intent play important roles in determining a project's efficiency and value. The focus should be on tangible goals and practical challenges related to daily work, with engineers and designers playing a key role in ensuring cost-effective and feasible designs. The Aberdeen to Inverness Rail Improvement case study showcases the challenges of infrastructure project cost estimation. Initially, the government's decision to proceed with the lowest cost estimates, despite warnings of potential uncertainties, led to budget overruns and necessitated cost-cutting measures. This situation highlights the complexities of decision-making and the importance of accurate cost estimations in the early stages of project planning. For a detailed account of this case study, please refer to the original survey response in Appendix A (page 186).

Irish Rail's response emphasises that:

- Irish Rail employs a continuous evaluative approach to ensure the effectiveness of CBA. Benefit realisations are conducted post-implementation to assess if the forecasted benefits align with actual outcomes. The practice of "value engineering" during the design and planning stages is integral to their process, ensuring feasibility and cost-effectiveness. They highlight that most changes in cost projections are due to adjustments in contingencies or scope rather than foundational construction costs. Regular re-evaluations of CBA are typical until the contract award stage, with further revisions being rare unless necessary for monitoring and benefit realisation.

- The value of CBA is recognised in capacity enhancement schemes, especially during times of increasing rail demand. On the other hand, while value for money is essential, it is not the only consideration. Regulatory aims, such as managing network capacity for different operators, often take precedence, even if they are not economically optimal. This approach indicates a balancing act between cost-effectiveness and regulatory compliance in infrastructure investment decisions.

French Rail's response emphasises that:

- **The IM** underscores the strategic importance of CBA in ensuring cost efficiency and value for money in infrastructure projects. CBA is viewed as more than a fiscal exercise; it is a tool for long-term economic efficiency assessment, aligning with financial sustainability and socio-economic advancement goals. The analysis, detailed with costs and benefits for each stakeholder, is augmented by financial and socio-economic KPIs. Regulatory frameworks, the Performance Contract (2021-2030), and advanced modelling techniques also play critical roles in guiding the IM's investment decisions, ensuring they meet efficiency objectives, service standards, and safety.
- **The RU** acknowledges the crucial role of CBA in investigating the overall utility of investments for the network, operators, and society. Factors like operator charges, energy efficiency costs, and the economic impacts of network disruptions are key in influencing cost efficiency. The challenges in external cooperation, as illustrated by challenges like land acquisition and compensation issues, highlight the complexities in achieving cost efficiency and value for money in large infrastructure projects.

Summary and Comparison

	1a. *Importance of CBA and other elements for infrastructure investment*	**1b.** *Contribution of operator's feedback to infrastructure investment strategic planning*	**1c.** *Contribution of CBA and any other elements to investments' value of money*
GB Rail	• The IM's strategies in both England and Scotland show a commitment to **integrating CBA with broader objectives**, emphasising socio-economic, political, and regional development impacts on investment decisions. • DfT highlights the role of CBA in government decisions, stressing political and strategic influences over purely economic analyses.	• The infrastructure planning process demonstrates a clear division between operator input and expert-led strategies, **balancing immediate feedback with long-term goals**. • DfT highlights the challenges of incorporating operator feedback due to the franchising system with short-term contracts, focusing on politically influenced projects over operator insights.	• While CBA is considered in infrastructure investment decisions, its actual influence is moderated by **broader factors beyond financial analysis**. • The strategic planning encompasses operational considerations and political influences, suggesting the need for a holistic approach that **integrates CBA with real-world operational goals and political contexts.**
Irish Rail	• Emphasises a balanced approach, integrating CBA with strategic, policy, and regulatory considerations, **highlighting the role of non-monetised benefits and political decisions** in shaping investment strategies. • Reflects the balance between financial prudence, regulatory compliance, and broader **policy alignment.**	• IR emphasises the critical role of operator feedback in strategic planning, showcasing a more collaborative approach compared to the UK. • Highlights the **efficiency of communication and collaboration** in enhancing network maintenance and planning.	• The responses from Irish Rail suggest a **dynamic and iterative approach** to using CBA in infrastructure investment projects. While emphasising the importance of continuous evaluation and benefit realisation to ensure cost-effectiveness, they also point out the need to consider regulatory objectives alongside economic factors.
French Rail	• The IM adopts a legally required, thorough approach to CBA, blending strategic, social, and environmental factors, in contrast to the RU's more financially focused perspective, showcasing the problematic complexity	• The IM values operator feedback for strategic planning and infrastructure management, integrating it with public consultations for a comprehensive approach. • The collaboration between the IM and RU showcases a proactive methodology	• In France, CBA is recognised as a fundamental element of the infrastructure investment process, significantly **contributing to achieving cost efficiency and value**. The IM's strategic application of CBA, **enriched by regulatory requirements and comprehensive stakeholder**

	of integrated planning within the SNCF group. • These diverse methodologies highlight the complexity of infrastructure investment decision-making, emphasising the **balance between detailed financial analysis and broader strategic and operational considerations**.	for addressing network disruptions and planning, supported by a structured collaboration framework developed by the SNCF holding company.	**engagement**, underpins a detailed approach to investment decision-making. • This framework seeks to ensure investments are not only financially viable but also align with **broader socio-economic objectives**.
Summarised Findings	• **GB Rail** and **French Rail** both highlight the importance of infrastructure investment appraisal, incorporating socio-economic and environmental considerations. However, GB Rail emphasises the political and strategic influences on decision-making, while French Rail focuses on legal mandates and comprehensive evaluations. **Irish Rail** balances traditional CBA with strategic, policy, and safety considerations, showing an approach to investment that includes non-monetised benefits and political decisions. • Across the countries, there's a common theme of blending financial, strategic, and qualitative factors in infrastructure investment decisions, but the weight and emphasis of each factor vary. The VI seems to have a **stronger political influence** on infrastructure investment decisions, which often weaken the role of CBA in the decision-making process.	• **GB Rail's** strategy shows a division between direct operator feedback and expert-led decisions, with a notable emphasis on long-term goals and political influences shaping investment decisions. **Irish Rail**, contrastingly, highlights a collaborative model where operator feedback directly influences strategic planning. **French Rail** demonstrates a strategy where the IM integrates operator feedback with broader consultations, supported by the SNCF's framework and technology utilisation for collaboration. • The VS regime tends toward segmented decision-making with political / contractual influence, while the VI enhances **direct operator engagement** in planning. The HC supports an approach with broad stakeholder inputs in the HC framework.	• The **GB Rail** highlights the limited influence of CBA in the face of operational and political factors. **Irish Rail** emphasises a pragmatic, iterative use of CBA, integrating continuous evaluation and regulatory considerations for aligned, cost-effective investments. **French Rail** regards CBA as a strategic tool that substantially contributes to cost efficiency and value, underpinned by regulatory compliance and strategic planning. • All the countries emphasise the influence of **political factors** on decision-making. The VS regime shows a preference for **expert-led strategies** with political considerations, while the VI regime facilitates a more collaborative, **operator-inclusive** planning process. The HC regime emphasises a **strict, legally mandated approach** to appraisal, integrating broad stakeholder feedback.

Theme 2 - Impact of structural reform on passenger demand

Question 2a. Do you think rail passengers are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?

GB Rail's response indicates that:

- **The IM** across both England and Scotland observes that passenger sensitivity to factors like price, service quality, reliability, and safety are influenced by changing travel patterns, especially post-COVID. Safety is a fundamental expectation, with any perceived lapses potentially deterring rail usage. The increase in remote working has heightened sensitivity to ticket pricing and service quality, particularly for leisure travel. Passengers are more likely to compare rail travel with alternatives such as car travel, emphasising the importance of competitive pricing and high service standards. This evolving landscape underlines the need for the rail industry to continuously adapt to these shifting preferences and expectations.
- The **DfT** suggests that the most reliable indicators for addressing this query are the demand drivers and their corresponding elasticities as detailed in the Passenger Demand Forecasting Handbook (PDFH). However, the confidential nature of PDFH means that the extraction of elasticity data for rail demand drivers from pertinent research studies is required. According to Dunkerley et al. (2021), elasticities for rail fares in Great Britain range from -0.18 to -1.58, varying significantly based on ticket type and flow group. Moreover, Toner et al. (2020) present the average elasticities of -0.9 for Generalised Journey Time (GJT), -0.71 for journey time, and -0.25 for headway, drawn from multiple studies. Conclusively, pinpointing the most sensitive factor affecting passenger behaviour is challenging due to the interdependence of various elements, including journey purpose and flow group.
- The **Operator** observes that GB rail passengers have become increasingly sensitive to price changes, particularly with the post-pandemic shift towards leisure travel. This change in price sensitivity highlights the importance of fare strategies in influencing rail travel demand in the GB. This trend suggests that pricing might now be a more significant factor in passenger decision-making than other aspects such as service quality, punctuality, and reliability.

Irish Rail's response emphasises that:

- **Sensitivity to Train Fares:** Passengers in Ireland are acutely sensitive to changes in train fares, particularly amidst the current cost of living crisis. Fare adjustments quickly become subjects of political debate, and recent interventions by the National Transport Authority to reduce public transport fares by 20% reflect this sensitivity. Any attempt to reverse these fare reductions might face significant resistance, especially considering the political advocacy for public transport over private car usage. Ireland's approach to fare adjustments is context-specific but aligns with broader European standards. The recent "bounce back" in public transport use in Ireland, attributed to fare reductions, contrasts with trends in other European countries and underscores the effectiveness of this strategy in increasing rail usage.
- **Service Quality, Reliability, and Timetable Enhancements**: The ongoing efforts to enhance service quality and reliability are evident in Irish Rail's timetable improvements since 2010. However, these changes have led to congestion challenges, particularly in Dublin. Post-COVID shifts in peak travel times have resulted in a more evenly distributed demand throughout the day, prompting discussions on modifying commuter timetables to alleviate congestion and enhance overall service performance.

French Rail's response emphasises that:

- From the IM's perspective, passenger preferences in France are influenced by multiple factors, including price, service quality, reliability, and safety. They emphasise that the financial support for the rail infrastructure, mainly through train access charges, plays a significant role in shaping service offerings. Their traffic modelling suggests passengers consider various aspects like journey nature, multimodal options, travel duration, and service quality when choosing transport modes. Long-distance travellers prioritise speed and cost, while short-distance passengers value service frequency and convenience. Additionally, there's a growing environmental consciousness affecting travel choices, indicating a shift towards more sustainable modes of transportation. They highlight the complexity of passenger preferences and the importance of tailoring services to meet these diverse needs, especially in the context of structural reforms in the rail industry.
- From the RU's perspective, French rail passengers' responsiveness to factors like price, service quality, reliability, and safety varies with the trip's purpose. Long-distance travellers primarily focus on price and reliability, whereas short-distance passengers also consider service frequency and connection times. This distinction

underscores the necessity for a differentiated approach in service provision, catering to specific needs based on travel distance and purpose.

Question 2b. Do you think any of the above factors changed significantly due to the previous rail structural reform in the country?

GB Rail's response indicates that:

- **DfT** observes that the rail structural reform in Great Britain has led to improvements in service quality and responsiveness, particularly in leisure travel, with enhancements such as modernised trains and customer-focused services. The impact on demand, especially due to increased service frequency on core intercity networks, is notable yet remains a complex "chicken and egg" situation. Smaller operations like Great Anglia demonstrate a potential for higher market sensitivity, benefiting from a scale that allows closer customer engagement.
- From **IM's** perspective, since the major privatisation reform in 1996, there has been an indication that the private sector's market-driven approach to service quality and ticket pricing has changed. Private entities have shown agility in innovation. In Scotland, Transport Scotland's authority to adjust fares independently of the DfT has enabled targeted responses to changing passenger behaviours. For instance, the trial of no peak fares and adapted service schedules on Saturdays was successful, as it is now the busiest day for rail travel within Scotland. These regional adaptations point to an evolving rail service structure that aims to meet current demands and anticipate future needs.
- From **Operator**'s perspective, rail structural reform in the UK, particularly the establishment of Great British Railways (GBR), is exploring new pricing strategies to simplify fare structures. This shift is driven by the need to make fares more transparent and understandable for passengers, as seen in trials by LNER (i.e. single-leg pricing). Historically, the complexity of UK rail fares has been linked to private operators' revenue-maximising strategies, leading to complex and user-unfriendly fare structures. The reform process, which shifts revenue risk from individual TOCs to the government, is expected to alter this approach, focusing on creating fare structures that prioritise ease of use and accessibility over maximising revenue. This indicates that revenue incentives play a crucial role in shaping fare strategies, with the ongoing reform potentially leading to a fundamental change in fare system design towards simplification and improved customer experience.

Irish Rail's response emphasises that:

- Following structural reform, Irish Rail has embarked on a continuous effort to improve timetables and service quality. This drive towards enhancement has led to congestion in certain areas, which has prompted the need to adjust peak travel times. The reform efforts reflect a commitment to refining service delivery in response to evolving passenger needs and travel patterns, though they also bring to light the infrastructural challenges that come with increased service demand.

French Rail's response emphasises that:

- **The IM's** Perspective: While is too early to assess the long-term impact of the introduction of competition in the French rail market, the IM notes an immediate effect (reduction) on pricing structures. The emergence of competitive pressures has introduced more dynamic pricing strategies, which may influence passenger demand patterns as consumers become exposed to a wider range of choices and potentially grow more price-sensitive.

- **The RU** observes that the 2018 structural reforms in the French rail sector, particularly the introduction of competition and SNCF's transformation into a national company, have prompted significant shifts in pricing and service quality. For example, the entry of new operators like Italian State Railways (FS) on routes such as Paris - Milan has introduced competitive pricing, with FS offering lower charges than the RU in the short term. Despite these changes, the IM's commitment to equitable treatment of all operators aims to maintain consistent service quality across the board.

Question 2c. Do you think the rail structural reform impacts passengers' travel behaviour / preference, i.e. change their demand response to the factors above?

GB Rail's response indicates that:

- **DfT:** The franchising system created incentives for operators to improve services and be responsive to passenger needs due to the direct financial benefits from increased demand and service enhancements. The stage at which operators take on revenue risk and express commercial interest is critical for their responsiveness to passenger demands and market changes.

- **NR:** Structural reform, particularly privatisation, has indirectly impacted passenger behaviour by introducing market dynamics that push companies to be more responsive to customer preferences, affecting pricing and service quality. Passengers care about service aspects such as timeliness, cleanliness, and safety over the identity of the operator, while the shift from commuting to leisure travel, influenced by factors like remote work, has led operators to adapt their strategies and offerings to new travel patterns.

- **The RU:** Rail reform in the UK is anticipated to influence passenger travel behaviour, especially through modifications in pricing strategies. The ongoing reform is testing new, simpler fare structures aimed at enhancing transparency and user-friendliness, which may alter passengers' sensitivity to pricing. This change in fare strategy, moving away from complex, revenue-maximising structures to government-set, straightforward fares, could shift fare elasticities, making rail travel more appealing and accessible. The simplification of fare systems is expected to positively impact passenger preferences, encouraging more straightforward travel decisions.

Irish Rail's response emphasises that:

- The reduction in rail fares in Ireland has positively influenced passenger travel behaviour, such as increasing public transport usage and altering demand distribution throughout the day. However, the recent transition to a Cost-plus contract has not significantly affected marketing, sales practices, or revenue protection responsibilities. Irish Rail's brand has maintained passenger trust and loyalty, contrasting with the UK's experience of franchise ownership changes. The value of a consistent and trusted brand, exemplified by the success of Virgin Trains, highlights the importance of branding in the public perception and acceptance of operational or structural rail reforms.

French Rail's response emphasises that:

- The separation of infrastructure management from transportation services in France has not resulted in significant changes in demand price elasticity. This restructuring, focusing more on internal governance and efficiency, has not dramatically altered passenger responses to price adjustments as core aspects of rail travel such as service frequency, reliability, and pricing remained relatively constant. However, the long-term impact on passenger behaviour, as the competitive environment evolves, requires ongoing observation to discern more variations in travel patterns.

- The structural reform, particularly the separation of the IM and RU and the entry of new operators like Italian State Railways (FS), has implications for passenger behaviour. The introduction of competition, resulting in lower ticket prices, could make rail travel more appealing and accessible, especially for long-distance passengers sensitive to price changes. Additionally, the potential improvements in service quality and reliability due to competition might further influence passengers to favour rail travel.

Summary and Comparison

	2a. *Do you think rail passengers are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?*	**2b.** *Do you think any of the above factors changed significantly due to the previous rail structural reform in the country?*	**2c.** *Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. changes their demand response to the factors above?*
GB Rail	• The GB rail sector notes the passenger sensitivity to pricing, service quality, and reliability, enhanced by **shifts in travel behaviour post-COVID**. • Competitive pricing and maintaining high service standards are essential as leisure travel preferences evolve, emphasising the importance of aligning with passenger expectations to maintain ridership.	• Structural reforms, notably privatisation, have positively influenced service quality and responsiveness, with smaller operators benefiting from the ability to **tailor services to customer preferences**. Reforms enabled more adaptable services to changing travel patterns, emphasising a customer-centric approach.	• The franchising system encourages service improvements and **market responsiveness**, potentially making rail more appealing through simplified fares and impacting travel choices. • Privatisation has led to a **customer-focused approach**, with quality and reliability being key factors for passengers, influencing demand.
Irish Rail	• IR Emphasises passengers' high sensitivity to fare changes and service quality, with IR's strategies to adjust fares considering political and economic factors. Improvements in service reliability and timetabling are critical too, with fare reduction strategies aiming to bolster sustainable transport and increase ridership.	• Reforms aim to improve service delivery, adjusting to new passenger needs and travel habits, despite facing infrastructural challenges.	• Fare reductions under structural reform have increased demand, with the transition to a Cost-plus contract system not significantly changing operations or culture. • **Brand stability and consistency** play a crucial role in maintaining customer trust and loyalty, despite structural changes.
French Rail	• Both the IM and RU acknowledge the complex nature of passenger sensitivity, underlining the importance of adapting services to meet diverse needs across different travel segments.	• French Rail is experiencing market shifts due to structural reforms, with a move towards **competitive pricing** and **high service quality standards**, anticipating ongoing evolution in service quality and pricing as competition increases.	• Early stages of structural reform, including market competition, have not yet significantly impacted passenger price sensitivity or travel behaviour. • Over time, **competitive pressures** may enhance service quality and reduce prices, potentially altering passenger preferences towards rail.

Findings	• The comparative analysis suggests that passenger sensitivity to factors like price, service quality, reliability, and safety **doesn't directly correlate with the vertical structure of rail systems**. Instead, these sensitivities are more influenced by market variables, journey purposes, and other contextual factors such as the post-COVID shift in travel behaviours.	• VS facilitates a **market-focused** strategy, enhancing service quality and price responsiveness to diverse travel patterns. Smaller operators, benefiting from market specialisation, adapt services to specific customer needs, indicating a dynamic, competitive environment. • VI applies **broad market strategies**, such as network-wide fare reductions, lacking targeted approaches for different passenger segments. • HC demonstrates tailored service offerings to meet diverse passenger needs, like VS does. However, this accessibility for new operators might **intensify competition**, potentially leading to pricing challenges.	• **Market Orientation vs. Brand Stability**: GB Rail's market-oriented, franchising approach contrasts with Ireland's focus on brand stability and culture, showing that reforms can either drive service innovation or underscore the importance of consistent branding in influencing passenger preferences. • **Competition and Impact Timeline:** The introduction of competition in France, specifically through new operators like Italian State Railways, has begun to reduce ticket prices and promises to enhance service quality, potentially making rail more attractive to long-distance travellers sensitive to price changes. This contrasts with the immediate impacts observed in Great Britain and Ireland, suggesting that while reforms may have direct effects in some regimes, in others like France, the benefits of competition and service improvements might unfold more gradually, leading to a slower but eventual shift in passenger demand and preferences.

Theme 3 - System-level benefits optimisation

Question 3a. Do you think that regulation is the most useful approach to ensure the system-level benefit is considered in the planning stage of the investment? Are there any mechanisms (i.e. consultation) that help to deliver system-level benefits in the investment implementation stage?

GB Rail's response indicates that:

- The **DfT** recognises that the regulatory framework, established during the era of privatisation, has not adequately prioritised system-wide benefits in rail infrastructure investment. This gap has persisted due to a focus on managing existing infrastructure and a lack of effective strategies to encourage collaborative enhancements. Since 2004, the requirement for considering system-wide benefits, including unpriced economic factors, has been formalised, yet there remains a degree of doubt about the result of this inclusion. However, doubts remain regarding the effectiveness of this inclusion. The DfT, now in charge of decision-making for all enhancements, implies that while there is an obligation to consider broader benefits, the practical execution of these considerations may still be influenced by infrastructure managers' priorities, which do not always align with the wider system's needs. This scenario underscores the importance of the DfT's role in re-evaluating regulatory processes to ensure that infrastructure investments are not only compliant with existing frameworks but also meaningfully contribute to the overall enhancement of the rail system, reflecting the DfT's centralised oversight in steering investments towards achieving system-wide benefits.
- **The IM** across England and Scotland acknowledges the value of regulations and stakeholder consultations in delivering system-level benefits. In England, there is an emphasis on the collective participation of stakeholders in planning and decision-making, ensuring that the industry's diverse perspectives are incorporated into the infrastructure development process. Scotland's approach, facilitated by a single-director structure, aims to address integration challenges and improve decision-making that accounts for end-user impacts and system interconnectivity. An example of this is the **LEVENMOUTH RAIL LINK** project, where Transport Scotland, the IM, and industry partners collaborated to expand the project scope, delivering additional investment and benefits. Initially led by the local authority with a flawed business case, the Scottish Government's directive for the IM to assume leadership allowed for a more comprehensive analysis, yielding a realistic business case that factored in

ongoing operational costs. This transition not only improved the project's financial viability but also ensured its alignment with broader system-wide benefits, reflecting an effective approach to addressing integration challenges and enhancing decision-making for the benefit of end-users and system interconnectivity. Details of this and other case studies demonstrating the approach's efficacy can be found in Appendix A (page 184). Despite these structural efforts, there is an acknowledgement that engineering decisions are sometimes made in isolation without considering the wider system optimisation. This requires a cultural shift towards more comprehensive project planning and delivery that considers the full scope of system-wide implications.

- **The Operator** highlights that for effective railway infrastructure investment, regulation alone is insufficient. Instead, a holistic approach, combining joint management and leadership alignment, is essential. This approach should integrate insights from both infrastructure managers and operators, overcoming short-term planning limitations. Such integration allows for a more realistic and effective planning process, attuned to operational realities and long-term socio-economic benefits.

Irish Rail's response emphasises that:

- The complexity of delivering system-level benefits is evident in the DART[24]+ project. The DART+ project, with its ambitious budget and scope, demonstrates the complex nature of ensuring system-level benefits. While the initiative promises several improvements, such as electrification and fleet standardisation, challenges like track capacity constraints raise concerns about potential disruptions. This highlights the delicate balance between ambitious service improvements and the physical limitations of existing rail infrastructure. Both significant planning and coordination are required to navigate these complexities and deliver comprehensive system-level improvements.

- The infrastructural advantages observed in the Great Britain rail system, notably separate tracks for different train speeds, contrast with the challenges faced in Ireland. This difference can be significantly attributed to the outcomes of structural reforms undertaken in each country. In Great Britain, such reforms have led to the development of infrastructure that supports varied rail services efficiently. On the other hand, Ireland's railway structure, shaped by its own set of reforms, has historically lacked such separation, impacting its operational efficiency. However, Irish

[24] The Dublin Area Rapid Transit system (stylised as DART) is an electrified commuter rail railway network serving the coastline and city of Dublin, Ireland.

Rail's future vision, according to recent or ongoing structural reforms, aims to bridge this gap through infrastructural enhancements like track segregation and cross tunnels, promising substantial improvements in efficiency. The bundled structure of the Irish system, a product of these reforms, is poised to offer simplified decision-making and project implementation, illustrating the impact of structural reforms on the capabilities and efficiencies of national rail systems.

French Rail's response emphasises that:

- **The IM** outlines the integral role of the French transport regulator, ART, in ensuring system-level benefits, particularly with its counter-expertise requirement for substantial investment projects. This regulatory process, exemplified by the Roissy-Picardie project, is designed to ensure investments align with collective network objectives rather than individual interests. Additionally, the French government and the European Commission's oversight, along with ex-post evaluations like the "bilan LOTI," provide further checks to guarantee that infrastructure investments fulfil their intended benefits and support the overall improvement of the rail network.
- **The RU** confirms the importance of regulatory oversight in France's rail investment planning, highlighting the requirement for counter-expertise analysis on significant projects to ensure comprehensive assessments. Counter-expertise analysis involves an independent review process, wherein external experts evaluate the socioeconomic assessments conducted by project sponsors. This ensures a comprehensive evaluation of the project's utility, taking into account regional and European impacts. The European Commission's review process and France's legislative requirement for ex-ante socioeconomic evaluations underscore a strict framework to ensure investments deliver widespread benefits. During the implementation phase, consultations with stakeholders and assessments by independent experts are key mechanisms that contribute to achieving broader project goals.

Question 3b. If the investment brings higher cost than benefit to the IM or RU, how to incentivise (or, maybe obligate) the IM or RU to coordinate with other organisations/companies to deliver the investment? Is there any circumstance that such schemes don't work well?

GB Rail's response indicates that:

- The **DfT** recognises that while mechanisms like Schedule 4[25] and the Network Code/Network Change[26] are in place to balance interests during large-scale rail investments, their effectiveness in promoting true system-wide coordination is under investigation. These mechanisms, intended to mitigate the financial impact on TOCs during infrastructure works, are sometimes perceived as a cost tool rather than a regime for collaboration. The case of London Bridge station exemplifies successful collaboration driven by practicality (i.e. IM and Southeastern Railway) and public interest, raising questions about the applicability of these mechanisms in promoting similar cooperation in smaller or less visible projects. The DfT's observations suggest that while the framework exists to consider system-level benefits and operator compensation, the depth and quality of coordination and the actual alignment with broader system needs might require more nuanced approaches and enhancements.
- **The IM** across England and Scotland underscores the importance of compensation and neutrality, primarily through mechanisms like Schedule 4, to incentivise coordination during infrastructure investments. However, these mechanisms are often supplemented by broader considerations, such as government support and regulatory compliance, particularly when investments lead to significant operational changes or require additional subsidies. In Scotland, the single-director management structure highlights the role of streamlined decision-making in ensuring investments align with regulatory standards and truly benefit the system. The LEVENMOUTH RAIL LINK serves as a case study demonstrating the positive impact of Scotland's single-director management structure on project planning and execution, leading to a comprehensive re-evaluation and enhancement of the project scope. Further details of this case study can be found in Appendix A (page 186). Both regions emphasise the need for contractual safeguards and regulatory alignment to ensure that investments are not only financially viable for operators but also contribute to the wider rail network's efficiency and service quality.
- **The RU** emphasises the critical function of mechanisms like Schedule 4, along with the DfT’s role in directing TOCs via Annual Business Plans (ABPs), to balance higher investment costs. These ABPs, although not as binding as franchise agreements, strategically guide TOCs towards improvements, considering qualitative and

[25] As a part of the Network Code, Schedule 4 outlines the compensation framework for RUs in the event of planned or unplanned disruptions caused by infrastructure projects or maintenance activities. It aims to mitigate financial losses incurred by TOCs due to changes in network availability.

[26] The Network Code is a comprehensive set of legal, regulatory, and administrative documents that govern the operation of the UK's rail network. It includes provisions for access, usage, and the management of the railway infrastructure. The "Network Change" section within the Network Code specifically deals with the processes and requirements for implementing changes to the rail network's infrastructure, operations, or services, ensuring that all changes are managed in a way that considers the interests of various stakeholders across the rail industry.

quantitative elements to influence their actions. Additionally, performance regimes in contracts, based on specific target methodologies, incentivise TOCs to meet set performance metrics. This approach integrates strategic planning with quantifiable objectives, ensuring that TOC activities are in line with overarching infrastructure investment goals.

Irish Rail's response emphasises that:

- Financial mechanisms in place, such as refunds for train cancellations and track access fees for unplanned train movements, generally balance out the costs associated with infrastructure investments. However, larger projects like the metro can cause significant disruptions, sparking debates over the potential closures of major commuter routes. Despite the track access charge being aligned with EU directives to theoretically allow new operators, the unique challenges of Ireland's railway system, including non-standard signalling and track capacity constraints, pose barriers to actualising a multi-operator environment for the future.

- The perspective suggests that long-term performance incentives linked to infrastructure investment are beneficial, as a well-operated railway enhances service quality and reduces operational costs. However, the compensation frameworks may sometimes create counterproductive incentives by prioritising compensation payments over actual passenger service. Despite this, in certain situations, financial mechanisms are acknowledged for incentivising the infrastructure manager to minimise their impact on train operations, particularly during extensive engineering works that lead to train cancellations.

French Rail's response emphasises that:

- The IM is committed to promoting a cooperative relationship with operators, such as SNCF Voyageurs and Fret SNCF, aiming for increased network utilisation and enhanced customer experience. While SNCF holding company does not directly manage operational coordination, its role as the parent company shapes the strategic framework within which the IM operates. The focus is on building a trustful relationship with operators, understanding their operational needs, and aligning strategies for mutual benefit, leading to increased train traffic and improved service levels. However, challenges in coordination can arise due to divergent operational priorities, strategic misalignments, or external factors like regulatory changes and market dynamics. Despite these challenges, the IM's commitment to engaging with regulators and maintaining clear communication with operators underscores its dedication to ensuring that infrastructure investments benefit the entire network and its users.

- The SNCF Group, as of 2020[27], operates under a restructured model with SNCF as the parent company overseeing subsidiaries like The IM and RU. This integrated model allows SNCF to:
    - Oversee and ensure the alignment of strategic goals between the IM and the RUs, enhancing the overall efficiency and effectiveness of rail operations.
    - Coordinate investments across the network that benefit the system as a whole, even if the immediate financial benefits are not apparent to individual entities within the group.

[27] SNCF. (2020). SNCF in 2020: New year, new group. Retrieved from https://www.sncf.com/en/group/profile-and-key-figures/about-us/sncf-2020-new-group

Summary and Comparison

	3a. *Do you think that regulation is the most useful approach to ensure the system-level benefit is considered in the planning stage of the investment? Are there any mechanisms (i.e. consultation) that help to deliver system-level benefits in the investment implementation stage?*	**3b.** *If the investment brings higher cost than benefit to the IM or RU, how to incentivise (or, maybe obligate) the IM or RU to coordinate with other organisations/companies to deliver the investment? Is there any circumstance that such schemes don't work well?*
GB Rail	• GB's evolving regulatory and planning frameworks aim to better include system-wide benefits, with initiatives like the DfT's calls for improvement and TOC's emphasis on joint management pointing towards more integrated planning and execution. • The challenge remains in aligning detailed decisions with broad network benefits, indicating a shift towards more robust and collaborative strategies for ensuring comprehensive rail investment benefits.	• GB employs compensation mechanisms like **Schedule 4** and strategic tools such as **ABPs** to align TOCs with infrastructure goals, incentivising collaboration for investments with broader system benefits, despite challenges in ensuring the effectiveness of these mechanisms across all projects.
Irish Rail	• Irish Railway's commitment to system-level benefits is shown through projects like DART+, addressing track capacity and other challenges through a vision inspired by other systems and facilitated by a unified rail structure, emphasising the value of collaborative planning.	• Ireland's investment framework, balancing costs through compensation and track access charges, faces challenges in practical implementation, with a preference for long-term performance incentives to align investments with service quality and system performance goals.
French Rail	• French Railway's investment process relies on regulatory evaluation and multi-layered oversight by bodies like the ART and the European Commission, ensuring investments meet broad network and socio-economic goals through structured evaluations and stakeholder consultations. • As the parent company, SNCF oversees major strategic and investment decisions for the IM.	• The IM's role, particularly through the SGC department, is crucial in incentivising coordination between the IM and RUs for investment through regulatory compliance, information transparency, and operational collaboration, ensuring all parties adhere to the validated train diagram and performance feedback mechanisms. This system aims to maintain operational efficiency and safety across the French rail network, facilitating investments even when they may not directly benefit individual stakeholders.

		• As the parent company, SNCF overseeing major strategic and investment decisions. This configuration emphasises SNCF's critical role in guiding strategy and ensuring the strategic alignment and operational efficacy across its entities, aiming for an efficient, unified rail network.
Findings	• All three countries/regimes demonstrate a move towards ensuring investments deliver broad network benefits, with GB Rail and French Rail focusing on regulatory evolution and oversight. Irish Rail leveraging its integrated structure for efficient decision-making and project implementation, underscoring different but complementary paths to achieving system-wide investment benefits.	• In the VS regime, the coordination between IMs and RUs for rail investments is primarily driven by compensation mechanisms and regulatory compliance, whereas France utilises the strategic oversight of the SNCF Group's parent company, showcasing a distinct model focused on ensuring alignment and system-wide benefits. • This **strategic oversight** in the HC regime is due to the existence of parent company. It highlights an integrated approach that leverages the parent company's role in aligning strategic goals and operational efficiency across the network, distinguishing it from the more regulatory-focused mechanisms in the VS regime.

Theme 4 - Coordination between RU and IM

Question 4a. In the daily operation, how does the IM ensure efficient coordination with the RU in daily train operations especially when a disruption on the network occurs?

GB Rail's response indicates that:

- The **DfT** emphasises that the success of the rail system depends on government policies, investment strategies, and political factors. Effective coordination in the sector goes beyond operational mechanisms, requiring a broader understanding of policy, investment considerations, and an adaptable approach to changing market and political circumstances.
- **The IM**'s strategy for ensuring efficient coordination between RUs and IMs during daily operations and disruptions encompasses both structured operational mechanisms and a forward-looking approach towards industry reform. In England, IM utilises Rail Operating Centres (ROC) to facilitate collaborative responses to disruptions, employing contingency plans and codes of practice. The anticipated integration under GBR is expected to strengthen this coordination by aligning objectives and fostering a more unified operational framework. In Scotland, the emphasis on joint management, financial incentives, and the potential of a single set of objectives under GBR reflects a strategic commitment to overcoming the historical challenges of industry unbundling and promoting a culture of collaboration. The reflections on past practices, such as the decision to contract out maintenance, highlight the importance of understanding the complex interplay between contract specifics, industry culture, and the broader operational context. The experiences from both England and Scotland region show that the rail sector's coordination requires adaptable, context-aware strategies that align operational efficiencies with industry goals.
- In daily operations and disruption management, **the RU** highlights the shared control approach between IM and TOCs, aimed at deriving collaborative decision-making. However, challenges arise due to the complexity of factors involved, occasionally leading to decision paralysis. The need for a singular, decisive guiding mind in disruption management is emphasised, as well as the importance of keeping the customer's perspective central in decision-making processes.

Irish Rail's response emphasises that:

- The coordination between the IM and RU teams in Irish Rail exemplifies a model of efficiency and collaboration, significantly attributed to their shared history and ongoing close relationship. The establishment of a new train control centre at Heuston station, featuring advanced traffic management systems, is expected to further enhance this coordination. This system, with its direct link to train planning and detailed routing information, represents a significant step towards reinforcing the operational coordination between IM and train operations.
- On the other hand, Irish Rail could have coordination challenges because given separate teams are working on train operation and infrastructure management. Good coordination is based on the good relationship between the two teams, especially the two team leaders. In other words, coordination could be even better in GB Rail if the two team leads from two different companies coordinate well.

French Rail's response emphasises that:

- **The RU** exemplifies an efficient coordination model with the IM, particularly during network disruptions, through an exchange of detailed information. This interactive process ensures that when disruptions occur, both entities are well-informed about the causes, implications, and anticipated resolutions. The standardisation of this communication process, not just for this RU but for all current and future rail operators, ensures consistency and effectiveness in coordination across the network. This approach ensures that disruptions are managed promptly and efficiently, minimising impact on services and maintaining high standards of operational reliability and customer satisfaction.
- Desktop research provides further findings. **The French government sets the regulatory framework** (i.e. Article 2111-9 of the Transport Code) for the nation's railways for the IM to follow. The government's central role in setting railway regulations, evidenced by the IM's Network Statement[28] underscores the integration of technology for operational efficiency and safety. This regulatory environment ensures the RU and other operators work under equitable conditions, supported by technologies like Transmission Voie-Machine (TVM) and A live information-sharing service (SPID tool) for effective coordination. On the other hand, **SNCF's role focuses on providing overarching management**, and centralising services across the group to ensure operational and safety standards are consistently upheld.

[28] https://www.sncf-reseau.com/medias-publics/2024-02/ns2025_eng.pdf

Question 4b. As I understand, the key incentives for the coordination between RU and IM (which are not in the same team) daily include joint management (reporting to a unique manager) and financial incentives. Are there any other ways that you think may improve the coordination?

GB Rail's response indicates that:

- The **DfT's** insights show that the coordination between RUs and IMs, especially in the context of UK rail reform, is a complicated and evolving challenge. Efforts like alliancing and joint control centres aimed to promote integration but faced practical limitations and did not yield the expected improvements in performance. The effect of these initiatives in deriving seamless coordination remains a subject of debate. The discussion also delves into the philosophical foundations of rail privatisation, the crucial role of government policies, and the impact of political factors on the dynamics of the rail industry. The reflections suggest that unbundling each company to focus on its efficiency could be beneficial, but they also emphasise the importance of taking a comprehensive approach that aligns political, policy, and operational strategies to improve system coordination.
- The IM's approach to enhancing coordination between RUs and IMs entails a blend of operational strategies, cultural considerations, and systemic reforms. In England, the focus on joint management, financial incentives, and the alignment under GBR could be a strategic move towards a more integrated and cooperative rail industry. The emphasis on culture, leadership, and the need for a systemic understanding of operations highlights the complexity of achieving effective coordination post-privatisation. In Scotland, the co-location of control centres and the implementation of performance regimes exemplify practical steps towards seamless daily coordination. The need for coordination mechanisms that are adaptable, clear and purpose-driven is underscored by the call for simplification, a focus on service delivery instead of contractual compliance, and a shift from blame attribution to operational improvement. These perspectives from England and Scotland illustrate the complex landscape of rail industry coordination, emphasising the requirement for structures that promote understanding, simplicity and a unified focus on delivering quality rail services.
- **The RU** highlights the significance of industry culture in enhancing coordination between RU and IM. While joint management and financial incentives are important, the traditional nature of the railway industry often leans on established cultural norms and working relationships. This cultural dimension becomes particularly crucial during

times of reform, such as the transition to GBR, underscoring the need to keep the customer perspective, primarily gathered by TOCs, at the forefront of decision-making.

Irish Rail's response emphasises that:

- Irish Rail demonstrates a strong commitment to collaboration between IM and RU teams, with management processes and organisational culture playing pivotal roles. The integration of fleet controllers into the IM control room and the emphasis on joint problem-solving in weekly meetings highlight the effective management structures in place. This approach ensures that both departments, despite their separate functions, operate in a coordinated fashion, addressing challenges and disruptions with a unified strategy.

- The insights from the former CEO of Irish Rail reinforce the significance of management alliances and performance incentives in enhancing daily coordination. The example of the Transport for London (TfL) Concession model, with its structured approach to operational management and clear performance targets, illustrates a successful framework for ensuring high-quality service delivery and effective coordination between the operator and the managing entity. The TfL concession model[29] represents a structured approach to operational management in public transport services, characterised by clear performance targets and regular monitoring. In this model, TfL assumes the revenue risk, allowing the operating company for the London Overground, to receive a fixed payment with adjustments based on performance metrics. This arrangement focuses the operator on efficiently running services and maintaining high standards of reliability and quality for passengers. The model facilitates a collaborative relationship between the operator and TfL, ensuring that service improvements, such as the extension of routes or capacity enhancements, are implemented effectively to meet passenger needs. The concession model differs from traditional franchising by shifting focus from revenue forecasts to service delivery, aiming to improve the overall passenger experience and service reliability across the network. This model, characterised by regular interactions, performance monitoring, and clear contractual obligations, serves as a benchmark for delivering efficient and customer-focused operations in the rail industry.

French Rail's response emphasises that:

[29] Transport for London. "London Overground Concession Agreement." Last modified March 2016. https://content.tfl.gov.uk/london-overground-concession-agreement.pdf.

- The IM[30] express a commitment to equitable treatment of all rail operators, including SNCF Voyageurs and Fret SNCF, by adhering to strict regulations and internal policies. This commitment is rooted in the foundational principle of non-discrimination, ensuring a fair and competitive railway network.
- The mechanisms of coordination and communication extend uniformly across all operators, reflecting the IM's dedication to a transparent and fair operational environment. The flexibility in negotiating access charges and the comprehensive catalogue of services available to all operators illustrate the organisation's approach to promoting a competitive landscape.
- Regular audits and oversight by regulatory authorities like the French Transport Regulator (ART) further reinforce this commitment, ensuring that operations such as track access allocations and charge structures adhere to the highest standards of fairness and transparency.
- To summarise, the IM's approach to ensuring equitable treatment among rail operators, including technology's (i.e. Transmission Voie-Machine (TVM) and Live information sharing service) critical role in coordination and SNCF Holding's strategic management, underscores a framework for operational harmony. This framework, complemented by the government's regulatory oversight, facilitates a transparent and competitive rail environment. Enhanced by regular audits and the flexibility in access charges, these elements collectively foster a fair, efficient network. The incorporation of technology and strategic oversight by SNCF Holding are pivotal in supporting this coordination, reinforcing the importance of a multifaceted approach to rail network management.

[30] Note: The response should be considered within the context of the interviewee's current employment with the IM, which may introduce a bias toward more positive representations of their operations and decision-making processes.

Summary and Comparison

	4a. *In daily operation, how does the IM ensure efficient coordination with the RU in daily train operations especially when a disruption on the network occurs?*	***4b****. As I understand, the key incentives for the coordination between RU and IM (which are not in the same team) daily include joint management (reporting to a unique manager) and financial incentives. Are there any other ways that you think may improve the coordination?*
GB Rail	• GB Rail has mechanisms like Rail Operating Centres and strategic reform (i.e. GBR) to enhance IM-RU coordination, emphasising shared control for decision-making during disruptions. Cultural understanding, leadership, and adaptability to market changes are key to effective coordination.	• GB Rail emphasises a future of greater collaboration and integration, suggesting simplification of operational regimes and a unified leadership approach to promote a culture of collaboration for better coordination between RUs and IMs.
Irish Rail	• Irish Rail benefits from a historical collaboration ethos and technological advancements, like advanced train control centres, fostering joint decision-making and operational integration. Strong leadership and relationship-building are essential for efficient IM-RU coordination.	• Irish Rail highlights a **culture-driven**, **performance-focused** strategy with managerial alignment and collaborative problem-solving, pointing towards structured performance incentives and organisational culture as keys to enhancing coordination.
French Rail	• The coordination model between The IM and RU is highly efficient, especially during network disruptions. They exchange detailed information to ensure that both parties are well-informed about the causes, implications, and expected resolutions of such disruptions. This interactive process is standardised to maintain consistency and effectiveness in coordination across the network, not only for the RU but also for all present and future rail operators. • The SNCF Group's holding company structure enhances this efficiency by ensuring strategic alignment and oversight, thereby facilitating a cooperative environment not just for the RU but also for all operators on the network.	• The IM's commitment to non-discrimination and equitable treatment, supported by a transparent operational environment and regulatory oversight, underscores the need for a multifaceted approach including **regular audits, technological integration, and strategic management** for improving coordination. **Note:** The above should be considered within the context of the interviewee's current employment with the IM, which may introduce a bias toward more positive representations of their operations and decision-making processes.

Findings	• GB Rail enhances IM-RU coordination through strategic reforms and mechanisms like ROC, emphasising leadership and adaptability. • Irish Rail relies on collaboration and bundled structure alliances for efficient operational integration and decision-making. • French Railway operates within a regulatory framework set by the government. the IM leverages technologies (i.e. TVM and SPID) for efficient coordination. Additionally, SNCF's management role across its subsidiaries ensures consistent operational and safety standards. • Comparatively, while the VS and VI regimes rely on strategic and cultural mechanisms to promote IM-RU coordination, the HC regime operates within a regulatory framework set by the government. For instance the IM leverages technologies (i.e. TVM and SPID) for efficient coordination. Additionally, SNCF's management role across its subsidiaries ensures consistent operational and safety standards.	• In the VS regime, the challenge lies in navigating the **complexities of a multi-organisational structure**, driving a push towards heightened collaboration and streamlined operations. Conversely, the VI regime benefits from a **well-established operational culture** afforded by its integrated structure, though it still necessitates performance incentives for optimal coordination. The HC regime leans on a **robust regulatory and technological framework** to promote coordination, under the strategic guidance of the holding company, highlighting a structured approach to enhancing inter-organisational cooperation. • While each country employs distinct methods to foster IM-RU coordination - ranging from strategic reforms in the VS regime, cultural and performance alignment in the VI regime, to regulatory adherence and technological advancement in the HC regime - the underlying principles of transparency, fairness, and collaboration emerge as universal themes. These principles are adapted to fit the specific industry structure showcasing how varying structures influence the strategies for enhancing rail network coordination and efficiency.

5.4 Discussions

The previous chapters (i.e. Chapters 3 and 4) detailed the quantitative analysis of rail structural reform's cost and demand effects. This subsection aims to merge these quantitative findings with qualitative insights from interview feedback, offering a comprehensive understanding of reform impacts. Additionally, it will conclude with observations on the coordination dynamics between IMs and RUs, illustrating how structural reforms influence their interaction and operational harmony.

5.4.1 Align with Quantitative Analysis (Cost)

The cost analysis investigates the cost structure of the railway industry, studying the relationship between vertical structure choices, train density, and infrastructure investment intensity. A notable outcome of this analysis was that the VS regime, when aligned with higher levels of infrastructure investment, demonstrates a pronounced ability to reduce costs across the rail system more effectively than the more integrated regimes (i.e. HC and VI). This finding contradicts traditional expectations, which have leaned towards the efficiencies of more integrated models in optimising infrastructure investment. This chapter (qualitative analysis) aims to contextualise the findings within the experiences and strategic considerations of industry professionals and test the validity of the hypotheses.

The above findings can be rationalised from two alternative perspectives. **Perspective A** recognises the role of infrastructure investment in reducing disruptions on the network. It provides a specific understanding of the relationship between train density and investment intensity. Targeted investments in track quality and signalling systems are designed to efficiently manage the higher volume of train movements associated with increased train density. Consequently, these investments are critical in mitigating the additional transaction costs arising from misalignment in high-density scenarios, ultimately contributing to a reduction in total system costs. Another possible explanation for this unexpected finding, **Perspective B**, is the increased transparency and focus of the VS railway system. In vertically separated environments, the clear division between rail operations and infrastructure management facilitates greater clarity in decision-making processes and accountability. This transparency allows for a more targeted and efficient allocation of investment resources, resulting in cost savings.

The insights derived from the responses to Question 1 present a multifaceted view of the strategic planning stage of infrastructure investment projects.

- While the importance of CBA is recognised, its actual influence on decision-making is complex and often secondary to a range of broader considerations. For instance, GB Rail's feedback indicates that although CBA forms a standard part of the planning stages, its effect on decision-making is somewhat limited, with a tendency to prioritise monetary aspects such as capital and operational costs. The response of the operator in GB concerning the Midland Mainline electrification project, where operational efficiency and environmental benefits are prioritised within the strategic fleet management decision-making process. This emphasis can result in an underestimation of operational costs and neglect the strategic long-term impact of infrastructure projects. This perspective challenges the assumption of Perspective B, which suggests that the VS regime's cost efficiency is primarily due to a clear, targeted, and efficient allocation of investment resources based on a rigorous CBA.

- Moreover, the responses highlight the significant role of non-monetised benefits, political influence, and strategic alignment in driving investment decisions. Political expediency, in particular, was frequently identified as a key factor in infrastructure investment decisions, suggesting that investments are often initiated based on broader policy objectives or political motives, rather than as a direct outcome of an economic evaluation. This complexity in decision-making contradicts the notion of transparency and focused decision-making in investment resource allocation as proposed in Perspective B.

The responses to Question 3 further enrich the understanding by discussing the effectiveness of regulatory frameworks in securing system-level benefits.

- While regulatory frameworks aim to maximise system-wide benefits, their effectiveness in aligning the priorities of infrastructure managers with the broader needs of the system is often challenged by the dynamics of stakeholder interests and operational requirements. For example, the DfT in the UK recognises that the current regulatory framework, established during the privatisation period, has not adequately focused on system-wide benefits, highlighting a disconnect between regulatory intentions and their practical implementation.

- GB Rail's responses indicate that, in the VS regime, the separation of operations and infrastructure management could naturally lead to coordination challenges, and the qualitative insights reveal a situation marked by extensive discussions and negotiations to reconcile diverse interests, which may diminish the efficiency and clarity of decision-making processes.

These narratives, derived from the qualitative survey responses, indicate a scenario where strategic alignment, collaborative stakeholder engagement, and broader policy objectives guide investment decisions and their impact on cost efficiency. The complexity and multifaceted nature of these processes contrasts with the straightforward decision-making process assumed in the VS regime in Perspective B. Hence, the qualitative insights provide a strong argument against the premises of Perspective B, instead highlighting the complicated and strategic nature of investment decision-making and its implications for cost efficiency in the railway industry's vertical structures. The evidence from Questions 1 and 3 further strengthens the justification for choosing Perspective A as the more appropriate explanation for the quantitative findings. The primary goal of infrastructure investments is to retain and enhance infrastructure quality, thereby ensuring smooth and safe train operations. This improvement is crucial in the VS regime, where it helps to minimise misalignment costs and generate overall cost savings. This is particularly significant in cases where there is high train density, which can result in coordination issues.

5.4.2 Align with Quantitative Analysis (Demand)

The quantitative investigation into the demand aspect analysed the interaction between rail structural reform and a set of variables, indicating their influence on rail passenger mode share. The econometric model provided key insights, particularly highlighting the distinct sensitivity of passengers to pricing under varying structural regimes. It indicated that under the VS regime, the yield variable demonstrated a negative impact on passenger rail mode share, illustrating a heightened sensitivity to price changes. This pattern corroborates earlier research - Tomeš (2017) and Mizutani and Uranishi (2020) - pinpointing the response of passenger demand to pricing.

Furthermore, the quantitative analysis found the complex effects of safety and rail infrastructure investment across various industry structures. For instance, safety concerns showed a stronger negative impact on mode share in the VS regime compared to the HC regime, while the VI regime displayed no significant correlation, indicating a structure-specific response to safety measures. Infrastructure investment had different impacts on mode share depending on the regime. Under the HC regime, it enhanced mode share, while under the VI regime, it had a negative influence. This unexpected finding suggests that despite infrastructure improvements aiming to boost connectivity and service quality, the actual effect on mode share might be negative, potentially due to disruptions or inefficiencies that negate the benefits. This hypothesis proposes a view of infrastructure investment's impact on the rail industry, indicating that enhancements might not always translate to increased usage or preference for rail transport.

The qualitative insights obtained from Question 2 serve to enrich and contextualise the quantitative findings. The responses underscore the significant influence of structural reform in modulating passenger sensitivity towards factors such as price, service quality, reliability, and safety. The key findings show that:

- GB Rail's insights highlight the preferences of passengers, especially the sensitivity towards safety, service quality, and ticket pricing. For example, the RU emphasises the sensitivity of UK rail passengers to price changes, providing further evidence of the significant impact of pricing strategies on travel demand. The current GB rail reform process, with initiatives aimed at simplifying fare structures, suggests a significant shift in pricing strategies that are more passenger-centric. These initiatives, as indicated by the RU, point towards a transition to more transparent and user-friendly fare systems, which may lead to a change in fare elasticities. This is supported by the quantitative findings, which suggest that passengers are more responsive to changes in service and pricing in the VS regime compared with the HC and VI regimes.

- Irish Rail's feedback and the case study of the Western Rail Corridor scheme bring to light the political dimensions influencing rail investments. The prioritisation of political objectives over strict cost-benefit analyses suggests that the infrastructure investments may not directly translate into substantial service quality improvements, especially in regions like the West of Ireland, where population density and demand might not justify extensive rail investments. This perspective sets the context for the hypothesis, suggesting that in the VI regime, the direct advantages of infrastructure investment in enhancing service and consequently, passenger mode share, are likely constrained.
- As an example, Irish Rail's recent implementation of a 20% fare reduction, aimed at easing the cost-of-living pressures and promoting public transport use, raises considerations. This significant fare decrease is designed to boost demand, yet it implies a specific sensitivity to price among Irish rail passengers. Contrasting with the situation in Great Britain, where even minor fare adjustments can significantly impact demand, this move by Irish Rail suggests a differing response to pricing in the VI regime. This observation supports the hypothesis that demand sensitivities vary across structural regimes, with passengers under systems like VI potentially reacting differently to fare changes than those in the VS regime, highlighting the complex dynamics of fare policies and their influence on passenger behaviour.

Considering the quantitative and qualitative analyses conducted, it becomes evident that structural reforms in the railway sector do not directly influence passenger demand or mode share in a straightforward manner. Instead, the impact on demand arises indirectly through strategic changes in factors like pricing and service quality that these reforms encourage. Specifically:

- The VS regime, with multiple operators, is conducive to a market-focused strategy, where service quality and price responsiveness are designed to meet diverse passenger needs. This environment, characterised by smaller operators specialising in specific market segments, fosters a competitive landscape where services are dynamically adapted to customer preferences.
- Conversely, the VI regime, with a single operator, might result in broad market strategies, such as across-the-board fare reductions, without the specific approaches that target distinct passenger groups.
- The HC regime, much like VS, allows for tailored service offerings designed to meet a wide range of passenger needs. However, the openness to new operators in this regime may lead to intensified competition, posing challenges in maintaining service quality while focusing on competitive pricing.

These strategic policies unique to each structural regime lead to different responses from passengers to changes within the rail network. A more market-level focused approach in the VS regime, for example, may generate more precise demand responses to service improvements or pricing strategies, aligning with our quantitative findings. This feedback from demand responses can guide future strategic decisions on pricing and service quality.

Thus, while it may not be concluded that any one structure inherently leads to higher passenger demand, our analysis suggests that the strategic focus enabled by VS tends to facilitate a more responsive and adaptable service environment. This, in turn, could lead to a more pronounced and precise passenger demand response to changes within the network.

5.4.3 Coordination between IM and RU

A longstanding debate in railway industry literature revolves around the impact of structural separation (i.e. VS) on the coordination between IM and RU. The predominant assumption has been that VS inherently leads to coordination challenges, with the separation of management and operations creating potential barriers to seamless interaction. However, the qualitative findings challenge this assumption, presenting a more specific view where effective coordination relies on cultural dynamics and collaborative approaches rather than structural forms alone.

The survey response indicates that the effective coordination between IM and RU is less about structural separation and more about the cultural approach to teamwork and mutual understanding. Insights from GB Rail and Irish Rail demonstrate that effective coordination is achievable in various structural setups, but only if there is a culture of collaboration. This finding challenges the assumption that vertical separation directly prevents effective coordination. GB Rail's experience illustrates that leadership, and a comprehensive understanding of operations, are key to successful coordination. The emphasis on industry culture and the need for a unified approach underline the importance of inter-team relationships. Similarly, Irish Rail's model of close collaboration, despite being a vertically integrated structure, highlights that structural differences can be overcome with a strong, collaborative culture and effective leadership.

These perspectives collectively illustrate that, while vertical separation has unique challenges due to misalignment between IM and RU, they do not inherently prevent effective coordination. Indeed, VS can make maintaining inter-team relationships more complex, particularly as it might lead to more frequent misalignments when there are changes in team management or operational approaches, underscoring the system's dependency on the quality of inter-team relationships and collaborative culture. The critical factor, then, is a culture that prioritises inter-team relationships and embraces collaborative problem-solving. This emphasises that while VS may facilitate misalignment more readily than other regimes due to the multiple interfaces in the system, successful coordination is significantly influenced by the quality of inter-team interactions and the collaborative atmosphere within the industry. Therefore, it's not that VS leads to poorer coordination directly, but it does present a higher chance of challenges arising from these complex interfaces, underscoring the importance of a robust collaborative culture to navigate and mitigate these potential barriers.

5.5 Limitations

This section explores the limitations of the qualitative analysis conducted as part of this thesis. While qualitative insights offer depth and contextual understanding of rail reform, it is important to acknowledge the constraints under which these findings were derived. These limitations range from the selection of participants to the scope and depth of the survey questions. Recognising these limitations is crucial for accurately interpreting the results and understanding their applicability and scope within the broader context of rail reform.

The limitations are:

1. Limited participants and subjective responses:

    - The study focused on a select group of countries in Europe, representing the VS, HC, and VI regimes. Despite targeting senior professionals with extensive industry experience, the limited number of participants may lead to a degree of subjectivity in their responses.
    - References to views from specific entities like 'GB Rail' or 'DfT' are based on responses from the individual participants and may not fully represent the entire range of perspectives within these organisations or regions.
    - In the case of GB Rail, this analysis primarily relied on insights from one TOC, to represent operators in the GB rail system. This approach poses a limitation due to the diverse strategies and operational practices among different TOCs. This approach may introduce a bias, as it does not fully capture the varied perspectives and approaches of other TOCs within the GB rail network.
    - The COVID-19 pandemic leads to a shift from traditional face-to-face interviews to virtual platforms like Microsoft Teams, introducing challenges in scheduling due to remote work dynamics and health-related absences.

2. Limited scope of survey questionnaire:

    - To accommodate the time constraints of the participants, the interview was designed to be completed within an hour. This limitation may have restricted the topics covered, focusing primarily on areas that integrate with the quantitative analysis findings of this thesis and existing debates in rail reform literature.

- Some case studies mentioned by interviewees were not explored in detail due to the survey's time constraints, requiring supplementary desktop research to complete the full picture[31].

3. Potential for confirmation bias:

    - Given the selection of participants and the framing of questions, there is a risk of confirmation bias, where the responses might align more closely with the challenges and problems in their own organisations.
    - This bias might affect the objectivity of the findings, as participants' views could be influenced by their professional backgrounds and experiences within the industry.

4. Regional specificities:

    - The geographical focus on European countries might limit the applicability of its findings to other regions with different rail systems, cultural contexts, and regulatory frameworks.

[31] To clarify, desktop research was conducted to support and expand upon the initial interview insights. These enhanced summaries were then confirmed by the interviewees, ensuring that the information reflected in Appendix A is accurate.

6. Conclusions and Policy Implications

This chapter is the conclusion of the thesis and aims to summarise the impact of rail structural reform on the cost and demand dynamics in the railway industry. The chapter uses both quantitative econometric analysis and qualitative insights from industry professionals to explain how different vertical structures affect operational costs and passenger demand. By exploring the cost and demand effects of rail structural reform, this chapter not only addresses the research objectives but also provides policy implications. The findings challenge conventional wisdom and contribute to the discourse on optimal railway industry structures. The insights from this thesis underscore that there is no "one-size-fits-all" solution when it comes to the optimal vertical structure for rail systems. The conclusion of this chapter emphasises the importance of selecting structural regimes based on comprehensive analyses of network characteristics, investment strategies, and the overarching cultural context of the rail industry.

6.1 Cost Effect of Rail Structural Reform

This thesis includes both quantitative and qualitative analysis to investigate the cost effect of rail structural reform. The quantitative analysis presents a new and up-to-date perspective on the impact of alternative railway vertical structures on rail system costs, focusing in particular on investment coordination and how these vary under alternative vertical railway structures and taking into account the most recent data and experience of railway reforms in Europe. Compared with the literature, i.e. Mizutani et al. (2015), the dataset extended from 2010 to 2017, enhances robustness and reflects more recent impacts of European rail reforms, particularly from countries like Spain and Hungary, which underwent reforms in the mid-2000s. The impacts of these reforms unfold over time, and the ongoing nature of European rail reforms further adds to the complexity of this analysis.

Utilising a Translog cost function, the empirical analysis included 650 observations across 33 railway companies in 26 countries over 24 years. The analysis first confirms earlier findings from the literature, suggesting that the cost-effectiveness of the VS regime is influenced by network train density, thereby aligning with the work of Mizutani et al. (2015). However, the precise cut-off points in terms of the level of train density at which different structures are optimal do shift, indicating that VS may be cost-reducing for a wider range of railways. Such a relationship between cost impacts and train density also exists in the HC regime, although the train density for the cost break-even point (from cost reduction to cost increase) seems to be higher than that for the vertically separated organisations. This is a new finding, showing that the HC regime can operate high-intensity services more cost-efficiently than the VS regime. This may be due to the closer integration of infrastructure management and service operations in the HC regime that enables better resource optimisation and reduced misalignments, leading to cost savings in high train density scenarios. More specifically, the cost-effective range of train density for each regime is derived, as illustrated in Section 3.4.1. It shows that the VS regime is more cost-effective for the network with a train density of less than 80.15 train-km/route-km, while the HC regime is more cost-effective for the network with a train density higher than 80.15 but lower than 90.31 train-km/route-km. The full integration regime might be preferred (from a purely cost-reducing perspective) for railways with utilisation higher than 90.31 train-km/route-km.

As noted, in addition to re-visiting and updating previous effects relating to train density and the vertical structure, this thesis further investigated the qualitative expectation from the literature that vertically separated structures lead to higher transaction costs due to long-term coordination effects (i.e. investment coordination); see van de Velde et al. (2012). the quantitative analysis results show the opposite finding, in that a higher intensity of infrastructure investment reduces railway system costs within the VS regime. This implies that the VS regime may be more efficient at implementing investment and achieving overall total system cost minimisation while operating high-intensity services.

Regarding the impacts of infrastructure investment in the VS regime, two perspectives emerge. Perspective A assumes that increased investment intensity in the VS regime reduces the transaction costs occurring in operations. This effect is exemplified by investments in technologies like real-time management systems, which mitigate disruptions and the associated misalignment costs. Perspective B, on the other hand, assumes that the VS regime might enable more effective investment coordination due to its inherent transparency and inclusiveness in decision-making processes.

The qualitative analysis aims to provide a critical contextual layer to the quantitative analysis. The qualitative approach, open-ended survey questions, is particularly effective in obtaining the information about internal workings of the industry. The insights derived from the qualitative analysis present a multifaceted view of the operational realities and strategic considerations within the railway industry.

The qualitative analysis shows that while economic appraisal is integral, its actual influence on decision-making is limited, often overshadowed by factors like political influence, as well as non-monetised benefits and strategic alignment. This complexity in investment decision-making is contrary to the assumption in Perspective B that the VS regime's efficiency is due to clear, targeted investment allocation based on a comprehensive business case. Furthermore, the qualitative responses also illustrate that regulatory frameworks' effectiveness in achieving system-wide benefits is not guaranteed. GB Rail's feedback highlights that the VS regime may indeed introduce coordination challenges, such as the need for extensive negotiations to align diverse interests. This situation can complicate the decision-making process, challenging the efficiency and clarity presumed by Perspective B. However, it's also noted that these challenges can be mitigated with a strong culture of collaboration, suggesting that while VS brings inherent barriers to seamless coordination, a collaborative environment can significantly mitigate these effects.

By integrating findings from both quantitative and qualitative analyses, this thesis provides a detailed understanding of how different vertical structures within the railway industry impact cost efficiency:

- Train density plays a critical role in determining the cost efficiency of different vertical structures - VS, HC, and VI - highlighting the necessity of tailoring structural choices to the specific characteristics of the rail network for optimal cost management.
- Increased infrastructure investment in the VS regime can lead to overall cost savings. This finding contradicts traditional views that the VS regime increases total costs by introducing transaction costs in the long-term planning coordination between IM and RU.

On the other hand, the qualitative insights, particularly from GB Rail, suggest that these cost efficiencies are not necessarily a result of enhanced coordination between IM and RU or superior planning methods like improved cost-benefit analysis. Instead, they highlight the complexities and challenges in aligning diverse interests through extensive negotiations. Thus, the **conclusions** are that the cost savings impact of infrastructure investment in the VS regime is likely derived from the enhanced network quality resulting from increased investment intensity, which effectively reduces transaction costs caused by misalignments between IM and RU in operations.

The combination of quantitative and qualitative analysis provides a comprehensive perspective on the dynamics of cost efficiency in different vertical structures, emphasising the role of investment intensity in reducing transaction costs in the VS regime. The econometric findings indicate that, while the VI and HC regimes tend to outperform the VS regime in terms of cost efficiency at higher levels of train density, the introduction of significant infrastructure investment can alter this dynamic. Specifically, in environments where train density is high, the VS regime typically exhibits increased total costs compared with the HC and VI regimes. However, this trend can be mitigated, or even reversed, when infrastructure investment intensity is heightened. This suggests that strategic, well-targeted investments in the rail infrastructure in the VS regime not only counterbalance the misalignment costs due to coordination challenges but also potentially enhance overall network performance and cost efficiency. This understanding underscores the importance of considering both structural configurations and network characteristics (e.g. train density and infrastructure investment intensity) when assessing the cost implications of rail structural reform, providing a more complete picture of the mechanisms through which rail reforms impact the economic landscape of rail transportation.

6.2 Demand Effect of Rail Structural Reform

The econometric analysis undertaken in this thesis concerning demand delves into how yield, infrastructure investment, and safety factors, underpinned by different rail industry structures, affect passenger rail mode share. Utilising a log-log regression model, this study analysed 310 observations across 24 countries over 18 years, revealing that GDP per capita, car ownership, fuel prices, and train frequency significantly impact rail mode share. This aligns with findings from earlier research, e.g. Tomeš (2017), van de Velde et al. (2012), and Mizutani and Uranishi (2020).

The analysis found that pricing affects rail passenger behaviour differently depending on the structure of the rail industry. In the VS regime, passengers are more sensitive to changes in price, while passengers in the VI regime are less affected by price and safety changes. This shows that the organisation of rail operations can influence passenger preferences and behaviours. The analysis also shows that higher levels of rail infrastructure investment tend to increase passenger mode share in the VS and HC regimes but have the opposite effect in the VI regime. This is probably because passengers in the VI regime tend to be unresponsive towards factors such as pricing, service frequency, and safety (as found in the empirical analysis). This lack of response underlines the negative impact of infrastructure investments on mode share. As a result, the enhancements in service quality and safety may be less noticeable to these passengers, making the drawbacks of infrastructure investments, such as disruptions and network closures, more significant and influential.

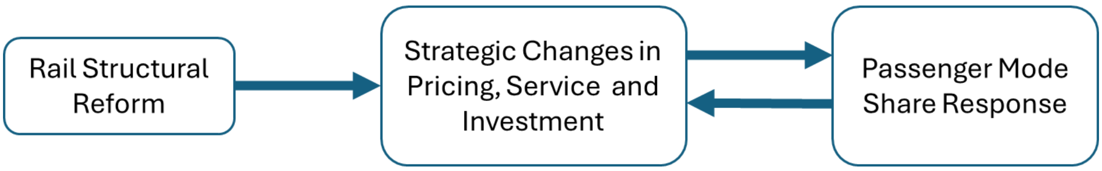
The analysis seeks to identify a link between the liberalisation of rail systems and passenger demand changes, aiming to substantiate the underlying hypothesis that structural reforms indirectly shape passenger preferences through changes in rail fares, performance, and service quality. Drawing on insights from IBM Global Services and Kirchner (2011), the analysis revealed that countries operating under the VI regime, such as Ireland and Luxembourg, exhibit lower levels of rail liberalisation within the EU. This reduced liberalisation translates to fewer external rail operators and, consequently, limited options for passengers, potentially explaining the weak responsiveness to price and safety changes observed. The VS and HC regimes, characterised by higher liberalisation, foster price competition, making passengers more sensitive to fare alterations. The connection between the level of openness in the rail system and passenger behaviour shows the significance of considering market openness when designing rail reform policies. This suggests that understanding the details of each structural system and its level of openness is vital in developing strategies that make use of demand drivers to improve the passenger mode share of the rail system.

To support the hypothesis on explaining the quantitative results, a series of qualitative analyses were conducted by engaging with stakeholders across the rail industry. The primary objective was to collect information that could contextualise and clarify the econometric results, particularly the observed impact of rail system liberalisation on passenger demand sensitivity. During the discussions with representatives from GB Rail, the research discovered ongoing efforts to reform fare structures. The ongoing fare reform efforts aim not only to simplify pricing schemes but also to significantly reduce the costs of single journeys. This strategy is not just about making rail travel more financially accessible; it's about tailoring travel options to suit diverse passenger needs, encouraging a balance between off-peak and peak travel. On the other hand, Irish Rail may focus more on the broad market, such as its recent 20% fare reduction across the board seeks to address the cost-of-living crisis and promote public transport use. While this broad market strategy aims to boost demand universally, it represents a different focus compared to GB Rail's more segmented approach to fare adjustments. These varied strategies illustrate the different emphases placed by VS and VI regimes on passenger preferences and market dynamics. These insights into fare reforms and strategic initiatives indicate the complexity of aligning fare policies with passenger preferences, influenced by the broader context of structural reforms.

In conclusion, this thesis offers an overview of how rail structural reforms, encompassing both vertical separation and integration, directly influence passenger rail mode share through factors like pricing strategies and infrastructure investments. The analysis showcases the particular sensitivity of passengers to pricing in the VS regime, underscoring the regime's propensity for market-focused strategies that adapt dynamically to passenger demands. This can be attributed to the liberalisation of the rail market, which often introduces multiple operators, each focusing on different markets and promoting passenger demands with specific market-focused strategies. Conversely, the qualitative findings suggest that the VI regime, often with its typically singular and state-run/state-contracted operator, may employ broader network-wide strategies. Such strategies may be impactful but offer a different degree of specificity in addressing passenger needs. This differentiation in strategic approaches across structural regimes could lead to distinct levels of passenger behaviour, specifically in terms of responsiveness to changes within the rail network.

Furthermore, passenger mode share response itself can become a feedback mechanism, influencing future strategic decisions regarding pricing, service quality, and investment as rail operators continually adapt to shifting travel patterns and preferences. Consequently, understanding the indirect effects of structural reform on passenger mode share becomes crucial. This interplay between reform-driven strategic changes and passenger response underscores the impact of different structural configurations on rail travel preferences – see below.

Figure 8 - The Diagram of the Impact of Structural Reform on Passenger Travel Behaviour



By integrating empirical analysis with stakeholder insights, this thesis constructs a comprehensive framework for rail policymakers and operators. It highlights the differences in reform strategies that are aligned with the distinct dynamics of structural contexts and market liberalisation, and the essential role of tailored approaches in enhancing rail passenger mode share.

6.3 Policy Implications for Rail Reform

Through this thesis, it has been discovered that the success of rail structural reforms in terms of improving cost efficiency and affecting passenger demand depends on a combination of network features, investment intensity, and a culture of collaboration within the rail industry. Tailored approaches are necessary for structural reform, investment strategies, and cultural transformation within the rail sector. The policy implications derived from this research emphasise the importance of taking into account these factors when implementing changes in the rail industry.

6.3.1 Infrastructure Investment and Train Density

The relationship between infrastructure investment and network performance emerges as a central theme in the analysis of rail structural reform. This thesis demonstrates that investment intensity has an impact on cost efficiency, particularly within the VS regime. Higher levels of infrastructure investment are shown to significantly reduce system costs. This suggests that strategic, well-coordinated investments can overcome the coordination challenges traditionally associated with VS, leading to enhanced network quality and operational efficiency.

In the context of rail reforms, it is evident that investment strategies need to be tailored to the specific characteristics and demands of the network. Investment effectiveness varies significantly across different vertical structures in networks with varying levels of train density. In networks with lower train density, the VS regime can achieve greater cost efficiencies even with an average level of investment intensity. Conversely, in networks with higher train density, the HC regime may offer more cost-effective solutions, but only up to a certain point. Once the train density threshold is surpassed, the VI regime becomes more viable. However, the VS regime may still perform well on cost efficiency, even beyond the train density threshold, with a high level of infrastructure investment intensity. This suggests a specific interplay between network utilisation and investment strategy.

This relationship underscores the need for policymakers and rail operators to adopt a dynamic approach to investment planning. Adopting a flexible approach to investment planning is crucial. It's essential for policymakers and rail operators to remain adaptable, allowing investment decisions to align with the evolving needs of the rail network. **In the context of VS regimes with higher network utilisation facing cost challenges, strategic infrastructure investments aimed at enhancing connectivity and service quality emerge as a vital consideration.** These investments, though initially adding to costs, are important for reducing costs from a long-term perspective. By improving network efficiency and passenger experience, such investments can mitigate the inherent cost pressures within VS systems, emphasising the importance of aligning investment strategies with the operational characteristics and demands of the rail network for sustained cost efficiency and service improvement.

6.3.2 Demand Sensitivity and Structural Reform Dynamics

The study on demand sensitivity in the context of rail structural reform reveals that passengers respond differently to pricing, safety, and service quality depending on the organisational structure. The research shows that within VS and HC regimes, characterised by greater market liberalization and competitive dynamics, passengers are highly sensitive to changes in rail prices, safety measures, and service quality. On the other hand, in the VI regime, passenger response to similar changes is significantly lower. This differential sensitivity across structures highlights the crucial role of structural reforms in influencing passenger behaviours and preferences.

Liberalisation, as evaluated by IBM Global Services and Kirchner (2011), has higher index values in VS regimes. Multiple operators and intensive competition among rail service providers promote market-specific strategies that meet the needs and preferences of individual passengers. This approach is reflected in the way VS and HC regimes respond to passenger demands, resulting in a more responsive and customer-centric rail market. In contrast, VI settings may adopt broader market strategies that lack this level of customisation, providing passengers with a less personalised experience. This difference in approach may affect the way passengers respond to rail service offerings, with VS & HC regimes better equipped to make precise adjustments to meet the needs of their customers.

The thesis argues that rail policies should not only focus on structural models. Effective policy development should consider the interplay between structural reform, liberalisation effects, and investment strategies. All these factors affect passenger demand sensitivities. Policymakers and rail operators should create strategies that are consistent with passenger preferences and promote a competitive environment through liberalisation.

The findings of this thesis suggest that policy implications go beyond just choosing a structural regime for the rail system. It is important to consider the relationship between rail system liberalisation, investment strategies, and passenger demand sensitivities. Policymakers and rail operators in the VS and HC regimes should align their strategies with passenger preferences and sensitivities and create a competitive environment through liberalisation. Furthermore, even within a VI regime, there is scope to cultivate a more specific strategy tailored to distinct market segments through in-depth market analysis, potentially heightening passenger demand with precise, targeted service improvements. This will enhance the appeal and efficiency of the rail sector, and help it cater more effectively to the evolving demands of its users within the broader economic and competitive landscape.

6.3.3 Cultural Dynamics

Culture plays a crucial role in the railway industry, affecting everything from maximising system-wide benefits to daily operational coordination. Although contracts and incentive regimes are important, they are not enough to address the various complexities of the rail industry. The key to effective coordination and strategic alignment is the organisational culture, as demonstrated by the experiences of GB Rail and Irish Rail.

This analysis suggests that, in the VS and HC regimes, contracts are helpful for collaboration, but they cannot account for the entire daily operations. Similarly, incentive programs, which are often designed with the organisation's broader goals in mind, struggle to be effective at an individual staff level. The interviews show that it is crucial to understand the purpose and context of these frameworks. This understanding can create a culture of informed decision-making, rather than blindly following procedures. It is essential to have a collaborative and adaptable culture to ensure that operational strategies, systemic reforms, and financial incentives work together to achieve the industry's overarching goals.

The synthesis of the insights leads us to understand that organisational culture plays a crucial role in bridging the gap between IM and RU. A culture that prioritises collaboration, adaptability, and mutual understanding can help to overcome structural and contractual barriers and enable the rail industry to achieve its strategic objectives more effectively. Therefore, policy initiatives should aim to promote such a culture. They should create an environment where the synergies between different components of the rail industry are not just recognised but actively followed. By promoting a culture of open communication, shared goals, and collective responsibility, the rail industry can enhance its coordination mechanisms, improve its operational efficiency, and deliver on broader strategic aims.

It is essential to acknowledge the structural challenges that come with vertical separation, which can lead to coordination difficulties due to multiple interfaces and diverging objectives among parties. These complexities can increase the likelihood of operational and strategic misalignments within the rail system. However, creating a strong organisational culture that emphasises collaboration, adaptability, and mutual understanding can significantly mitigate these challenges. Such a culture acts as a bridge, enabling effective coordination despite the structural complexities of the VS regime.

While structural reform is vital in addressing inherent system inefficiencies, it is equally important to cultivate a collaborative work environment. Policy initiatives should focus not only on structural adjustments but also on promoting a culture where open communication, shared goals, and collective responsibility are paramount. This balanced approach ensures that the rail industry can overcome the coordination challenges posed by vertical separation, enhancing operational efficiency, and achieving strategic objectives more effectively.

6.3.4 Structural Reform Recommendations

When considering the optimisation of rail industry structures, it is important to identify the strengths and limitations of each model against the specific context of the rail network in question. "Optimisation" here refers not to an absolute best, but to the most suitable structure given the unique conditions and objectives of a railway system.

Cost Efficiency Considerations:

Network characteristics such as train density and infrastructure quality are critical in determining the most suitable industry structure.

- For newly built or well-maintained (i.e. with a high level of infrastructure investment) networks with moderate to low train densities, a **Vertically Separated** structure could be advantageous, promoting market dynamism and potentially reducing costs through competitive pressures.
- Medium-density networks with reasonable infrastructure quality may benefit from a **Holding Company** regime, balancing integration benefits with competitive incentives.
- For networks with high train density and ageing infrastructure, a **Vertically Integrated** structure may be more effective, as close coordination can help manage congestion and optimise the existing network's capacity.

In every case, the underlying culture of collaboration emerges as a vital element. A strong collaborative culture can mitigate transaction costs associated with structural separation and should be recommended across all regimes, including HC and VI, to enhance systemic success.

Demand Dynamics:

The direct influence of structural reform on passenger demand is less clear, but the adoption of **market-focused strategies** can be influential. Strategies that are responsive to market demands and passenger behaviours - such as pricing and service quality - are often more feasible within **VS and HC regimes** due to the liberalisation of the market and the presence of multiple operators.

Policymakers are encouraged to:

- Ensure that market-focused strategies are based on comprehensive market analyses, positively influencing passenger behaviour by meeting diverse passenger requirements.
- Promote a culture of continuous improvement and adaptation, allowing rail operators to respond to changing passenger needs and competitive pressures effectively.

To conclude, for rail reforms to be successful in improving both cost efficiency and mode share, they must be tailored to the network's specific characteristics and be accompanied by supportive policies that promote a competitive, innovative, and collaborative environment within the rail industry.

Appendix A Survey Responses

Survey Response from Irish Rail (two participants)

Questions

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions is about the planning stage before implementing an infrastructure investment.*

    a. *How important is the role of cost-benefit analysis within Irish Rail (IR)'s strategic planning stage of the infrastructure investment projects? What elements do you think are as important as cost and benefit for IR to consider in different types of investment (i.e. renewal and enhancement)?*

The project outline document, equivalent to the Strategic Outline Case (SOC) in the UK, provides an early-stage overview of the need for a project, its alignment with policy, its objectives, some KPIs, and a cost range. It sets out an appraisal plan for how a detailed appraisal will be conducted later. **A Cost Benefit Analysis (CBA) is typically not conducted at this early stage but becomes relevant during later stages like preliminary design.** Some projects might have had previous CBAs that can be updated and re-baselined to current construction costs.

Non-monetised benefits are now becoming more significant, especially in the context of green business cases. Ireland has a low electrification rate of its rail network compared to the EU and the UK, and there's pressure to achieve electrification to meet net-zero targets by 2050. Agglomeration tools and reliability tools have been developed to consider non-monetised benefits, but even when they are taken into account, some projects may still not be deemed cost-effective. This means a lot of projects, in the end, would be based on political decisions. Spain's high-speed railway is a good example. They expanded their high-speed rail network significantly over 30 years without always relying on robust CBAs, instead making policy decisions. Such a direction might be needed in Ireland to meet certain targets.

From a capacity perspective, the interviewee emphasised that often **projects have a funding ceiling, and planners are tasked with maximising what can be achieved within that limit.** Ideally, infrastructure should be designed around the desired service level, but often the available funding dictates what can be done.

Most of the infrastructure investment, particularly for railways, is funded by the Irish Government. However, some road schemes were partly funded through the European Regional Development Fund or via PPPs (Public-Private Partnerships). Irish Rail can't borrow cash directly; any borrowing would be through CIE (Coras

Iompair Éireann) on their behalf. The primary reason for this approach is the favourable interest rates that governments get.

Regarding funding caps, the government typically sets a maximum expenditure, and entities like Irish Rail must work within that limit. However, they submit funding bids and propose projects they could deliver within a specified period. This submission process is part of the National Development Plan in Ireland, a 10-year capital investment plan set by the government. The government may or may not allocate the full amount requested, often leading to scope adjustments to fit the allocated budget.

b. *Do you think the operation department plays a vital role in helping infrastructure management inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Does such feedback contribute to IR's strategic planning of infrastructure investment?*

The IR company transitioned after the Forth railway package in 2013, splitting into infrastructure manager (IM) and railway undertaking (RU) formations. Previously, train planning and train control were part of a single department. Post-split, there was a change, but the relationship between IM and RU remains collaborative. They analyse train performance and work together to address network issues like speed restrictions and congestion. **There is no clear isolation between the IM and RU teams, which all work together. As a result, the Irish rail infrastructure management approach contrasts with the UK's approach.** In the UK, the infrastructure manager has more autonomy in deciding when to conduct maintenance, leading to potential conflicts with operational needs. In the Irish rail context, more coordination and collaboration are emphasised.

To be more specific, in an ideal multi-TOC (Train Operating Company) environment, like the one in the UK, there should have been a dedicated capacity allocation section within the Infrastructure Manager (IM). This setup would allow for the smooth management of multiple TOCs. However, for a single-operator scenario, such as Irish Rail, having such a structure could lead to unnecessary costs. In this single-operator environment, the train planning would be conducted and then forwarded to another section for analysis. Given the absence of other operators on the network, this was seen as an added expense without tangible value.

However, EU legislation mandated the creation of an Essential Functions Body (EFB). This body's role was crucial for ensuring compliance with EU regulations, given that both the RU and the IM reported to the same CEO of Irish Rail, creating a potential conflict of interest. As per the requirements, the EFB would act as an independent entity, standing between the IM and the RU. With the appointment of the EFB within the holding company CIE, Irish Rail started submitting its working timetables and other ad hoc train paths to the EFB. The latter would then pass these on to the IM. While this ensured compliance with EU law, the process was bureaucratic and resembled previous procedures, especially since there wasn't another operator on the network. Despite this separation of roles into IM and RU, the operations are still predominantly within one overarching company.

Addressing the actual operation of trains, Irish Rail conducts performance analyses regularly. The train performance segment is located within the capacity allocation section of the IM. Regular meetings occur between the two entities, identifying potential network issues like speed restrictions or area congestion. They also explore alterations such as optimising level crossing gate operations to enhance the rail service. This approach demonstrates the close collaboration between the RU and the IM. Furthermore, unlike practices in the UK, **Irish Rail's infrastructure manager is obliged to consult with the RU annually regarding disruptive possession plans, signifying the intertwined relationship and mutual dependence they share**.

*Case study about GB rail's inefficiency**********

The management of train diversions in the UK's railway industry, particularly on the **West Coast Mainline**, is a complex and bureaucratic process. A commercial manager who has worked on the West Coast Mainline revealed that the establishment of a single diversion could require several months of numerous meetings. For instance, a specific diversion that involved routing via Banbury and coordination between Cross Country and Virgin Trains for training on the Voyager trains, the 221s, and the 220s. However, the intricacy did not cease there. The training of drivers became a contentious issue, with Cross Country being hesitant to train the drivers, which resulted in The IM intervening. Conflicts over payments arose, and training was halted until financial matters were resolved. This seemingly unending back and forth for just a single weekend diversion was described as utter madness.

These experiences reveal the potential inefficiencies inherent in the UK rail system, especially when compared to the operations in Ireland. Those who have worked on both networks know that there is a simplicity in Irish operations that is often taken for granted. Despite its challenges, there is a consensus that the Irish rail system operates with less friction. In Ireland, disagreements may emerge, as with any close-knit group or "family," but they are generally less convoluted, particularly when private equity and multiple parties are not involved in decision-making processes.

In the UK, even a basic rail closure can often take several months due to various complexities and the involvement of multiple stakeholders. Another recurring issue is with diversions, particularly when determining who bears the responsibility for various elements, such as driver training, maintaining competencies for different routes, and handling associated costs. For example, when there is a diversion north of Preston involving the Settle Carlisle line, there have been difficulties in reaching agreements. Consequently, bus transfers frequently become the default solution, particularly when the challenges of driver training and route knowledge become insurmountable. Such issues further underscore the contrast between the streamlined operations in Ireland and the more intricate, sometimes problematic, processes in the UK.

c. *Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?*

During the final stage of the business case, benefit realisations are carried out to ensure that the expected benefits are being achieved as forecasted in the Cost-Benefit Analysis (CBA). Benefit owners are appointed to evaluate the benefits one year after the implementation of the project, and then again between three to five years later. For long-term projects expected to be rolled out over a decade, a ten-year implementation review may be conducted.

To ensure cost-effectiveness, a continuous evaluative approach is adopted, especially if the results of the CBA are not satisfactory. The "value engineering" exercise is carried out during the phase known as "phase two", which involves a systematic review of feasibility, detailed design, and planning application stages. The value engineering practice is integral and is enshrined in project management procedures.

The CBA can be consistently revisited until the contract award stage. After the contract is awarded, revisiting the CBA is not typical, except in the unique context of monitoring and evaluation to ensure the realisation of benefits. While some cases may prompt the need to revisit a CBA, no disastrous situations have been experienced that required a re-examination of a poorly performing CBA. Most changes in cost projections stem from the escalation environment and not necessarily from foundational construction costs.

Most sudden increases in project costs are attributed to adjustments in contingencies. Some inflation factors are in, but much of it is captured in general inflation for future escalation. Major project cost increases are usually due to changes in scope, approach, or contract-related costs, but these are typically encompassed within risk contingency profiles. At the stage of the final business case, benefit realisations are conducted. These involve designating benefit owners to ensure that the anticipated benefits are genuinely materialising as forecasted in the CBA. Evaluations are typically conducted one year after a project's implementation, and then again between three to five years later. For larger, long-term projects expected to be rolled out over a decade, a 10-year implementation review might be conducted.

2. *System-wide benefit (total benefit of rail system) has been argued as the main challenge for unbundled structure, i.e. each party only focus on their benefit from the infrastructure investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.*

    a. *Do you think that delivering the system-level benefit is also a challenge for a bundled structure like IR? Are there any mechanisms that help to deliver system-level benefits in the investment implementation stage?*

    Regardless of the structural model, delivering system-level benefits remains a complex endeavour. The DART+ project is a prime example of this complexity.

    DART+ Overview and Implications:

    The DART+ initiative is a significant investment in rail infrastructure. With a budget exceeding 3 billion, its primary goals are to expand electrification zones, promote environmental sustainability, and standardise the rolling stock. The benefits of the project include the introduction of a consistent fleet that can meet demand efficiently. However, the lack of plans to increase the track capacity is a concern, especially with the proposed continuous running of trains every 4 minutes at peak times, which will put a strain on the existing infrastructure that has seen minimal modifications since the Victorian era. This could lead to significant disruptions if any minor delay occurs, given the limited room for adjustments. The existing state, characterised by a mix of rolling stock and irregular timetables, further exacerbates the challenge. Despite these hurdles, the interviewee believes that the improvements accompanying the DART+ initiative will lead to a more reliable timetable, even with higher service levels.

    The interviewee supplements the interviewee’s insights by drawing a comparison with the Great Britain (GB) rail system. Unlike the challenges highlighted by the interviewee, the GB system has certain infrastructural advantages, such as separate tracks for fast and slow trains. The absence of such facilities complicates operations and maintenance in the current setting. The interviewee references the All-Island Rail review, revealing plans for the future that echo the GB system's advantages. The key principle revolves around the segregation of fast and slow tracks. Although these changes may not be realised for decades, they underline the vision for a truly efficient railway system that prioritises uninterrupted services and ample recovery time.

    The interviewee further elaborates on plans like the 'ambulance motorway', which is designed to bypass several double track sections and the introduction of a cross tunnel for both intercity and commuter trains. These infrastructural enhancements would substantially alleviate the existing challenges and pave the way for a more efficient rail system.

One of the interviewee's important insights is the significance of stakeholder collaboration in achieving a unified vision. **A bundled system, as illustrated by the Irish scenario, enables key decisions to be streamlined between entities like Irish Rail, the NTA, and the DLC, making it less convoluted to reach a consensus.** This contrasts with the GB system, where reaching a consensus among a myriad of stakeholders proves more cumbersome. In essence, a bundled structure like that in Ireland could facilitate faster decision-making and more efficient implementation of visionary projects.

b. If the investment brings higher cost and disruption than benefit to train operation, does the system need to incentivise the operation team to coordinate with the infrastructure team to deliver the investment?

Train cancellations due to supplementary possession works qualify for refunds provided by an essential functions body. However, unplanned train movements result in additional expenses in the form of track access fees. These financial implications generally balance out, with costs for unforeseen train movements roughly equalling the refunds given for cancellations resulting from infrastructure undertakings. Engineering projects in the Dublin area may not cause significant disruption, but larger ventures such as the metro project can lead to considerable closures and disturbances. This has led to debates, particularly when considering potential extended closures of major commuter pathways.

The "DASH programme" was a historically disruptive initiative, although it came before the organisational division. Complications arise from Ireland's unique railway challenges, including non-standard signalling systems and track capacity constraints. Although Ireland does not currently function in a multi-operator environment, there are hurdles to accommodating new operators due to the distinctive nature of the Irish rail system.

The track access charge in Ireland, which aims to align with EU directives, fosters an environment where new operators could, in theory, join the network, even if this has not materialised extensively. The National Transport Authority funds rail operations and holds the authority to set a cap on train fares, a factor that may discourage private operators from entering the market.

The operational structures of Ireland's railway system bear similarities to the UK's framework after the Williams Review.

3. *This question is mainly about the potential demand impact of rail structural reform.*

   a. *Do you think the rail passengers in Ireland are more sensitive to change in any* *particular factor(s), such as price, service quality, reliability, and safety?*

Rail passengers in Ireland are highly aware of changes in train fares, particularly in light of the current cost of living crisis. Any adjustment in prices quickly becomes a topic of political debate. In the last two years, the National Transport Authority intervened to reduce public transport fares by 20%. Reversing this decision could be seen as a regressive measure and may face significant opposition. This sensitivity to fare changes is evident in the context of multi-party governance, with parties like the Green Party advocating for a shift from private cars to public transport. While adjusting service levels in Dublin or regional cities is challenging and rare, some underused lines have occasionally been closed and replaced by bus services.

Ireland's appraisal process for fare adjustments is robust and set within a local context, albeit informed by broader European standards. Notably, Ireland has experienced a significant "bounce back" in public transport use compared to other European nations. One of the primary reasons for this rebound is the fare reduction; while many countries increased fares, Ireland lowered them, leading to a substantial increase in rail and public transport usage. This fare reduction, although initiated as a post-COVID measure, also serves as a green initiative to promote public transport over private car usage. Despite the economic challenges, the fare decrease was maintained to promote sustainable transport. In terms of historical fare adjustments, before the 2019 pandemic, fare hikes were minimal, rarely exceeding one or two per cent. This conservative approach to fare changes is largely due to the National Transport Authority's inclination to promote public transport.

Regarding service quality and reliability, there's been an ongoing effort to enhance timetables, particularly since 2010. However, these improvements have led to congestion, especially in areas like Dublin. The traditional peak travel times have shifted post-COVID, leading to a more evenly distributed travel demand throughout the day. This shift has opened discussions about spreading commuter timetables more evenly to alleviate congestion and improve performance.

b. *Do you think any of the above factors changed significantly due to rail structural reform?*

Since the structural reform, there's been an ongoing effort to enhance timetables and service quality, leading to congestion in certain areas and necessitating adjustments in peak travel times.

c. *Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. change their demand response to the factors above?*

The reduction in rail fares has had a positive impact on the travel behaviour of passengers, leading to a significant increase in the use of public transport in comparison to other European countries. It has also resulted in a shift in travel demand distribution throughout the day.

On the other hand, the latest reform, which is the Cost-plus contract, has not brought about any significant changes. The responsibility for marketing and sales, as well as revenue protection, remains the same. The staff and culture have also remained unchanged. It is important to note that passengers have continued to trust the brand of IR. Irish Rail's consistency and stability foster loyalty among customers and employees. We compared it to the UK system where franchise ownership changes disrupt operations and morale. Branding consistency is critical to success, as seen with Virgin Trains, which garnered significant loyalty through its longstanding operation. The external brand's value and consistency play an indispensable role in determining the overall perception of any operational or structural reform in the rail industry.

4. *This series of questions aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

    a. *In the daily operation, is there any challenge for the IM team to have efficient coordination with the operators in daily train operations especially when a disruption on the network occurs?*

    The IM team and train operators coordinate efficiently on a daily basis, even during disruptions. This smooth collaboration is due to their shared history - they were part of the same department until 2013. They still report to the same CEO and have frequent meetings to ensure they stay on the same page. To further improve their coordination, a new train control centre has been established at Heuston station, which will soon be operational. This centre will feature a traffic management system directly linked to the train planning system. It will provide information on train routing, details, priorities, and connections, thereby strengthening the bond between the IM and train operations.

    b. *What do you think are key incentives for the coordination between the RU and IM teams on a daily basis and long-term basis respectively?*

    The culture and structure of management are two crucial factors that incentivise collaboration within Irish Rail. For instance, fleet management, which is currently the responsibility of the RU department, will now have fleet controllers stationed in the IM control room to manage disruptions and adjust driver and train host rosters. This collaborative approach extends beyond just service delivery as it also applies to aspects like track maintenance. Despite belonging to separate departments, the IM and train operations teams work closely together, thanks to the management structure and organisational culture. The CEO oversees the directors of both departments, who attend weekly meetings that emphasise collaboration and address any issues that arise. This managerial alignment ensures that challenges are jointly addressed, underscoring the benefits of a unified management structure.

Survey Response from Irish Rail (Former CEO)

Questions

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions is about the planning stage before implementing an infrastructure investment.*

    a. *Is cost-benefit analysis the main approach IM uses to work out the priority of each infrastructure investment project in the strategic planning stage? What are the other top elements to consider and are these elements the same for renewal and enhancement investment?*

    For a substantial investment, cost-benefit analysis is a critical but not fundamental element of the decision-making process. This is because rail infrastructure investment is generally high-cost and has long-term payback. The strategic plan for a big project may begin with a cost-benefit analysis but is subject to other key elements such as rail safety. For example, rail signalling enhancement could end up with safety improvement (which is another area of benefit). Regulatory element also plays an important role in safety. The rolling stock always needs to follow the railway safety regulations in the EU/UK.

    Another element may be the policy influences from the government (or local authority), i.e. environment target, population, mode shift, etc. The Irish railway seems to be affected/led by the policy more than the GB railway.

    ************ case study in Irland **********

    Irish Railway took a review of the cost and benefit of reopening railway lines named “Western Rail Corridor” scheme in 2006. This scheme involved reopening a section of a closed railway line between the West of Ireland towns of Ennis and Athenry. Its reopening also had the effect of reconnecting a direct rail link between the cities of Limerick and Galway. However, the towns and villages on the route have very small populations and road improvements had already been made to improve access to them. Nevertheless, the Irish Government had a political desire to spread its rail investment into the West of Ireland and not to concentrate it solely on the much more densely areas around the capital city, Dublin. The government doesn’t like the priority list of the railway network that the Irish Railway produced and suggested prioritising the small towns and villages which generally have low cost-benefit ratios. Once the financial crisis occurred in 2009, this reopening scheme brought even less benefit than expected. There could be far more arguments in the GB rail investment process concerning such schemes, given there are more institutions and stakeholders involved.

    Concerning the Renew and Enhancement schemes, the conditions of the network (i.e. track, signal, station) matter more, thus the network renews are sometimes prioritised to maintain the reliability of rail operation.

b. *Do you think the operators' feedback plays a vital role in helping IM inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Do these feedbacks contribute to IM's strategic planning of infrastructure investment?*

Feedback from operators is important for network investment. More often, the operator would report to IM the issues on the infrastructure. For example, if the operator considers the train speeds on a particular line need to be restricted because the track condition is deteriorating, the TOC will immediately report this to NR.

Day-to-day performance feedback is a critical input for renewing prioritisation. Besides, the TOCs may know more about the benefit (revenue/capacity) of the smaller/quick enhancements, i.e. the expansion of a station. IM do get influenced by the TOCs and the TOCs are keen to report such findings to NR. For example, in March 2023, both the passenger and freight train operators reported to IM that they would like to see a short line called the Poplars line to be electrified. Poplars line runs for only about one mile in North West London, which provides a direct link between the electrified Great Western Main Line that runs into London Paddington and the electrified West Coast Main Line into London Euston. If this short section of line is electrified, it will provide great flexibility for electric train diversions when required (i.e. disruption occurs on the current line due to engineering work). Although, the British Government is not currently prepared to fund the scheme so The IM cannot proceed with it.

In the latest rail reform in GB rail, operating performance is focused more than previously due to the more crucial role of cost reduction in the new contract and the development of incentive regimes for TOCs.

c. *Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project (including both renewal and enhancement)? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?*

During the pre-covid years (with steadily increasing rail demand), the capacity enhancement schemes can provide a good value for money with the contribution from the cost-benefit analysis. On the other hand, value for money is not everything. Regulatory aims to manage the use of network capacity by franchised and open access operators, to ensure the fair usage of the network which may not be the economic-optimal option.

2. *System-wide benefit (total benefit of TOCs and NR) has been argued as the main challenge for unbundled structure, i.e. each party only focus on their benefit from the infrastructure investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.*

    a. *Do you think that regulation is the most useful approach to ensure the system-level benefit is considered in the planning stage of the investment? Are there any mechanisms (i.e. consultation) that continue to deliver the system-level benefit in the investment implementation stage?*

    Since The IM became a wholly owned government company, there has been continuous improvement in coordination with the operators. IM is not operated for profit, which means their own benefit is not the top element to consider an infrastructure investment. Instead, the operators are deeply involved in the investment planning stage (i.e. as mentioned above, their feedback contributes to the prioritisation of the investment schemes). Therefore, most of the investments can deliver a system-level benefit. Coordination (i.e. a constant dialogue between IM and TOCs) is the key factor to ensure the delivery of system-level benefits from infrastructure investment.

    b. *If the investment brings higher cost than benefit to the other companies (i.e. TOCs), how to incentivise (or, maybe obligate) them to coordinate with IM to deliver the investment? For instance, has Schedule 8 been a successful incentive regime to deliver that?*

    Day-to-day performance incentives on a long-term basis may be more helpful. Infrastructure investment aims to improve the performance and good performance railway is cheaper to run. A well-operated railway saves money for each company, and the TOCs can get rewards due to the improved performance caused by investment. The regimes like Schedule 8 sometimes provide perverse incentives to the detriment of passengers and freight customers, because Schedule 8 compensation paid to a train operator by The IM can often be worth more financially to the train operator than the passenger revenue that the train operator has forgone.

    On the other hand, Schedule 8 may be helpful in the short term. For example, extra engineering work to install a signalling system may lead to the cancellation of trains, whereas Schedule 8 compensates the TOC for such loss. From this perspective, Schedule 8 does provide an incentive for The IM to minimise their impact on train performance.

3. *This series of questions aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

a. *In the daily operation, how does IM ensure efficient coordination with the operators in daily train operations especially when a disruption on the network) occurs? Do you think the current coordination approaches will remain for GBR or will be reformed to improve?*

The dominant TOCs develop a management alliance with NR. It's a management process in which the two companies make decisions jointly. For example, The IM signed a formal alliance with GWR at Swindon station in 2016. This agreement covers five key areas of working and commits both companies to a more aligned approach to further improve performance and increase efficiencies. It also covers improved joint planning for major upgrade projects such as the electrification of the Great Western Main Line, to help minimise disruption for passengers as much as possible.

TOCs may still have conflicts with IM under the alliance, however, the conflicts help to demonstrate and solve an issue. A good example here may be the issue of overnight stabling of trains. Modern passenger trains do not need to go back to the maintenance depots every night. So, for the greatest efficiency, the train operators want to leave them in locations close to where they will recommence service the following morning. This is often in platforms at terminal stations, or in recognised stabling locations adjacent to mainline stations. Sometimes leaving trains in these locations, or even running them at night to these locations, can interrupt The IM's overnight engineering and maintenance works and can become a point of conflict between The IM and TOCs. This sort of day-to-day problem can best be resolved through an alliance process and a commitment to much greater coordination in operations between The IM and the TOCs (i.e. by working out a schedule and plan for TOCs to leave their trains overnight.

Another interesting view, based on the Ireland case, is that the same coordination challenge exists in Ireland because there are separate teams working on train operation and infrastructure management within Irish Railway. Good coordination is based on the good relationship between the two teams, especially the two team leaders. In GB rail, coordination could be even better if the two team leads coordinate well. Thus, GBR will retain the current coordination style as a good lesson learnt from the past.

b. *As I understand, the key incentives for the coordination between RU and IM (which are not in the same team) on a daily basis include joint management (report to a unique manager) and financial incentives like track access charges. Are there any other ways to improve the coordination with TOCs?*

Good coordination relies more on management processes (i.e. alliance) and short-term (i.e. daily) performance incentives. The old franchise may have incentives more on the revenue side but less on the true system-level benefit and performance.

TfL Concession is another good example. The TfL Concession is a contract awarded to private companies to operate some of the services on behalf of TfL. Under the concession agreement, the operator is responsible for the day-to-day operation of the London Overground network, including the management of staff, maintenance of trains and infrastructure, and the provision of customer service. TfL sets the fares and timetables and also specifies the quality of service that the operator is required to deliver.

To ensure effective coordination between the operator and TfL, there are regular meetings between the two organisations to discuss operational issues and plan improvements to the network. Additionally, there are performance targets (i.e. punctuality, service quality, customer experience, etc.) that the operator must meet, which are monitored by TfL. If the operator fails to meet these targets, there are financial penalties that they may be subject to. Overall, the TfL Concession allows for private companies like MTR to operate transport services on behalf of TfL, while still maintaining control over the network and ensuring that high-quality service is provided to customers.

The latest rail reform in the UK actually follows some areas from TfL Concession, e.g. the performance and service quality incentive regime.

Survey Response from GB Rail (IM England Region)

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions is about the planning stage before implementing an infrastructure investment.*

    a. *How important is the role of cost-benefit analysis within IM's strategic planning stage of the infrastructure investment projects? What elements do you think are as important as cost & benefit for IM to consider in different types of investment (i.e. renewal and enhancement)?*

    It is fundamental in decision-making related to infrastructure investment projects, and it is not necessarily confined to a single numerical Benefit-Cost Ratio (BCR). Apart from the BCR, the CBA also provides us with why a scheme or change might be needed, and what's driving that need, particularly in terms of service changes to passengers or freight. For example, important considerations include clear passenger benefits, such as reduced journey times and increased frequency that can boost revenue.

    Wider economic and social benefit (i.e. job productivity, connectivity, land use, regeneration) is another area that influences the decision-making process. Investments might be aimed not just at benefits seen on the railway but for broader economic gains, including "levelling up", rebalancing, or disconnected communities. Specific examples like Northern powerhouse rail aimed to create more productive jobs and alter land use in the north to mitigate GDP disparity between regions. These benefits sometimes are involved in the Level 2 or Level 3 benefits of the Economic Appraisal. Although they may appear small in some cases, they can be included in investment considerations, contributing to the understanding of the transformational impact of an investment.

    For enhancement of the network, strategic considerations, political influence, and investment funding sources are the other areas to affect decision-making.

    - When contemplating significant projects, it is crucial to envision the scope of the transformation and determine whether the anticipated change, such as economic or structural, justifies the investment. This involves comprehending and persuading all stakeholders that the desired results will indeed be achieved through the planned activities.
    - Political influence - Politics plays a significant role in railway investments, especially in areas like England where the respondent mainly operates. Even though a business case is always prepared, and a numeric result is produced, political variables heavily influence investment decisions. Some projects might be strategically chosen to be in key political regions.
    - Investment funding – private money involved in the project investment can

reduce the political influence, whilst focusing more on the CBA outcome, i.e. value of money. However, private money has not been a part of railway investments recently, with very little private money coming into infrastructure investments like rail tracks. Sometimes, the so-called "third party" money, which often comes from local councils (which is essentially government money), is talked about in the context of private money. This is because many railway investments generally cover large areas (i.e. Northern Powerhouse, EWR, and HS2), which means the benefits are distributed across multiple cities, making it challenging to attract private funds. In contrast, for the project focusing on a smaller area, such as Crossrail, private money did play a part, through a surcharge on the ratable value of properties around stations, because the benefits were distinctly observed close to those stations.

Notice that the government (DfT) is responsible for making decisions on enhancement-type of investment. IM's strategic planning mainly focuses on renewal projects and works differently. The purpose of the renewal is to keep the network running as it is, with a minimum-level investment. This means that cost-benefit analysis is not the key element to affect renewal projects. The network conditions and operational reasons (i.e. efficiency and safety) are the main factors to consider in the renewal projects.

b. *Do you think the operators' feedback plays a vital role in helping IM inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Does this feedback contribute to IM's strategic planning of infrastructure investment?*

Enhancement investments mainly start from the **DfT** or local authorities. Whilst, renewals are funded differently, often through a five-year settlement with the government and are essential to maintain the network's capability. While renewals might utilise capital money, they are not considered investments that change the network's capability but maintain it. Occasionally, additional funding might allow them to do something bigger and enhance the network's capability.

For renewals, advice and decisions predominantly come from IM's asset managers and engineers. These professionals understand the conditions of their assets and determine which needs renewing in each five-year cycle, and which can have their life extended. Train drivers might be the first to notice when something isn't working on the network. However, discussions on asset condition and investment predominantly revolve around unseen deterioration and long-term planning, typically handled by asset managers and engineers rather than the operators. For example, even when an asset deteriorates, it may not be visible in terms of its impact on trains and services. Efforts are made to maintain and extend its life so that it doesn't impact services.

Although TOCs are made up of industry veterans with significant experience and ideas, they have not been involved sufficiently in discussions about infrastructure schemes and service changes.

On the other hand, the government and the Office of Rail and Road (ORR) play significant roles in determining, validating, and regulating funding and investment in the rail network. There's a back-and-forth process in determining how much will be spent and where.

c. *Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?*

When it comes to infrastructure investment projects, **Cost Benefit Analysis (CBA) is often viewed as a decision-making tool rather than a driving force.** This is because it can be too abstract and nebulous to effectively engage and motivate project teams. **Instead, factors like culture, processes, and behavioural intent are seen as more important in determining the efficiency and value of money in a project.**

The "people" factor is crucial in maintaining efficiency around money since **individuals within project teams may only focus on their specific tasks and contributions rather than the broader financial picture.** To ensure that everyone is working towards the same goal, project teams need to focus on delivering specified outputs that have a direct impact on passengers and freight users, at the lowest possible cost.

Engineers and designers play an important role in contributing to the project's cost efficiency and value. While they focus on delivering the minimum viable goals and specifications, they implicitly contribute to the BCR by ensuring that designs are cost-effective and feasible for construction. However, to be effective, they need tangible goals and practical aspects to focus on rather than abstract financial metrics.

Practical, immediate goals and challenges directly related to the daily work are necessary for individuals to be effectively engaged and contribute to the project's cost efficiency and value. While periodic assessments can help manage and reduce costs, it is important to make the project come "alive" for everyone involved.

2. *System-wide benefit (total benefit of TOCs and NR) has been argued as the main challenge for unbundled structure, i.e. each party only focus on their benefit from the infrastructure*

investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.

a. *Do you think that regulation is the most useful approach to ensure the system-level benefit is considered in the planning stage of the investment? Are there any mechanisms (i.e. consultation) that help to deliver system-level benefits in the investment implementation stage?*

Apart from regulations, the following areas also contribute to system-level benefit optimisation.

- **Collaborative Planning (Brings the Industry Together)**: Facilitating a platform for key stakeholders - including infrastructure managers, operators, and governmental bodies - to collectively participate in the planning and decision-making processes ensures diverse perspectives and systemic insights are considered. For instance, the interaction between different actors (like IM & DfT) in discussing enhancement projects underlines this collaborative approach.
- **Stakeholder Consultations**: Engaging various stakeholders, such as operators, passengers, and local communities, can provide a comprehensive understanding of the systemic needs and potential impacts of investments. This could be especially pertinent when contemplating enhancements and upgrades, as observed in the electrification example in the dialogue.
- **Flexible and Adaptive Strategies:** It is important to use adaptable strategies that can respond to unexpected developments and changing scenarios. This ensures that investments remain relevant and beneficial in different future contexts, even if there are changes in revenue or schedules. Therefore, adaptability is crucial.
- **Coordination Mechanisms**: Introducing formalised coordination mechanisms, such as Schedules 4 and Significant Restrictions Review on use in the railway sector, can provide structured frameworks for effectively managing disruptions and coordinating between different actors. These mechanisms could help balance the need for operational and infrastructural improvements while minimising negative impacts on operators and service delivery.
- **Risk Mitigation Strategies:** Implementing risk mitigation strategies that safeguard against investment failures or unexpected challenges, ensuring sustained benefits and reduced likelihoods of detrimental impacts on the

overall system.

b. *If the investment brings higher cost than benefit to the TOCs, how to incentivise (or, maybe obligate) them to coordinate with IM to deliver the investment (i.e. Schedule 4)? Is there any circumstance that such schemes don't work well?*

Compensation and neutrality are the most important elements of incentivising TOCs. The Schedule 4 mechanism seems to aim at holding TOCs financially neutral when disruptions occur due to investments and enhancements in the railway infrastructure. This mechanism is, at its core, a compensation regime designed to offset the costs incurred by TOCs during such disruptions, trying to ensure they don't bear a financial burden due to improvements or changes implemented by NR.

In certain situations where the implementation of investments or change leads to an increase in subsidies required for TOCs, it may be necessary for the government or the party holding the contract with the TOCs to provide additional financial support. To ensure that these demands are met, **it is important to have contractual safeguards in place**. This is particularly relevant when changes require additional staffing or resources that may not be immediately offset by increased revenues. For example, the freeze in fare increases (e.g., RPI plus zero from 2016-2020) reveals a structural approach to maintaining operational viability for TOCs despite changes in the economic or operational landscape. This model provides a protective cushion to TOCs, insulating them against financial strains that might emerge from changes mandated or implemented by external entities.

If such mechanisms don't work, then the system needs to introduce alternatives or adjustments to these mechanisms to ensure they remain robust and reflective of the actual challenges and financial implications TOCs face in the dynamic environment of railway operations and investments.

3. *This question is mainly about the potential demand impact of rail structural reform.*

a. *Do you think the rail passengers in the UK are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?*

Safety: Passengers expect the railways to be safe. There isn't so much a sensitivity but a foundational expectation. **If passengers perceive that railways are unsafe, they won't use them at all**.

Ticket Price and Service Quality: There is an increasing sensitivity to ticket price and service quality, especially due to changes in working patterns and the opportunity to work remotely. The shift from commuting patterns, like journeys into London, to more leisure-based travel has made the market more sensitive to price and quality. Why would someone choose the train for leisure if it's cheaper to use a car, or if they perceive the train experience as poor?

b. *Do you think any of the above factors changed significantly due to rail structural reform?*

There hasn't been significant reform since the 1996 privatisation. However, privatisation itself seems to have brought about changes. The market-driven nature of the private sector led to changes in ticket prices and service quality. There are references to the private sector being more "mobilised to change things," suggesting that some improvements and innovations came about due to privatisation.

c. *Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. change their demand response to the factors above?*

The structural reform, specifically privatisation, seems to have had an **indirect impact on passenger behaviour**. Privatisation introduced market-driven dynamics, making some railway companies more attuned to customer preferences, leading to changes in pricing, service quality, and offerings. Post structural reforms like privatisation, **passengers primarily care about the quality and reliability of the service rather than who operates it**. They assess if the ticket offers value for money, whether the train runs on time, its cleanliness, and its safety onboard. The identity of the operating company is of secondary concern to them. The passengers don't care which company run the trains, but the private operator may want the passengers to know they are running the trains in order to **enhance the brand influence in the market**.

The shift in travel behaviour, especially moving from commuting to leisure-based travel, was also influenced by external factors like remote work. However, how the rail industry responds to these shifts might be influenced by their structural nature (private vs. public).

4. *This series of questions aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

a. *In the daily operation, how does IM ensure efficient coordination with the operators in daily train operations especially when a disruption on the network) occurs? Do you think the current coordination approaches will remain (or be enhanced) for GBR or will be reformed to improve?*

In daily operations, especially during disruptions, The IM (NR) coordinates with operators through a series of Rail Operating Centres (ROC). ROCs are made up of employees from different departments who work together to run the train service. They also follow contingency plans and codes of practice. The structure of management might vary, and there are places where integration is at a deep level, with some stations having a single manager overseeing operations.

GBR has the ability to get things more integrated with the changes in the contract.

b. *As I understand, the key incentives for the coordination between RU and IM (which are not in the same team) on a daily basis include joint management (reporting to a unique manager) and financial incentives. Are there any other ways that you think may improve the coordination with TOCs?*

   Key incentives for coordination between RU and IM currently include **joint management and financial incentives.** Besides, the potential of a single set of objectives and a unified scorecard for both financial and operational aspects also help. The premise of the Great British Railways (GBR) reform is to hold the entire profit and loss (P&L) for the industry, thus aligning the financial targets of all involved entities.

   Culture plays a significant role in determining the behaviour and approach of entities in the railway industry. Structural changes can remove barriers and facilitate potential cultural change, but they do not guarantee it. Leadership is essential to shift behaviours and ways of thinking. One significant shift that happened post-privatisation was the compartmentalisation of the industry into different companies, leading to less collaboration and more of an "us vs. them" mentality.

   In the initial phases, the reform drove some benefits for passengers, leading to a more dynamic rail market. However, the decision to contract out maintenance, driven by political motivations, was deemed misguided. Over time, this led to an under-investment in essential aspects of the network like drainage management. The focus on contract specifics without understanding the experience and culture of the job can lead to inefficiencies.

Survey Response from GB Rail (IM Scotland Region)

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions is about the planning stage before implementing an infrastructure investment.*

    a. *How important is the role of cost-benefit analysis within ScotRail (SR)'s strategic planning stage of the infrastructure investment projects? What elements do you think are as important as cost and benefit for SR to consider in different types of investment (i.e. renewal and enhancement)?*

    - Planning is a trilateral activity between Network, Rail, ScotRail and Transport Scotland (TS). Transport Scotland has Scottish Transport Appraisal Guidance (STAG), which is used as the basis for appraisal transport investment. Cost-benefit analysis is the core part of STAG (i.e. part of the five-case model).
    - As an operator, SR has limited responsibilities in infrastructure investment compared with TS and NR. IM has its licence obligation to do Strategic Planning and TS sets both the funding and the outputs of the industry. However, given Scotland's rail network is smaller than the network in England, each of the three organisations works closely with each other to deliver the business case of infrastructure investment projects. For example, people from the three organisations will sit in the same room to develop a proposal for a change of train service.

*************** Case study *********************

LEVENMOUTH RAIL LINK

Transport Scotland, The IM and industry partners have worked closely to develop the delivery programme which now includes a significantly expanded project scope delivering additional investment and realising additional opportunities and benefits.

This project was previously led by the local authority who had come to a rather strange conclusion that once the infrastructure had been funded, there would be no ongoing costs of running the new service. So they came up with an absolutely massive positive BCR on that basis. So, when the Scottish Government asked IM to take over, we were then able to do much more work in terms of understanding how its short-term capital impacts, as well as the revenue impact, would be on the network, which developed a more realistic business case,

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- Much infrastructure investments in Scotland have been driven from outside the rail industry. For example, electrification or re-openings are not purely driven by the railways, but IM plays a role as the expert for the government to overview and provide advice for the political expediency of doing something. TS makes the final decision on the investment, so IM cannot take accountability for the best value of money.

- Economic appraisal is crucial; however, the Minister must sign off on the final decision. Thus, political and local/country-level strategy reasons can also play an important role here. Besides, CBA is more important for enhancement than renewal. It’s not saying CBA is not required for renewal, but renewal considers other things, i.e. safety and reliability have a higher priority. But it doesn't have to be a full appraisal (i.e. a formal cost-benefit analysis), but actually getting people in the industry to think about how the whole system fits together.
- There is one of the areas I think the GB railway has been very bad at over the last 30 years is aligning renewals and enhancements and even maintenance with a long-term business goal. IM is obviously required to maintain its assets on a continuous basis. Maintaining the network effectively is how the renewal system works. Enhancement is then considered almost as an overlay. Both the renewal and enhancement plan should be aligned with the long-term business plan for the key stakeholders.

*************** Case study *********************

Carstairs Junction

There is a major junction called Carstairs on the West Coast Main Line between Carlisle and Edinburgh/Glasgow. However, it has been facing issues for around 10 years due to its ageing assets, signalling, and track. The main users of this network/junction are cross-border passenger and freight instead of ScotRail. Hence, TS could see no direct benefit to the rail system in Scotland in terms of significantly enhancing this junction to give higher speed and reduced journey times. In contrast, IM has an obligation to provide good infrastructure to all of the operators who run on their network, not just the people in Scotland.

As a result, IM and the cross-border operators, governments, and cross-border operations had to have a lot of difficult discussions both with Transport Scotland and ORR (nearly led to a breakdown of relationships in some parts of the organisations because there were conflicts).

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b. *Do you think the operation department plays a vital role in helping infrastructure management inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Does such feedback contribute to IR’s strategic planning of infrastructure investment?*

Yes, they are very important as they run the train daily, so they know what impacts their performance. For example, they may report signalling problems or any other types of issues on the network anytime they want. Such feedback could contribute to the IM's investment plan, only if they are investment-driven (instead of other reasons such as the operator doesn't use resources effectively)

In Scotland, there wasn't a wholesale change of personnel even after privatisation, so we ended up with more dialogue and more understanding of the interactions across the system.

*************** Background Knowledge**********************

The structure of the railway system in Scotland

In Scotland, IM is the infrastructure manager and ScotRail is the operator. However, ScotRail is owned by Transport Scotland (via a holding company, with legal and accounting separation) and is directly accountable to Scottish Ministers. In fact, every party is aligned in Scotland because the Scottish Ministers set the high-level output specification and fund The IM as well. Whereas IM is accountable to ORR. So, there is a tension here between TS and NR. The Minister's target may come from a political perspective, and saying that "We write the cheques, you do what you're told to do. But the response from IM is "Yes, we will do what we're told only if it doesn't cut across the regulatory determination".

As a result, there does exist a tension between good planning, good analysis and wise political decision-making. IM clearly cannot control everything. For example, the new LEVENMOUTH RAIL LINK is going to open next year. IM flagged the requirement for new rolling stock to serve this new service 5 years ago, and TS needs to identify where these come from. However, the process on the TS side has been slow, there will be at least another two years before there are enough rolling stocks to maintain the existing level of service and support the new branch line.

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c. *Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?*

   CBA has its contribution to the value of money for an investment project, but the contribution could be limited. Decision-making also plays a critical role. Sometimes, the CBA is good, but the cost in reality is uncertain which is the main challenge due to the implementation plan. Politicians sometimes ignore the weaknesses or the stage of the CBA. This could happen or be influenced by the culture of doing things, rather than the rail industry structure.

*************** Case study *********************

Aberdeen to Inverness Rail Improvements

The Aberdeen to Inverness line is approximately 108 miles long and is primarily single-track with some passing loops. The current passenger journey times (typically around 2 hours, 25 minutes) and irregular through service (approximately every 2 hours) between Aberdeen and Inverness means that it does not offer an attractive alternative to road travel. The rail improvements project is being delivered in phases and aims to provide incremental benefits throughout the life of the scheme, with the whole project being delivered by 2030

Concerning this project, there have been several improvements made to increase train frequency and build new stations. However, five years ago, the government announced they were moving forward with a project based on preliminary cost estimates. IM warned them that the estimates were uncertain due to unknown infrastructure conditions and gave the government a range of cost estimations, but TS chose the lower number from the given range. Later, when more detailed analysis was done, it was found that the costs were higher than initially estimated. We were then criticised for doubling the cost of the project when in reality we had only provided preliminary estimates with limited confidence around the range.

Therefore, there was a lot of what is now described as "value engineering," but I prefer to call it "cost-cutting" in order to bring these projects back within budget because they had gone over budget. As a result, the quality of decision-making was much lower than it should have been. However, it was politically expedient to announce the expenditure without fully understanding what was being purchased. The appraisal, business case development, and costings were all done well. Nevertheless, we ended up with a project that was deemed "too expensive" because decisions were made at the wrong point, and as a result, we ended up with a less satisfactory project in the long term.

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HS2

If HS2 had been allowed to develop some aspects and establish stability in its goals, I think some current issues would have been avoided. It's a lesson in the consequences of excessive political interference in what should fundamentally be a neutrally based development, aimed at enabling politicians to make informed choices. Furthermore, detailed cost-benefit analyses can sometimes produce an overwhelming amount of detail. Politicians might seize upon specific details without fully comprehending the limitations of the data quality or underlying assumptions about train services or revenue levels. These assumptions can, unfortunately, become deeply embedded into a project, even though it was clear that they were just initial propositions to facilitate the development of the appraisal and business case.

2. *System-wide benefit (total benefit of rail system) has been argued as the main challenge for unbundled structure, i.e. each party only focus on their benefit from the infrastructure*

investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.

a. *Do you think delivering the system-level benefit is challenging for SR? Are there any mechanisms that help to deliver system-level benefits in the investment implementation stage?*

   Yes, it could be a challenge. However, the single-director structure in Scotland (SR and NR) was designed to resolve this challenge.

   The IM encounters issues when specialists in civil engineering or signalling, who may not fully grasp passenger demand or understand how systems interconnect, make decisions. If you're a civil engineer tasked with building a tunnel for £10 million, you might not think about the end user's impact or consult with signalling engineers. Thus, two projects might emerge instead of one coordinated effort. It's not just about the organisation's setup; it's also about the industry's culture and processes. I've been in meetings where engineering decisions were made without considering broader impacts. For instance, shutting down a railway during the peak season can have severe repercussions for the economy due to decreased passenger demand. Even within a single company, like Irish Rail, civil engineers might still lack a comprehensive understanding.

   My view is that a significant opportunity for reform is to alter this situation. There's a requirement for delivering to the end user, but even with structures in place, like having a single managing director in Scotland for ScotRail and The IM, it's not always clear that the intended benefits are being realised. Issues arise when there's a deviation in project delivery. This might be due to unforeseen challenges or even resource constraints. Then, how do train operators like ScotRail handle the situation, especially when other network operators are affected? There's a tension in prioritising Scottish rail needs over those of others (i.e. LNER who run trains in Scotland). If this happens, the other operators would be encouraged to raise this issue to ORR to enforce their rights. It depends on case by case and the capabilities of each organisation to actually address the situation.

b. *If the investment brings higher cost and disruption than benefit to train operation, does the system need to incentivise the operation team to coordinate with the infrastructure team to deliver the investment?*

   When considering a business case for railway infrastructure, it's important to factor in costs and benefits, as well as regulatory requirements. The impact on overall cost should be carefully evaluated, rather than just looking at infrastructure provision. To ensure coordination, a single-director management structure is vital for incentivising organisations. While Transport Scotland funds the investment, they must adhere to the regulatory framework. Ultimately, the decision to fund enhancements rests with the Scottish Government. The ORR must also determine if the investment aligns with The IM's license. Theoretically, Transport Scotland should not approve anything without involving the ORR in the process.

3. *This question is mainly about the potential demand impact of rail structural reform.*

   a. *Do you think the rail passengers in Scotland are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?*

      The rail industry in Scotland also follows PDFH, which means it is believed that the passengers change their travel behaviour due to the changes in price, service quality, reliability and safety. The actual elasticities for these factors could be different and rely on sensitivity tests. Actually, the elasticities in the PDFH could be affected more by the travel behaviour change due to COVID-19.

   b. *Do you think any of the above factors changed significantly due to rail structural reform?*

      Yes, it could be. It is possible that TS has the authority to modify fares, enabling them to increase or decrease the number of passengers on a specific route or at a particular time. TS can do this without reference to DfT or Treasury because they are fully devolved. They take the risk in terms of the overall cost of running ScotRail.

      An excellent illustration of this is the present six-month trial by TS of no peak fares. This trial is in response to the post-COVID era, where commuter volumes have not fully recovered, and capacity challenges tend to occur during the shoulder peaks rather than the peaks. Another example is the operation change on Saturday - which is now the busiest day of the week for rail travel within Scotland. Hence the service is often more frequent or with longer trains then.

   c. *Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. change their demand response to the factors above?*

      Yes, the answer is affirmative. However, it may not directly influence travel behaviour. Rather, the reformation of rail structure may alter the level of motivation for the organisation to implement change, including policy and infrastructure changes. This indirectly affects the passenger demand level.

      In the UK railway system, each train operator has contractual accountability for implementing fares and determining service quality for their respective network. This allows for different fare strategies and levels of reliability for each route, resulting in a specific marketing approach for each area. This approach can increase the overall revenue for the railway system from an economic standpoint. The operators' profits are influenced by their ability to run a quality service with a sound fare strategy, which impacts the level of demand.

4. *This series of questions aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

a. *In the daily operation, is there any challenge for the IM team to have efficient coordination with the operators in daily train operations especially when a disruption on the network occurs?*

Yes, the challenge is the culture and behaviour in the daily operation.

First, we need to know that there exist regulatory settlements for NR, track access contracts and delay attribution mechanisms, which can be seen as a very strong formal alignment through the performance regimes. The two regulation performance regimes are Schedule 4 with respect to engineering work and Schedule 8 with respect to network management. They're very complex, so I think that only a very small proportion of the industry actually understands how they work in detail, but they do understand in principle how the relationship between the infrastructure and training operations is meant to work.

There is a contractual and regulatory relationship, but the main concern lies in the cultural and behavioural (i.e. experience and knowledge-based) issues across the industry. In my opinion, these issues are just as important, if not more important, than the contractual underpinning. If a train is going to be delayed, it's important to make the best decision possible to minimise the impact not only on the operator of the delayed train but also on the rest of the day's schedule. Theoretically, the Schedule 8 regime takes into account the consequential delays. For instance, if a train is already running 4 minutes late, delaying it further could have a significant knock-on effect later in the day. In that case, it might be better to delay another train by two minutes to minimise the delay caused by the first train. The challenge is that these decisions are made in real-time, without necessarily considering the impact on performance payments, but with the best available knowledge at the time. As a result, it’s the knowledge and behaviour of the IM team to solve the disruption on the network in real-time. The people who sit and run the signalling won't actually be thinking about Schedule 8 but think about how it does to the trains there. Btw, Schedule 8 is not in itself intended to drive perverse outcomes, and is continually refined through the Periodic Review process. Of course, such knowledge and behaviour are influenced by the contractual and regulatory requirements at a basic level.

b. *What do you think are key incentives for the coordination between the RU and IM teams on a daily basis and long-term basis respectively?*

For coordination on a daily basis, IM and the operator have their control centre in the same location. This means that the operators and infrastructure person sitting in the same office can talk to each other. On a long-term basis, the Performance regimes provide strong alignments between IM and RU. TS, IM and SR also need to work together to identify the key weaknesses in the network and what the solutions are.

I think a simple incentive mechanism that everybody understands is better than a complex one that requires detailed knowledge of the contract and the regulatory framework to implement. If one is only taught to follow rules without understanding the reasoning behind them, they will simply follow them. However, if they are able to comprehend the purpose behind these rules, as previously discussed, they may be able to make more informed decisions rather than blindly following a set procedure or manual.

In the industry, there's a tendency to complicate things by adding more rules-based solutions to solve a problem. This creates more problems and makes it difficult to disentangle the regulatory regimes. To address this, we need to simplify and remove unnecessary structures. The operational regime should be designed for running a service instead of running a contract. We should simplify performance regimes to ensure good decision-making for delivering chain services. The philosophy behind this is to determine what should be contractualised and regulated under the performance regime. The contract should serve as a foundation but does not establish a maximum output or specify evolving behaviours and requirements. It needs to be simplified with more flexibility.

For example, delays have always been a significant issue in the GB industry. Previously, before privatisation, we would analyse delay causes every week to understand network issues and operate the rail system. However, it is now about shifting blame and less about diagnostics. Managing the operational interface becomes more difficult when delay attribution is placed in a contractual space. Consequently, companies may focus on shifting blame to another company to improve their bottom line rather than learning from the delay and improving the system. Delay attribution has become a contractual rather than an operational diagnostic activity. While it may not be possible to separate it from the contractual relationship, it is essential to consider what is being accomplished. At the moment, TS is trying to primarily focus on passenger outcomes rather than transferring resources between different parts of the industry.

Survey Response from GB Rail (Government, DfT)

Questions

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions is about the planning stage before implementing a rail infrastructure investment.*

    a. *How important do you think is the role of cost-benefit analysis for the government's rail infrastructure investment projects? What elements do you think are as important as cost & benefit for the DfT to consider in infrastructure investment?*

    The role of cost-benefit analysis (CBA) in government rail infrastructure investment, particularly in the UK, is seen as limited in practice. The interviewee emphasises that the focus is often more on the monetary aspects, such as capital expenditure (CAPEX) and operational expenditure (OPEX), rather than the broader benefits. He notes that CBA tends to be more post-facto, often confirming decisions already made for political reasons, rather than driving them.

    Train operators, viewed as glorified management contractors with limited long-term risk-taking, have their opinions less regarded in this context. This situation leads to an underestimation of operational costs and a lack of consideration for the strategic long-term impact of projects. It is pointed out that the modelling for benefits is vague and uncertain, and the application of CBA often reinforces investment in already busy areas, potentially neglecting regions that could benefit more from new investments.

    Political reasons and strategic thinking, including considerations like regional balance, are highlighted as equally or more important than CBA. The strategic outline business case (SOBC) is mentioned as a critical part of project evaluation, focusing on qualitative aspects rather than just quantitative metrics. The interviewee underscores the limitations of current forecasting methods and suggests a need for a more systematic approach to cost and revenue forecasting.

    In conclusion, while CBA is a component of the planning stage, its actual influence and effectiveness in guiding decisions are questioned. The emphasis is on the need for a more balanced approach that includes political, strategic, and qualitative factors in infrastructure investment decision-making.

    b. *Do you think the train operators' opinions are considered by DfT for rail infrastructure investment?*

    The interviewee's response indicates that the opinions of train operators (TOCs) are not significantly considered by the Department for Transport (DfT) in rail infrastructure investment. He suggests that this is primarily due to the short duration of running contracts for TOCs, typically around seven years. This short timeframe disincentivises TOCs from engaging in long-term investments, as they may not reap the benefits within the duration of their contract.

Additionally, The interviewee notes that short-term investments, such as smaller-scale track renewals and Installation of switches and crossings, which could potentially offer more immediate benefits (i.e. allowing faster speeds and turnouts to enhance the efficiency and speed of train movements), often get overlooked or deprioritised by the DfT. He mentions that while there is an acknowledgement of the potential value of such investments, they rarely reach the top of the priority list. This lack of prioritisation could be due to the political nature of larger, more visible projects which might be seen as bringing more significant benefits.

In conclusion, the train operators' opinions on rail infrastructure investments are not heavily weighted by the DfT, partly due to the structure of the franchising system and the short-term nature of TOC contracts, as well as the DfT's focus on more extensive, politically influenced projects.

c. *Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?*

The CBA does not significantly contribute to the cost efficiency and value for money in rail infrastructure investment projects. The current UK rail regulator (ORR) is disinterested in infrastructure enhancement, and hence, plays no role in influencing these aspects.

The complexity of regulating a public sector company, where there is no commercial risk involved, presents a unique challenge. In such a scenario, the regulator's views are often seen as irrelevant, especially since the government assumes the long-term cost risks.

With the introduction of Great British Railways (GBR), there has been a shift in approach within the UK rail industry. However, this shift hasn't fundamentally solved the issues related to cost efficiency and value for money in rail infrastructure projects. The situation points to a need for more effective regulatory frameworks and strategies to enhance the cost efficiency and value of these projects.

2. *System-wide benefit (total benefit of TOCs, IM and other stakeholders) has been argued as the main challenge for unbundled structure, i.e. each party only focuses on their benefit from the infrastructure investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.*

   a. *Do you think that regulation is the most useful approach to ensure the system-level benefit is considered in the planning stage of the investment? Are there any mechanisms (i.e. consultation) that help to deliver system-level benefits in the* *investment implementation stage?*

The response suggests that the current regulatory system has largely ignored the issue of achieving system-wide benefits in rail infrastructure investment. This neglect dates back to the privatisation era, where the focus was more on managing existing infrastructure rather than planning for improvements. The regulatory framework hasn't effectively addressed how infrastructure managers and railway undertakings can work together to enhance the overall system.

The conversation also highlights the perspective that infrastructure managers, particularly in Great Britain, tend to believe they have the exclusive right to plan and decide on infrastructure developments. This belief can lead to a somewhat narrow focus, prioritising engineering-driven decisions and overlooking the broader system-wide benefits.

Since 2004, there has been a shift with IM becoming subject to a process overseen by ministers. This process requires considering total system-wide benefits, including economic aspects, both priced and unpriced, for any proposed investment. However, there is scepticism about the quality and thoroughness of this approach. It's implied that while IM does consider system-level benefits, they can be swayed by their priorities, such as the emphasis on digital rail, which might not always align with broader system needs.

In principle, the system-level benefits are supposed to be a part of investment considerations, and consultation with operators is expected. However, the quality of the work done in evaluating these benefits is seen as inadequate, suggesting a need for improved mechanisms to ensure that investments truly cater to the wider system's needs and not just the priorities of individual stakeholders like infrastructure managers.

b. *If the investment brings higher cost than benefit to the TOCs, how to incentivise (or, maybe obligate) them to coordinate with IM to deliver the investment (i.e. Schedule 4)? Is there any circumstance that such schemes don't work well?*

There are mechanisms in place, like Schedule 4 and the Network Code/Network Change, which are designed to compensate TOCs for disruptions and additional costs caused by infrastructure investments by The IM (NR). These mechanisms aim to balance the interests of infrastructure managers (like NR) and operators (TOCs) when large-scale investments or changes occur.

Schedule 4 specifically deals with compensations to TOCs for disruptions caused by engineering work. This ensures that TOCs are compensated for any service interruptions or difficulties arising from infrastructure investments by The IM. The Network Code, on the other hand, is a broader set of rules that are part of the contractual relationship between The IM and the train operators. It includes various parts that govern service performance monitoring, modifications to the network, environmental protection, and other key operational aspects. Part C of the Network Code outlines processes for making changes to the Code, providing a structured way for The IM, train operators, or the ORR to propose and implement modifications. This system was notably invoked for the GSMR (train radio fitment) project, where the costs were fully covered by NR, including training for drivers and conductors.

However, there's scepticism about the effectiveness of these mechanisms. It's noted that the role of The IM still takes long positions, and few people fully understand the intricacies of Schedule 4. Payments made under these mechanisms are sometimes seen merely as a cost of doing business, rather than as a tool for effective coordination or incentivisation.

A **case study** illustrating a more collaborative approach is the rebuilding of London Bridge station. In this project, IM and Southeastern worked closely, not necessarily for commercial reasons, but for practical considerations such as platform closures and replacements. This example suggests that effective collaboration and investment can happen despite the existing rules, rather than because of them, and tends to be more successful in larger projects that attract governmental and public interest.

For smaller projects, there might be less inclination from IM to collaborate closely with TOCs, indicating a potential gap in the system where smaller investments might not benefit from the same level of coordination or shared focus on system-wide benefits. This trend is observed not just in the UK, but in similar rail systems in other European countries like Sweden and France, where there has been a move towards more integrated structures.

3. *This question is mainly about the potential demand impact of rail structural reform.*

   a. *Do you think the rail passengers in the UK are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?*

   The demand drivers and their associated elasticities within PDFH would be the best evidence to answer this question.

   b. *Do you think any of the above factors changed significantly due to rail structural reform?*

   Based on the discussion, it seems that the rail structural reform in Great Britain has had some noticeable effects on service quality and market responsiveness, though the extent and nature of these changes are detailed.

   Service Quality and Frequency: There's a perspective that improved service quality, such as modern and cleaner trains and more customer-oriented staff, has significantly impacted demand, particularly in leisure travel. However, quantifying this impact is challenging, as much of it is based on passenger perception rather than hard data like performance metrics.

Demand and Service Frequency: The frequency of train services on core intercity networks has increased, in some cases doubling. This change is observed as being partly due to increased demand. However, it's noted that this is a bit of a "chicken and egg" scenario – does increased service lead to higher demand, or vice versa?

Smaller Operations and Market Sensitivity: The discussion suggests that smaller operations, such as Great Anglia, may have a better understanding of and responsiveness to their customers due to their scale. This "small is beautiful" approach implies that smaller companies might be more attuned to the needs and preferences of their passengers.

In conclusion, while the rail structural reform in Great Britain has led to some improvements in service quality and responsiveness to market changes, these improvements are multifaceted and dependent on various factors, including the scale of operations, the nature of franchising agreements, and the specific market dynamics in different regions and routes.

c. *Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. change their demand response to the factors above?*

Incentives and Operational Management: Under the franchising system, there was a significant incentive for operators to improve services since they directly benefited financially from increased ridership and service enhancements. This system arguably made operators more responsive to market changes and passenger needs.

Impact of Revenue Risk and Commercial Interest: The discussion also touches on the importance of understanding at what stage operators were taking on revenue risk and were commercially interested in revenue. This factor seems to play a crucial role in how operators respond to market changes and demands.

4. *This question aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

    a. *Based on my understanding, RU and IM, who are not part of the same team, are motivated to coordinate with each other on a daily basis due to the shared management structure (reporting to a single manager) and financial incentives. Are there any other measures that you believe could improve this coordination? Also, do you think the coordination will continue or be enhanced with the establishment of GBR?*

The discussion about the coordination between rail undertakings (RU) and infrastructure management (IM) in the context of different separation policies, especially in light of UK rail reform, suggests several points:

- Alliancing and Integration Attempts: There was an attempt a few years ago to pool financial resources between RUs and The IM for maintenance and plan it on an integrated basis (referred to as 'alliancing'). However, this initiative did not work out as planned and was abandoned by 2008.
- Joint Control Centres: There has been general support from The IM for joint control centres with train operators, but the impact of this on overall performance is unclear. National train performance has been declining on average for several years, except during the COVID period when passenger numbers dropped.
- Coordination Efforts and Effectiveness: The effectiveness of coordination efforts between RUs and IMs seems to be oversold, as performance metrics do not show significant improvements resulting from these measures.

In conclusion, while there are efforts to improve coordination between RUs and IMs, the effectiveness of these measures is still debatable. The approach to rail system organisation, whether integrated or separated, coupled with government policy and investment, plays a critical role in the overall performance and efficiency of the rail system.

There are some opinions from The interviewee concerning the rail reform/privatisation in the UK rail:

- Rail Privatisation Philosophy: The initial philosophy behind rail privatisation focused on unbundling, where each unbundled company focused on its efficiency. This approach might still hold potential, considering the challenges in achieving effective coordination under the current system.
- Government Policy and Investment: The role of government policy and investment in rail is crucial. The UK rail privatisation was not initially designed around investment and planning, leading to significant changes in requirements over the years. The government's approach to public transport and willingness to invest heavily influences the success of any rail system.
- Political Influence: Political factors significantly influence decisions in the rail industry, including investment decisions and reforms. The success of a rail system in a particular country might depend more on political decisions aligning with the right strategies than on technical aspects alone.

Survey Response from GB Rail (Operator)

Questions

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions is about the planning stage before implementing an infrastructure investment.*

    a. *Do you think the cost-benefit analysis (CBA) contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What is the TOC's role in the CBA?*

    Cost-benefit analysis (CBA) plays a crucial role in large infrastructure projects, exemplified by the Midland Mainline electrification. The emphasis is on achieving cost efficiency and environmental benefits through strategic decisions in fleet management and operational methods. TOCs contribute significantly to this process by evaluating different aspects like the choice of rolling stock, which impacts operational efficiency and costs. The transition from diesel to electric operation not only offers operational efficiency but also environmental advantages.

    There is a noted engagement of TOCs with The IM (NR) and the DfT, involving discussions around operational aspects such as train speeds. However, a persistent challenge is the disconnect between the planning stage of infrastructure projects and their real-world operational implementation. This gap, often widened by evolving circumstances over time, can lead to variations from the anticipated outcomes of the CBA, thereby affecting the overall efficiency and value derived from such investments.

    b. *Do you think the operators' feedback plays a vital role in helping IM inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Does the feedback contribute to IM's strategic planning of infrastructure investment?*

    Operator feedback is crucial in shaping both the day-to-day operations and strategic infrastructure planning of NR. The use of a joint head of performance is a key strategy in this process. This role ensures a cohesive feedback loop between the operator and NR, influencing immediate operational decisions and long-term investment strategies. This integrated approach, where a single individual is accountable for performance from both the IM and operator perspectives, enhances collaboration and strategic alignment.

    It should be noted that different operators collaborate with IM in varied ways. The RU's approach, focused on joint performance management, is instrumental in guiding IM's investment decisions. However, aligning the priorities between IM and the operators can be challenging, primarily due to differing operational horizons and business planning cycles. This complexity underscores the challenges in aligning diverse priorities and operational timelines, making the feedback and collaboration process between operators and IM a critical and complicated aspect of railway infrastructure planning and investment.

2. *System-wide benefit (total benefit of TOCs and NR) has been argued as the main challenge for unbundled structure, i.e. each party only focus on their benefit from the infrastructure investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.*

    a. *Do you think that regulation is the most useful approach to ensure the system-level benefit is considered in the planning stage of the investment? Are there any mechanisms (i.e. consultation) that help to deliver system-level benefits in the investment implementation stage?*

    In addressing the challenge of achieving system-wide benefits within the unbundled structure of railway infrastructure investment, it becomes clear that regulation, while important, is not the sole solution. The conversation points to the limitations of regulatory bodies in controlling all aspects of infrastructure investment, particularly at the detailed level of network knowledge-based benefit/cost discussions. Instead, the emphasis shifts towards the integration of joint management and leadership as critical elements in maximising system-level benefits. This approach focuses on aligning the cultural and incentive frameworks of different parties, such as IM and TOCs, towards common goals.

    A significant challenge identified is the current short-termism in planning, which can hinder the recognition and realisation of broader socio-economic benefits from such investments. This approach should not only align with the strategic objectives set by regulatory bodies and government agencies but also resonate with the operational and business realities faced by TOCs. This inclusion is crucial because TOCs, being on the frontline of railway operations, can offer valuable insights into operational realities, customer needs, and practical challenges. Their perspective could significantly enrich the planning process, making it more grounded in the operational realities and therefore more likely to yield beneficial outcomes.

    b. *If the investment brings a higher cost than benefit to the TOC, how to incentivise (or, maybe obligate) the TOC to coordinate with IM to deliver the investment (i.e. Schedule 8)? Is there any circumstance that such schemes don't work well?*

    Schedule 4 is pretty relevant, DfT can describe the ABP of TOC which the TOC commit to some changes, i.e. speed of the line, etc. the ABP provide directions and also quantitative analysis in it.

Performance regime in the contract.

3. *This question is mainly about the potential demand impact of rail structural reform.*

   a. *Do you think the rail passengers in the UK are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?*

   UK rail passengers seem to show higher sensitivity to price changes, a trend that has become more significant in the shift towards leisure travel post-pandemic. This sensitivity underscores the critical role of pricing in influencing rail travel demand, probably more than other factors like service quality, punctuality, and reliability.

   b. *Do you think any of the above factors changed significantly due to rail structural reform?*

   Rail structural reform has the potential to significantly influence factors like pricing strategies. The current GB rail reform (i.e. the establishment of GBR) process is testing new ways of pricing, with initiatives aimed at simplifying and making fare structures more understandable to the public. These initiatives, such as those being trailed by LNER, suggest a move towards a different pricing structure for the industry.

   The current complexity of the fare structure in the UK rail system can be attributed to the revenue-maximising strategies of private operators. When operators bear the revenue risk, there is a strong incentive to design fare structures that capture as much customer surplus as possible, leading to complexity. This approach often results in fare systems that are not user-friendly and can be challenging for passengers to navigate. The ongoing rail structural reform, which includes a shift in revenue risk from individual TOCs to the government, could fundamentally change this strategy. With the government retaining the revenue risk, the focus is likely to shift towards creating a more transparent and straightforward fare strategy. The purpose is to prioritise ease of use and accessibility over maximising revenue. This shift indicates that who keeps the revenue risk is a critical factor in the potential changes to rail fare structures under the reform. Simplifying the fare system is seen not only as a response to passenger needs but also as a reflection of the changing priorities under the current GB rail reform.

   c. *Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. change their demand response to the factors above?*

   Rail structural reform is assumed to impact passenger travel behaviour and preferences, particularly through different pricing strategies. The reform's emphasis on simplifying fare structures and making pricing more transparent and user-friendly could lead to changes in how passengers respond to pricing, possibly making rail travel more appealing and accessible. The potential shift away from the complex, revenue-maximising fare structures towards simpler, government-set fares may lead to a change in the fare elasticities. Such change is based on the fact that less complex pricing could make rail travel more attractive and straightforward for passengers, influencing their travel choices and preferences.

4. *This series of questions aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

    a. *In the daily operation, how does IM ensure efficient coordination with the operators in daily train operations especially when a disruption on the network occurs? Do you think the current coordination approaches will remain (or be enhanced) for GBR or will be reformed to improve?*

    The coordination between IM and TOCs in daily operations, especially during disruptions, is currently facilitated through a shared control approach. While IM and TOC have separate teams within this shared space, this mechanism aims to foster collaborative decision-making, incorporating operator insights, particularly regarding customer impact. However, this can sometimes lead to decision-making challenges due to the need to consider numerous factors, resulting in a tendency towards paralysis. The need for a single guiding mind in decision-making during service disruptions is highlighted, along with the importance of maintaining the customer voice in these decisions.

    b. *As I understand, the key incentives for the coordination between RU and IM (which are not in the same team) on a daily basis include joint management (reporting to a unique manager) and financial incentives. Are there any other ways that you think may improve such coordination?*

    While joint management and financial incentives are key drivers for coordination between rail undertakings and infrastructure management, the conversation suggests that culture plays a more significant role than formal schemes in daily operations. The railway industry, being traditional in nature, often relies on established cultures and working relationships to guide coordination efforts. This cultural aspect is seen as critical, especially in times of reform and structural changes like the transition to GBR. Ensuring that the customer voice, primarily collected by TOCs, remains a central part of decision-making is vital in this context.

Survey Response from the French Railway (IM)

Questions

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions is about the planning stage before implementing an infrastructure investment.*

   We answered as part of the IM. the answers here below cannot be taken as official, nor complete. SNCF Voyageurs and other companies of the SNCF group would have a vision and approach.

   a. *How important is the role of cost-benefit analysis within SNCF's strategic planning stage of the infrastructure investment projects? What elements do you think are as important as cost & benefit for SNCF to consider in different types of investment (i.e. renewal and enhancement)?*

      The role of cost-benefit analysis in the strategic planning of the IM's infrastructure investment is not only important but also mandated by law for projects exceeding 23 million euros. This rigorous analysis is a critical component of the decision-making process as stipulated by the décret 97-444 du 5 mai 1997 and the arrêté du 08/12/1997. It serves as a foundational tool to ensure that any proposed infrastructure development is subjected to a thorough examination of its potential impacts, thereby safeguarding the interests of all stakeholders involved.

      Beyond this quantitative measure, the IM is tasked with producing an ex-ante cost-benefit analysis that contributes to a comprehensive dossier for public inquiry. This requirement underscores the responsibility to demonstrate the utility and added value of investment projects. We must ascertain that each project not only stands up to financial scrutiny but also aligns with broader policy goals, aligns with sustainability considerations, addresses social needs, and supports the long-term vision of the rail network's evolution.

      It is also pivotal to recognise that while cost and benefit analysis is a cornerstone of the investment strategy, other elements are equally vital. In the planning for different types of investments, such as renewal and enhancement, we must also weigh factors such as environmental sustainability, social equity, regional economic development, interoperability with existing and future transportation systems, and the overall enhancement of customer experience. These dimensions are integral to the comprehensive evaluation process, ensuring that the investments transcend mere economic calculus and contribute holistically to the fabric of public transportation.

   b. *Do you think the feedback from the operators (i.e. SNCF Voyageurs and Fret SNCF) plays a vital role in helping SNCF inspect the infrastructure issues on the current network (i.e. where can lead to a disruption in the operation)? Do these feedbacks contribute to SNCF's strategic planning of infrastructure investment?*

Feedback from operators such as SNCF Voyageurs and Fret SNCF is not just a formality; it is an integral part of the IM's operational assessment and strategic decision-making. We recognise that the operators are the ones who experience the day-to-day realities of the infrastructure's strengths and weaknesses. Their insights are crucial in identifying potential disruptions and informing the prioritisation of maintenance and investment needs.

To institutionalise this feedback, the IM convenes a dedicated committee that brings together representatives from all operating entities. The purpose of this committee is to ensure that feedback is systematically collected, analysed, and acted upon. It is a platform for dialogue and shared decision-making, where operators can articulate the challenges they face and influence the agenda for infrastructure development and maintenance.

While operator feedback is a key input, the IM also adheres to stringent public procedures for large-scale investments. This includes structured public debates and consultations that allow for a broader range of stakeholders to voice their opinions. During these public forums, the feedback from operators is supplemented with perspectives from other stakeholders, which might include regional planning bodies, passenger organisations, environmental groups, and the general public. This inclusive approach ensures that strategic planning for infrastructure investment is not only aligned with the technical and operational insights from operators but is also responsive to wider societal, environmental, and economic considerations.

In summary, the insights provided by SNCF Voyageurs, Fret SNCF, and other operators are indispensable to the IM. These contributions, coupled with a democratic public consultation process, enable us to refine the strategic planning and ensure that the investments are robust, responsive, and tailored to the comprehensive needs of the rail network.

c. *Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?*

Cost-benefit analysis is more than just a fiscal exercise; it's a strategic tool that significantly contributes to ensuring cost efficiency and value for money in infrastructure investment projects. By offering a long-term projection of the economic efficiency, it allows us to ascertain whether the investment aligns with the overall financial sustainability and socio-economic advancement goals. It meticulously details the costs and potential benefits for each stakeholder, providing a detailed view of who gains and at what cost. Additionally, the analysis is augmented by financial and socio-economic Key Performance Indicators (KPIs), which provide insights into the projected return on investment over time.

Incorporating this analysis into the public inquiry's administrative dossier serves to enhance transparency, allowing stakeholders to understand the investment objectives and expected outcomes clearly. Through this process, we demonstrate the commitment to meticulous planning and accountability.

Moreover, cost efficiency and value for money are not determined by financial analysis alone. Several other elements within the rail system play pivotal roles, including:

- French Regulation: Regulatory frameworks set forth by French law and transport regulators establish clear efficiency objectives that the IM must adhere to. These regulations ensure that investments are not just economically viable but also meet predefined standards of service and safety.
- Performance Contract (2021-2030): the IM operates under a performance contract which outlines the investment levels and performance expectations over the next decade. This contract serves as a blueprint for aligning investment strategies with broader operational objectives, driving both efficiency and effectiveness in service delivery.
- Modelling and Cost Coverage: Advanced modelling techniques enable us to refine the projections and ensure that investments are cost-efficient, covering the entirety of both direct and indirect costs. This foresight aids in the strategic allocation of resources and the pursuit of operational excellence.

In essence, while cost-benefit analysis provides the foundation for evaluating investment projects, it is the interplay with regulatory mandates and strategic contracts that ultimately guides the IM toward investments that promise both cost efficiency and maximum value for money, benefiting the broader ecosystem of the rail network.

2. *System-wide benefit (total benefits for the rail system) has been argued as the main challenge for unbundled structure, i.e. each party only focus on their benefit from the infrastructure investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.*

    a. *What role does the regulator play to oversee the system-wide benefit of infrastructure investment? Are there any other mechanisms or oversight that help to deliver system-level benefits in the investment implementation stage?*

    In the context of infrastructure investment, the French transport regulator, known as Autorité de Régulation des Transports (ART), plays a critical role in safeguarding the system-wide benefits. For any development project with an investment exceeding 200 million euros, the ART conducts a thorough counter-expertise to evaluate the project's alignment with broader system objectives. This regulatory oversight ensures that projects do not solely benefit individual stakeholders but contribute to the collective efficiency and service quality of the rail network. An illustration of ART's scrutiny can be seen through its advisory opinion on the Roissy-Picardie investment project, which is publicly accessible.

Beyond the regulatory oversight, there are additional checks and balances to promote system-level benefits:

- Governmental and European Commission Oversight: The French government, through entities like the Conseil d'Orientation des Infrastructures (COI), and the European Commission play pivotal roles in the oversight of infrastructure investments. Their involvement often extends to the financial aspect, deciding whether to fund a project or not, which inherently influences the direction and scope of investments. The decisions made by these bodies are inherently tied to the project's ability to deliver on system-wide improvements and EU-wide interoperability standards.
- Bilan LOTI: the IM conducts an ex-post evaluation (i.e. socio-economic and environmental evaluation 3 to 5 years after the commissioning of major transport infrastructures), known as the "bilan LOTI" (after the French Law on Inland Transport), to assess the actual impact of investment projects against their anticipated benefits. This retrospective analysis serves as a mechanism to measure whether the investments have achieved their intended system-level benefits, taking into account factors such as passenger experience, environmental impact, and economic development.

Through these multi-layered oversight measures, the IM and its stakeholders strive to ensure that the benefits of infrastructure investments extend beyond the narrow confines of individual organisational interests and contribute to the rail system's overall performance and sustainability.

*******SNCF Réseau investment project for the Roissy-Picardie railway link ******

The project's compliance with specific investment thresholds set by legislation and decrees, particularly those established for projects exceeding 200 million euros. The Authority, ART, has a mandate to pre-emptively ensure the financial equilibrium and credible planning of such large-scale investments. The project entails two phases: the creation of a new 65-km railway line, station adjustments, and signal modifications with an initial phase completion planned for 2027, and a second phase aimed at increasing capacity on the existing Paris-Creil line at a future date.

ART plays a crucial role in overseeing the system-wide benefit of infrastructure investment by:

- Pre-emptive Financial Evaluation: ART is mandated to evaluate financial plans for large-scale investments like the Roissy-Picardie railway link before they are undertaken to ensure financial equilibrium and credible planning. This pre-emptive check helps to ensure that projects are financially viable and beneficial to the system as a whole.
- Compliance Checks: ART checks the project's compliance with investment thresholds and legislative requirements. This ensures that the investment aligns with national transport policy and legal frameworks, which are designed to deliver system-level benefits.
- Financial Oversight: ART's opinion in the document outlines that the IM is not to financially contribute to the project costs until a set date, and under certain conditions. This oversight role ensures that financial risks are balanced and that the IM's economic stability is not compromised by the investment.
- Project Cost Analysis: ART engages in analysing the revised cost estimates for the project, which is essential for keeping the project within reasonable financial limits and preventing cost overruns that could negatively impact the system.
- Risk Assessment: By evaluating different risk scenarios, ART assists in understanding the potential impacts on traffic and costs, which can directly affect system-level benefits and sustainability of the project.

Concerning the other mechanisms that may help with the system-level benefit achievement for this particular case study, the following point is mentioned in the document:

- Financial Documentation Revisions: The document suggests that contractual documentation be revised to confirm that the IM will not bear any financial investment costs, which implies a mechanism for protecting the entity's financial health and ensuring the investment's intended benefits are not undermined by financial burdens.
- Negotiations for Funding: The challenges of financing, particularly with the rejection of European funding and the need for negotiations between territorial communities and the state, suggest a collaborative oversight mechanism. Such collaboration can help in sourcing investment funds while maintaining the focus on delivering system-wide benefits.
- Clear Contractual Agreements: The emphasis on clear contractual documentation ensures that all parties involved are aware of their financial commitments and roles, which is a crucial oversight mechanism for the transparent and effective delivery of infrastructure investments.

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b. *As the parent company, SNCF should have the responsibility to ensure the coordination between the operators (i.e. SNCF Voyageurs and Fret SNCF) and the IM. Except for such a management scheme, what else do you think may incentivise the IM to coordinate with the operators to deliver the investment on the network (i.e. enhancement and renewal of the network)? Is there any circumstance that such coordination doesn't work well?*

As a pivotal entity within the French rail system, the IM's mandate goes beyond mere compliance with regulatory requirements; it seeks to foster a synergistic relationship with operators such as SNCF Voyageurs and Fret SNCF. While SNCF Holding does not exercise direct power over operational coordination, its role as the parent company is foundational in establishing an overarching vision and strategic direction for the subsidiaries. This indirectly influences the IM to ensure alignment and coherence in its interactions with train operators.

Incentives for the IM to collaborate effectively with the operators include the pursuit of increased network utilisation and the enhancement of the customer experience. A harmonious relationship and clear communication channels are essential for understanding and effectively responding to the operational needs of the operators, which in turn, drives network enhancements and renewal efforts. Building a trustful relationship with operators is also strategically beneficial for the IM, as it can lead to increased train traffic, higher service levels, and ultimately, stronger financial performance for the entire SNCF group.

However, there are circumstances where coordination may face challenges. One such scenario could be when operational priorities diverge or when there is a misalignment of strategic goals between the IM and the operators. Another potential challenge arises in the context of external factors such as regulatory changes, market competition, or shifts in passenger demand, which can complicate the planning and execution of infrastructure investments. In addressing these challenges, the IM remains committed to engaging with the French regulator and leveraging its guidance to maintain system-wide benefits. This commitment to collaboration, bolstered by a regulatory framework, ensures that even when difficulties arise, the parties involved strive to resolve them in the best interest of the network and its users.

3. *This question is mainly about the potential demand impact of rail structural reform.*

   a. *Do you think the rail passengers in France are more sensitive to change in any particular factor(s), such as price, service quality, reliability, and safety?*

Rail passengers in France, much like their counterparts globally, have discerning preferences that are influenced by a variety of factors, with price, service quality, reliability, and safety being chief among them. It is essential to acknowledge that the financial backbone of the French rail infrastructure, which encompasses maintenance and renewal, is significantly supported by train access charges and, to a lesser extent, by direct investment.

This empirical evidence, drawn from sophisticated traffic modelling, suggests that the decision-making process of passengers when choosing their mode of transport is multifaceted. Travelers weigh their options based on the nature of their journey, available multimodal alternatives, competitive offerings, travel duration, and the overarching quality of service, which for the IM, hinges primarily on route quality and timeliness. To illustrate, passengers travelling long distances tend to have a heightened sensitivity to travel time and cost. A faster journey at a reasonable price is typically their priority. Conversely, those travelling shorter distances prioritise frequency of service. They value the ability to depart and arrive at their convenience, making regular and reliable service paramount. Additionally, there is a growing environmental consciousness among passengers, who are increasingly factoring in the ecological footprint of their travel choices.

This detailed sensitivity to various factors underscores the complexity of passenger preferences and highlights the need for a tailored approach to service provision. It also suggests that any structural reform within the rail industry must take into consideration these diverse priorities to ensure that the demand for rail travel is not only preserved but also enhanced.

b. *Do you think any of the above factors changed significantly due to rail structural reform?*

Regarding the introduction of competition within the rail market, it is indeed too soon to definitively gauge its long-term effects on demand. Nevertheless, in the short term, we have witnessed a discernible influence on pricing structures. Competitive pressures have led to more dynamic pricing strategies, which could potentially reshape passenger demand patterns over time. Passengers may become more price-sensitive as they are presented with a broader array of choices, or they may value service quality and reliability even more if the market offers a range of options.

c. *Do you think the rail structural reform impacts passengers' travel behaviour/preference, i.e. change their demand response to the factors above?*

The impact of rail structural reforms on passenger travel behaviour and preferences is a multifaceted issue. When examining the separation of infrastructure management from transportation services — such as the split between RFF and now the IM, and operators like SNCF Voyageurs or Fret SNCF — the observations suggest that there have not been significant shifts in demand price elasticity. In essence, the restructuring has not led to dramatic changes in how passengers respond to price adjustments.

It is important to note that the continuity in demand response may be attributable to the fact that, from a passenger perspective, the core aspects of rail travel – such as service frequency, reliability, and pricing – remained relatively constant through this organisational transformation. The division was more about internal governance and efficiency rather than a direct alteration of the passenger experience.

While the immediate visibility of these reforms on passenger behaviour may be limited, the evolving landscape suggests that continued monitoring is essential. As the competitive environment matures, we expect more pronounced variations in passenger travel patterns to emerge. It will be crucial to analyse these changes over time to fully understand the demand responses and to adjust service offerings accordingly to meet the evolving needs and preferences of rail passengers.

4. *This series of questions aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

   a. *In the daily operation, how does the IM ensure efficient coordination with the operators in daily train operations especially when a disruption on the network) occurs?*

   This is one of the IM's functions. If more information is needed on this topic, we would have to check with the operations direction.

   b. *Do you think the IM coordinate with SNCF Voyageurs/Fret SNCF better than the other operators on the network? How does the IM avoid discrimination on the network (i.e. fair track access)?*

   At the IM, we adhere to strict regulations and internal policies to ensure that all rail operators, including SNCF Voyageurs and Fret SNCF, are treated equitably. This is crucial for maintaining a fair and competitive railway network. the commitment to non-discrimination is not just a statutory obligation but a foundational principle of the operations.

   In terms of coordination, while the IM operates near SNCF Voyageurs and Fret SNCF due to historical and operational linkages, we extend the same level of collaboration and communication to all operators on the network. The established procedures and the transparent mechanism of the train access charges are designed to prevent any unfair advantages. We have a system in place where new operators can negotiate access charges, a feature that demonstrates the flexibility and commitment to fostering a competitive environment.

To further facilitate fair access, we provide a comprehensive catalogue of services, which is openly available to all train operators. This catalogue details various services and amenities that operators can avail themselves of, ensuring they have the necessary resources to access the network efficiently. Moreover, regular audits and oversight by regulatory authorities, including the French Transport Regulator (ART), help us maintain transparency and non-discriminatory practices. These audits ensure that the operations, including track access allocations and charge structures, comply with fairness principles.

In summary, the IM is committed to impartiality in all interactions with rail undertakings and continues to evolve its practices to uphold and strengthen this stance, thereby ensuring fair track access and promoting a healthy competitive environment within the French rail network.

Survey Response from the French Railway (RU)

Questions

1. *Public transport infrastructure planning based on social cost-benefit analysis and broader policy aims is common in Europe. This series of questions concerns the planning stage before implementing an infrastructure investment.*

   a. *Do you think the RU contribute significantly to the cost-benefit analysis of the planning stage of an infrastructure investment? If so, can you identify the areas the RU currently contribute and should contribute more in the future?*

   The RU, under the SNCF umbrella, actively participates in the socioeconomic studies of the IM's infrastructure projects, frequently attending meetings to stay updated on outcomes. However, within the RU, the focus is predominantly on financial analysis for any given project. Enhancing the socioeconomic analysis could be achieved by incorporating actual charges and pricing information.

   It's crucial to understand that, despite being part of the same parent company, SNCF, the IM and RU operate with separate accounting systems. This structural division means that their financial objectives differ. For instance, if the RU incurs losses from an investment project, these are not offset by the IM. This distinct financial approach could explain why there isn't a complete exchange of information between the two entities regarding Cost-Benefit Analysis (CBA). Each company, given their unique financial targets, may have differing perspectives on the CBA, which aligns with the interviewee's observations about the selective sharing of information by the IM.

   b. *Do you think the feedback from the RU plays a vital role in helping the IM inspect the infrastructure issues on the current network (i.e. the ones that can lead to a disruption in the operation)? Do you think such feedback contributes to SNCF's strategic planning of infrastructure investment?*

   Certainly, feedback from the RU is instrumental in aiding the IM with the inspection and identification of infrastructure issues within the current rail network, particularly those that could lead to operational disruptions. In every instance of a network disruption, a specialised committee is convened. This committee's primary role is to collect and analyse various data points, including potential causes, the impact on resources, and the broader consequences for operators.

   This process of meticulous data gathering and analysis is not just reactive but also feeds into the strategic planning for future infrastructure investments. By understanding the intricacies of past disruptions, the IM can better anticipate potential challenges and allocate resources more effectively. In this way, the feedback from the RU not only addresses immediate operational concerns but also contributes to a more resilient and efficient network in the long term. The collaboration between The IM and RU in these committees exemplifies a proactive approach to both problem-solving and strategic infrastructure planning.

c. *Do you think the cost-benefit analysis contributes significantly to the cost efficiency and value of money of an infrastructure investment project? What are the other elements (i.e. regulation) in the rail system that may influence the cost efficiency and value for money of infrastructure investment?*

Certainly, cost-benefit analysis (CBA) is a crucial factor in enhancing cost efficiency and value for money in infrastructure investment projects. The primary goal of CBA is to gauge the overall utility of an investment, not just for the network manager and rail operators, but also for society at large. This includes considering external factors like environmental and social impacts. Other crucial elements influencing cost efficiency and value for money include charges for operators, costs associated with energy efficiency, and the economic impacts of disruptions to interconnected networks.

Regarding the additional point about cooperation from external parties, it's notable that the process can be complex and fraught with challenges. In the case of the HS2 project in the UK, there have been significant concerns regarding the compensation rates for land acquisition. Reports[32] suggest that the project has been over budget, with questionable methods used in calculating land acquisition costs and compensation claims. The principle of "equivalence" in compulsory purchase is meant to ensure fair compensation, but often, landowners and businesses feel they are undercompensated.

This situation highlights the complexity of external cooperation in infrastructure projects, where legal, policy and financial considerations intertwine, impacting the efficiency and value of the investment.

2. *System-wide benefit (total benefits for the rail system) has been argued as the main challenge for unbundled structure, i.e. each party only focus on their benefit from the infrastructure investment. This series of questions aims to investigate the potential challenge to achieve system-wide optimal benefits in different stages of the investment.*

a. *Do you think that regulation from the government and regulator can ensure the system-level benefit is considered in the planning stage of the investment? Are there any mechanisms (i.e. internal/external consultation) that help to deliver system-level benefits in the investment implementation stage?*

Government regulations and oversight from regulators indeed play a pivotal role in ensuring system-level benefits are considered during the planning stages of infrastructure investments. In France, the authority for transport regulation

[32] https://www.wrighthassall.co.uk/knowledge-base/hs2-the-compensation-conundrum

mandates a counter-expertise analysis for transport investments exceeding 100 million euros. This process is part of ensuring a comprehensive evaluation of the project's utility at both regional and European levels. The European Commission may also review the project's utility, especially for significant investments.

The Act of 31 December 2012 about Public Finance Planning in France requires project sponsors to conduct an ex-ante socioeconomic evaluation for all public civil investments made by the State and its public institutions. For the largest projects, an independent counter-expert assessment of this evaluation is conducted. Additionally, a permanent committee of experts has been established to define the methodological rules for socioeconomic evaluation and to determine the necessary studies and research[33].

In the implementation stage, mechanisms like internal and external consultations help deliver system-level benefits. These include dialogues with stakeholders, assessments by independent experts, and reviews by regulatory bodies to ensure that the project aligns with broader social, economic, and environmental goals.

b. *What do you think incentivises the IM to coordinate with the RU to deliver the investment (i.e. consider the RU's requirements and benefits)? Is there any circumstance that such schemes don't work well?*

   Answer is missing here.

3. *This question is mainly about the potential demand impact of rail structural reform.*

   a. *Do you think the rail passengers in France are more sensitive to change in any of the following particular factors: price, service quality, reliability, and safety?*

      Transport modelling indicates that French rail passengers are responsive to a variety of factors, including price, service quality, reliability, and safety, though their sensitivity to these factors differs based on the purpose of their trip. Generally, for long-distance travel, price and reliability are the most critical factors influencing passenger decisions. In contrast, for short-distance trips, while these factors remain important, other aspects such as frequency of service and connection times also significantly impact travellers' choices. This variation in sensitivity highlights the need for a detailed approach to addressing passenger needs, tailoring services according to the distance and purpose of travel.

   b. *Do you think any of the above factors changed significantly due to rail structural reform? For example, are there cases like separate the IM and RU that lead to price increase/decrease or service quality improvement/decline?*

[33] Baumstark, L., Guesnerie, R., Ni, J., & Ourliac, J. (2021). Cost–Benefit Assessment of Public Investments in France: The Use of Counter-Experts. Journal of Benefit-Cost Analysis, 12(1), 152-169. doi:10.1017/bca.2020.30

The structural reforms in the French rail sector announced in early 2018, have significantly impacted various aspects of the railway system, including pricing and service quality. One of the major changes was the opening of the railway system to competition and the transformation of SNCF into a national company with public-sector capital. This reform has led to the introduction of new operators in the market, with Italian State Railways (FS) as a notable example, set to launch high-speed trains on the Paris - Milan route in competition with SNCF.

In the short term, these reforms have resulted in new operators like FS offering lower charges than the RU, leading to more competitive pricing for consumers. This trend is expected to last for the first three years, marking a significant shift in the rail market dynamics. In terms of service quality, the IM 's commitment to treating all operators equitably implies that the reforms should not negatively impact service standards. This equitable treatment ensures consistent service quality across all operators, regardless of the recent structural changes in the rail system.

c. *Do you think the rail structural reform impacts passengers' travel behaviour/preference? For example, are there cases like separate the IM and RU that lead to fewer/more business/leisure trips or passengers are more sensitive to the price/reliability changes?*

The structural reform in the French rail system, notably the separation of the IM and RU and the introduction of competition, has potential implications for passengers' travel behaviour and preferences. As mentioned earlier, the introduction of new operators in the market, such as Italian State Railways (FS), has led to a decrease in average ticket prices. This cost reduction could incentivise more people to travel by rail, whether for business or leisure purposes. Long-distance passengers, in particular, tend to be more sensitive to price changes. Therefore, the reform's impact on pricing is likely to make rail travel more attractive and accessible, possibly leading to an increase in the number of rail trips. Additionally, as competition often leads to improvements in service quality and reliability, passengers might also be more inclined to choose rail travel due to enhanced service standards.

4. *This series of questions aims to investigate the difference in coordination between rail undertaking (RU) and infrastructure management (IM) in different separation policies.*

a. *In the daily operation, how does the RU ensure efficient coordination with the IM in daily train operations especially when a disruption on the network occurs?*

In daily operations, the RU maintains efficient coordination with the IM, especially during network disruptions. This process involves a reciprocal exchange of detailed information. When a disruption occurs, the RU informs the IM and, in turn, receives updates about the implications of the disruption, including delays, cancellations, and any necessary route changes. This communication includes both the causes of the disruption and the anticipated timeline for resolution. Importantly, this level of interaction and information sharing is standard and applies equally to the RU and any other future rail operators, ensuring consistent and effective coordination across the network.

b. *Do you think the RU coordinates with the IM better or worse than the other operators on the network? If not, do you think that is due to the fair track access charge or any other particular reasons?*

   There is no difference in the coordination between the IM and all the operators in the rail transport market.

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