# Study on the Cost and Contribution of the Rail Sector

European Commission
Directorate General for Mobility and Transport

Final Report
September 2015

Our ref: 22783801
Client ref: MOVE/B2/2014-761

Prepared by Steer Davies Gleave

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# 1 Introduction

## Background

1.1 The rail sector makes a substantial contribution to the European Union (EU) economy, directly employing 577,000 people across passenger and freight operations and the provision of track and station infrastructure[1]. Some estimates suggest that, once the entire supply chain for rail services is taken into account (e.g. including train manufacturing, catering services etc.), the economic footprint of the rail sector in Europe extends to 2.3 million employees and €143 billion of Gross Value Added (some 1.1% of the total)[2]. It is also critical to the EU strategy for improving economic and social cohesion and connectivity within and between Member States, including through the further development of the TEN-T rail corridors, and is expected to play a major role in the reduction of carbon and other emissions from transport. The development of the sector has been encouraged over a period of more than 20 years through the implementation of an extensive legislative framework, including three major packages of legislation, and a fourth package currently being considered by the European Council and Parliament.

1.2 Accordingly, the 2011 White Paper, *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*, envisages much greater use of rail transport in the future. More specifically, the White Paper includes a number of rail-related objectives supporting a more efficient and sustainable transport system for the EU, in particular:

- 30% of road freight over 300km shifting to other modes by 2030, and 50% by 2050;
- Completion of the European high speed rail network by 2050, and maintaining a dense rail network in all Member States;
- By 2050 the majority of medium-distance passenger transport should go by rail;
- A fully functional TEN-T core network by 2030, with a high quality/capacity network by 2050;
- Connection of all core network airports to the rail network (ideally the high speed network) by 2050;
- Deployment of the European Rail Traffic Management System (ERTMS);
- The establishment of the framework for a European multimodal information, management and payment system by 2020; and
- Full application of user pays/polluter pays principles in transport.

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[1] *EU Transport in Figures: Statistical Pocketbook 2015* (European Commission)

[2] *The Economic Footprint of Railway Transport in Europe* (CER, 2014)

1.3 However, while the rail sector has achieved significant volume growth in recent years, rail's modal share remains below expectations, accounting for only 6.6% of passenger km and 10.8% of tonne-km within the EU28 in 2012[3]. These average shares reflect a wide range of experience in different Member States, but are generally considered symptomatic of an overall lack of competitiveness driven by insufficient investment and inadequate customer-focused innovation across the EU (notwithstanding that the sector also absorbs at least €36 billion of public funds annually, some €80 for every European citizen)[4].

1.4 As a result of these and other factors, rail has failed to challenge the dominance of road in both freight and passenger transport and, despite the considerable growth of high speed networks, has been unable to arrest the small but steady increase in the share of short to medium distance passenger transport taken by aviation since the mid-1990s. Moreover, ongoing constraints on the availability of public funds following the financial crisis are expected to reduce the traditional resources available for rail investment in a number of Member States.

1.5 Therefore it is opportune to look in depth at how different national rail systems have performed over recent years, and to learn from the best how to improve the efficiency of railways.

## Study objectives and methodology

### Study objectives

1.6 Against this background, the primary objectives of this study are to:

- provide a 'broad brush' analysis of the trends in overall performance of different national rail systems; and
- conduct a scenario analysis assessing the potential societal benefits of a better performing rail sector.

1.7 In meeting these objectives, the study encompasses:

- An analysis of recent trends in passenger and freight volumes as well as associated fare levels and revenues;
- A review of operating and capital expenditure, recognising that this may be incurred by train operators, infrastructure managers and other parties, and of the related flow of funding between rail sector stakeholders;
- Estimation of the contribution of the sector according to a range of economic, social and sustainability metrics including GVA, employment and emissions; and
- An analysis of sector efficiency, based on measures of asset utilisation and indicators of financial performance.

### Overview of methodology

1.8 The methodology developed to meet the study objectives is broadly sequential, although there is, necessarily, some iteration required between analytical steps described below.

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[3] *EU Transport in Figures: Statistical Pocketbook 2015* (European Commission) – includes non-surface modes

[4] *Fourth Report on Monitoring Development of the Rail Market* (European Commission, 2014)

1.9 The first step was to collect and harmonise data for all Member States that have a rail network (i.e. excluding Malta and Cyprus). This included demographic and economic data, indicators of rail sector resources and the value added by rail. This data was then used to generate primary and secondary Key Performance Indicators (KPIs), which measure the performance of an economic entity (in this case Member State railways) and allow comparability over time as well as against other entities. KPIs are typically ratios of key outputs to inputs, but can also be measures of service quality derived, for example, from customer surveys. Our approach to selecting and finalising KPIs for this study was based on the following criteria:

- Adherence to policy goals (do the KPIs match the policy levers available to the Commission to improve performance?);
- Literature review (which input and output measures have been successfully identified and analysed in past studies?); and
- Data availability (obtaining good quality, comparable data on railway operations across the whole of the European Union is challenging).

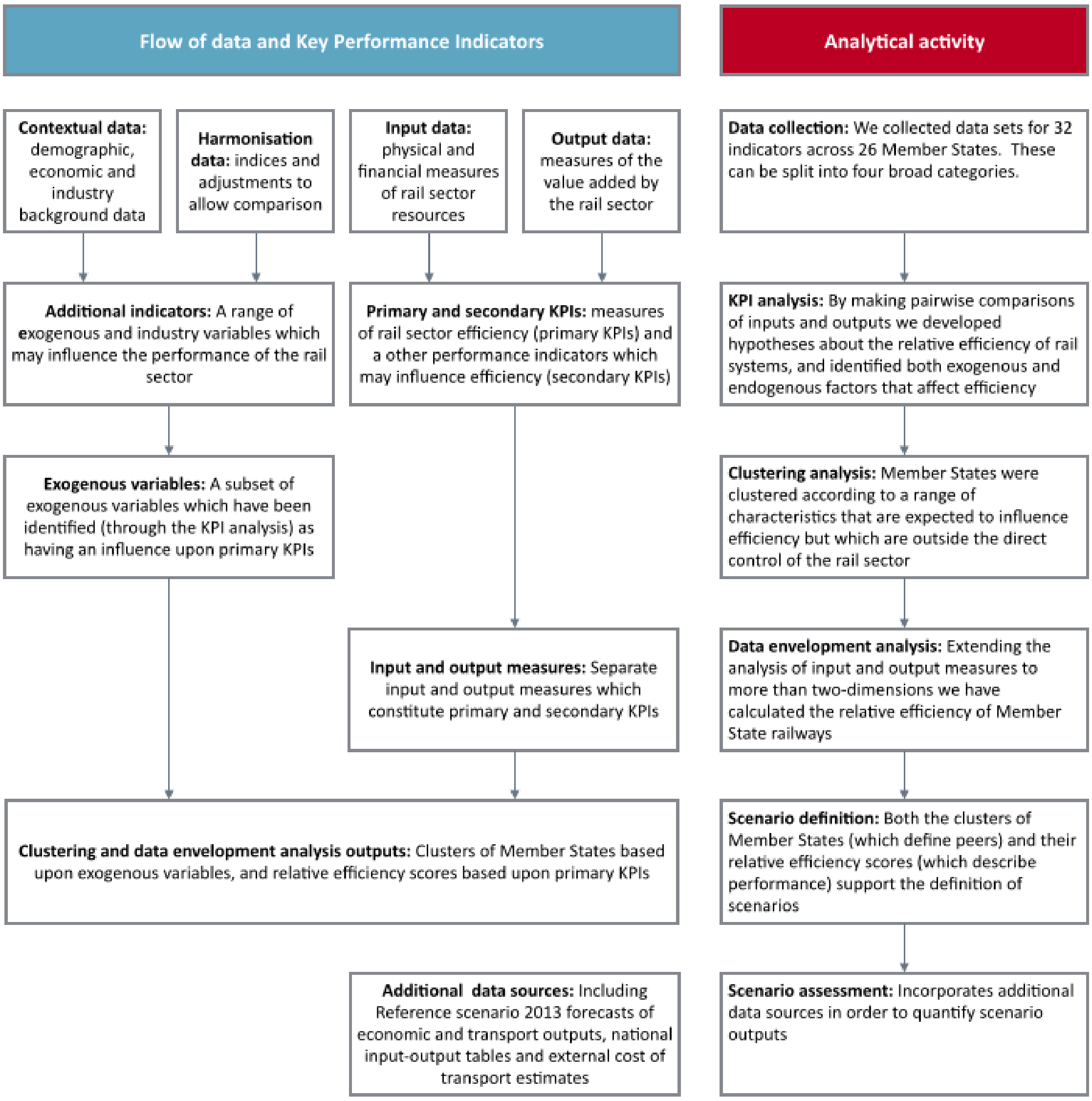
1.10 We then analysed relationships between primary and secondary KPIs, and a range of exogenous variables in order to inform the subsequent clustering exercise. This step is intended to control for the variation in the performance of Member State rail systems that could be attributed to exogenous factors. Clustering analysis is conducive to achieving two objectives: first, to establish a basic categorisation of national rail systems for the purpose of the current analysis and to inform future benchmarking exercises at the EU level; and secondly, to increase the discriminatory power of the efficiency analysis which follows by reducing the heterogeneity of the sample.

1.11 A technique called data envelopment analysis (DEA) was then used to measure the technical efficiency gap between rail systems. Given a set of inputs (e.g. rail sector employees, track-km) and outputs (e.g. passenger-km, train-km), DEA fits an efficiency frontier which envelops the data. In specifying the DEA analysis, the choice of inputs and outputs was determined to match the capital efficiency measures established in the analysis of KPIs.

1.12 Finally, both the outputs of the clustering exercise and the DEA were used to define the scope of achievable efficiency improvements. Further assumptions were required regarding the timescales over which these improvements can be made and the mechanisms through which they can be achieved (informed by consideration of secondary KPIs and additional indicators). Supplementary data sources and analyses were then used to quantify the impact of efficiency improvements over time, on a range of economic and social indicators.

1.13 Figure 1.1 illustrates the broad structure of the analytical framework that has been developed to meet the objectives described above. It indicates how we have ensured internal consistency across each phase of analytical work and, in particular, the clustering, DEA and scenario analysis.

**Figure 1.1: The analytical framework**




## Organisation of this report

1.14 This remainder of this report is organised according to the following structure, which aligns with the methodology described above:

- Chapter 2: Data collection and harmonisation
- Chapter 3: Development of Key Performance Indicators
- Chapter 4: Clustering analysis
- Chapter 5: Measuring the efficiency gap
- Chapter 6: Scenario assessment
- Chapter 7: Policy implications.

# 2 Data collection

## Overview

2.1 In order to understand the nature and performance of railways across Member States, we undertook an extensive data collection and harmonisation exercise. As summarised in Table 2.1, we have collected data sets for 32 indicators across 26 Member States.

**Table 2.1: Summary of study data**

| Contextual and infrastructure data | Harmonisation data | Rail sector data |
|---|---|---|
| Area | Currencies (average) | Freight rolling stock |
| Border countries | Currencies (year-end) | Passenger rolling stock |
| Urban population | Market share | Employees |
| Ports linked by rail | | Operating costs |
| TEN corridors | | Public subsidies |
| Cost of congestion | | Passenger revenue |
| Rail Satisfaction | | Freight revenue |
| Population | | Train kilometres |
| GDP per capita | | Rail passenger kilometres |
| Registered cars | | Rail tonne kilometres |
| Motorways | | Rail mode share |
| Total passenger kilometres | | |
| Total tonne kilometres | | |
| Road fatalities | | |
| Rail fatalities | | |
| In-use rail network track kilometres | | |
| High speed rail network kilometres | | |
| Electrified rail network kilometres | | |

2.2 This chapter provides an overview of the data collection process, and provides commentary regarding the quality of data collected. It describes the following stages of the data collection, collation and review process:

- **Contextual and infrastructure data**: the sources of the demographic, economic and infrastructure data used to understand the context in which each Member State's rail network operates.
- **Harmonisation data**: the data used to ensure comparability between Member States, and the approach to making comparisons where the data was incomplete (as in the case of rail market share).

- **Input and output data**: the data collected to understand the resources used by, and the outputs from, each rail system. The inputs are expressed in terms of rolling stock, employees, operational costs and subsidy, with outputs measured in terms of revenues, passenger kilometres, tonne kilometres and mode share.
- **Data limitations and gaps**: issues encountered in seeking to collect a complete data set (covering all indicators across all Member States and years) and the actions taken to address these as far as possible.
- **Country specific issues:** the key data-related issues that are particular to each Member State, and the actions taken to address these.
- **Quality assurance:** the measures we have taken to ensure that the data set is as robust as possible given the scope of, and timescales for, the study.
- **Rail industry characteristics and trends**: presentation of trends in key input and output indicators over time.

2.3 We have obtained data for the period 2003 to 2013 wherever possible. For a number of reasons, however, we have focussed our subsequent analysis on the period 2007 to 2012. In particular:

- Member States were only captured within the dataset from the year of their accession to the European Union. Since 11 Member States considered in this study joined after 2004, it is not possible to draw meaningful comparisons before this point.
- Where it exists, data from primary sources prior to 2007 is increasingly difficult to access and interpret through time.
- Non-statutory third-party datasets (such as that provided by the International Union of Railways), while often being the only consistently available source, suffer from coverage and self-selection bias.
- Data release schedules mean that comprehensive data for 2013 has been difficult to obtain.

2.4 For some indicators, such as “Country Area”, we have only collected data for one year, since we would not expect any material changes in the value of the indicator over a 10-year period. For a small number of data series (for example, total passenger kilometres and mode share) it has been necessary to use secondary data sources to calculate indicators for some Member States.

2.5 In line with the study requirements we have attempted to capture at least 90% of all activity across freight and passenger railway undertakings and infrastructure providers.

## Data collection

### Contextual and infrastructure data

2.6 A summary of the contextual and infrastructure related data that we have collected for this study is provided in Table 2.2.

**Table 2.2: Contextual and Infrastructure Data**

| Data | Unit | Date(s) | Source | Comment |
|---|---|---|---|---|
| **CONTEXTUAL DATA** | | | | |
| Area | $Km^2$ | 2013 | CIA Factbook | It has been assumed this data has not changed significantly between 2003-14 |
| Border countries | Number | 2013 | CIA Factbook | |
| Urban population | % | 2013 | Eurostat | |
| Ports linked by rail | Number | 2013 | EU TENtec | |
| TEN corridors | Number | 2013 | EU TENtec | |
| Cost of congestion | €m | 2010 | PRIMES model | Data limited to 2010 |
| Rail Satisfaction | % satisfied | 2012 | Eurobarometer | Data limited to 2012 |
| Population | Million people | 2003-13 | EU Statistical Pocketbook | |
| GDP per capita | € | 2006-13 | Eurostat | In real terms |
| Registered cars | Thousand cars | 2003-12 | EU Statistical Pocketbook | |
| Motorways | Length in km | 2003-11 | EU Statistical Pocketbook | Definitions of "motorway" vary by Member State |
| Total passenger kilometres | Billion passenger km | 2003-12 | EU Statistical Pocketbook | Sum of passenger km for car, bus, coach, tram and rail |
| Total tonne kilometres | Billion tonne km | 2003-12 | EU Statistical Pocketbook | Sum of road, rail and inland waterway tonne km |
| Road fatalities | Fatalities | 2003-12 | EU Statistical Pocketbook | |
| Rail fatalities | Fatalities | 2003-12 | EU Statistical Pocketbook | |
| **INFRASTRUCTURE DATA** | | | | |
| In-use rail network (line length) | Length in km | 2003-12 | EU Statistical Pocketbook | |
| High speed rail network | Length in km | 2003-13 | EU Statistical Pocketbook | High speed is defined as >250 km per hour |
| Electrified rail network | Length in km | 2007-12 | EU Statistical Pocketbook | |

2.7 We are satisfied that the data summarised in Table 2.2 is sufficiently consistent and complete for the purposes of this study. There are a small number of apparent anomalies in some data sets. For example, the Italian High Speed Rail network appears to have reduced in size between 2006 and 2007. However, we do not believe that these inconsistencies will have any material impact on the study.

### Harmonisation data

2.8 We have also collected the information to enable us to understand the comparability of the Member State data sets, as shown in Table 2.3. This data includes estimates for the market share of the passenger and freight markets (based on RMMS estimates), which can be used to adjust financial totals for Member States for which complete data is not available.

**Table 2.3: Harmonisation Data**

| Data | Unit | Date(s) | Source | Comment |
|---|---|---|---|---|
| Currencies (average) | € | 2007-2012 | European Central Bank | Used to convert all non € financial data except debt |
| Currencies (year-end) | € | 2007-2012 | European Central Bank | Used to convert € debt data |
| Market share | % | 2006, 2008, 2010 & 2012 | RMMS | Used to adjust incomplete data sets |

### Input and output data

2.9 We have defined "inputs" as the resources that are used to deliver rail transport outputs. These include rolling stock, operating costs (of both railway undertakings and infrastructure managers) and employees. A summary of the input and output data that we have collected is provided in Table 2.4.

**Table 2.4: Input and Output Data**

| Data | Unit | Date(s) | Source | Comment |
|---|---|---|---|---|
| **INPUT DATA** | | | | |
| Freight rolling stock | Wagons | 2003-12 | EU Statistical Pocketbook<br>European Rail Agency | Stock of vehicles |
| Passenger rolling stock | Vehicles | 2003-12 | EU Statistical Pocketbook | Stock of coaches, railcars and trailers |
| Employees | Full Time Equivalent | 2003-13 | See Table 2.5 | |
| Operating costs | €m per annum | 2003-13 | See Table 2.5 | Includes infrastructure manager and railway undertakings, net of track access charges |
| Public subsidies | €m per annum | 2003-13 | See Table 2.5 | Includes public service contracts and concessions, freight operator grants and grants to infrastructure managers. Excludes public funding for capital projects |
| **OUTPUT DATA** | | | | |
| Passenger revenue | €m per annum | 2003-13 | See Table 2.5 | Includes all farebox income for passenger operators. For UIC data, subsidy has been excluded from total revenue |
| Freight revenue | €m per annum | 2003-13 | See Table 2.5 | |
| Train kilometres | Million train km | 2007-12 | UIC Database | |
| Rail passenger kilometres | Billion passenger km | 2003-12 | EU Statistical Pocketbook | |

| | | | | |
|---|---|---|---|---|
| Rail tonne kilometres | Billion tonne km | 2003-12 | EU Statistical Pocketbook | |
| Rail mode share (split into freight and passenger) | % | 2003-12 | EU Statistical Pocketbook and calculations by SDG (which align) | Ratio of rail passenger or tonne kilometres to total passenger or tonne kilometres (across all modes) |

2.10 Very little financial and staffing data was available from the sources listed in Table 2.4. In order to fill these gaps, we commissioned a group of country experts to investigate each Member State. In most cases, this involved studying the Annual Reports and Accounts for the largest Infrastructure Managers and Operators in each country. A summary of the data sources used to complete the country data sets is provided in Table 2.5.

**Table 2.5: Financial and Staffing Data Sources**

| MS | Source | Source Type | Year(s) | Revenue | Costs | Staffing | Debt |
|---|---|---|---|---|---|---|---|
| AT | OBB | Annual Reports | 2003-12 | ✓ | ✓ | ✓ | ✓ |
| BE | Infrabel | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| BE | SNCB | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| BG | DB Schenker | Company Website | 2013 | ✓ | | | |
| BG | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | ✓ |
| CZ | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | |
| DE | DB AG | Annual Reports | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| DK | DB Schenker | Company Website | 2013 | ✓ | | | |
| DK | Banedanmark | Regulatory Accounts | 2003-13 | ✓ | | ✓ | |
| DK | DSB | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| EE | UIC | Database | 2009-12 | ✓ | ✓ | ✓ | |
| EL | OSE | Regulatory Accounts | 2006-13 | ✓ | | | ✓ |
| EL | TrainOSE | Regulatory Accounts | 2006-13 | ✓ | ✓ | | ✓ |
| EL | UIC | Database | 2007-13 | ✓ | ✓ | ✓ | |
| ES | ADIF | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | |
| ES | DB Schenker | Company Website | 2013 | ✓ | | | |
| ES | RENFE | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | |
| FI | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | |
| FI | RMMS | Survey Data | 2013 | | | ✓ | |
| FR | DB Schenker | Company Website | 2013 | ✓ | | | |
| FR | RFF | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| FR | SNCF | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| HU | DB Schenker | Company Website | 2014 | ✓ | | | |
| HU | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | |
| IE | Iarnród Éireann | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| IT | DB Schenker | Company Website | 2014 | ✓ | | | |
| IT | Arrigo, Di Foggia | Academic Paper | 2003-13 | ✓ | | | |
| IT | Corte dei Conti | Publication | 2003-12 | | | | ✓ |
| IT | Eurofound | Statistical bulletin | 2005 | | | ✓ | |
| IT | FS Group | Regulatory Accounts | 2003-12 | ✓ | ✓ | | |
| IT | NTV | Regulatory Accounts | 2011-12 | ✓ | ✓ | | |
| IT | UIC | Database | 2003-12 | ✓ | ✓ | ✓ | |
| IT | Wikipedia | Article | 2007-08 | ✓ | | | |
| LT | UIC | Database | 2009-12 | ✓ | ✓ | ✓ | |
| LU | CFR | Annual Report | 2007-12 | ✓ | | ✓ | ✓ |
| LV | UIC | Database | 2009-12 | ✓ | ✓ | ✓ | ✓ |
| NL | DB Schenker | Company Website | 2014 | ✓ | | | |
| NL | NS | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | |
| NL | Prorail | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| PL | DB Schenker | Company Website | 2013 | ✓ | | | |
| PL | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | ✓ |
| PT | CP | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | |

| MS | Source | Source Type | Year(s) | Revenue | Costs | Staffing | Debt |
|---|---|---|---|---|---|---|---|
| PT | REFER | Regulatory Accounts | 2003-13 | ✓ | ✓ | ✓ | |
| RO | DB Schenker | Company Website | 2013 | ✓ | | | |
| RO | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | |
| SE | Banverkets | Regulatory Accounts | 2004-09 | ✓ | ✓ | ✓ | |
| SE | RMMS | Survey Data | 2009-12 | | | | ✓ |
| SE | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | |
| SK | UIC | Database | 2007-12 | ✓ | ✓ | ✓ | ✓ |
| UK | BRES | Labour statistics | 2003-13 | | | ✓ | |
| UK | DB Schenker | Company Website | 2013 | ✓ | | | |
| UK | DRDNI | Regulatory accounts | 2003-13 | ✓ | | | |
| UK | Network Rail | Regulatory accounts | 2003-13 | ✓ | ✓ | ✓ | ✓ |
| UK | ORR | Data portal reports | 2003-13 | ✓ | ✓ | | |
| UK | Uni. Leeds | Academic paper | 2007-09 | | | ✓ | |

## Addressing data limitations and gaps

### Summary of key limitations and gaps

2.11 While the process outlined above enabled us to fill in a number of gaps, we were not able to compile a complete data set for all Member States. The principal outstanding gaps and limitations are summarised below.

- Not all private sector operators (particularly freight operators) report at a Member State level. In part, this is because many transport operators prefer to present their regulatory accounts as consolidated accounts, which often combine modes and/or markets. We were able to obtain a very small amount of country specific data from some operators (for example, DB Schenker for the year 2013). However, this data is insufficient to allow an analysis of trends over time. In order to address this issue, we used RMMS data to estimate the proportion of the market captured by the data collected. We then inflated incomplete totals (notably for revenues and operating costs) on the basis of the associated estimates of missing values. This issue relates only to operators and not to infrastructure managers.
- Employee data usually does not include employees who work for sub-contractors or agencies. Additionally, some organisations report their staffing data on a Full Time Equivalent (FTE) basis, while others simply report the number of employees. The absence of supply chain and, in most cases, smaller operator data from our database leads us to believe that the total employment figures represent an underestimate. We have been able to cross-reference some Member State data with other published data. For example, our UK estimate for 2013 is within 5% of the Rail Delivery Group's estimate for direct employment in the rail industry in the same year (although their estimate for indirect employment is much higher).
- The public subsidy stated in each operator's regulatory accounts may not include indirect public subsidy, such as that provided through capital programmes or tax relief. The definition of subsidy is not always clear in some Annual Reports and Accounts. Where possible, we have included Public Service Contracts and Concessions – although these funding streams are not always obvious. Additionally, not all public funding intended for capital investment is explicitly separated from the subsidy intended to help operators meet their day-to-day costs. While we have taken a number of steps to exclude funding intended for capital investment projects from our data, it is possible that some costs related to capital expenditure have been captured in the dataset.
- Net debt data is not widely reported by the UIC or in regulated accounts, and it has therefore not been possible to provide aggregate debt figures for several Member States.

In spite of these constraints, we have estimated debt for some of the largest Infrastructure Managers in the EU, in particular those in Germany, France, the UK and Italy. However, we do not believe that debt data is sufficiently robust or comparable to use in this study.

- We have tried as far as possible to be consistent in the interpretation of operating expenditure (net of track access charges), which for the purposes of this study includes depreciation, amortisation, maintenance, renewals and finance costs for both railway undertakings and infrastructure managers[5]. However, not all Annual Reports and Accounts disaggregate their operating expenditure in this manner. It is therefore possible that some capital expenditure (e.g. for enhancements) may have been included in the operating costs of some organisations.
- In many cases it has been difficult to obtain complete data for the years prior to 2007 and after 2012. We have therefore limited most of our analysis to the years 2007 to 2012 (inclusive).

**Quality assurance**

2.12 Notwithstanding the issues and limitations of the datasets collected (see Appendix A for further details for each Member State), we have taken a number of steps to give assurance that the data collected provides a reasonable representation of the rail operations in each Member State. Checks have included:

- Comparing data provided in published annual accounts data with the UIC database;
- Comparing academic studies with other data sources including government statistics and the UIC database;
- Examining trends in each indicator to identify anomalous or outlying data points;
- Generating and reviewing the relationship between datasets to ensure that they demonstrate a reasonable spread and consistency through time and across Member States;
- Supplementing data obtained from desk research with other information provided by Member State experts, who bring local and sector knowledge and experience; and
- Where multiple datasets report the same observations, selecting a preferred value or series based on the completeness and consistency of the datasets themselves.

2.13 However, notwithstanding these checks, we have not been able to verify the accuracy of the individual datasets used to inform this study. By focussing on the most recent data in the subsequent tasks, we have sought to ensure that our analysis is based upon the most accurate data available.

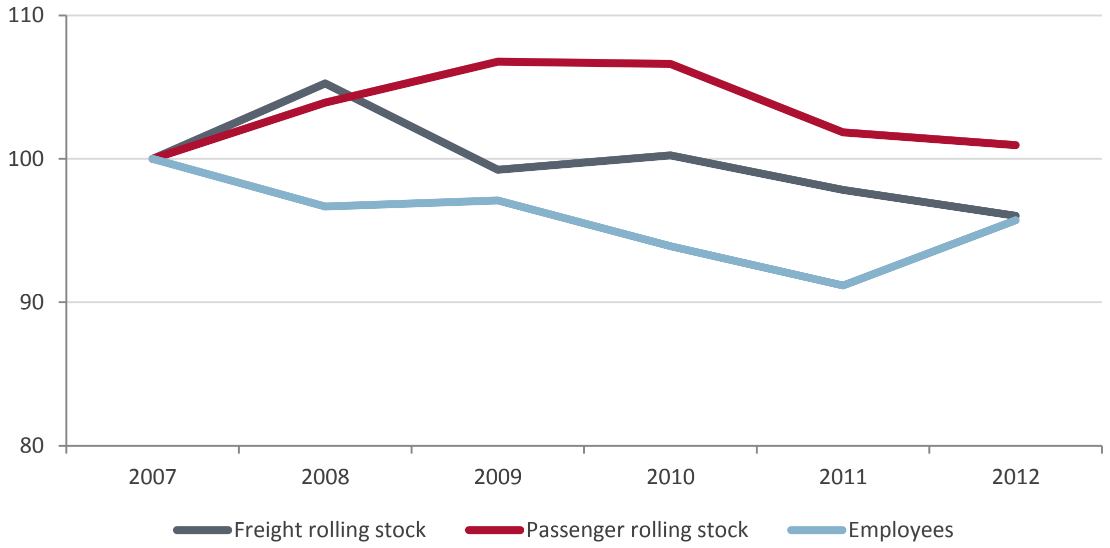
## Summary of rail industry characteristics and trends

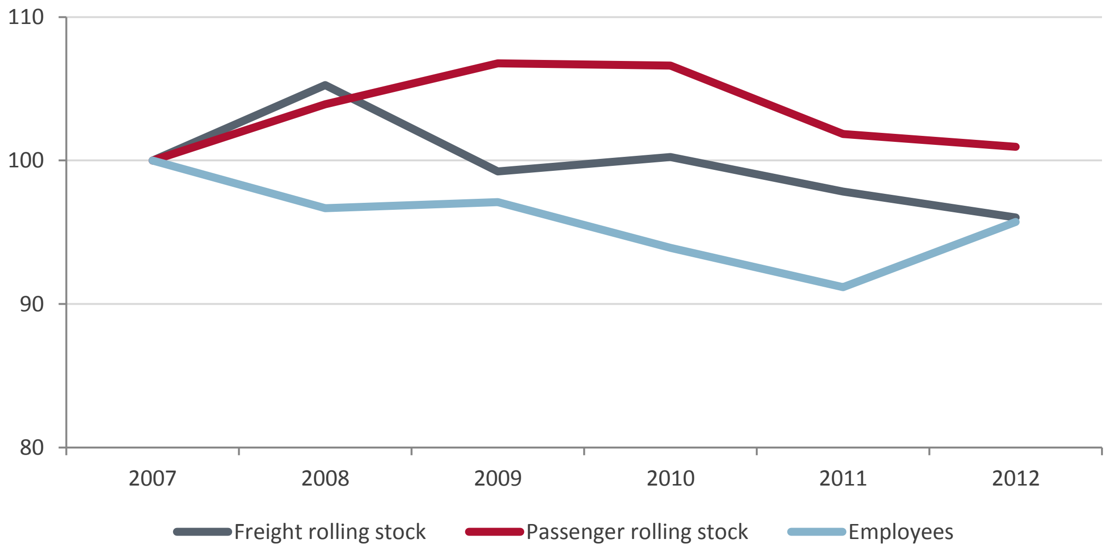
2.14 The data collection exercise has enabled us to examine trends in the rail industry at a Member State and EU level. A summary of high-level trends at an EU-wide level is provided below, with the underlying data for each Member State reported in Appendix B.

[5] Adjustments to avoid the double-counting of track access charges have been applied.

## Input indicators

**Figure 2.1: Trends in input indicators (2007 = 100)**




2.15 Rolling stock fleet sizes (vehicles) for both passenger and freight appear to have been in decline since 2009. This may be due to changes to the characteristics of rolling stock such as increasing seat densities and larger freight wagons, or economic effects such as asset disposal or stabling during the economic crisis. Without detailed investigation at a national level, it is not reasonable to draw any firm conclusions regarding the drivers of these trends, since many of the observed changes through time may be driven naturally by the rolling stock fleet replacement cycle rather than any particular policy or commercial imperative.

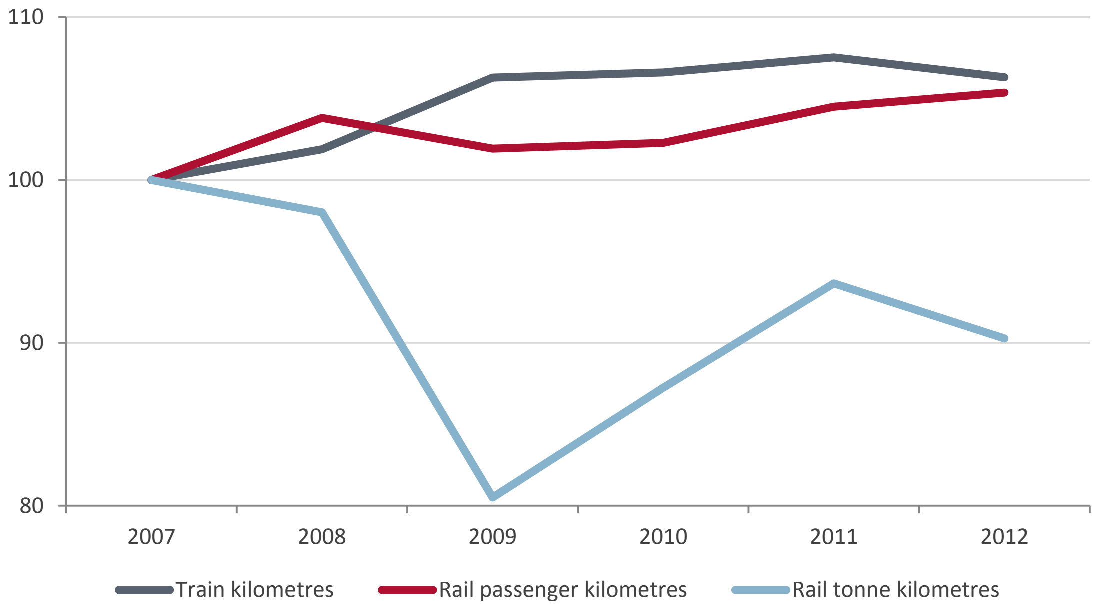
2.16 At a national level, we note that only 7 out of 26 Member States (Bulgaria, Germany, Latvia, Luxembourg, Netherlands, Portugal and Romania) have increased the size of their freight fleets over the five year period, with typical reductions elsewhere of 5% – 15%. In the passenger market there is a more even split in the number of Member States increasing or decreasing their fleet sizes but, with the exception of Bulgaria, the railway systems that are expanding are exclusively higher-income Western European nations.

2.17 There has also been a marked decrease in employment in the rail sector. However, this trend could be attributed to structural changes in the industry (particularly outsourcing). The practice of outsourcing is of particular importance when considering absolute levels of performance whereby, through reducing the number of individuals directly employed by a railway undertaking or infrastructure manager, the output per employee is perceived to increase.

2.18 When considering relative performance (i.e. between Member States) it is more important to understand the prevalence of outsourcing in each country. In this sense, we would expect the level of outsourcing to vary, primarily, according to network size. In particular, we would expect larger, more divisible rail networks to have a greater proportion of outsourcing, thereby over-stating their efficiency relative to smaller Member States. National data suggests that some Member States may have outsourced activities during the period 2007-2012 (for example Bulgaria, Czech Republic, Estonia and Greece), although it is not possible to separate out this effect from general reductions in staff numbers observed across the EU rail sector over this period.

### Output indicators

**Figure 2.2: Trends in output indicators (2007 = 100)**




2.19 Despite an unfavourable economic climate across much of the EU over this period, rail passenger outputs have grown. Figure 2.2 shows that both passenger kilometres and train kilometres (which include both passenger and freight train movements) have increased by approximately 1% each year. This is in contrast to the change in rail freight outputs (tonne kilometres), which have declined by 10% overall in the five years to 2012 despite recovering substantially since the depth of the recession in 2009.

2.20 The most significant increases in train kilometres have been observed in Western Europe, with six Member States (Denmark, Germany, Luxembourg, Netherlands, Sweden, UK) expanding their rail operations by more than 15% between 2007 and 2012. In many cases this is a consequence of major infrastructure enhancements coming into use during the period, such as the HSL-Zuid line in the Netherlands (2009), and the West Coast Main Line upgrade works in the UK (2008). While the majority of other Member States have seen relatively minor changes in train kilometres since 2007, three countries (Bulgaria, Estonia and Greece) have seen a significant downturn in activity. Train kilometres in Bulgaria have fallen by 24%, largely because of the consolidation activity required by its Railway Reform Programme. In Greece, however, the 38% reduction in train kilometres can be attributed to the reduction in state funding required as part of the wider fiscal austerity packages implemented from 2010.

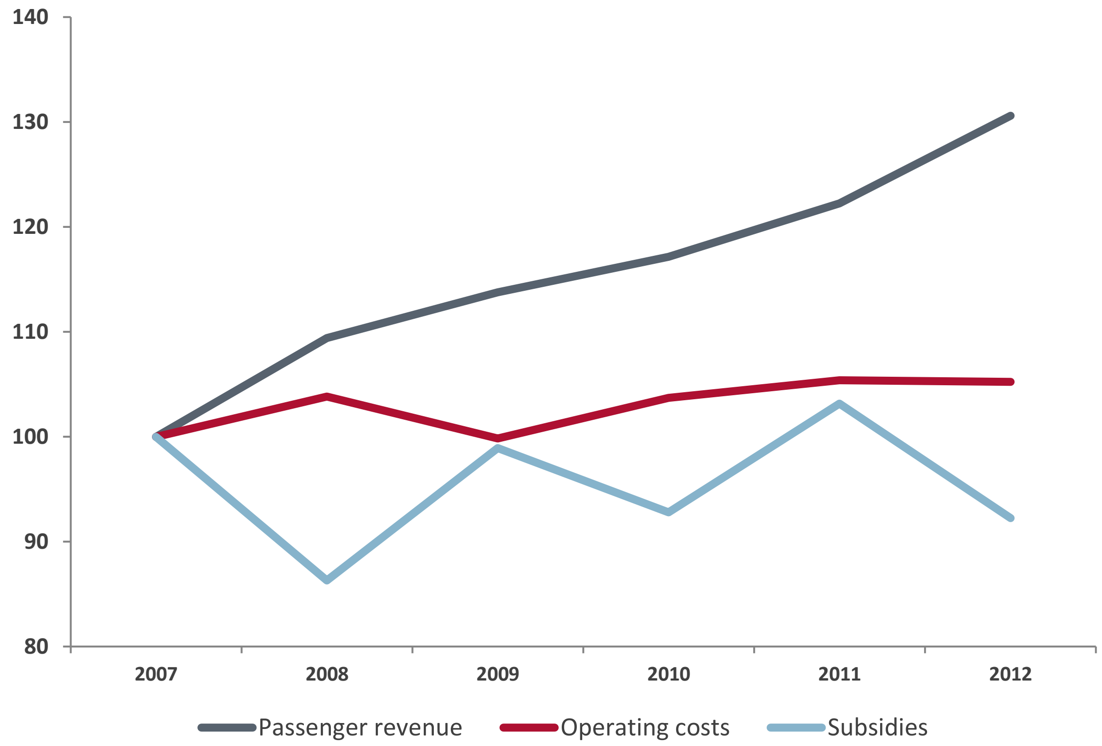
2.21 While there have been modest increases in rail passenger kilometres across the EU, this hides significant variation at a Member State level. In line with trends in train kilometres, the best performing countries are typically higher income Western European Member States, with the UK reporting the largest increase in passenger usage of 21%. Slovakia (13%) and the Czech Republic (5%) are notable exceptions. Alongside Greece (-57%), three Member States (Croatia, Latvia and Romania) observed reductions in patronage of more than 25%.

In contrast to the passenger railway, freight outputs almost universally declined across Europe between 2007 and 2012. Only three Member States reported any increase in rail freight activity, with Denmark (27%) and Latvia (19%) considerably ahead of the UK (< 1%). Some of the increase in Latvia (3.6 billion tonne kilometres) may be freight traffic that has been displaced from neighbouring Estonia, which observed a decline in freight volumes of 39% (or 3.3 billion freight kilometres).

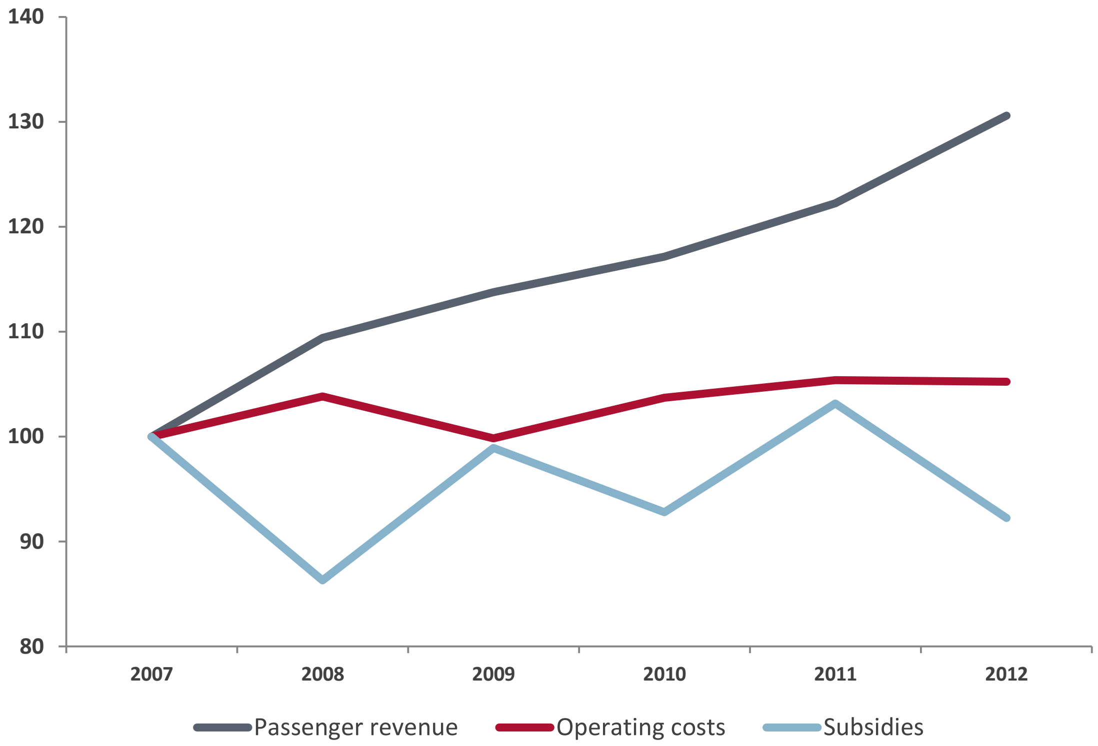
This displacement of freight activity between Baltic States is, in part, due to lower access charges (both track access charges and port fees) for transit flows in Latvia coupled with the delivery of increased port capacity[6]. It may also reflect the political impact of the so called "scandal of the bronze soldier" when, in 2007, Russia completely stopped its coal and oil transit via the ports in Estonia. Meanwhile, Latvia managed to attract a considerable amount of these cargos to its transit corridor.

## Financial indicators

**Figure 2.3: Trends in financial indicators (2007 = 100, adjusted for HICP)**




[6] Cargo volumes handled at Latvian ports increased by 23% between 2004 and 2012 (see Rijkure. A and Sare. I (2013), *The Role of Latvian Ports Within Baltic Sea Region*, European Integration Studies, 2013 No 7)




2.22 We have also examined trends in key financial indicators at an EU-wide level. Figure 2.3 presents EU-wide trends in passenger revenue, total operating costs and subsidies, adjusted to reflect 2007 prices by using the European Central Bank's Harmonised Index of Consumer Prices (HICP). Operating costs cover both passenger and freight operations and are inclusive of financing and depreciation costs but, to avoid double counting, net of track access revenues. It has not been possible to include freight revenue within this analysis as we were unable to obtain a comprehensive dataset for all Member States and all time periods presented.

2.23 Figure 2.3 suggests that passenger revenue has increased significantly, while total operating costs have remained broadly static in real terms. It is not, however, possible to draw definitive conclusions regarding unit costs due to the mixed fortunes of passenger (increase) and freight (decrease) traffic over the period. Data regarding the quantity of public subsidy is volatile at an EU-wide level and there is no discernible long-term trend. In broad terms, therefore, the burden of financing Europe's railways has remained relatively static between 2007 and 2012, but with considerable year-on-year variation.

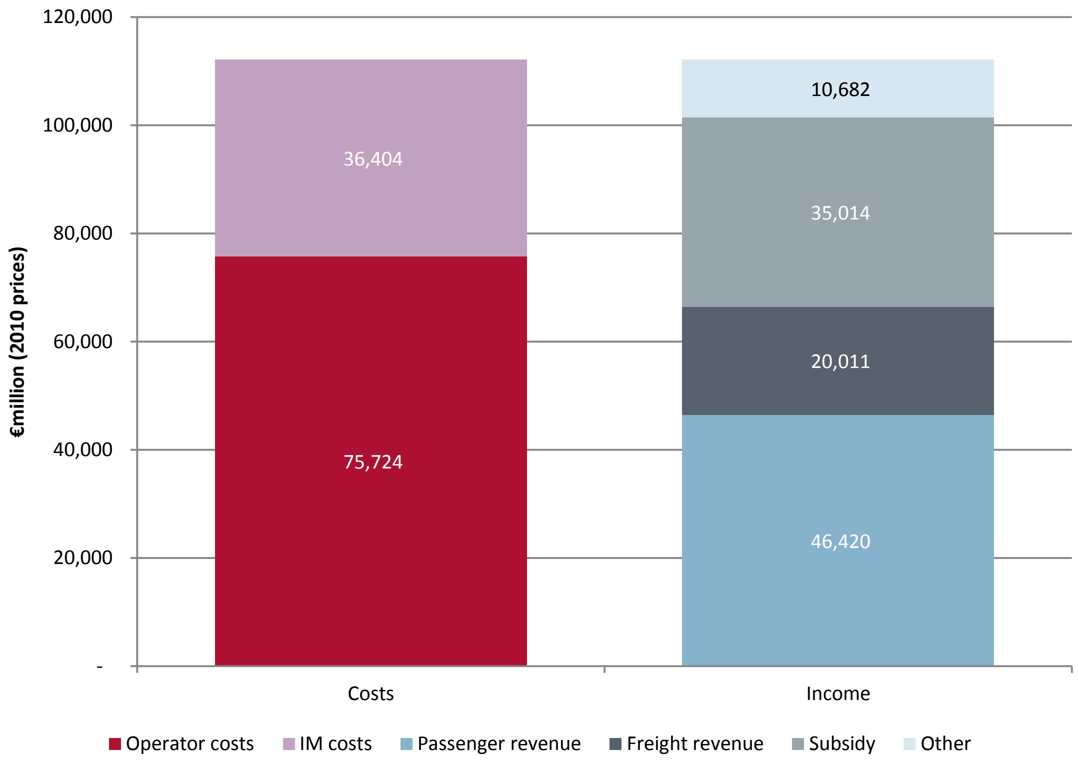
2.24 Closer examination of the financial data reported by railway undertakings, infrastructure managers and/or at a system-wide level highlights considerable variation between Member States and year-on-year. The emerging liberalisation of European rail networks, multiple market models and levels of vertical/horizontal separation, and different treatment of depreciation and interest introduce distortions that require extensive adjustment to overcome. Therefore, while it may be possible to examine medium and long-term trends in the cost efficiency of railways, the limited quality of financial information means that it is difficult to draw meaningful comparisons on a year-by-year basis.

2.25 Headline costs and contributions to the EU rail sector in 2012 are presented in Figure 2.4. On average the split between infrastructure and operator costs is approximately 30%:70%. This is largely a function of the dominance of passenger railways in a number of larger, higher income

Member States. In those countries where freight traffic plays a more significant role, the proportion of total costs borne by the infrastructure manager is greater.

2.26 On the income side of the equation, roughly 60% of observed costs are covered by fare-box and freight revenue (40% passenger and 20% freight) and a further 30% by subsidy[7]. The remaining 10% (or roughly €10.7bn) is a residual balancing item that is likely to include freight income not captured at the Member State level (data was not available for all Member States) and other sources of income such as property rents and retail revenue.

**Figure 2.4: Cost and contribution of the EU rail sector (2012)**



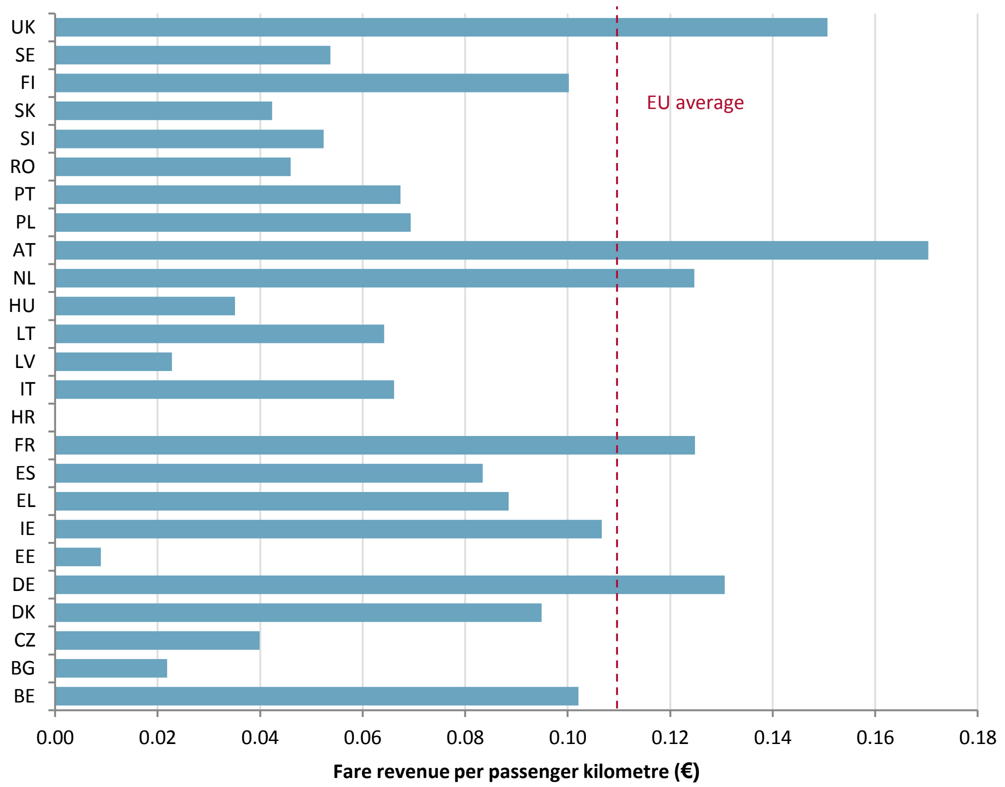

Source: SDG analysis

2.27 Figure 2.5 highlights the disparity in the average fare revenue per passenger kilometre between Member States. Of course, average fares hide considerable variation between the various routes, operators and ticket-types available within Member States. They may also reflect the typically heavy regulation of rail fares by national governments, with passengers often paying a fixed fare per kilometre ("kilometric fare") for standard class travel and a fixed multiplier for first class travel. Pure kilometric pricing is increasingly rare, but distance-based fares are still common in a number of Member States. For instance, in the Netherlands the introduction of the OV-chipcard has been accompanied by a return to kilometric prices, although these are modulated by region and class of travel and subject to discounts. Trenitalia in Italy continues to apply kilometric pricing to most regional services operated under Public Service Contracts.

[7] It should be noted that, in some Member States, there may be unobserved or 'hidden' cost items, such as maintenance backlogs, that are not captured in this analysis.

2.28 As we might expect, the highest average fares are charged in high-income Western European Member States with well-developed, high-quality passenger networks. Fares in Sweden are a notable exception to this general observation, where average fares are roughly half those charged in neighbouring Denmark and Finland.

**Figure 2.5: Fare revenue per passenger kilometre (2012)**

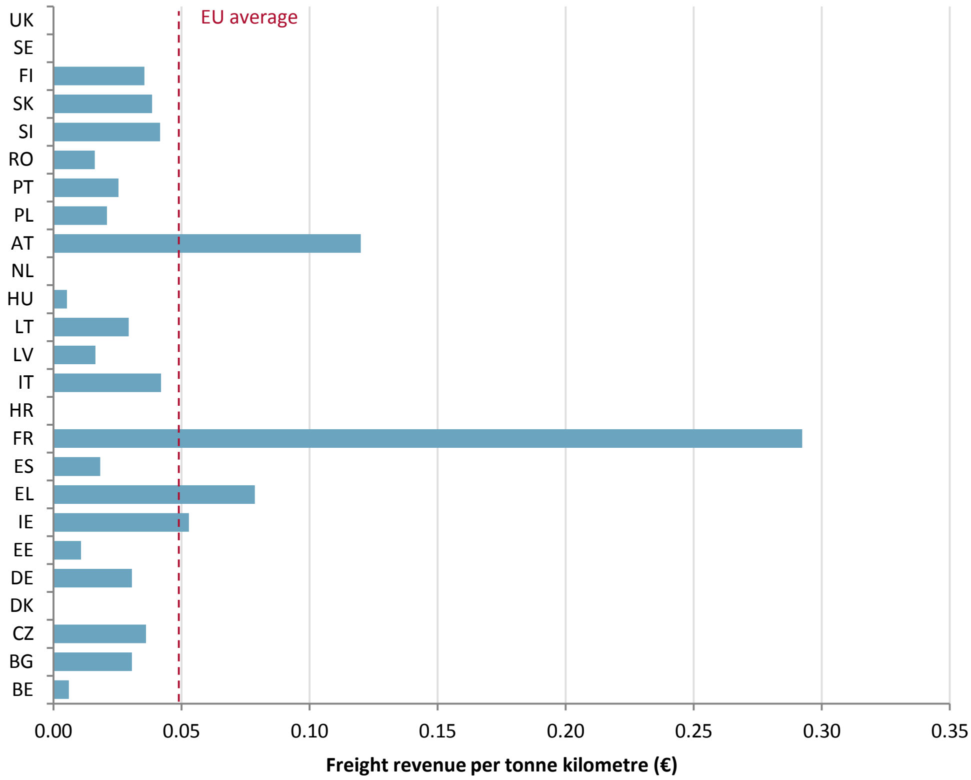



Source: SDG analysis (note that for ease of presentation Luxembourg €0.58/passenger km has been excluded, farebox revenue data was not available for Croatia)

2.29 Figure 2.6 provides equivalent revenue per tonne kilometre data for a sample of Member States where data was available. While there is less variation in freight yields compared to the passenger market across the majority of Member States, France, Austria and Greece appear to charge considerably more than the EU average. Data from 2010 and 2011 indicate that while there is some year-on-year variation in the data, the higher freight yields in these Member States are a persistent feature and not simply outliers caused by data-related issues or one-off events[8]. Further work is required to establish whether this observation is an artefact of the way freight revenue and volume data is captured and reported, or to what extent it reflects genuine charging practices. Unlike the passenger market there does not appear to be a discernible trend in freight yield according to the characteristics of the Member State.

[8] Freight revenue per tonne kilometre in 2011 was €0.46 (Luxembourg), €0.28 (France), €0.12 (Austria) and €0.06 (Greece)

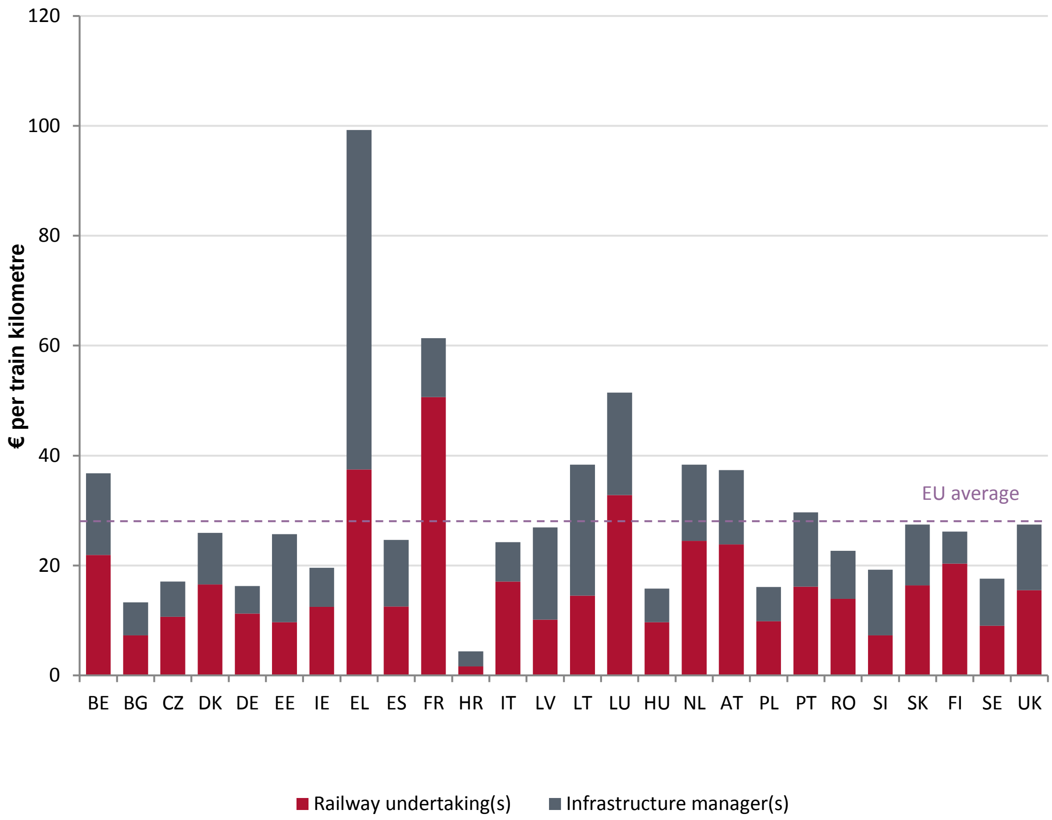
**Figure 2.6: Freight revenue per tonne kilometre (2012)**




Source: SDG analysis (note that for ease of presentation Luxembourg €0.52/tonne km has been excluded, it was not possible to obtain sufficiently comprehensive freight revenue data for United Kingdom, Sweden, Netherlands, Croatia and Denmark)

2.30 Finally, Figure 2.7 describes total operating costs per train kilometre by Member State. While there are a few notable outliers (in particular Greece and Croatia), the spread of operating costs lies broadly in the range of €20 - €40 per train kilometre. Towards the upper end of this range lie high-income Western European Member States including Belgium, the Netherlands and Austria with France and Luxembourg higher still. A number of Central European member States lie towards the lower end of the range including the Czech Republic, Hungary and Poland.

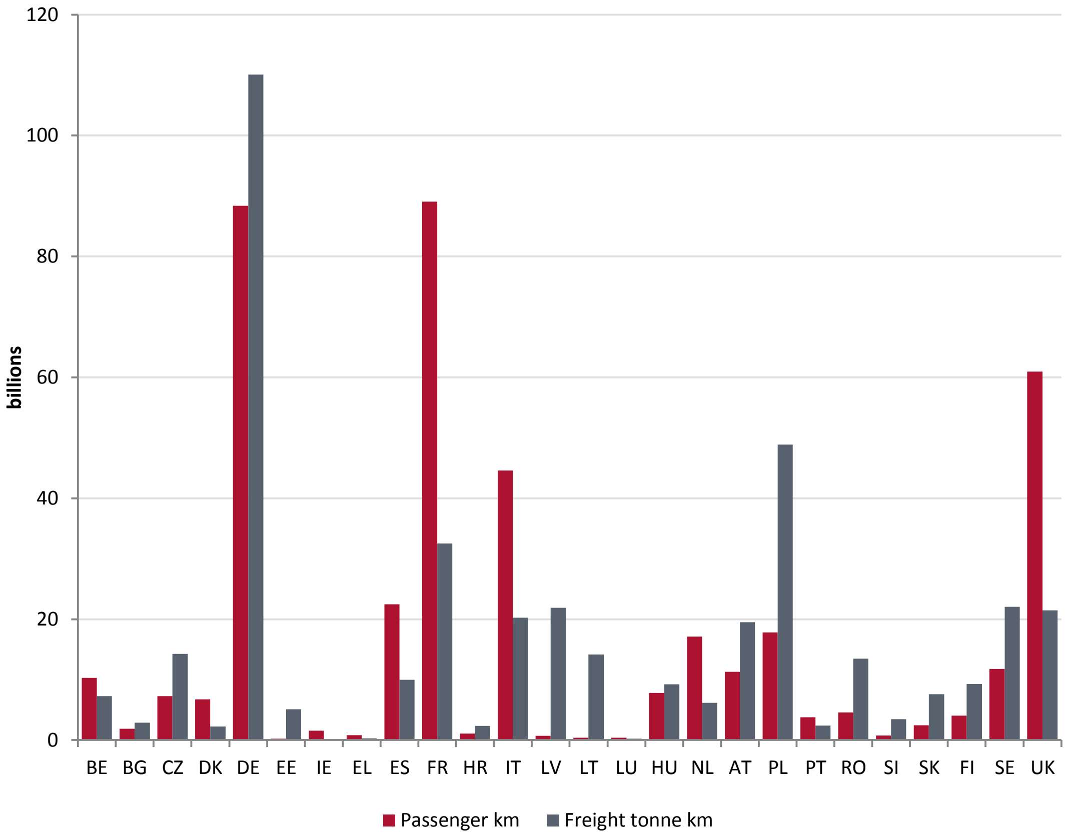
**Figure 2.7: Operating costs per train kilometre by Member State (2012)**



### Rail market characteristics by Member State

2.31 Figure 2.8 provides high-level statistics regarding the absolute scale of the market for rail by Member State, as measured by passenger kilometres and freight tonne kilometres. There is considerable variation in both the size and distribution of rail activity between Member States. Given the scale of divergence, it will be important to ensure that scale effects are captured within this study. It is highly likely that the scale of a Member State and its rail network will have some bearing on the efficiency of delivering rail outputs.

**Figure 2.8: Passenger and freight activity (2012)**




Source: SDG analysis

2.32 Figure 2.9, Figure 2.10 and Figure 2.11 use population size and economic output to normalise rail outputs and permit comparison of rail markets on a more consistent basis. Unsurprisingly, due to the dominance of passenger rail in a number of Member States, there is a remarkably close relationship between train kilometres per inhabitant and passenger kilometres per inhabitant. The top three Member States (excluding Luxembourg) as measured by train kilometres per inhabitant are Austria, Czech Republic and Sweden[9]. These share similar geographic characteristics, in particular the location of all their major cities along the same rail corridor.

[9] Per capita measures for Luxembourg are often skewed due to the significant difference between workplace and residential populations as a consequence of commuting from neighbouring countries. While we might expect the workplace population to affect rail usage, population statistics are recorded on a residential basis.

2.33 The Baltic States (Latvia, Lithuania and Estonia) show, by far, the highest levels of freight activity relative to economic output. The data for Greece and Ireland confirms the very low utilisation of their rail networks for freight transport. In general, Central and Eastern European Member States have higher levels of freight activity compared to the EU15.

**Figure 2.9: Train km per inhabitant (2012)**

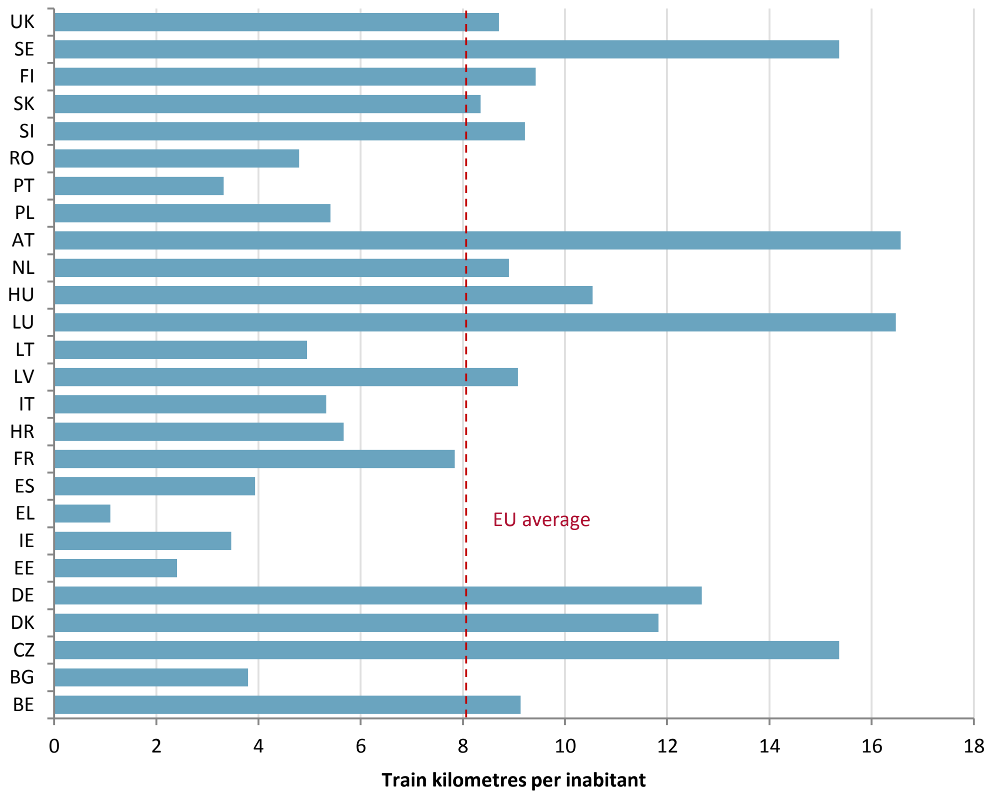


**Figure 2.10: Passenger km per inhabitant (2012)**

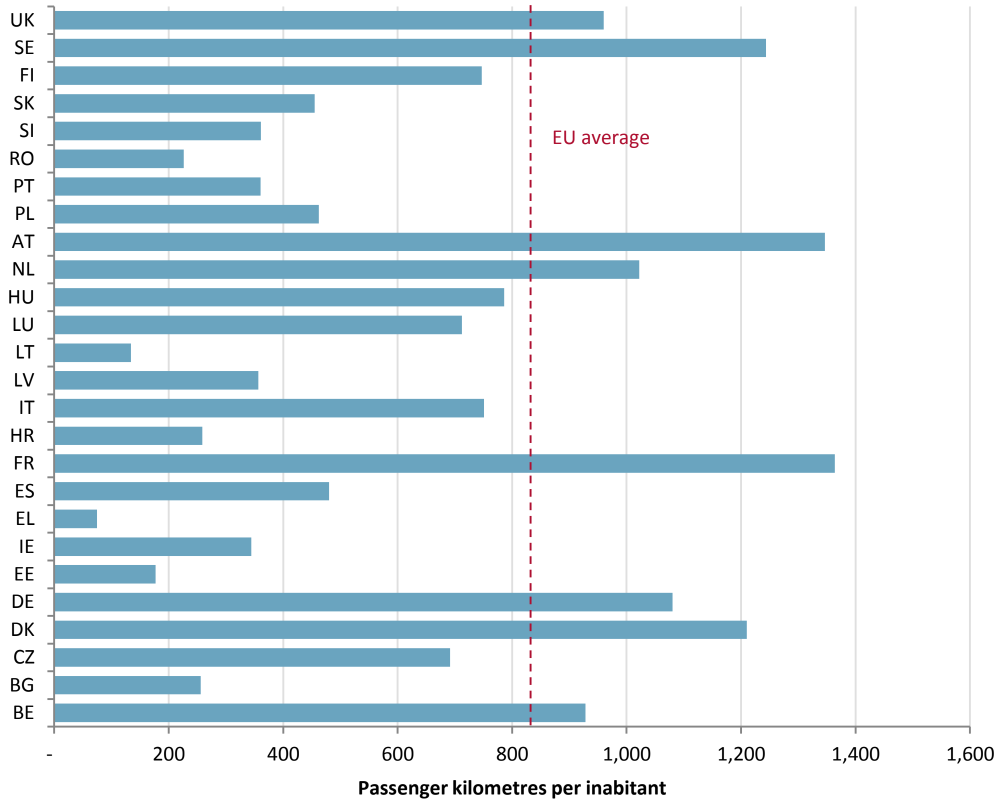
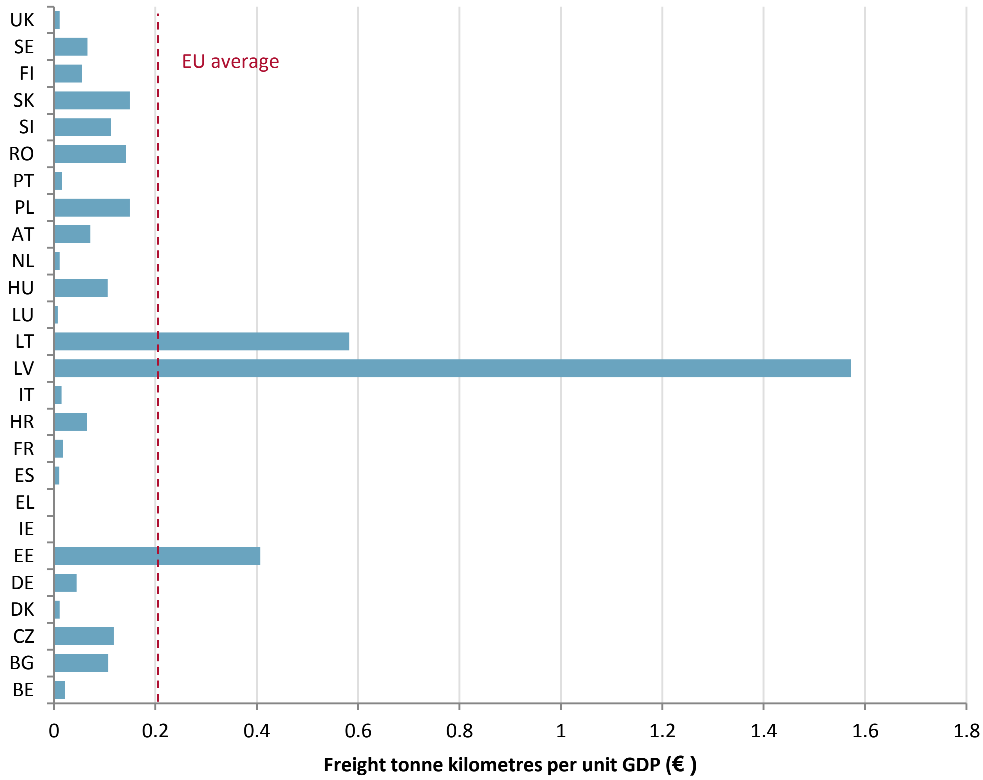



**Figure 2.11: Freight tonne kilometres per unit GDP (2012)**



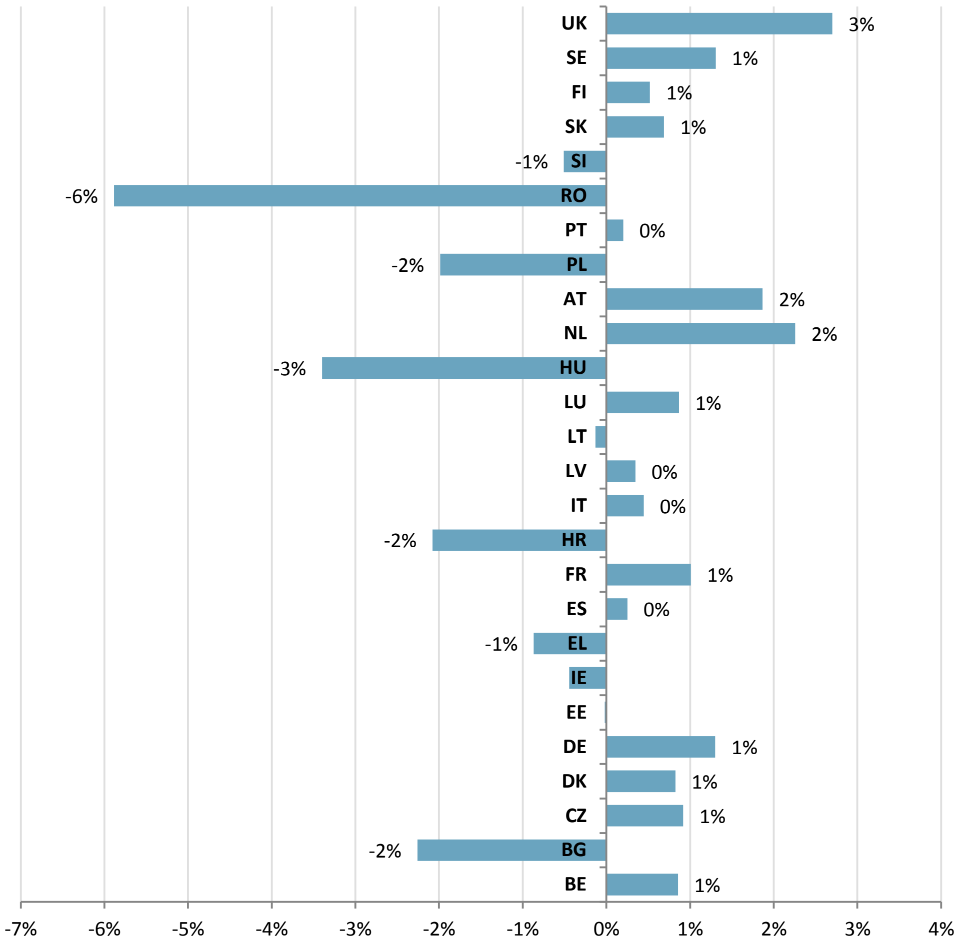

Source: SDG analysis

### Rail mode share

2.34 Figure 2.12 shows that the United Kingdom and the Netherlands have experienced the largest mode shift in favour of passenger rail over the last decade. This could be due to a number of largely exogenous factors, such as road congestion and increasing motoring costs, or endogenous factors such as shifts in public policy towards increasing investment in the railways and improvements to service quality.

2.35 Conversely, many Eastern European countries, notably Romania and Bulgaria, have experienced a significant mode shift away from passenger rail. This could be attributed to recent improvements to the road networks and an increase in car ownership in these countries in-line with rising incomes.

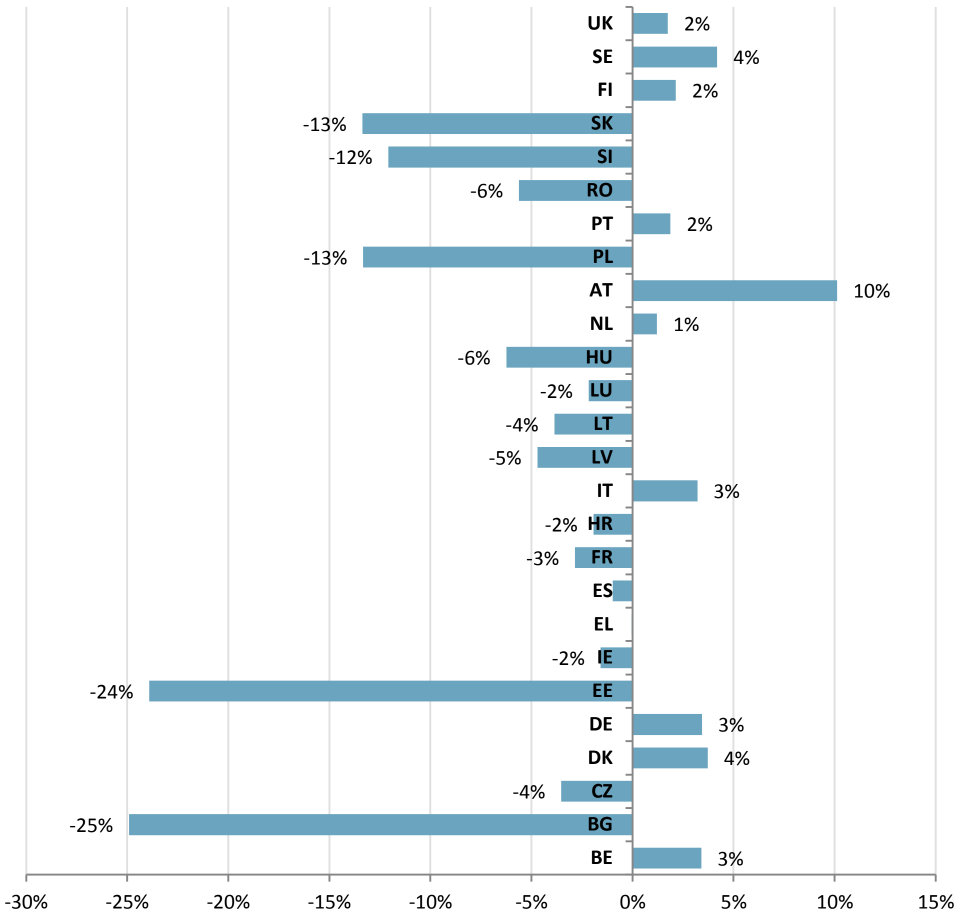
**Figure 2.12: Change in Passenger Rail Mode Share (2003 to 2012)**




Source: SDG analysis

2.36 Figure 2.13 presents the same mode share information for rail freight traffic. While there have been modest increases of 2% - 4% across a number of Western European countries, a large number of Central and Eastern European Member States have seen the share of freight tonnage carried by rail fall by between 2% and 13%. Two Member States, Bulgaria and Estonia, have seen the share fall by 25% over the same period. In the case of Bulgaria this represents the continuation of a long-run trend in which total rail freight volume has fallen by two-thirds since 1990. Estonia, on the other hand, experienced a reduction in rail freight volumes of over 40% between 2006 and 2008. Following a modest recovery, freight volumes have fallen further since 2010, partly because of the economic downturn and partly as a consequence of political instability and sanctions within the region.

**Figure 2.13: Change in Rail Freight Mode Share (2003 to 2012)**




Source: SDG analysis

# 3 Key performance indicators

## Overview

3.1 This chapter describes the development and treatment of Key Performance Indicators (KPIs). These are used to measure the relative efficiency of rail systems and to draw comparisons between the performance of individual Member States. KPIs can be defined as a set of quantifiable measures that an industry uses to gauge or compare performance in terms of meeting their strategic and operational goals.

3.2 The choice of KPIs will vary between industries, depending on their priorities or performance criteria. They will also be affected by a range of exogenous factors that are outside the direct control of the industry in question and its agents. Therefore, for this study, we have defined the following:

- Primary KPIs: direct measures of rail sector efficiency such as passenger kilometres per train kilometre;
- Secondary KPIs: potential indicators of efficiency that are within the control of the rail industry, for example train kilometres per employee; and
- Additional indicators: a combination of exogenous measures (e.g. population density) and endogenous measures (e.g. passenger satisfaction) which may also indirectly affect rail sector efficiency, largely from a demand-side perspective.

3.3 Primary indicators are the main focus for this study since they describe the relative performance of rail systems according to efficiency measures over which the Commission has relatively more influence (e.g. through rolling stock and infrastructure standards, ERTMS, funding and policy on market access). Secondary indicators provide additional information about the characteristics and performance of rail systems. Any policy prescription identified through consideration of secondary KPIs may, however, be beyond the direct control of the Commission. Other exogenous factors that affect rail sector efficiency but which are largely outside of the control of both the Commission and individual Member State administrations also need to be taken into account.

3.4 The remainder of this chapter explains the process we followed to select KPIs, describes key trends in those KPIs through time, and explores relationships between KPIs and a range of exogenous variables in order to inform the subsequent clustering analysis set out in Chapter 4.

## Selection of KPIs

3.5 KPIs measure the performance of an economic entity and allow comparability over time as well as against other entities. KPIs are typically ratios of key outputs to inputs, but can also be measures of service quality derived, for example, from customer surveys.

3.6 For the purposes of this study, past and present performance must be measured against the key policy objectives identified in Chapter 1. These objectives underpin the scenario assessment exercise and have been identified in close dialogue with the Commission to be targeted on improvements in capital productivity. As discussed further in Chapter 6, we have identified a core scenario focused on total capital productivity (i.e. track and train utilisation in combination) and undertaken further analysis of a scenario in which additional rail demand is generated as a result of an increase in the costs of road transport. We have therefore developed primary KPIs that provide information on capital productivity measures.

3.7 Second, we have reviewed the existing literature to support an evidence-based definition of KPIs and to ensure that we cover the main indicators from previous studies. Table 3.1 below identifies a range of KPIs reviewed by the OECD and highlights some issues associated with their interpretation. For instance, train kilometres per track kilometre is a useful indicator of infrastructure utilisation, but this measure is influenced by the extent to which the network is congested, and the existing capacity allocation rules which may favour passenger traffic and penalise freight operations.

**Table 3.1: Key performance indicators for rail systems and their main issues**

| Performance measure - KPIs | What it measures | Main issues |
|---|---|---|
| Train-km per track-km | Infrastructure utilisation | Impacted by congestion and passenger / freight policies |
| Train-km per staff | Labour productivity | Less influenced by government policy and external factors. However, affected by outsourcing practices. |
| Total cost per train-km | Underlying cost of operations | Accounting conventions and factors prices (e.g. wages) differ |
| Revenue per traffic unit[10] | Revenue generation | Affected by government policies on fares affordability |
| Revenue / Operating cost | Cost recovery | Affected by fare and service obligations imposed on operators |
| Market share | Competitiveness of rail | Ignores overall growth / decline in patronage |

Source: Steer Davies Gleave analysis of Transport Benchmarking Methodologies, Applications and Data Needs – European Conference of Ministers of Transport, OECD, 2000

3.8 A recent study by Merkert et al (2010) presents a list of the main inputs and outputs (which form the basis of any KPI) used in previous studies assessing the efficiency of national railway systems. These are reported in Table 3.2 below. We have added the work carried out by Mizutani and Uranishi (2010) to the list as this was not captured in the Merkert et al study, and it provides some interesting indicators of total input costs and outputs.

[10] Traffic units are calculated as a weighted average of passenger kilometres and freight tonne kilometres. This relies on the assumption that average traffic unit costs are broadly constant. Otherwise, increasing productivity may simply mean that the railway is moving towards producing more freight traffic and less passenger traffic or vice versa. Hence, such a simple measure of output has significant shortcomings.

**Table 3.2: Review of the inputs and outputs used in previous studies**

| Study | Inputs | Outputs |
|---|---|---|
| Nash and Preston (1994) | Total cost<br>Staff | Train-km<br>Market share |
| Nash and Shires (1994) | Track-km<br>Staff<br>Total cost | Train-km<br>Passenger-km<br>Freight -tonne-km |
| Oum and Yu (1994) | Staff<br>Energy consumption<br>Rolling stock | Passenger-km<br>Freight-tonne-km |
| Gathon and Pestieau (1995) | Engines and railcars<br>Staff<br>Length of electrified lines | Traffic units (sum of passenger-km and freight-tonne-km) |
| Coelli and Perelman (1999) | Staff<br>Rolling stock<br>Track-km | Passenger-km<br>Freight-tonne-km |
| Cantos and Maudos (2001) | Operating cost<br>Labour cost<br>Energy<br>Material/external services | Passenger-km<br>Freight-tonne-km |
| Loizides and Tsionas (2004) | Staff<br>Capital cost (interest and depreciation)<br>Energy cost | Traffic units (weighted with revenue share) |
| Hatano (2005) | Route length | Passenger-km<br>Freight tonne-km |
| Growitsch and Wetzel (2007) | Staff<br>Rolling stock<br>Track-km<br>Operating expenditure | Train-km<br>Passenger-km<br>Freight-tonne-km |
| Driessen et al. (2006) | Staff<br>Track-km<br>Rolling stock | Passenger-km<br>Freight-tonne-km |
| Wetzel (2008) | Staff<br>Rolling stock<br>Network length | Passenger-km<br>Freight-tonne-km |
| Cantos et al. (2010) | Staff<br>Rolling stock (passenger + freight)<br>Network length | Passenger-km<br>Freight-tonne-km |
| Mizutani and Uranishi (2010) | Sum of labour, energy and capital costs<br>Total route km<br>% of electrified line | Total train-km (passenger + freight) |

Source: Steer Davies Gleave summary of Merkert et al (2010), Benchmarking of train operating firms – a transaction cost efficiency analysis, Table 1

3.9 Third, the availability of data is a primary concern when deciding which KPIs to select for the remainder of the analysis. The data collection exercise described in Chapter 2 has enabled us to compile a large dataset. However, as noted in paragraph 2.11 there are gaps and limitations. Gaps arise mainly in time-series data, with the result that it is not possible to observe a specific KPI for every Member State for each year over the period 2003-2012.

3.10 There are also limitations relating to both the quality of data and the impact of external influences. For instance, total track length may be an imprecise measure of productive capital stock in Member States with a network comprised largely of assets nearing the end of their economic life. A potential alternative would be to use the length of electrified lines, but this measure is heavily influenced by the legacy of previous policy decisions and the availability of investment funds.

3.11 Another measure subject to limitations is the value of subsidy. For example, a network that benefits from substantial capital investment may require less maintenance expenditure and, as a result, attract a lower level of operating subsidy. However, this apparently low level of public resources used to support operations may be more than offset by public funding of capital investment.

3.12 The primary and secondary KPIs considered in subsequent phases of the study have been developed in the light of the three criteria described above (adherence to policy goals, literature review and data availability). They are:

- Primary KPIs
  - Track utilisation (train kilometres/track kilometres)
  - Passenger train utilisation (passenger kilometres/passenger rolling stock)
  - Freight train utilisation (freight tonne kilometres/freight rolling stock)
- Secondary KPIs
  - Cost efficiency 1 (train kilometres/total operating costs)
  - Cost efficiency 2 (passenger kilometres/passenger operating costs)
  - Cost efficiency 3 (freight tonne kilometres/freight operating costs)
  - Staff efficiency (train kilometres/employees).

## KPI analysis

3.13 As with all benchmarking activities, comparing the performance of rail systems across Member States is not straightforward and any results should be interpreted with care. Benchmarking simply compares outturn figures between observations and does not take into account the broad range of micro and macro factors that may have contributed to a given level of performance, and whether these are one-off or ongoing factors (e.g. outsourcing of labour). Nor does benchmarking contribute to resolving any of the potential issues identified. Notwithstanding these qualifications, by considering a broad range of performance measures for each Member State it is possible to identify insights into the operating practices and relative strengths and weaknesses of each railway system under consideration.

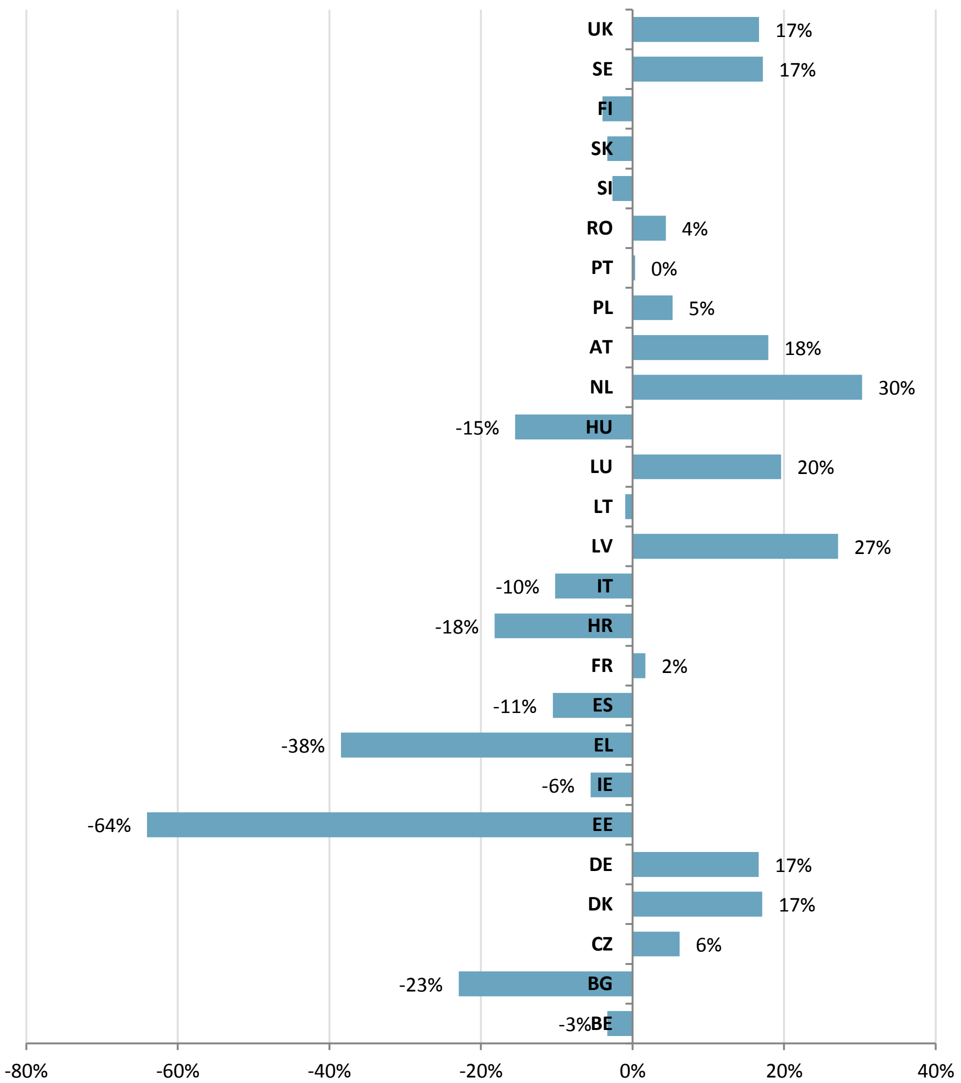
3.14 In order to develop hypotheses about the relative performance of rail systems across Member States, we calculated and analysed relationships between combinations of primary and secondary KPIs, together with a range of other explanatory variables. Bivariate analysis of this nature allows investigation of how efficiency (as measured by primary KPIs) for a particular Member State may be correlated with changes in secondary KPIs and/or exogenous factors. The observed correlation between indicators does not imply causality, but indicates relationships to be explored further in the subsequent clustering and data envelopment analysis exercises. This section begins with a brief commentary on recent trends in KPIs and then summarises the most useful evidence identified through correlation analysis. Detailed outputs by Member State are provided in Appendix B.

### Trends in Key Performance Indicators

*Track utilisation*

3.15 As shown in Figure 3.1 there was a noticeable difference between Western and Eastern Europe in track utilisation growth over the period 2007-2012. Although it fell in some Member States, track utilisation in Western Europe grew by an average 8%, with the Netherlands (30%) experiencing the largest increase. Track utilisation in Eastern Europe fell by an average of 10%, with the largest decreases in Greece and Estonia, where track utilisation fell by more than 30% and 60% respectively.

**Figure 3.1: Change in Track Utilisation (2007 to 2012) – train kilometres per track kilometre**

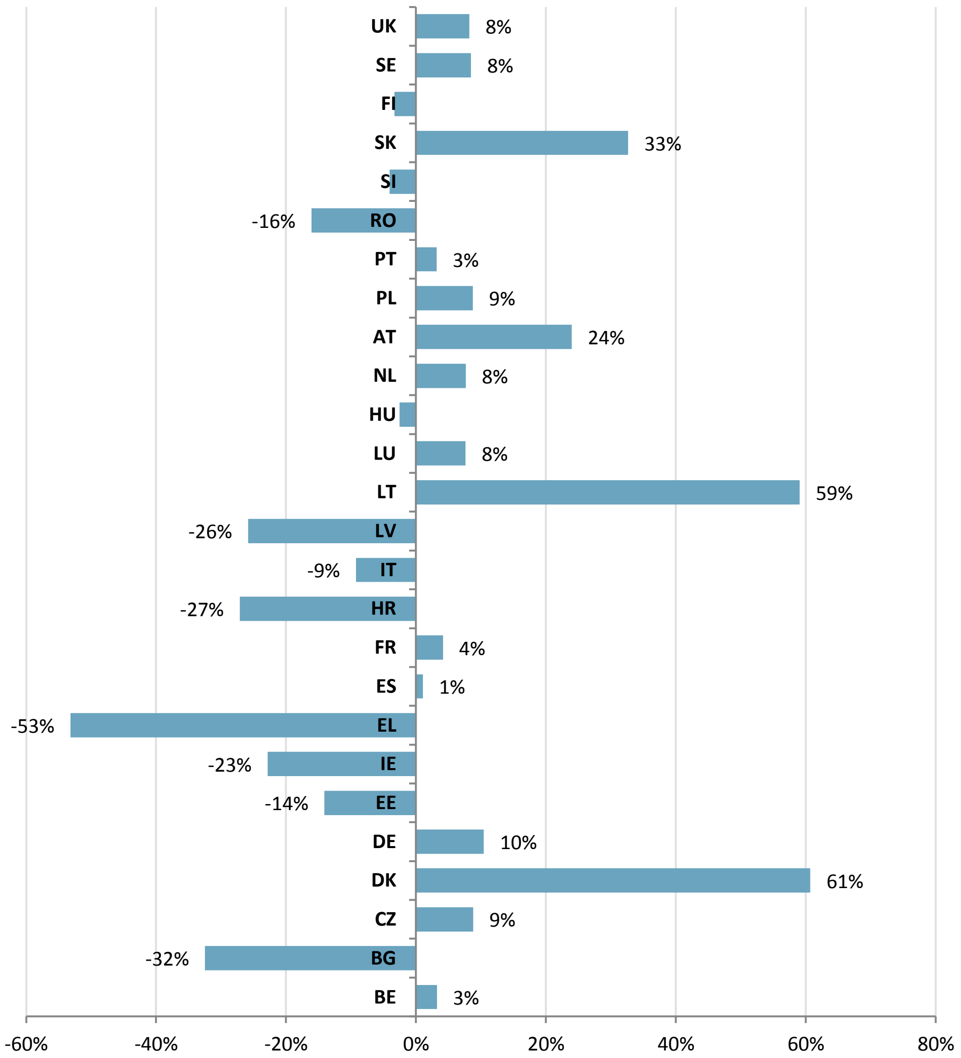



Source: SDG analysis

*Passenger train utilisation*

3.16 As with track train utilisation, there was a contrast between Western and Eastern Europe in passenger train utilisation growth over the period 2007-2012. Figure 3.2 indicates that passenger train utilisation increased by an average of 8% in Western Europe over the period 2007-2012, with only Italy and Ireland experiencing a reduction. In Eastern Europe growth was more varied, with Slovakia and Lithuania experiencing increases of more than 30% and five countries - Bulgaria, Estonia, Greece, Croatia, Latvia and Romania - contracting by more than 10%.

**Figure 3.2: Change in Passenger Train Utilisation (2007 to 2012) – passenger kilometres per passenger train kilometre**

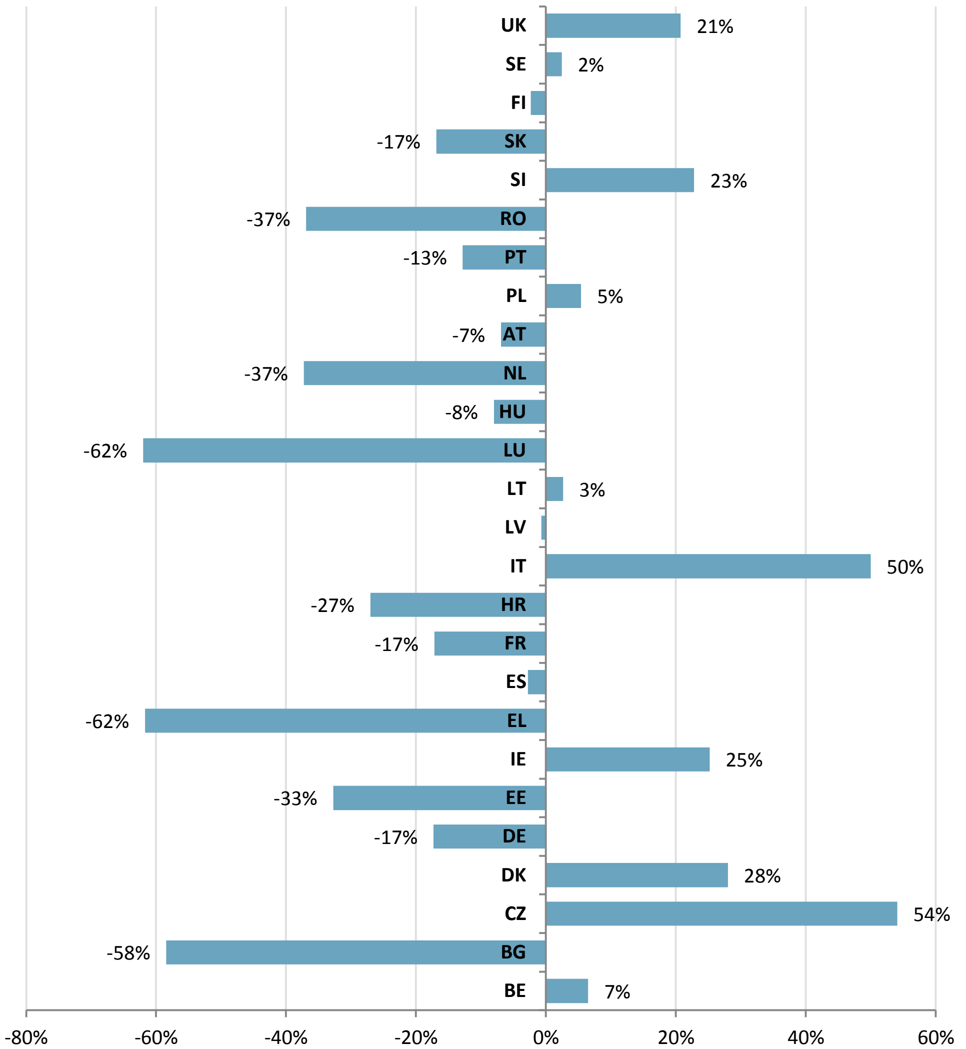



Source: SDG analysis

*Freight train utilisation*

3.17 Figure 3.3 illustrates that the majority of Member States experienced a decrease in freight train utilisation during the period 2007-2012, with seven countries worsening by more than 20% and Bulgaria, Greece and Luxembourg experiencing a fall of roughly 60%. Nine Member States improved during the period, with Italy and the Czech Republic experiencing the largest improvements in freight train utilisation of over 40%.

**Figure 3.3: Change in Freight Train Utilisation (2007 to 2012) – freight tonne kilometres per freight train kilometre**




Source: SDG analysis

*Secondary KPIs*

3.18 As shown in Table 3.3 there has been considerable variation in the performance of Member States against a range of secondary KPIs. At a system-wide level, there has been a significant reduction in the number of train kilometres (freight and passenger combined) per unit of operating cost expenditure, with only six Member States demonstrating any improvement. Similar trends are observed when we compare passenger and freight tonne kilometres to passenger and freight operating costs respectively, with the deterioration in freight cost efficiency on average greater than that for passenger rail. This is unsurprising since in each case the denominator of the KPI is a cost measure that is derived from the same source.

3.19 In contrast, when comparing outputs to the number of employees we observe improvements in staff efficiency across 18 Member States. While there has been a modest reduction of 44,000 (or 4%) employees in the EU rail sector between 2007 and 2012, this is insufficient to explain the discrepancy between physical and financial measures of efficiency. Changes to wage rates may explain some of the discrepancy, but over the period in question wage growth was subdued due to the ongoing impact of the financial crisis. Alternatively, deterioration in capital efficiency and/or capital cost inflation may be generated by increases in operating costs that exceed the growth in rail sector outputs.

3.20 One explanation for the divergence in performance between cost efficiency and capital utilisation is that as the unit cost of inputs rise, agents in the rail market are forced to use them more effectively and/or substitute inputs (e.g. capital for labour). This may be the case in Sweden where all of the primary KPIs (which capture capital-based measures of efficiency) demonstrated an improvement over the period 2007 – 2012, while all of its secondary KPIs deteriorated. Within the scope of this study it has not been possible to explore the relationship between KPIs over time in any detail. However, we recommend further work to explore in greater detail the sequence of events which lead to changes in rail efficiency and, where possible, to identify leading indicators.

3.21 Finally, changes in the quality of service may affect the observed cost efficiency of the sector. Quality initiatives which are intended to encourage mode shift or, in established rail markets, allow the operator to increase fares or charges typically involve a ramp-up period as customers respond to the new offer. In many cases, such as the examples described in paragraph 2.20, the higher operating costs as a result of providing additional services may be offset by additional revenue but, due to the increased yields achievable, may not be reflected in physical measures of rail use.

**Table 3.3: Change in secondary KPIs (2007 – 2012)**

| | Train kilometres per €m total operating costs | Train kilometres per employee (FTE) | Passenger kilometres (thousands) per €m passenger operating costs | Freight tonne kilometres (thousands) per €m freight operating costs |
|---|---|---|---|---|
| Belgium | -8% | 6% | -7% | -30% |
| Bulgaria | -14% | 11% | -12% | -37% |
| Czech Republic | -16% | 62% | -16% | -30% |
| Denmark | -5% | 19% | -11% | 4% |
| Germany | -2% | 9% | -5% | -19% |
| Estonia | -49%* | -40% | -5%* | -5%* |
| Ireland | 20% | 16% | 0% | -10% |
| Greece | -11% | 31% | -38% | -51% |
| Spain | -28% | -8% | -20% | -31% |
| France | -20% | 10% | -16% | -41% |
| Croatia | | | | |
| Italy | 10% | 21% | 7% | -4% |
| Latvia | -2%* | 16% | -27%* | 7%* |
| Lithuania | -24% | -2% | -25% | -25% |
| Luxembourg | -39% | 23% | -40% | -79% |
| Hungary | 7% | -2% | 14% | 17% |
| Netherlands | 20% | 16% | -3% | -25% |
| Austria | -22% | 2% | -8% | -29% |
| Poland | 8% | -18% | -9% | -9% |
| Portugal | -15% | 18% | -10% | -11% |
| Romania | -25% | 28% | -56% | -38% |
| Slovenia | -30% | -12% | -34% | -30% |
| Slovakia | -17% | 17% | -2% | -32% |
| Finland | -1% | 19% | 9% | -9% |

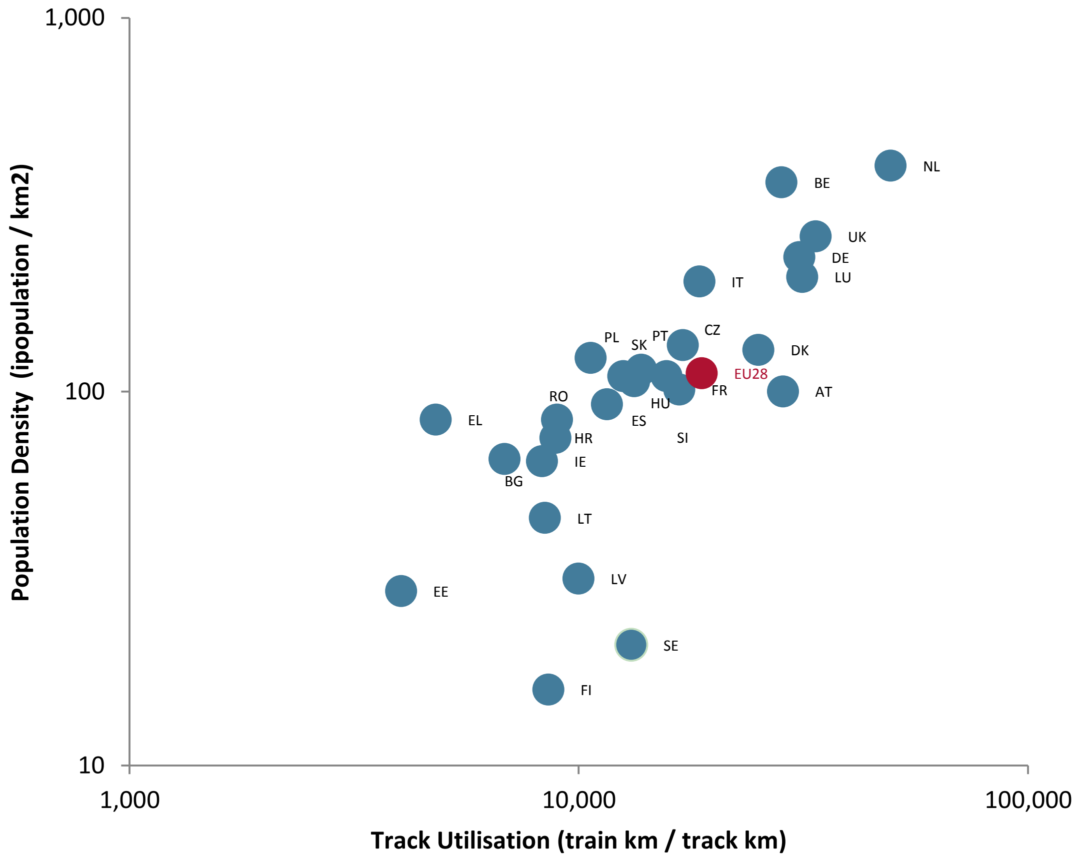
| | | | | |
|---|---|---|---|---|
| Sweden | -29% | -22% | -31% | -43% |
| United Kingdom | 3% | 13% | 6% | -12% |

Source: SDG analysis (* % figures calculated between 2008 – 2012 as data for 2007 not available)

*Capital asset utilisation*

3.22 Figure 3.4 shows the relationship between track utilisation and population density (each measured on a logarithmic scale), and suggests that more densely populated Member States such as the Netherlands and Germany generally have higher levels of track utilisation than less densely populated Member States such as Estonia and Ireland[11]. Track utilisation also appears to be higher in Sweden and Finland than might be expected given the low population densities in these countries. This may be explained by the geographical characteristics and coverage of their respective rail systems, and the relatively high proportion of single-track infrastructure. In particular, we note that the rail networks in both countries are generally focussed on linking urban centres and do not serve the sparsely populated northern regions.

**Figure 3.4: Track utilisation and population density (2012) – logarithmic scale**




Source: SDG analysis

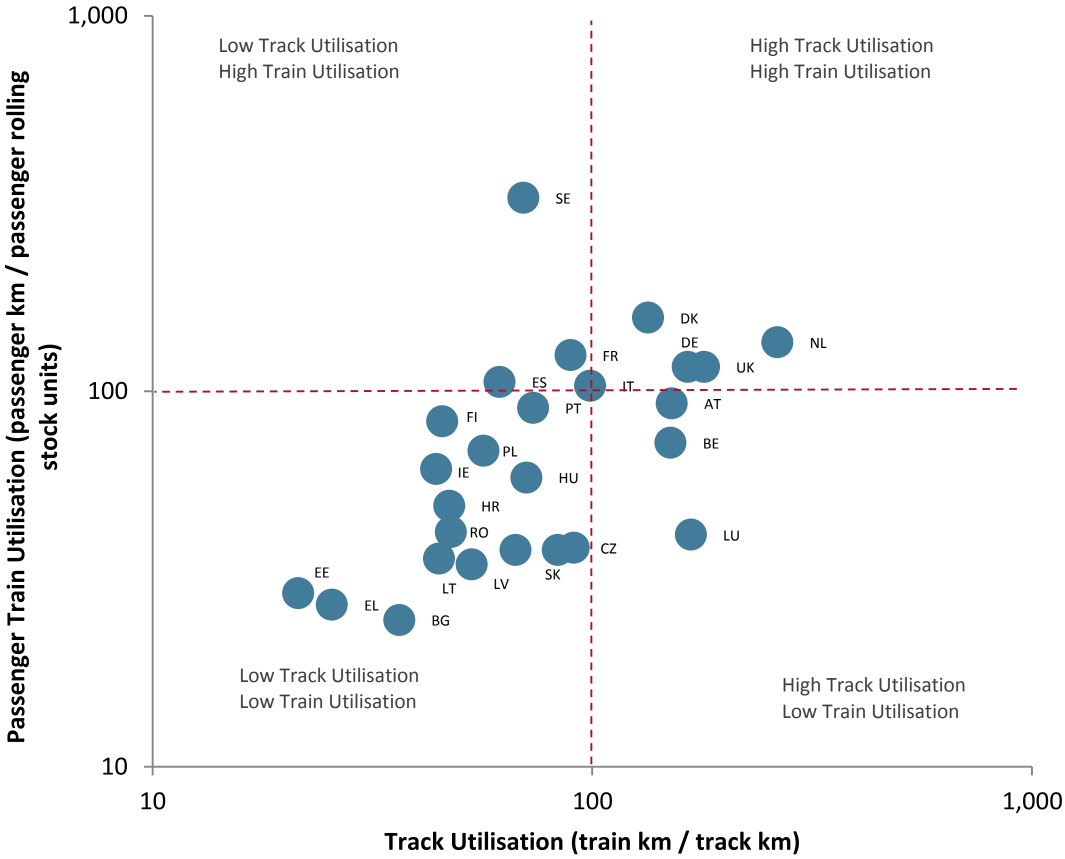
3.23 Figure 3.5 shows the relationship between track utilisation and passenger train utilisation. Again, both metrics are measured on a logarithmic scale but, in contrast to Figure 3.4, the data

[11] All of the KPI data presented in this chapter is reported by Member State in Appendix B

has been normalised such that a score of 100 represents the EU average in each case. The relative importance of track versus train utilisation is one of the features that is considered in greater detail as part of data envelopment analysis described in Chapter 5.

3.24 The figure shows that from the perspective of passenger operations the Netherlands, UK, Denmark, and Germany appear to be leveraging their capital assets more efficiently than other Member States. Sweden and France also report higher than average levels of passenger train utilisation but lower than average levels of track utilisation. This may be explained by the lower than average population density in these Member States, and a greater focus on long-distance rail travel between urban centres. In contrast, Austria, Belgium and Luxembourg report higher than average levels of track utilisation which may be reflective of the small rail network size in these Member States.

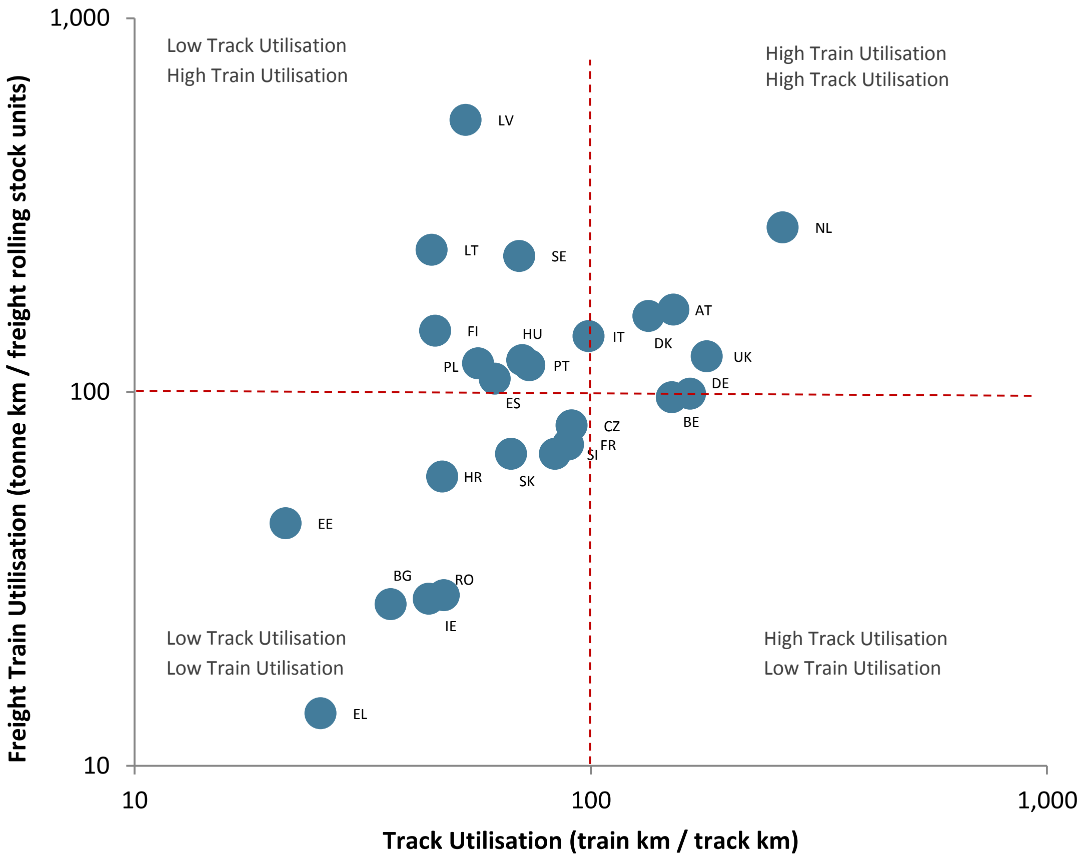
**Figure 3.5: Track utilisation and passenger train utilisation (2012) – logarithmic scale**




3.25 Source: SDG analysis

3.26 Figure 3.6 uses the same horizontal axis (track utilisation) as Figure 3.5, but shows instead freight train utilisation on the vertical axis. This chart suggests that from a freight operations perspective Member States that border the North Sea and/or serve the Alpine region have higher capital utilisation levels than other Member States. Member States that are geographically more isolated from Central Europe (e.g. Ireland, Greece and Bulgaria) report much lower than average levels of freight train utilisation. This, in turn, suggests that the number of ports (as a proxy for the total tonnage passing through a Member State's ports) may be an important exogenous influence upon performance of the freight sector.

**Figure 3.6: Track utilisation and freight train utilisation (2012) – logarithmic scale**




Source: SDG analysis (note that Luxembourg is not shown in the chart as it lies outside the area illustrated)

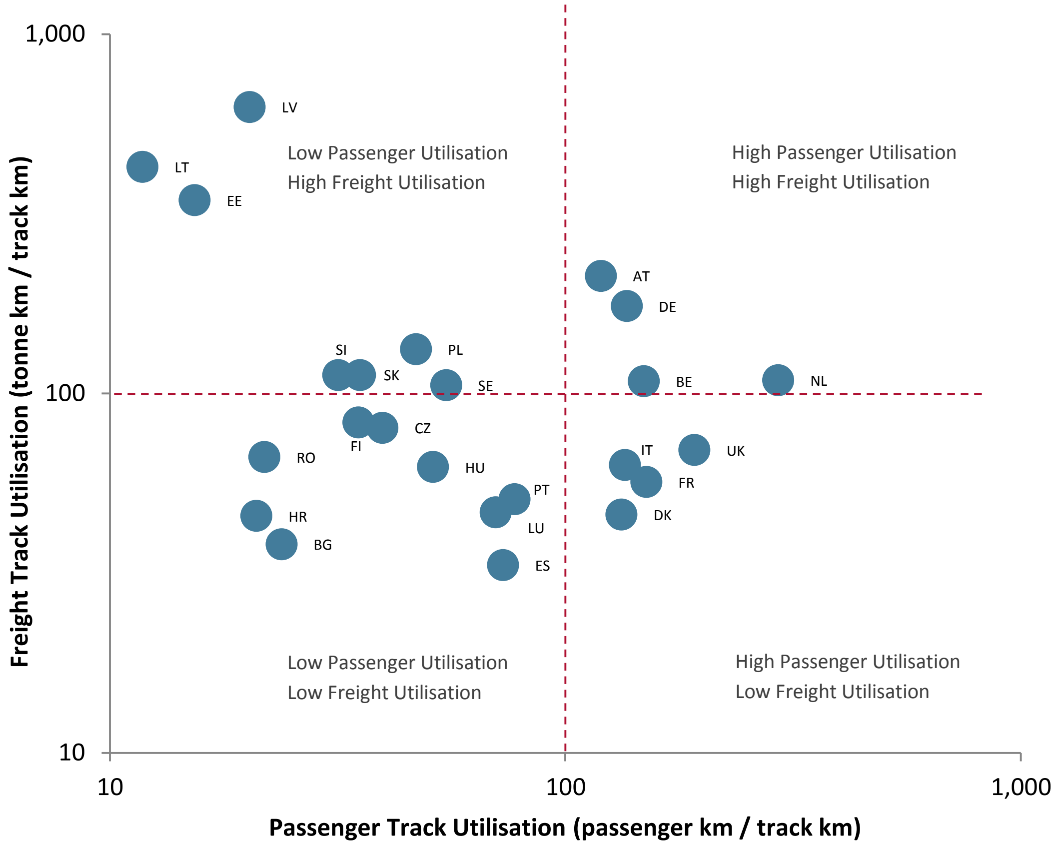
Figure 3.7 shows the relationship between passenger track utilisation and freight track utilisation using a logarithmic scale where a score of 100 represents the EU average for that indicator[12]. This helps us to categorise Member States according to the main market served by their railway network (passenger-centric, freight-centric or both). It is notable that most Member States with higher than average passenger track utilisation are relatively high income, Western European countries. However, those Member States with the very highest freight track utilisation are the three Baltic States. The high utilisation rates are as a result of large freight transit traffic volumes to Russia and other countries in the Commonwealth of Independent States (CIS).

3.27 Figure 3.8 shows the same relationship on an absolute scale and suggests there may be a trade-off between freight track utilisation and passenger track utilisation, as indicated by the

[12] Care should be taken when comparing Figures 3.5 and 3.6 with Figures 3.7 and 3.8. The 'track utilisation' metric is formulated differently whereby in the former figures it measures train kilometres per track kilometre while in the latter figures it measures passenger kilometres or freight kilometres per track kilometre.

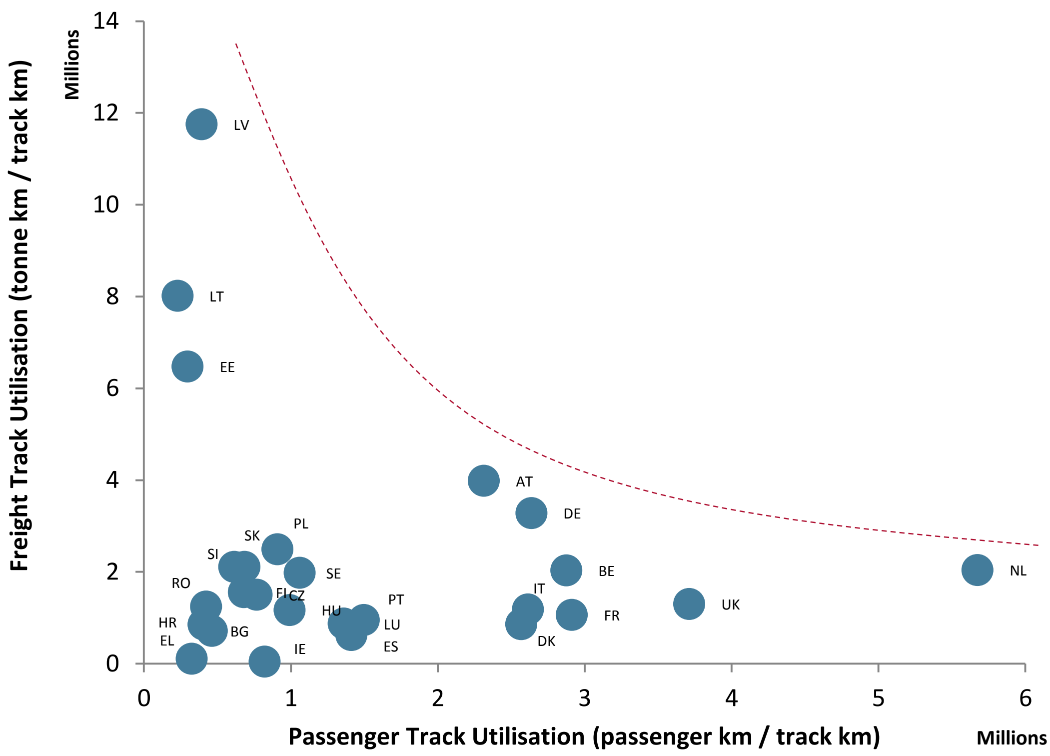
illustrative efficiency frontier[13]. This is unsurprising given that both types of operations often use the same network and compete for scarce paths.

**Figure 3.7: Passenger track utilisation and freight track utilisation (2012) – logarithmic scale**




[13] Note that the efficiency frontier has been shown for illustrative purposes only. No statistical tests were carried out to determine the significance, nor test the functional form of this relationship.

**Figure 3.8: Passenger track utilisation and freight track utilisation (2012) – absolute figures**



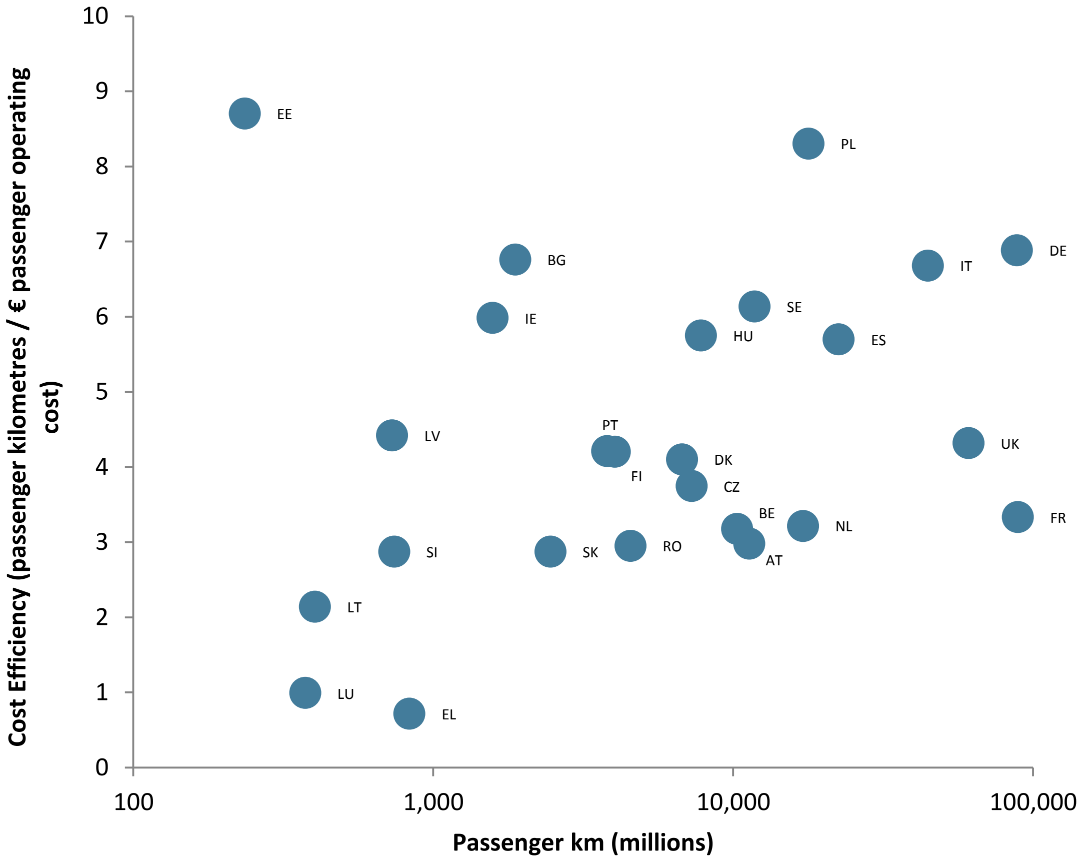

Source: SDG analysis

## Asset Utilisation

3.28 Figure 3.9 shows the relationship between cost efficiency and rail sector size, the former defined as the number of passenger kilometres delivered for each Euro of operating costs for the passenger rail sector, and the latter measured in terms of the number of passenger kilometres[14]. The cost efficiency measure includes both the cost of delivering passenger rail services and the costs associated with operating and maintaining the infrastructure attributable to passenger services, net of track access charges. It therefore avoids any potential issues regarding the influence of different funding channels on track access charges (which in turn could undermine the reliability of the results). Alternative measures of the size of the rail sector (including both input and output measures) generate broadly similar results.

[14] At the request of the Commission we have disaggregated operating costs for both railway undertakings and infrastructure managers split by freight and passenger operations. Where figures have been reported separately we have used primary data sources. Elsewhere it has been necessary to disaggregate costs according to the freight/passenger split of train kilometres as reported by the Independent Regulators Group *Rail Market Monitoring Report 2014*.

**Figure 3.9: Cost efficiency and passenger km (2012) – logarithmic scale**




Source: SDG analysis

3.29 The chart indicates a weak relationship between rail system size and efficiency, with larger railway systems marginally more cost efficient than smaller ones. This, in turn, suggests that economies of scale (and potentially network benefits) may play a relatively limited role in delivering high levels of efficiency, and that relative efficiency is likely to be affected by a range of factors other than scale.

3.30 The rail network in Germany delivered 88.4 billion passenger kilometres in 2012, 6.9 passenger kilometres for every Euro of operating costs spent. By contrast, France delivered marginally higher passenger outputs of 89.1 billion passenger kilometres but at more than twice the cost (3.3 passenger kilometres per € operating cost). In practice this is due, in part, to the considerably larger labour force employed by the French railways (158,000) compared to German railways (100,000).

3.31 While a number of smaller, Eastern European rail systems appear to deliver higher than average passenger kilometres per unit of operating costs this may, in part, be an artefact of the methodology used to disaggregate total operating costs into freight and passenger costs[15].

[15] By disaggregating total operating costs (for both operators and infrastructure managers) according to the proportion of passenger and freight train kilometres, in those Member States where freight delivers a large proportion of total train kilometres relative to passenger-focussed rail systems it may be the case that the operating costs for the passenger railway are under-estimated.

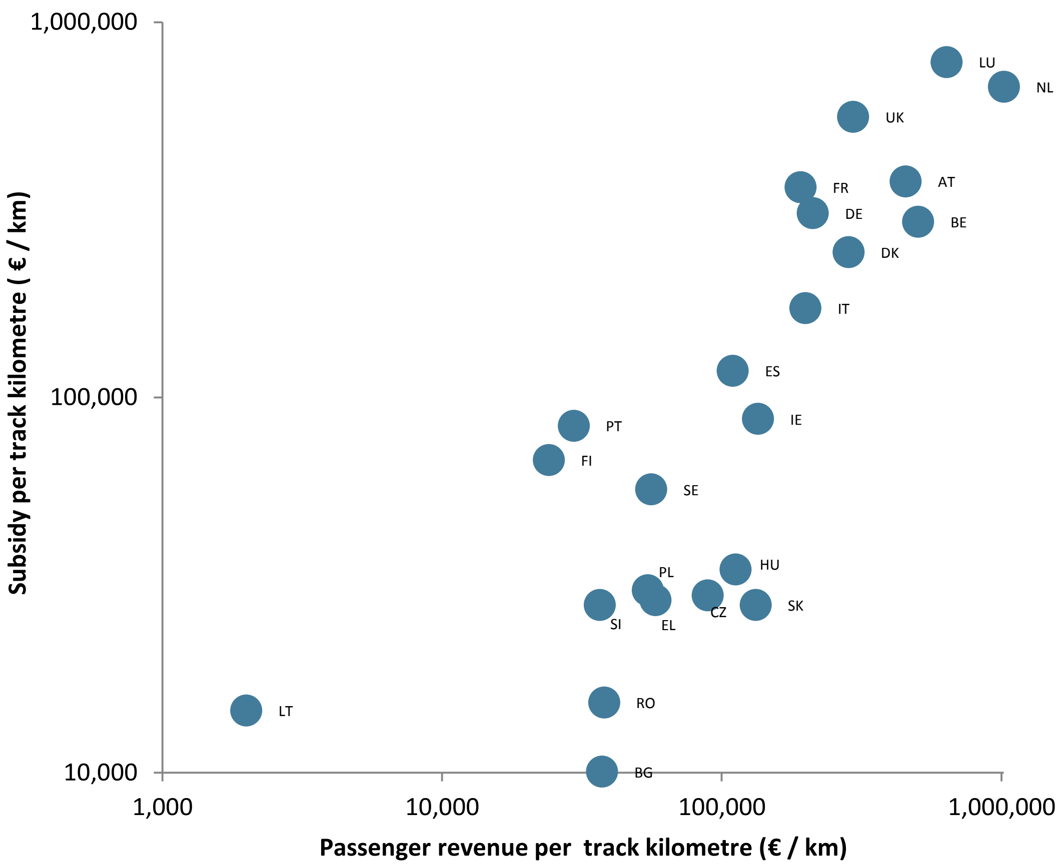
Ireland, on the other hand, which has relatively small freight sector, provides a more direct comparison to the larger Member States and appears to deliver high levels of rail patronage relative to its operating costs.

### Subsidies

3.32 Figure 3.10 illustrates the relationship between passenger revenues and total subsidies[16]. These have been normalised using track kilometres as a scaling measure. The strong positive correlation suggests that subsidy and revenue increase is in-line with each other and we note that, in absolute terms, subsidies tend to be greater in large, higher income Member States. From a purely financial perspective, we might have expected to observe a negative relationship. In practice, however, this suggests either that:

- Member States which provide a high-quality, high-frequency railway generate higher levels of patronage and fare revenue (e.g. Netherlands);
- Member States which generate high levels of patronage and revenue are willing to subsidise higher quality rail services (e.g. United Kingdom); or
- Some combination of the two points above (e.g. Germany).

**Figure 3.10: Subsidy and revenue (2012) – logarithmic scale**




[16] Freight operations should, in principle, not be subsidised. They may, however, benefit indirectly from the subsidies provided to infrastructure managers - higher subsidies to infrastructure managers lead to lower track access charges.

Source: SDG analysis (note that it has not been possible to obtain reliable revenue data for Estonia and Croatia. Latvia is not shown on the charts as it lies outside the area illustrated)

## Conclusions

3.33 In carrying out this investigation it was notable how few relationships could be identified on a bivariate basis, suggesting that the range of factors which affect the efficiency of rail networks between Member States are many and/or the relationships are complex.

3.34 This chapter summarises the results of an extensive data mining exercise in which relationships between primary KPIs and secondary KPIs/exogenous variables were explored in depth. The purpose of this exercise was to develop hypotheses regarding the variables that are likely to have greatest influence upon the efficiency of the rail sector, and to test these hypotheses through the subsequent clustering (exogenous) and data envelopment analysis (endogenous) exercises.

# 4 Clustering analysis

## Overview

4.1 The primary goal of the clustering exercise is to control for the impact of exogenous factors that are beyond the control of managers and policy-makers and can only be changed over the long term, if at all. This allows us to focus on differences in industry performance that are explained by endogenous factors, including investment and innovation. We therefore cluster Member States into subsets consisting of countries for which the impact of exogenous factors is expected to be broadly similar. In analytical terms, the aim is to minimise the similarity between the subsets while maximising the similarity between countries within each subset. This will:

- Establish a basic categorisation of national rail systems for the purpose of the current analysis and to inform future benchmarking exercises at the EU level; and
- Increase the discriminatory power of the subsequent efficiency analysis by reducing the heterogeneity of the sample.

4.2 Clustering analysis is intended to provide a bridge between the bivariate analysis of key performance indicators described in Chapter 3 and the more formal measurement of efficiency generated by the data envelopment analysis described in Chapter 5.

## Clustering principles

4.3 The choice of exogenous variables to include within the clustering analysis was informed by:

- Empirical evidence;
- Economic theory; and
- Investigation of KPIs discussed in the previous chapter.

4.4 In order to identify relevant exogenous factors we reviewed a selection of academic and industry literature on the determinants of utilisation and efficiency of national rail services (e.g. mode share, productivity) and isolated the exogenous factors that appear most frequently. From our review of the literature (summarised in Table 4.1), we concluded that:

- Measures of population density (inhabitants per $km^2$) and wealth (GDP per capita) should be included as explanatory variables within the clustering analysis;
- Where available, specific measures closely related to rail (e.g. the number of major ports linked by rail) are preferred to broader definitions such as the length of the coastline and should be included;
- The external cost of car travel is highly correlated with GDP per capita and should not be included in the analysis;
- While the existing length/density of the rail network is arguably endogenous over the long term, we consider that it should be treated as exogenous given the timeframe of our

analysis, since it depends on the legacy assets in place at the beginning of the period under investigation; and

- Some measure of technological development (recognised as critical in the majority of the studies surveyed) should be included[17].

**Table 4.1: Literature review – key determinants of utilisation and efficiency of rail**

| Year | Author, Title | Significant exogenous factors |
|---|---|---|
| 2012 | Laabsch, Sanner: "The Impact of Vertical Separation on the Success of the Railways" | GDP/capita |
| | | Share of rail as % of public expenditure |
| 2010 | Mizutani, Uranishi: "Does Vertical Separation Reduce Cost?" | Rail network length |
| 2008 | Wetzel: European Railway Deregulation : "The influence of regulatory and environmental conditions on efficiency" | Population density |
| | | Rail network density |
| 2008 | Pvlyuk: "Efficiency analysis of European countries railways" | GDP/capita |
| | | Population density |
| 2007 | Vassallo, Fagan: "Nature or nurture: why do railroads carry greater freight share in the United States than in Europe?" | Length of coastline |
| 2006 | Wardman: "Demand for rail travel and the effects of external factors" | GDP |
| | | Cost of travel by road |
| 2003 | Friebel, Ivaldi, Vibes: Railway deregulation: A European efficiency comparison | Country size measured by network length and density |
| 1994 | Oum and Yu: "Economic efficiency of railways and implications for public policy" | Rail network density |

Source: Steer Davies Gleave analysis

4.5 We also considered the insights identified from our analysis of KPIs described in Chapter 3. More specifically, we took account of:

- The strongest observed trends related to the utilisation of capital assets, according to the following primary KPIs:
  - Track utilisation: Train km / track km
  - Passenger train utilisation: Passenger km / passenger rolling stock fleet size
  - Freight train utilisation: Tonne km / freight rolling stock size
- A number of specific relationships which appeared to be particularly important:
  - the strong positive relationship between track utilisation and population density;
  - the apparent trade-off between freight and passenger track utilisation;
  - some evidence of scale effects and network benefits - larger rail systems were on average more efficient; and

[17] As shown in Table 4.2 we used a measure of high-speed network length as a proxy for technological development.

- The limited evidence relating to the utilisation of non-capital assets generated through our examination of KPIs.

4.6 On the basis of these exercises, the exogenous variables described Table 4.2 were used in the clustering exercise as the measures against which the similarity between Member States would be estimated.

**Table 4.2: Clustering variables**

| | Passenger | Freight | Comments |
|---|---|---|---|
| Population | ✓ | ✓ | Affects the overall level of activity in the economy |
| Area | ✓ | ✓ | Rail has a particular advantage over medium distances |
| Population density | ✓ | | Goods carried by freight not typically affected by settlement patterns |
| Urban population (%) | ✓ | | As above |
| GDP per capita | ✓ | ✓ | Direct measure of economic activity |
| Border countries (#) | | ✓ | Long-distance transit freight supports international trade |
| Ports connected by rail | | ✓ | Majority of goods conveyed by freight travel to/from sea ports |
| Network length | ✓ | ✓ | Direct measure of network size |
| High speed network length | ✓ | | Indirect measure of innovation |

4.7 The number of clusters needs to be large enough to ensure that it is possible to differentiate between them, while at the same time the number of observations within each cluster needs to be large enough to ensure the data envelopment analysis generates meaningful estimates of relative efficiency between Member States. In addition, while clustering should be based on the most recent data available, it is important to avoid allocating Member States to clusters based on what might be one-off events in a given year. We have reviewed historical series and, where outliers were found, taken an average across a three year time period.

## Clustering methodology

### Trial methodologies

4.8 While it is necessary to use an approach that is rooted in evidence, the methodology underpinning the definition of clusters should also be transparent and robust. Using the principles described above as a guide, we considered and applied a number of alternative clustering techniques before identifying a preferred approach. More specifically, we considered three distinct yet complementary methodologies that appeared promising but which were ultimately discarded. These were:

- Regression modelling;
- Hierarchical partitioning; and
- Expert review.

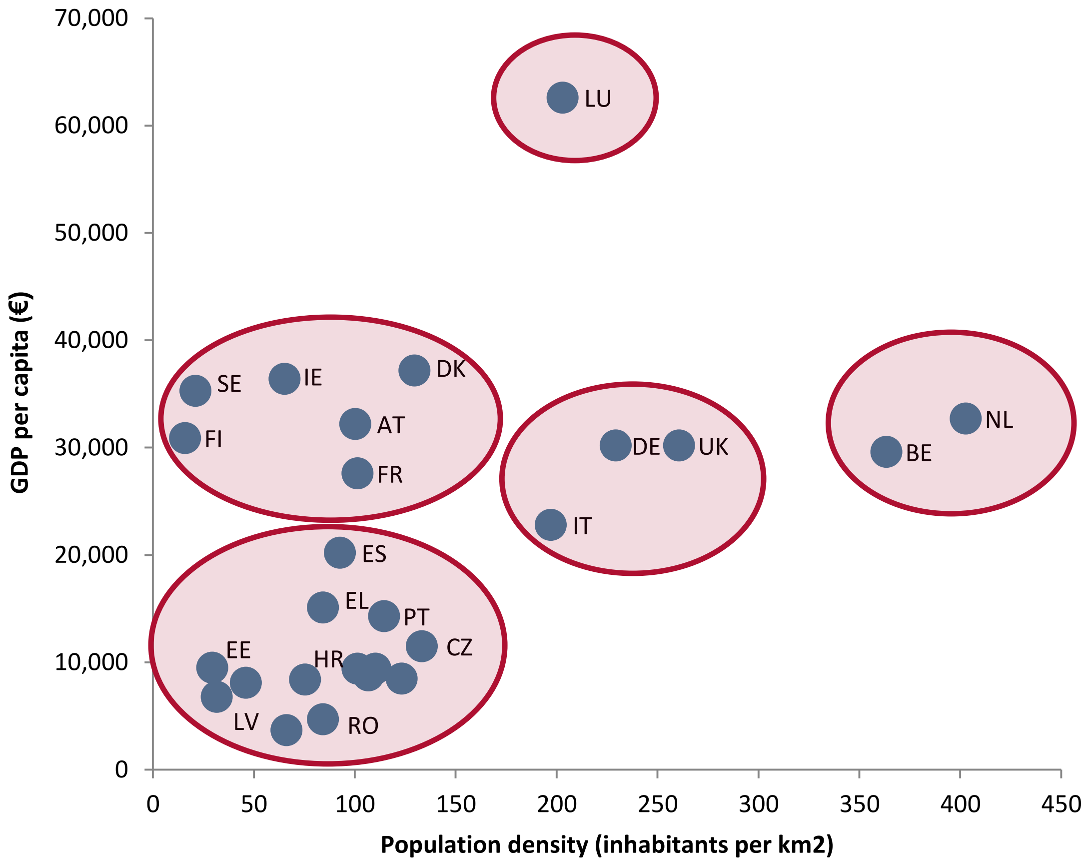
4.9 Given the limitations of these approaches, as reported in Appendix B, we concluded that there would be a significant risk of misallocation of a Member State to a cluster if any one of them were applied in isolation. This, in turn, could have significant implications for the results of the scenario assessment exercise (for example, if the best performing observation in a given cluster were misallocated and became the worst performing Member State in another). We therefore identified an alternative approach, using non-parametric analysis, which places greater weight on the use of data to determine cluster boundaries.

### Multi-dimensional clustering analysis

4.10 Cluster analysis is a non-parametric statistical technique used to group 'similar' objects into clusters, by searching for groups among multi-dimensional data points. Similarity can be defined in a number of ways, but is essentially the distance (or separation) between measurements of characteristics, such as the population density for two Member States.

4.11 For example, as shown in Figure 4.1, if all Member States were defined by only two exogenous criteria – GDP per capita and population density - they could be plotted on a two-dimensional scatterplot, with the two axes corresponding to those criteria. Cluster analysis would then identify 'clouds' of points that could be grouped together according to a distance criterion.

**Figure 4.1: Illustration of clustering analysis (2012)**




Source: SDG analysis (clusters shown are for illustrative purposes only)

4.12 By avoiding the need to impose thresholds or watersheds between clusters, this approach avoids many of the pitfalls of regression-based analysis, where the partitioning of clusters according to predetermined thresholds may ignore particular features and characteristics of the Members States.

4.13 There are multiple functional forms for the distance measure used to identify how near or far observations are from each other. There are also multiple criteria against which clusters can be defined and a range of optimisation strategies that can each lead to different clusters. To ensure that the approach chosen generated meaningful results we specified a clustering approach with the following characteristics:

- Hierarchical: the set of clusters generated is nested and organised as a tree. Each node (cluster) in the tree is the union of its branches (sub-clusters) and the root of the tree is the cluster containing all the objects (in this case Member States).
- Exclusive: Member States cannot belong to more than one cluster. Each object is assigned to a single cluster only.
- Complete: Every Member State is assigned to a cluster.

4.14 Given the requirements described above, and to avoid predetermining the number of clusters, we used agglomerative hierarchical clustering techniques, which tend to be the most common methods used in practice[18]. Agglomerative clustering methods begin with every object (Member State) defined as an individual cluster, following which, at each iterative step, the closest pairs of clusters are merged.

4.15 More specifically, for this study we have used an agglomerative technique known as Ward's minimum variance method[19]. This aims to minimise the total 'within cluster' variance across all the clusters and ensures the clusters are compact with a good level of similarity between observations in the same cluster. The distance measure used to calculate the distance between clusters is given by the following formula[20]:

$$\left[\sum_{p=1}^{P}(x_{i,p}-x_{j,p})^2\right]^{1/2}$$

4.16 A hierarchical clustering can be displayed graphically using a tree-like diagram called a dendrogram, which shows both the cluster/sub-cluster relationship and the order in which the clusters were merged. Figure 4.2 shows an example dendrogram (and its associated nested cluster diagram) for a set of four two-dimensional points. Dendrograms showing the results of the clustering analysis carried out for this study are provided in Appendix D.

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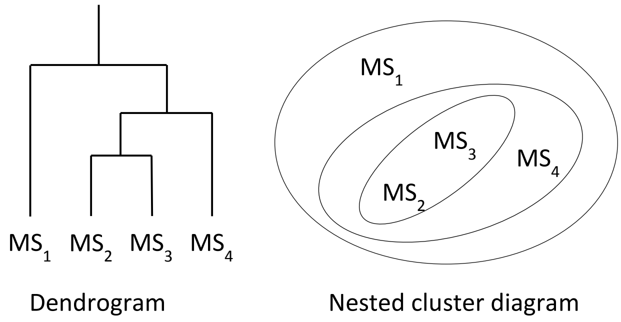
[18] See *Introduction to Data Mining* (Tan, Steinbach and Kumar, 2006)

[19] See Ward, J.H. (1963) *Hierarchical Grouping to Optimize and Objective Function*, Journal of the American Statistical Association

[20] We also considered an alternative distance measure (the squared Euclidean) but this had no impact upon the results of the clustering analysis.

**Figure 4.2: Dendrogram and nested cluster examples**




## Application and results

4.17 Based on the measures reported in Table 4.2, we identified combinations of variables to be used in the clustering exercise. In doing so we carried out both freight and passenger-oriented clustering exercises using variables that are expected to affect the efficiency of that sector (for example, we would not expect the number of ports linked by rail to have a material influence on the efficiency of the passenger railway).

**Table 4.3: Summary of clustering analysis**

| | Passenger | | | | | Freight | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Clustering model** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| Population | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Area | | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ |
| Population density | ✓ | | | ✓ | | | | | |
| Urban population (%) | ✓ | ✓ | | ✓ | ✓ | | | | |
| GDP per capita | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Border countries (#) | | | | | | | ✓ | ✓ | |
| Ports connected by rail | | | | | | ✓ | ✓ | ✓ | ✓ |
| Network length | | | | ✓ | ✓ | | | | ✓ |
| High speed network length | | | | ✓ | | | | | |

4.18 In carrying out the clustering analysis, we identified the following features and trends. For the passenger-based clustering exercises (1 to 5):

- Separate measures of population and land mass strongly dominate all other variables. This leads to very stable (but counterintuitive) clusters.
- Using a measure of population density is preferable to using separate measures of population and land mass (area) and fits with insights drawn from the KPI analysis exercise reported in Chapter 3.
- Clustering based on population density (among other measures) consistently identified Luxembourg as an outlier – this may be a result of both Luxembourg's size and the divergence between resident population and employment.
- Including measures of network length led to an allocation of Member States to clusters according to their size. These results were considered preferable to those derived using an approach that ignored network size, as network length can be regarded as a proxy for scale effects.

- The specification of the high-speed network length (in absolute or proportionate terms) had no impact on the results of the clustering exercise.

4.19 For the freight-based clustering exercises (6 to 9):

- As with the passenger-focussed clustering tests, the inclusion of land mass within the analysis strongly dominates all other variables. In the presence of a land mass variable, the inclusion of measures that describe the number of ports linked by rail or number of border countries did not affect the specification of clusters.
- Removing measures of land mass from the clustering analysis increases the influence of those measures thought to be more closely linked to freight performance, such as the number of ports and border countries.
- Again, Luxembourg was consistently identified as an outlier.

4.20 For each of the clustering exercises, we sought to identify four to six clusters[21]. As labelled in Figure 4.3, clustering exercises four (passenger-based) and eight (freight-based) generated the most stable and intuitive results and are presented in Table 4.4 and Table 4.5 below. The colour coding represents the allocation of Member States to clusters. A full set of clustering outputs, including the associated dendrograms is provided in Appendix D.

**Table 4.4: Clustering outputs (passenger) – test 4**

| | 6 clusters | 5 clusters | 4 clusters |
|---|---|---|---|
| Belgium | Red | Red | Red |
| Denmark | Red | Red | Red |
| Ireland | Red | Red | Red |
| Netherlands | Red | Red | Red |
| Austria | Red | Red | Red |
| Finland | Red | Red | Red |
| Luxembourg | Purple | Purple | Purple |
| Germany | Mid blue | Mid blue | Mid blue |
| France | Mid blue | Mid blue | Mid blue |
| Spain | Light blue | Light blue | Mid blue |
| Italy | Light blue | Light blue | Mid blue |
| Sweden | Light blue | Light blue | Mid blue |
| UK | Light blue | Light blue | Mid blue |
| Poland | Light green | Light green | Light green |
| Hungary | Light green | Light green | Light green |
| Czech Republic | Light green | Light green | Light green |
| Bulgaria | Light green | Light green | Light green |
| Romania | Light green | Light green | Light green |
| Estonia | Dark green | Light green | Light green |
| Greece | Dark green | Light green | Light green |
| Croatia | Dark green | Light green | Light green |
| Latvia | Dark green | Light green | Light green |
| Lithuania | Dark green | Light green | Light green |
| Slovenia | Dark green | Light green | Light green |
| Slovakia | Dark green | Light green | Light green |
| Portugal | Dark green | Light green | Light green |

Source: SDG analysis

[21] Note that, due to the hierarchical nature of the clustering methodology, in order to generate one of the clusters identified in the '4-cluster' specification, two cluster from '5-cluster' specification must be combined, and vice-versa.

**Table 4.5: Clustering outputs (freight) – test 8**

| | 6 clusters | 5 clusters | 4 clusters |
|---|---|---|---|
| Belgium | | | |
| Germany | | | |
| France | | | |
| Netherlands | | | |
| Austria | | | |
| Finland | | | |
| UK | | | |
| Denmark | | | |
| Ireland | | | |
| Sweden | | | |
| Luxembourg | | | |
| Bulgaria | | | |
| Romania | | | |
| Czech Republic | | | |
| Estonia | | | |
| Croatia | | | |
| Latvia | | | |
| Lithuania | | | |
| Hungary | | | |
| Poland | | | |
| Slovakia | | | |
| Greece | | | |
| Spain | | | |
| Italy | | | |
| Portugal | | | |
| Slovenia | | | |

Source: SDG analysis

4.21 After reviewing the clustering results presented above, we made a small number of adjustments based on our experience and professional judgement in order to improve the explanatory power of the clusters, and improve alignment between the results of the clustering and KPI analysis. Our starting point for the adjustments were the six passenger-oriented clusters reported in Table 4.4. However, we were careful to ensure that important features of the freight market in Europe were retained, for example, the dominance of freight traffic in the Baltic States suggested these Member States should be captured within one cluster.

4.22 The specific adjustments were as follows:

- Since Luxembourg was consistently identified as an outlier (in other words, classed as a cluster containing just one Member State) we chose to combine it with the cluster including Belgium, Denmark, Ireland, Netherlands, Austria and Finland. This was supported by the data as in both the freight and passenger clustering analysis Luxembourg was grouped with members of these clusters at higher levels of aggregation i.e. where only two or three clusters were identified.
- We combined the cluster including Germany and France with that including Spain, Italy, Sweden and the UK, directly in-line with the results from the passenger-oriented clustering exercise.

- We split the large residual cluster according to the 6-cluster results from the passenger-oriented clustering exercise[22].

4.23 The final set of clusters are presented in Table 4.6.

**Table 4.6: Final clusters**

| Cluster A | Cluster B | Cluster C | Cluster D |
|---|---|---|---|
| Belgium | Germany | Poland | Estonia |
| Denmark | France | Hungary | Greece |
| Ireland | Spain | Czech Republic | Croatia |
| Netherlands | Italy | Bulgaria | Latvia |
| Austria | Sweden | Romania | Lithuania |
| Finland | UK | | Slovenia |
| Luxembourg | | | Slovakia |
| | | | Portugal |

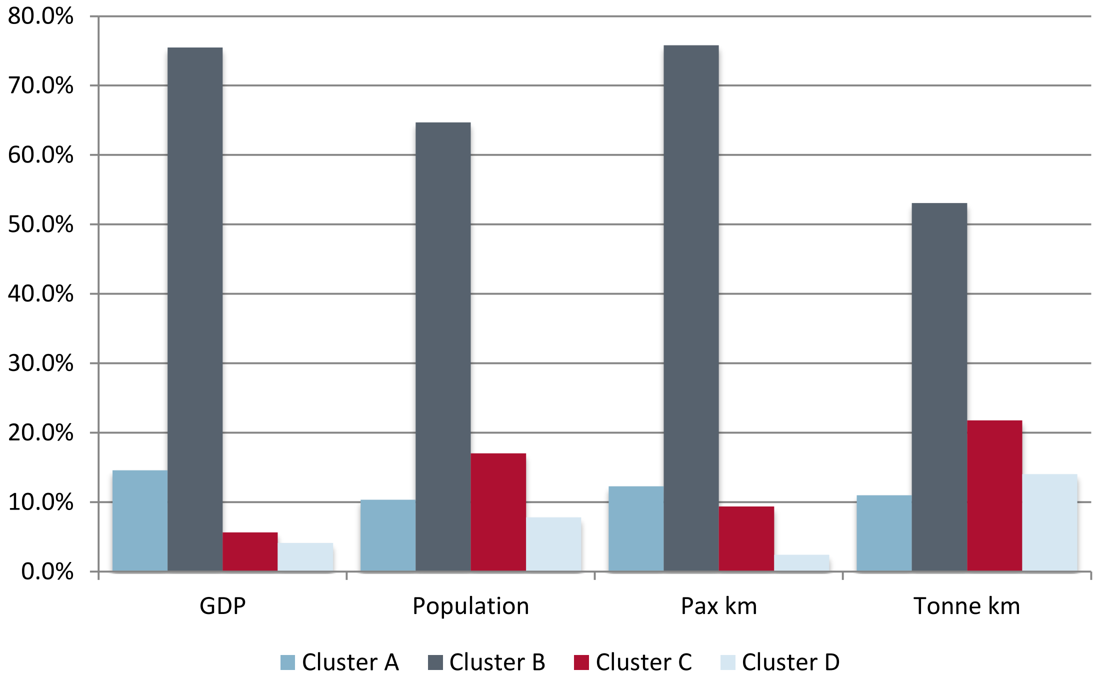
4.24 Upon initial inspection, the clusters may be broadly categorised as follows:

- Cluster A: Relatively small, high income western European countries;
- Cluster B: Large, populous western European countries;
- Cluster C: Medium-sized, lower income central and eastern European countries; and
- Cluster D: Baltic states and Mediterranean fringe countries with lower incomes.

4.25 Figure 4.3 summarises the size of the clusters obtained above with respect to population, GDP, passenger-kilometres and freight tonne kilometres. While clusters A, C and D are broadly of the same size, particularly with respect to population, cluster B is significantly larger. This is unsurprising since cluster B includes Europe's five largest economies. It is notable that the variable with least variation between clusters is freight tonne kilometres, consistent with the observation that the rail networks of the larger Member States captured within cluster B are focused primarily on the provision of passenger rather than freight services.

[22] Since 78% of the market for rail services in the European Union is passenger traffic, we have placed greater, but not exclusive, weight on the findings of the passenger-based clustering exercise

**Figure 4.3: Relative size of clusters by GDP, population, passenger km and freight tonne km (2012)**




Source: SDG analysis

4.26 Figure 4.4 and Figure 4.5 examine a subset of the variables used to inform the clustering exercise in more detail. It is clear from Figure 4.4 that the Member States that make up clusters A and B have significantly higher income per capita than those Member States in clusters C and D. However, as Figure 4.5 indicates, the countries in cluster A are significantly smaller than those in cluster B and this is reflected in the size of their rail network. The rail networks within cluster C are generally larger than those in cluster D, but there is considerable variation between individual Member States.

**Figure 4.4: GDP per capita by Member State and cluster (2012)**

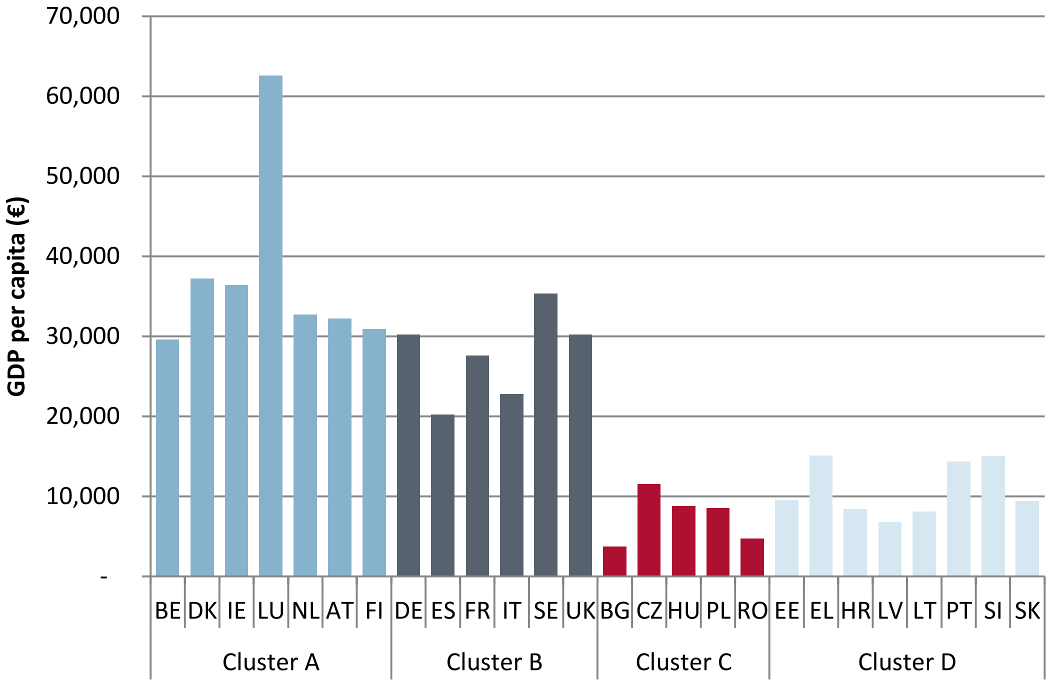
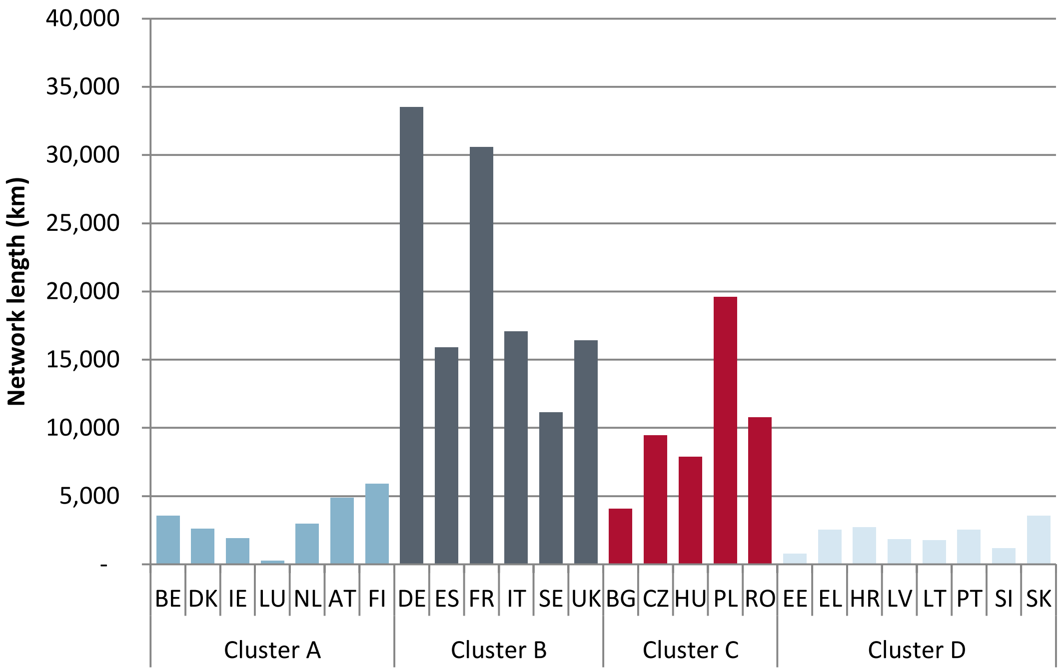


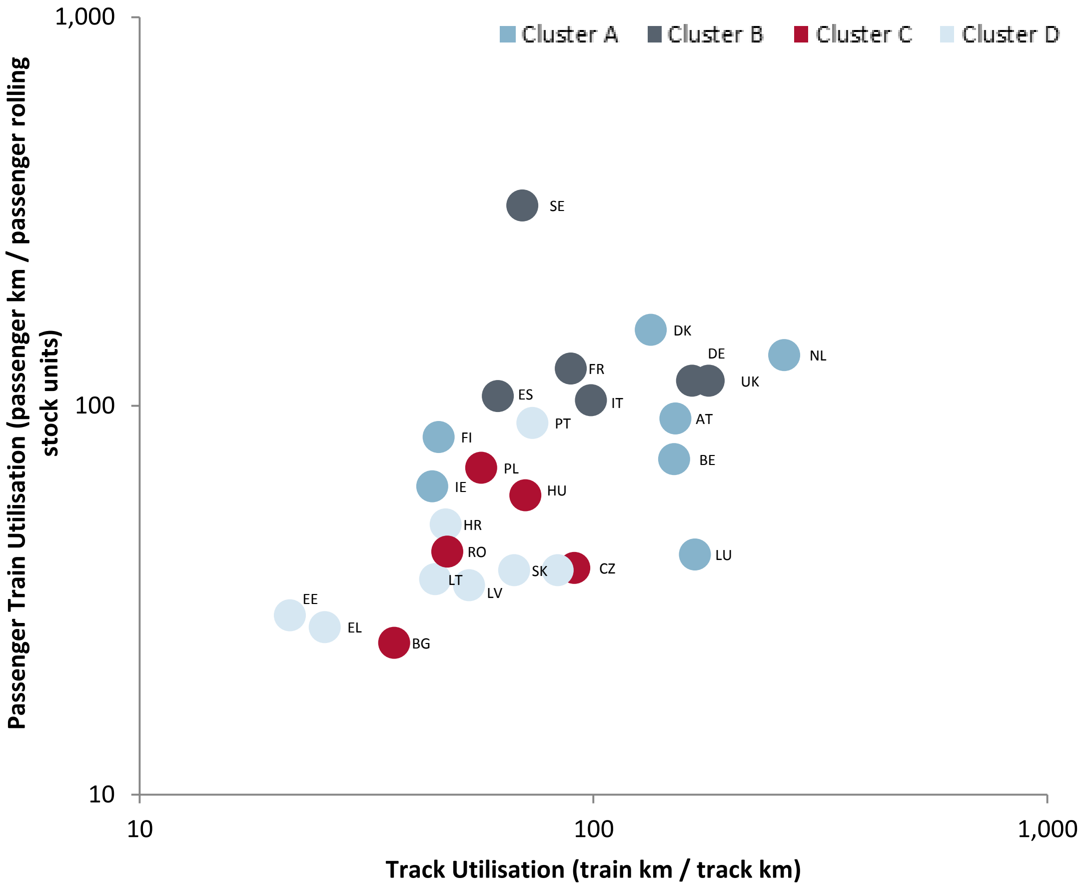

**Figure 4.5: Rail network length by Member State and cluster (2012)**




Source: SDG analysis

4.27 In order to understand the extent to which the clustering analysis has captured variations in the relative performance of Member State rail systems (as measured by primary KPIs), Figure 4.6 and Figure 4.7 replicate Figure 3.5 and Figure 3.6 with the data points coloured according to the cluster to which the Member State is assigned. If the data points for a given cluster are located close to each other, we can infer that exogenous variables account for a large proportion of the variation between Member States. Conversely, if the data points remain dispersed, this suggests that endogenous (and potentially unobserved) factors have a greater role to play in explaining relative performance.

**Figure 4.6: Passenger train utilisation versus total track utilisation by Member State and cluster (2012)**



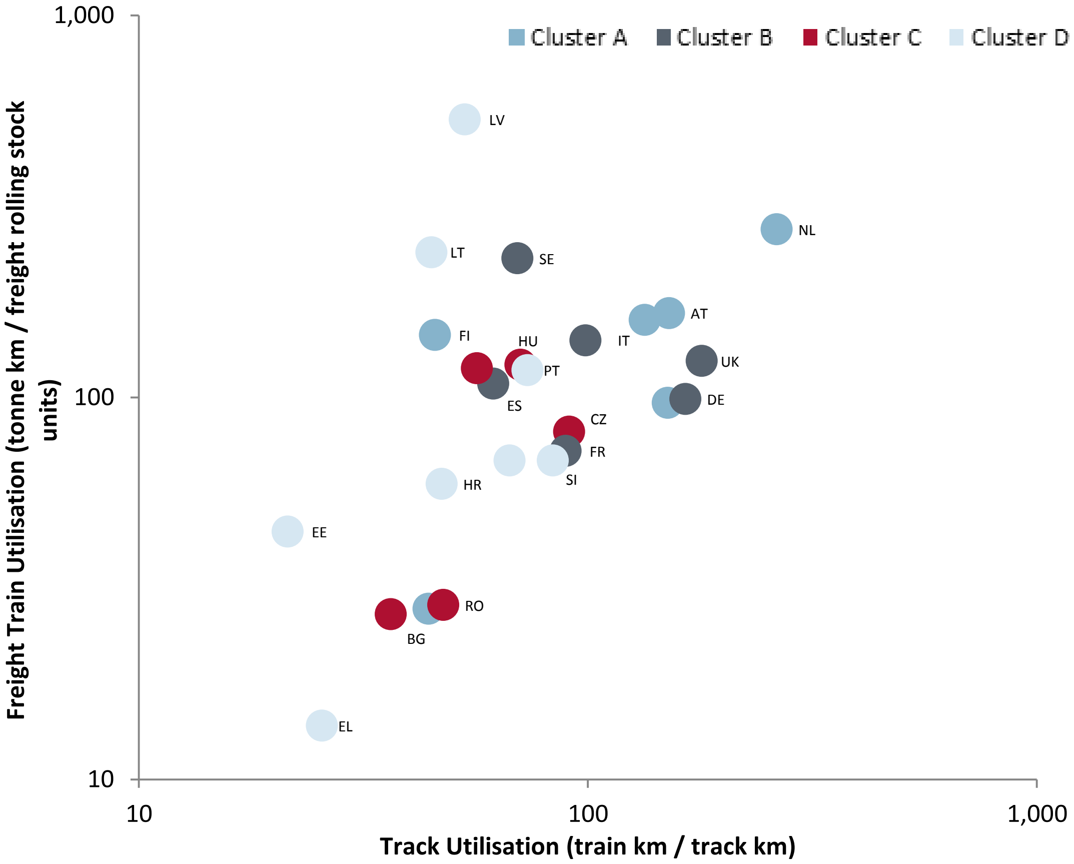

Source: SDG analysis

4.28 Typically, high levels of passenger track utilisation are often representative of extensive public service obligations and, due to the requirement to deliver service level commitments, can often lead to lower levels of train utilisation. Figure 4.6 suggests that the exogenous variables used in the clustering exercise perform well in explaining variation in the performance of Member States in clusters C and D against both passenger train utilisation and track utilisation.

4.29 In clusters A and B, however, the explanatory power of these variables is more mixed. Observations for cluster B are relatively tightly grouped against the train utilisation metric, but there is considerably greater variation against the track utilisation measure. The converse appears to be true for cluster A, where performance against the track utilisation measure is uniform (with Ireland and Finland obvious outliers) but there is greater variation in performance against the train utilisation measure.

4.30 In contrast, Figure 4.7 suggests that the exogenous variables used to cluster Member States are better for explaining variation in freight train utilisation for clusters A and B than for clusters C and D. This is likely to be a consequence of the significant variation in the relative importance of freight to the overall market in the Member States in clusters C and D, and the greater weight placed upon the results of the passenger clustering exercise when determining the final clusters.

**Figure 4.7: Freight train utilisation versus total track utilisation by Member State and cluster (2012)**




Source: SDG analysis

# 5 Efficiency gap analysis

5.1 This chapter describes our approach to comparing the efficiency of national rail systems and presents our findings. First, it describes the analytical framework that we have used to assess the relative efficiency of different systems. It then explains how the analysis was applied in practice, and the approach taken to refining the selection of rail industry inputs and outputs subsequently used to define the core efficiency scenario selected for assessment. Finally, the chapter presents a summary of results for the most relevant combinations of inputs and outputs.

## Data Envelopment Analysis

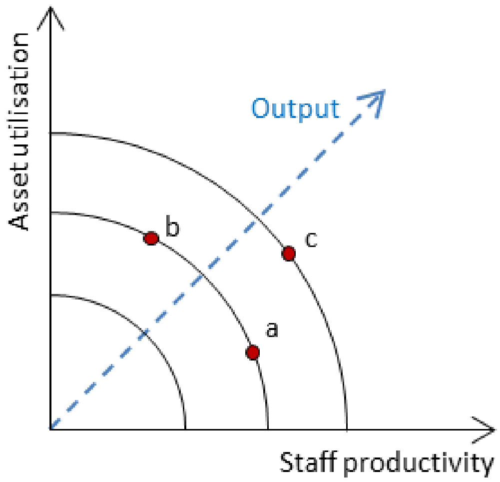
### Analytical framework

5.2 From a national perspective, an efficient railway is one which maximises outputs and minimises inputs while providing the desired level of service. Within a cluster it should therefore, in theory, be possible for Member States to influence the drivers of costs and/or revenues such that individual railway systems deliver the same level of efficiency as the 'best in cluster'. An example is provided in Figure 5.1, which shows a stylised relationship between output and efficiency.

5.3 In this example economic entities a and b (which could be different national rail industries) are producing the same level of output, albeit with different levels of capital and staff productivity. Entity c, on the other hand, is able to combine inputs more efficiently and is therefore able to generate a greater level of output for a given level of inputs. It operates on the efficiency frontier, which defines the level of output that can be achieved by 'best in class' railway systems using different combinations of input (given the available technology).

5.4 In this example, and throughout the remainder of this chapter, the efficiency frontier is defined relative to the observed levels of output relative to input for the Member States included within the analysis. It may be the case, however, that the observed efficiency frontier from our sample of Member States is not the efficiency frontier for the wider population of rail systems across the world. This may arise, for example, due to missing observations in the efficiency analysis e.g. by including additional countries we may observe that EU Member States still have room for improvement. The results of this exercise, therefore, represent the scope for relative efficiency improvement compared to observed efficiency within the sample of EU Member States. Further efficiency gains may be achievable which are not captured in this study.

**Figure 5.1: Indicative efficiency frontier for railway operations**




5.5 Various techniques are available to assess the comparative efficiency of national rail systems. For the purposes of this study, we used data envelopment analysis (DEA), a non-parametric technique that relies on linear programming analysis. Given a set of inputs (e.g. rolling stock units, track-km) and outputs (e.g. passenger-km, tonne-km), DEA fits an efficiency frontier which envelops the data. In comparison with other techniques, DEA has the advantage that it does not assume a functional form for the efficiency frontier, nor a distributional form for the data. It therefore avoids the potential bias of selecting the wrong functional form or distributional assumptions.

5.6 DEA can compute the efficiency frontier either as output-orientated (maximising outputs for a given level of inputs), input-orientated (minimising inputs for a given level of outputs) or through mixed approaches called 'graph measures of efficiency'. We have carried out our analysis under input-orientated settings, as this mirrors the logic used to build the scenarios identified for assessment[23]. Once the efficiency frontier is determined, we calculate the inefficiency score as the distance between each data point and the frontier, with Member States on the frontier assigned a score of unity.

5.7 In addition to measuring efficiency under an assumption of constant returns to scale (CRS), we have also provided estimates using a variable returns to scale (VRS) approach[24]. The latter method allowed us to isolate the impact of size on efficiency and thus extract a measure of 'pure' technical efficiency irrespective of the size of Member State being considered. VRS has been chosen as our preferred approach, and the measure of technical efficiency reported is broken down into two components - "pure" technical efficiency and the effect of scale.

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[23] 'Rail firms have higher influence on the inputs, since output volumes are substantially influenced by macro-economic factors and […] exogenously controlled public transport service level requirements' (Merkert et al, 2010, p.40).

[24] Returns to scale describe the quantitative change in the output of a firm or industry resulting from a proportionate increase in all inputs. If the quantity of output rises in direct proportion to the increase in inputs, the firm or industry is said to exhibit constant returns to scale. By relaxing this constraint and allowing variable returns to scale we can identify whether output increases by more (increasing returns to scale) or less (decreasing returns to scale) than the change in inputs.

5.8 The clustering analysis presented in the previous chapter has also informed the DEA as follows:

- EU-wide efficiency scores are calculated using all 26 Member States within the sample;
- Member States (and their efficiency scores) are grouped according to the clusters estimated in Chapter 4; and
- Efficiency scores are subsequently re-based according to the level of efficiency achieved by the best-in-cluster Member State (a worked example is provided in paragraphs 6.4 to 6.8).

### Application of data envelopment analysis

5.9 Given the flexibility of DEA to incorporate measures of inputs and outputs across multiple dimensions, we followed a systematic but iterative approach to analyse the efficiency of national railway systems. Table 5.1 describes the combination of inputs and outputs used in the six DEA models on which our efficiency assessment is based. These combinations of inputs and outputs have been chosen as they most closely reflect the KPIs described in Chapter 3 and the scenario development activities explained in Chapter 6. A single model was then selected to inform the scenario assessment exercise. Detailed results for the six models described in Table 5.1 are provided in Appendix E.

**Table 5.1: Selected data envelopment analysis models**

| | | Total capital productivity^ | | Passenger only | Freight only | Track utilisation | Train utilisation |
|---|---|---|---|---|---|---|---|
| **DEA model** | | 1 | 2* | 3 | 4 | 5 | 6 |
| Outputs | Passenger km | ✓ | ✓ | ✓ | | ✓ | ✓ |
| | Tonne km | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Inputs | Track km | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Rolling stock (passenger) | ✓ | ✓ | ✓ | | | ✓ |
| | Rolling stock (freight) | ✓ | ✓ | | ✓ | | ✓ |

^ Total capital productivity is defined as including both track and train (freight and passenger) related inputs simultaneously within the data envelopment model

* Model 2 is identical to model 1 except that it captures three years of data rather than one (2012)

### Results

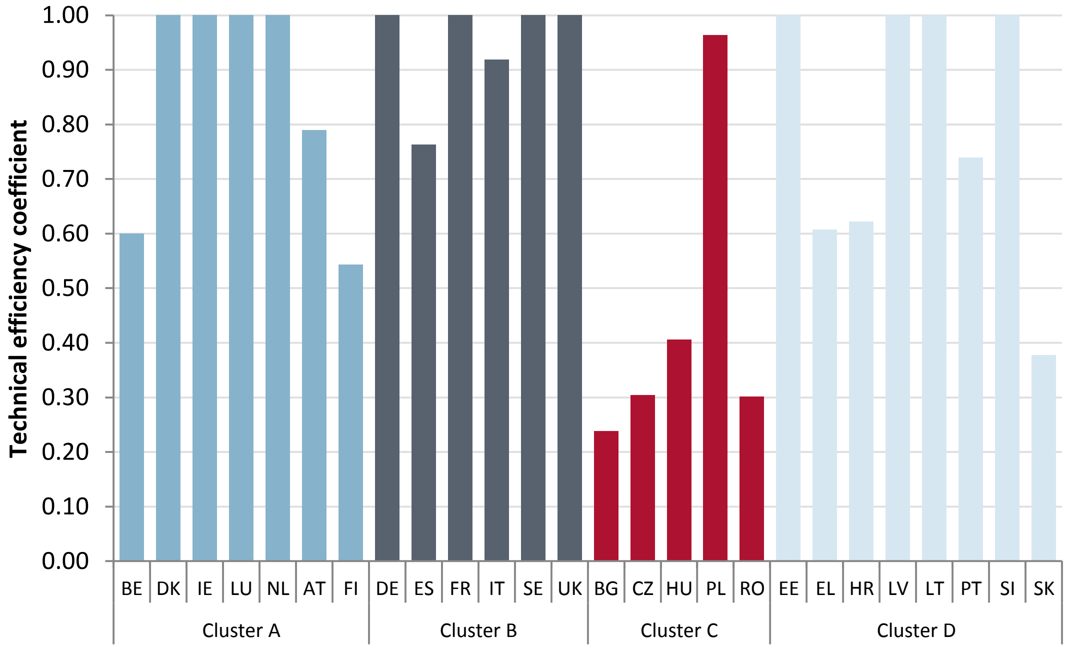
5.10 The remainder of this chapter summarises the results from the data envelopment models described in Table 5.1 with greater focus on the ‘total capital productivity’, ‘track utilisation’ and ‘train utilisation’ results as these most directly correspond to the levers available to the Commission to influence rail efficiency across Europe. Detailed results from the data envelopment analysis are provided in Appendix E.

5.11 It should be noted that, when reporting the results of the DEA, we have used the convention that the term ‘productivity coefficient’ describes the efficiency scores generated when assuming constant returns to scale. We use the term ‘technical efficiency coefficient’ to represent efficiency scores when assuming variable returns to scale, which is now measured separately from the ‘scale effect’ that takes into account the size of the rail system across Member States. By definition, the productivity coefficient is the product of the technical efficiency coefficient and the scale coefficient.

*Total capital productivity*

5.12 We developed two DEA models to explore the characteristics of total capital productivity (defined as including both track, freight train and passenger train related inputs simultaneously within a single data envelopment model). The first was a static model which only took account of the relative performance of Member States in 2012. The rationale behind this model was to understand how well Member States are able to combine both track infrastructure and rolling stock assets to deliver both passenger and freight outputs. Under an assumption of variable returns to scale, half of the Member States included were considered to be on the efficiency frontier. This is a function of the large number of both inputs and outputs that are included within the analysis and the fact that individual observations are therefore more likely to be captured by the efficiency frontier (which is expressed in a large number of dimensions). As can be seen in Figure 5.2, with the exception of Poland, Member States in cluster C appear to perform particularly poorly against this specification of inputs and outputs.

**Figure 5.2: Total capital productivity technical efficiency scores (DEA model 1 VRS) - 2012 (not re-based)**




Source: SDG analysis

5.13 A second DEA model was developed using identical input and output measures, but which included observations from 2010 to 2012, chain-linked using a Malmquist Index[25]. The purpose of this test was to examine the stability of technical efficiency coefficients through time. In-line with a number of modelled but un-reported DEA assessments (considering both three and six-year time horizons), the results of this model showed that coefficients were

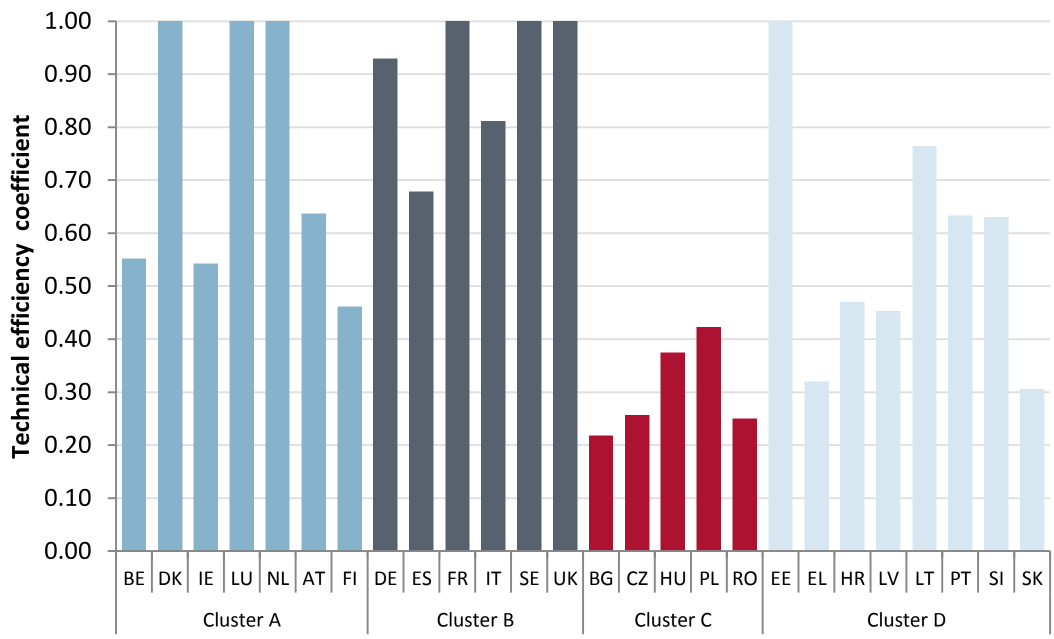
[25] The Malmquist Index (MI) is a bilateral index that can be used to compare the production technology of two economies. It is also called the Malmquist Productivity Index and is based on the concept of the production function.

largely static through time and could not be used to discern efficiency trajectories. Further details can be found in Appendix E.

*Passenger efficiency*

5.14 We examined passenger efficiency by limiting the input measures used to track kilometres and passenger rolling stock, and the output measures to passenger kilometres. While the results are broadly as expected, with primarily higher-income western European Member States dominating the efficiency frontier, the presence of Estonia on the frontier was surprising (see Figure 5.3. Upon inspection of the results generated under an assumption of constant returns to scale, we observed that Estonia is the least efficient Member State. It is likely, therefore, that the very small size of the Estonian passenger network (delivering just 235m passenger kilometres in 2012) means that scale effects are having a significant (and potentially spurious) impact upon the technical efficiency score for the country under an assumption of variable returns to scale.

**Figure 5.3: Technical efficiency scores for passenger rail (DEA model 3 VRS) – 2012 (not re-based)**

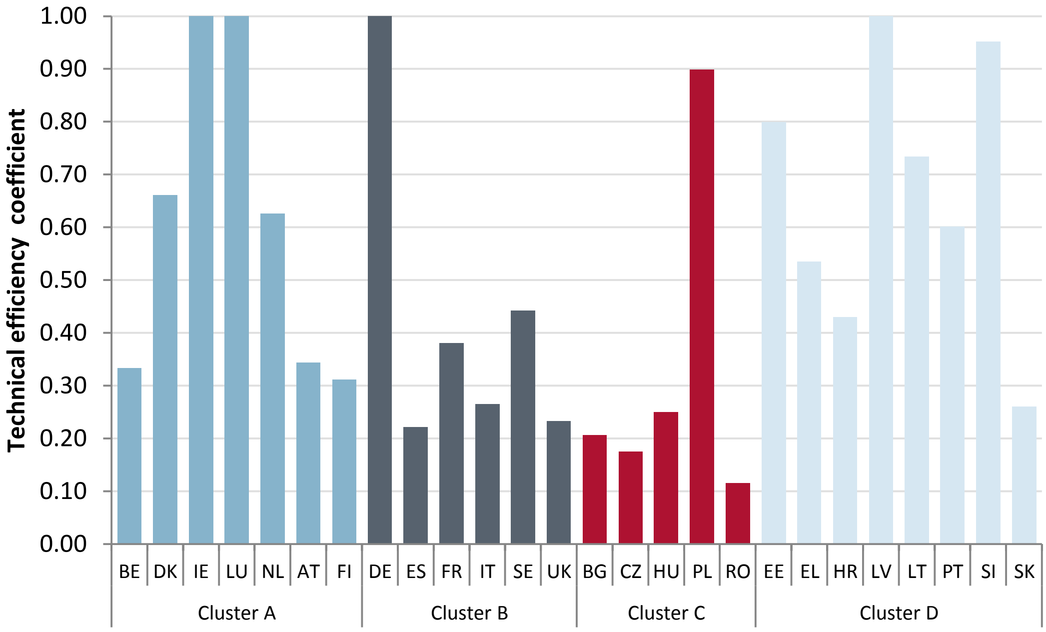



Source: SDG analysis

*Freight efficiency*

5.15 The freight efficiency model is a direct parallel to the passenger efficiency model in that the inputs are track kilometres and freight wagons, and the only output is tonne kilometres. As shown in Figure 5.4, the best performing Member States are all relatively small, Northern European countries and, given the dominance of Russian transit freight it is unsurprising to see two Baltic States represented. There is no discernible trend in freight technical efficiency by cluster, although Member States in clusters B and C perform less well than those in clusters A and D.

**Figure 5.4: Technical efficiency scores for rail freight (DEA model 4 VRS) – 2012 (not re-based)**



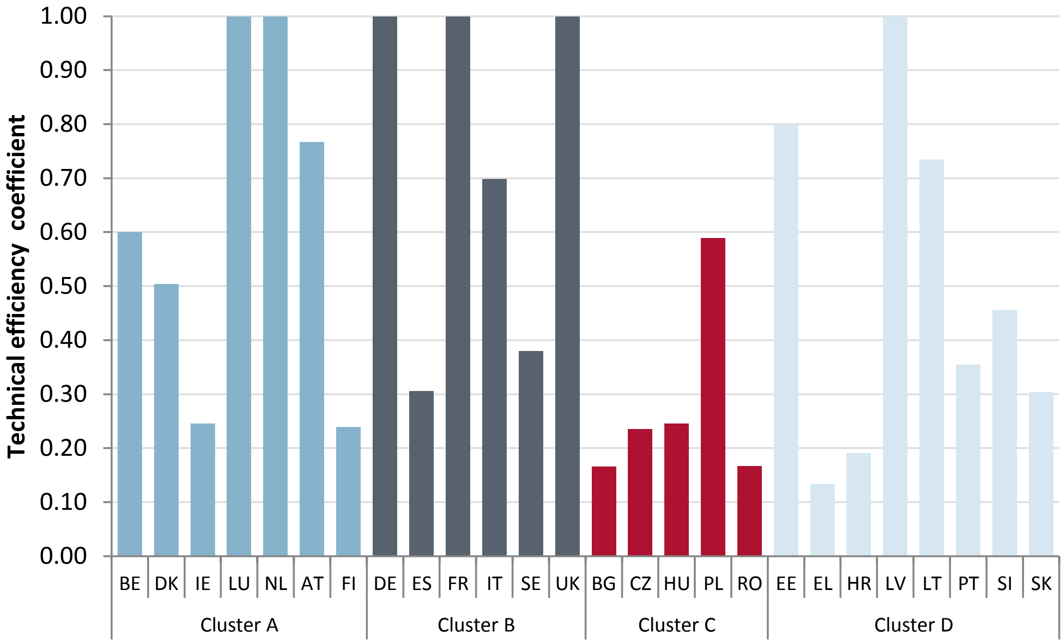

Source: SDG analysis

*Track utilisation*

5.16 Figure 5.5 shows that five of the six Member States on the efficient frontier generated by this model are higher-income western European countries, all of which procure a large proportion of their passenger services through public service contracts (this proportion is lower in Luxembourg due to the importance of international services). It is, therefore, unsurprising that they demonstrate high levels of track utilisation. The presence of Latvia on the efficient frontier is notable since we might expect this to be a result of the scaling process when considering variable returns to scale. However, under constant returns to scale both Latvia and the Netherlands are on the efficient frontier.

5.17 This result is highly likely to be the result of the intensity with which freight traffic uses the rail network in Latvia. Despite having the third most disperse network in the European Union (measured by rail network length per capita), the Latvian rail network conveys more than double the quantity of freight per capita than its nearest rival Lithuania, and twenty times that of France.

**Figure 5.5: Track utilisation technical efficiency scores (DEA model 5 VRS) – 2012 (not re-based)**



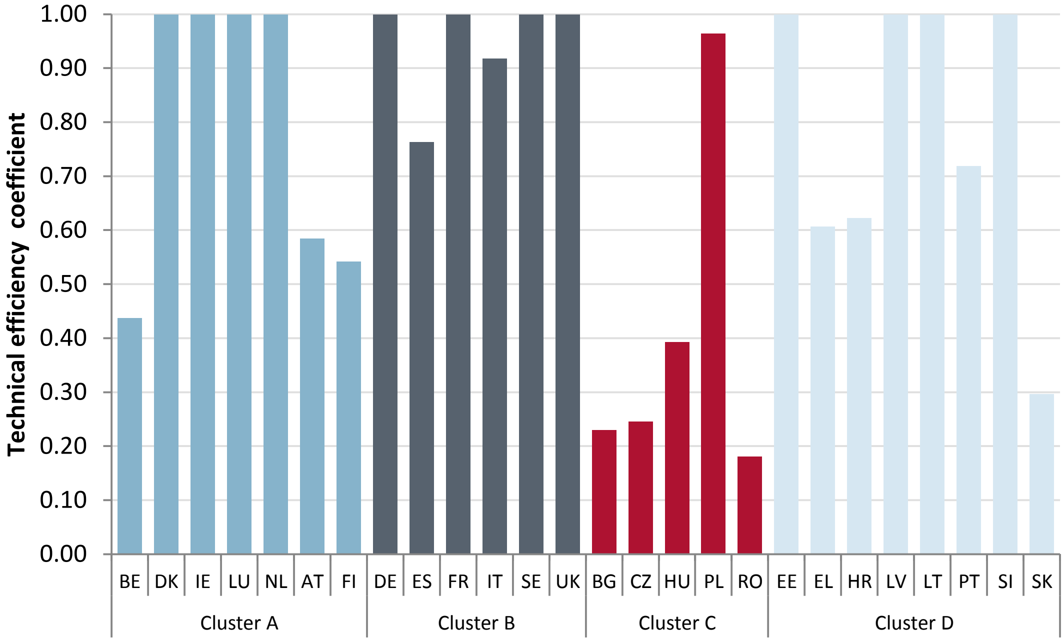

Source: SDG analysis

*Train utilisation*

5.18 As can be seen in Figure 5.6, it is notable that a very large number of Member States are on the efficiency frontier in the train utilisation model. In the case of some Member States, this is because the variable returns to scale assumption identifies the cost minimising size of rail systems and then limits the comparison between Member States to those within a similar distance from the optimum. In contrast to many of the other models, however, in this case many large Member States are perceived to be operating at a level of output beyond the cost efficient level and therefore exhibit decreasing returns to scale. If their operations were smaller, i.e. they delivered fewer train kilometres, they would be able to operate more efficiently. Under an assumption of constant returns to scale, only smaller Member States (Denmark, Sweden, Netherlands, Latvia and Lithuania) can be found on the efficient frontier.

5.19 This result suggests that further work to investigate the optimal size of rail networks may provide insights on the mechanisms and policy levers through which greater efficiency can be achieved. In the presence of diseconomies of scale there may be a case for horizontal and/or vertical separation. It is notable, however, that the UK rail network in aggregate exhibits diseconomies of scale despite considerable horizontal separation. The observed outcome may, therefore, be a feature of co-ordination failure, coupled with extensive public service obligations that require the provision of services on sparsely utilised sections of the network.

**Figure 5.6: Train utilisation technical efficiency scores (DEA model 6 VRS) – 2012 (not re-based)**




Source: SDG analysis

## Conclusions

5.20 The findings of the data envelopment analysis have extended our understanding of the performance measures obtained through the analysis of KPIs. They provide an estimate of the efficiency gap between best and worst performing Member States (both across the entire dataset and within clusters) across a range of scenarios. As discussed further in Chapter 6, the 'total capital productivity' model discussed here will be used to define the core scenario used in the scenario assessment exercise. They also support the rationale for selecting those Member States that are used to estimate output and employment multipliers. Further details are provided in the following chapter.

# 6 Scenario assessment

6.1 This chapter describes our approach to scenario definition and assessment. A single core scenario has been defined, and an assessment made of the direct and indirect impacts of a 'best performing' rail system upon the wider economy. In addition to economic impacts (e.g. GDP and employment impacts), we have estimated the impacts in terms of transport system externalities (emissions, noise and safety).

6.2 In this chapter, we describe the core scenario, the steps taken to quantify its impacts and the results obtained. We also set out the methodology used to estimate output and employment multipliers, which capture the upstream impacts of changes to rail industry outputs on the wider economy. Finally, we describe the results of an additional, supplementary scenario, based upon assumptions about the impact of a change in the relative cost of road and rail travel.

## Scenario definition

6.3 After consideration of the range of policy levers available to the Commission that can be used to support improvements to the efficiency of the EU rail sector, we focused on scenarios which captured measures of capital productivity rather than staff or total factor productivity. We therefore considered the following three scenarios:

- Total capital productivity: considers how Member States combine all capital inputs (both track and train) to deliver rail outputs (passenger km and tonne km);
- Track utilisation: considers how Member States can, in isolation, optimise the number of trains running on their network to improve track utilisation and hence deliver rail outputs more efficiently; and
- Train utilisation: considers how Member States can, in isolation, optimise load factors on freight and passenger trains in order to deliver rail outputs more efficiently.

6.4 To reflect the trade-offs available to Member States when planning and delivering rail services we decided to take forward the total capital productivity option as our core scenario. The basic premise of the core scenario is that all Member States currently operating away from the efficient frontier move, over a period of time, towards the frontier. In doing so, however, they are constrained such that they cannot exceed the current performance of the most-efficient Member State within the same cluster.

6.5 Table 6.1 provides a stylised example of this process for five Member States (1 to 5) and two clusters (A and B). The left-hand panel represents the efficiency scores directly generated by the DEA using the full sample of Member States. Member State 1 is the best in class (and best in cluster A), and Member State 3 is the best in cluster B.

6.6 The middle panel shows the results of the rebasing exercise. In cluster A the efficiency scores are unchanged since Member State 1 is on the efficiency frontier and therefore other Member

States in the cluster are expected to be able to reach this level of efficiency. In cluster B, however, the best-in-cluster Member State is not on the efficiency frontier. We assume that other Member States in cluster B will not be able to exceed the performance of the best-in-cluster Member State, and therefore the efficiency scores are re-based accordingly (e.g. the rebased efficiency score for Member State 4 is 0.40 ÷ 0.80 = 0.50 where 0.80 is the efficiency score of the best-in-cluster).

6.7 Finally, as shown in the right-hand panel, it is possible to express the efficiency scores as an 'efficiency gap' that describes the reduction in inputs that could be achieved while maintaining the same level of outputs for a given Member State. A score of 0% indicates that the Member State is performing as well as the best in cluster.

**Table 6.1: Using clusters to re-base DEA outputs**

| DEA outputs | | | | Re-based DEA outputs | | | | Re-based efficiency gap | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Member State | Cluster | Efficiency Score | | Member State | Cluster | Re-based Efficiency Score | | Member State | Cluster | Efficiency Gap |
| 1 | A | 1.00 | → | 1 | A | 1.00 | → | 1 | A | 0% |
| 2 | A | 0.80 | | 2 | A | 0.80 | | 2 | A | 20% |
| 3 | B | 0.80 | | 3 | B | 1.00 | | 3 | B | 0% |
| 4 | B | 0.40 | | 4 | B | 0.50 | | 4 | B | 50% |
| 5 | B | 0.60 | | 5 | B | 0.75 | | 5 | B | 25% |

6.8 The purpose of this approach is two-fold. First, controlling for the influence of exogenous factors outside the efficiency analysis allows us to use the full sample within the estimation process. Second, limiting the size of the efficiency gap is a prudent assumption. It means that less efficient Member States are only expected to catch-up with their peers, rather than with the very best performing railways across the EU.

6.9 This approach requires us to adopt the following assumptions:

- The best-performing railways in Europe are on the efficient frontier. While there may be rail systems outside the EU that are more efficient, these are unobserved and it is not, therefore, possible to estimate any residual technical efficiency gap.
- The efficiency savings gained are, and can be directly translated into, additional railway outputs e.g. passenger kilometres or freight tonne kilometres. In practice, there may be a range of constraints, particularly network capacity and households' propensity to travel by rail, which may limit expansion in rail output that is possible and/or desirable.

6.10 In addition, the scope of the analysis has certain limitations:

- The analysis considers only efficiency gains related to the utilisation of physical assets and ignores differences in unit costs. Therefore Member States already on the efficiency frontier (measured in terms of their asset utilisation rate) could, potentially, still improve their cost efficiency in line with that of the best performers[26].
- Only capital productivity is considered, leaving labour productivity out of scope.
- Service quality and safety performance are not within scope.

[26] For example, in Table 6.2 both France and Germany are considered to be on the efficient frontier. However, cost efficiency in Germany is demonstrably better than in France.

6.11 The impacts of these assumptions and limitations on the results of the scenario assessment are likely to counteract each other. It is not, however, possible to indicate ex ante whether the net effect on the results of the scenario assessment will be positive or negative.

*Defining the core scenario*

6.12 The core efficiency scenario is defined by two measures:

- Efficiency scores – these are generated by the DEA and subsequently rebased by cluster, such that no Member State is forecast to exceed the current level of efficiency of the best-performing Member State within the same cluster; and
- Efficiency trajectory – all Member States with an efficiency score less than one (i.e. those not on the efficiency frontier) are expected to reach the frontier for their cluster by the year 2050, commencing in 2015.

6.13 The core scenario described in paragraph 6.3 corresponds directly to output from the DEA models summarised in Table 5.1 which are estimated across the entire sample of Member States. The relevant DEA results are then re-based according to the methodology described above and expressed as efficiency gaps (i.e. the proportion by which inputs could be reduced while delivering the same level of outputs).

6.14 Were it possible to realise all productivity savings instantaneously, rail sector operating costs across the EU could be 10% lower than at present. This equates to a saving of €11bn. Identified efficiency gaps and potential cost savings by Member State are provided in Table 6.2 below[27]. Member States that are, within the analytical framework we have adopted, considered to be operating on the efficiency frontier have 0% efficiency gap and hence do not generate any operating cost savings.

**Table 6.2: The core scenario efficiency gaps and potential operating cost savings**

| | | Operating costs (€m - 2012) | Efficiency gap | Potential operating cost savings (€m) |
|---|---|---|---|---|
| A | Belgium | 3,724 | 40% | 1,490 |
| | Denmark | 1,714 | 0% | - |
| | Ireland | 312 | 0% | - |
| | Luxembourg | 445 | 0% | - |
| | Netherlands | 5,713 | 0% | - |
| | Austria | 5,201 | 21% | 1,097 |
| | Finland | 1,332 | 46% | 609 |
| B | Germany | 16,891 | 0% | - |
| | Spain | 4,533 | 24% | 1,074 |
| | France | 31,419 | 0% | - |
| | Italy | 7,673 | 8% | 629 |
| | Sweden | 2,562 | 0% | - |
| | United Kingdom | 15,171 | 0% | - |

[27] It should be noted that the cost savings described in Table 6.3 arise through improvements to the deployment of physical assets alone.

| | | | | |
|---|---|---|---|---|
| C | Bulgaria | 370 | 75% | 279 |
| | Czech Republic | 2,753 | 68% | 1,885 |
| | Hungary | 1,655 | 58% | 958 |
| | Poland | 3,354 | 0% | - |
| | Romania | 2,188 | 69% | 1,505 |
| D | Estonia | 82 | 0% | - |
| | Greece | 1,217 | 39% | 478 |
| | Croatia | 106 | 38% | 40 |
| | Latvia | 500 | 0% | - |
| | Lithuania | 570 | 0% | - |
| | Portugal | 1,038 | 26% | 271 |
| | Slovenia | 365 | 0% | - |
| | Slovakia | 1,239 | 62% | 771 |
| | **EU26** | **112,128** | **10%** | **11,086** |

6.15 In practice, it is unrealistic to assume that rail operations can realise efficiency savings instantaneously. Therefore, for the purposes of the core scenario assessment we have assumed that all Member States currently operating below the efficiency frontier would follow a linear improvement to reach the level of performance of the best-in-cluster Member State by 2050.

6.16 There are a number of mechanisms via which potential efficiency savings can be achieved, examples of which are provided in Chapter 7. For the purposes of this study, however, regardless of the time-horizon or mechanism through which cost savings are achieved, we have assumed that the savings gained are directly translated into additional railway outputs as measured by passenger and freight tonne kilometres rather than reducing railway sector resources.

*Assessing the core scenario*

6.17 The long-term impacts of efficiency improvements have been considered with reference to a counterfactual scenario. For this study, the counterfactual scenario against which the core 'efficiency scenario' is compared is the European Commission Reference Scenario 2013, with the EU-wide assessment aggregated from separate calculations for each Member State[28]. It is defined in terms of:

- Exogenous variables: GDP and population;
- Rail Inputs: track kilometres, rolling stock, operating costs;
- Transport Outputs: road passenger and freight kilometres, rail passenger and freight kilometres; and
- Externalities: road passenger and freight $CO_2$ emissions, rail passenger and freight $CO_2$ emissions.

6.18 Baseline data is provided at five-year intervals between 2010 and 2050, and we have applied linear interpolation between these dates in order to generate estimates for intermediate years.

[28] http://ec.europa.eu/transport/media/publications/doc/trends-to-2050-update-2013.pdf

6.19 In applying the core scenario we have:

- Estimated the change in value added/operating surplus that would result if all efficiency savings were retained;
- Estimated the change in rail sector outputs (e.g. passenger kilometres) that could be achieved if all efficiency savings were reinvested into the rail sector (using outputs from the DEA) in order to define the comparator 'efficiency scenario'[29];
- Applied output and employment multipliers (estimated according to the methodology described in the following section) to calculate the change in direct/indirect GVA and employment;
- Applied external cost valuations from the *Update of the Handbook on External Costs of Transport* (European Commission, 2014) alongside estimates of rail/road diversion factors to calculate the welfare impacts of increased rail usage; and
- Generated net present value estimates for all monetary values[30].

## Estimating economic impacts

### Methodology

6.20 We have used a static input-output analysis framework to estimate the impact of changes in productivity in the rail sector on the wider economy. Input-output analysis is one of a set of related quantitative methods that represents macroeconomic activity as a system of interrelated goods and services and shows how the parts of the system are affected by a specific change in one particular sector (in this case a change in the efficiency of the rail sector).

6.21 This approach requires the adoption of assumptions that are implicit in the input-output methodology, including:

- Relative prices remaining constant: the analysis assumes that the relative prices of sector inputs remain constant;
- Factor supplies meeting demand: it is assumed that the supply of factors of production (e.g. capital) do not constrain the production of output and hence the supply of output of a sector will increase to match demand; and
- Factor proportions remaining fixed: over the time horizons defined by the scenario assessment we might expect factor proportions to change. This suggests that, notwithstanding the constraints identified previously, the true impact of an efficiency improvement is likely to be larger than estimated by this study.

*Creating the sectors of interest using direct employment data*

6.22 The first step was to isolate the rail sector from all other sectors within the input-output tables as these only report outputs from the rail sector at a high level of industrial disaggregation (NACE Rev.2). The transport of passengers and freight by rail is contained within the 'land

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[29] By using variable returns to scale assumptions the data envelopment analysis accounts for size in determining the distance to the efficient frontier. As Member States re-invest efficiency savings and increase output we might, therefore, expect the scope for improvement to vary in-line with the change in scale. In practice, however, the scale of variation captured by the data envelopment analysis is far greater than the potential change in scale delivered through re-investment and the impact is expected to be marginal.

[30] We have used the standard European Commission discount rate of 4%

transport and transport via pipelines' branch (49), which also includes transport by road and the movement of freight via pipeline. The activities of the infrastructure manager are included in 'service activities incidental to land transportation' (52.21).

6.23 In order to estimate the economic effects specifically for the rail sector, we have further differentiated the original input-output tables so that the provision of passenger and freight rail services is extracted from the rest of the sector. The goal here was to introduce a new sector that reflected the composition of the national rail market, for which we could then estimate indirect output and employment multipliers.

6.24 To generate the relevant sub-sectors within the input-output tables, we used structural data (employment and GVA per worker) from individual Member States to identify the sub-sectors' share of the higher-level sectors (e.g. share of rail transport in relation to all activities in the 'land transport and transport via pipelines' branch)[31]. Following best practice, we have also included a productivity adjustment based on average GVA per worker in the sectors of interest. This results in different multipliers for the output and employment effects, as presented in Table 6.3 below. In the small number of cases where GVA data at the correct level of granularity was unavailable, or when the GVA-based results were counter-intuitive, our approach was to use direct employment in the rail sector[32].

6.25 The process for isolating the rail sector in the input-output tables was as follows:

- Direct employment and GVA per worker figures for the broader sectors that make up the rail sector were collected and the overall value added for each of the components of the original sectors was derived (where unavailable, direct employment only was used)[33];
- These value added figures were then used to estimate the share of each original sector (NACE sectors 49 and 52) to be apportioned to the new sector (rail sector);
- We treated the supply, use, and compensation for employees in a proportional manner to GVA; and
- Following this apportionment, the results were consolidated into the new 'rail sector'.

*Input-output analysis*

6.26 In determining the relationship between the inputs required to provide rail services and the outputs generated by the rail sector, we used an open-static model based on national input-output tables as inputs[34].

6.27 To understand how the rail industry of individual Member States combines inputs, we have applied a classic input-output analysis which allows the estimation of the indirect effects of

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[31] GVA and employment data were sourced from Eurostat, the European Annual Business Survey and the European Union Labour Force Survey

[32] This was the case for Slovakia and the Czech Republic

[33] While excluding productivity-based measures from the analysis may introduce a small bias into the isolation of the rail sector from other NACE sectors, once applied in subsequent steps to generate a weighted average employment and output multiplier for the rail sector, the impact is expected to be small.

[34] An "open" model is one in which inflows and outflows caused by imports and exports within and beyond the European Union are captured such that the multipliers estimated can capture the impact of leakages and injections. A static model is one in which factor proportions are assumed to remain fixed through time.

the economic activity of a certain industry (in this case, the newly created 'rail sector') on output and employment over the whole supply chain. For example, in order to provide rail passenger services, a train operator needs inputs from other sectors such as energy, consulting, financial services, food and beverage services etc. In turn, the energy sector will require a range of inputs, including the extraction of crude petroleum and gas, manufacture of coke and refined petroleum products and possibly rail freight services.

6.28 The relationship between the rail sector and the range of upstream sectors required to generate rail services was quantified by our Leontief model. In the first stage of the analysis, we estimated the economic effects of interrelations between the rail industry and its direct suppliers from different sectors. We then calculated the direct supply interrelations of the first-stage supplying sectors e.g. the energy sector[35]. In theory, we would have run this process infinitely, which would result in an infinite number of calculations. A so-called "Leontief inverse" provides a mathematical approximation of the output of the infinite process.

6.29 Having obtained the output multipliers, we have augmented the calculation of the Leontief inverse multipliers with an assessment of labour intensities. Labour intensity is defined as the relative number of employees compared to value added or production output. In some cases, this adjustment results in a higher employment multiplier than the output multipliers. In other cases, the opposite occurs, given the relative productivity, labour laws and historical employment in the railway sector in different Member States.

6.30 We carried out the analysis for eight Member States, selecting two in each cluster. In each case, we analysed both the domestic multipliers (assuming imports and exports are treated as leakages) and total multipliers (assuming that only imports and exports to/from countries outside the EU are treated as leakages).

6.31 The choice of Member States within a cluster upon which to carry out the input-output analysis was primarily a function of data availability. Given that we have used a static modelling approach in which factor proportions are assumed fixed, it was important to obtain the most up-to-date input-output data such that the factor proportions it describes reflect recent technological developments. At the same time, based upon the assessment of KPIs described in Chapter 3 we sought to identify 'typical' Member States within each cluster and which provided a representative split between passenger and freight outputs.

### Key results

6.32 The main results of our analysis are presented in Table 6.3, Figure 6.1 and Figure 6.2.

**Table 6.3: Rail sector output and employment multipliers (indirect) for a sample of Member States**

| Cluster | Member State | Output multiplier | | Employment multiplier | |
|---|---|---|---|---|---|
| | | Domestic SIOT | Total SIOT | Domestic SIOT | Total SIOT |
| A | Austria | 1.90 | 2.36 | 1.88 | 2.23 |
| | Netherlands | 1.55 | 1.90 | 1.38 | 1.54 |
| B | Italy | 2.30 | 2.72 | 2.76 | 3.30 |
| | UK | 1.98 | 2.35 | 2.50 | 2.99 |

[35] The 'energy' sector is captured within the NACE2 classification as *electricity, gas, steam and air conditioning supply*.

| | | | | | |
|---|---|---|---|---|---|
| C | Czech Republic | 2.10 | 2.88 | 2.26 | 3.19 |
| | Poland | 1.81 | 2.47 | 1.63 | 2.10 |
| D | Portugal | 1.85 | 2.23 | 1.75 | 2.15 |
| | Slovakia | 2.70 | 3.27 | 2.73 | 3.34 |

Source: SDG analysis of national input output tables

6.33 The above multipliers indicate that for every Euro of output produced by the railway sector, between 0.55 and 1.70 indirect outputs are produced (see column 3). These multipliers are higher once imports and exports are considered (see column 4). Similarly, the employment multipliers indicate that for every job created in the rail sector, between 0.38 and 1.76 indirect jobs will be created in the rest of the domestic economy (see column 5).

**Figure 6.1: Rail sector output multipliers for a sample of Member States**

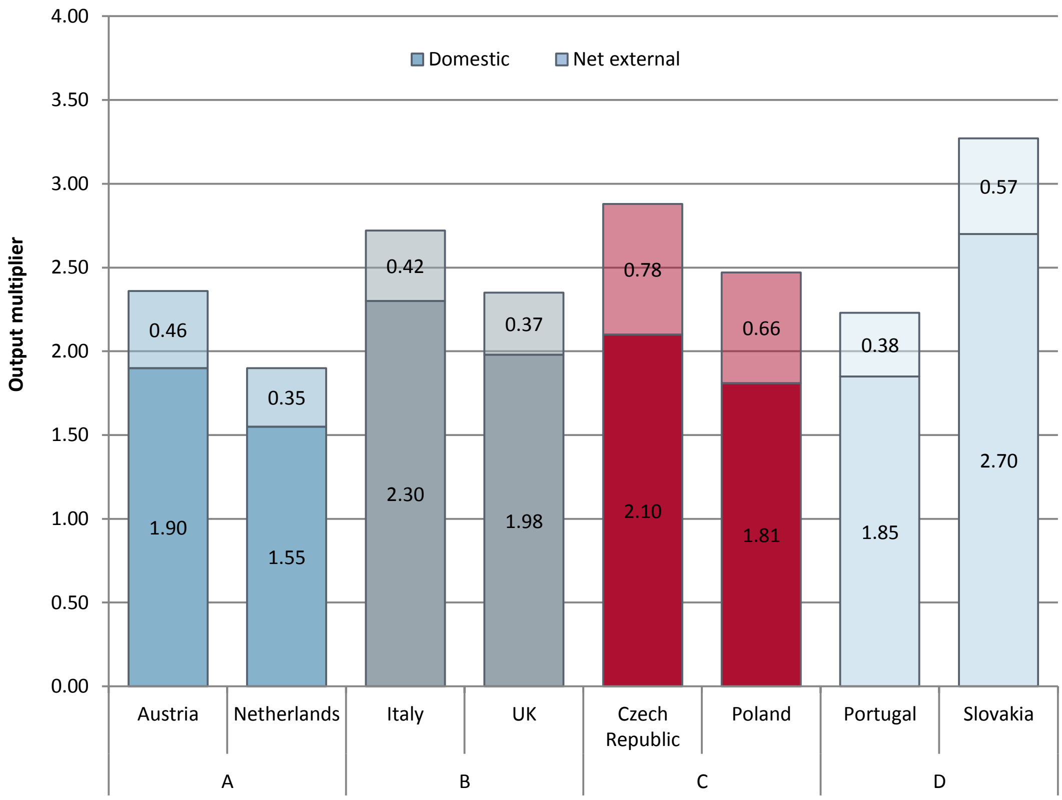
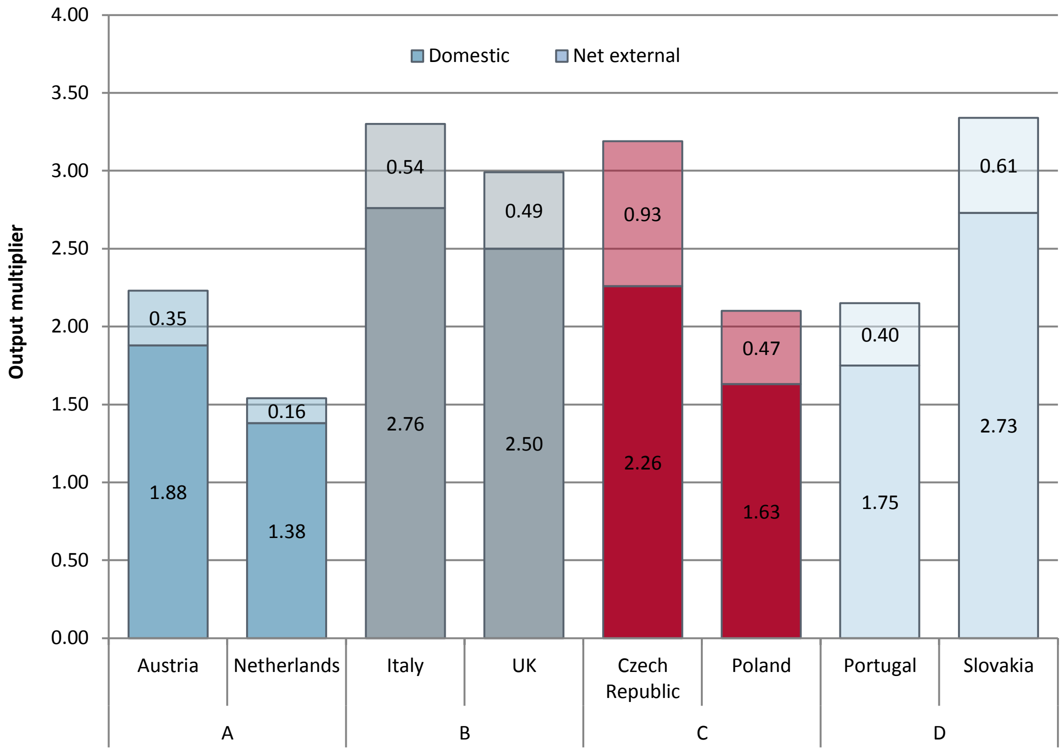


**Figure 6.2: Rail sector employment multipliers for a sample of Member States**




6.34 These values are broadly comparable with output and employment multipliers for the rail sector estimated in other studies. For example, the recent study *What is the contribution of rail to the UK economy?* (Oxera, 2014) estimated an output multiplier of 1.6, and an employment multiplier of 2.3 for the UK rail sector (domestic). Another study *The economic footprint of railway travel in Europe* (CER, 2014) reported an output multiplier of 1.65 for the UK, and an employment multiplier of 1.61. On this basis, we are confident that the output and employment multipliers reported in Figure 6.1 and Figure 6.2 are reasonable.

6.35 Employment and output multipliers are applied as follows. By reducing the quantity of inputs needed to deliver a given level of outputs, the cost savings achieved in a given period can be considered as an increase in operating surplus or value added. Alternatively, they can be thought of as an intermediate baseline against which the subsequent increase in output (as described in paragraph 6.15) can be compared. By increasing the outputs delivered by (and therefore expenditure of) the rail sector at a given unit cost, we would expect there to be second and third-round effects on other sectors of the economy. Therefore, in addition to the direct increase in output and employment within the rail sector, indirect impacts are estimated through output and employment multipliers.

6.36 For those Member States where we have a direct estimate (Austria, Netherlands, Italy, UK, Czech Republic, Poland, Portugal and Slovakia), the domestic output and employment multipliers summarised in Table 6.3 have been applied to the total operating cost savings/additional expenditure. For those Member States where no direct estimate is available, an arithmetic mean of the domestic multipliers for those countries in their cluster has been applied.

## Core scenario

### Overview

6.37 Having estimated output and employment multipliers as described above, and following the methodology summarised in paragraph 6.19 we have estimated the long-term impacts of the efficiency improvements identified by building a Calculator that combines the various analytical streams reported above. Impacts are estimated with respect to the EU Reference Scenario 2013. We have anchored the development of all other variables (e.g. operating cost) to this reference scenario.

6.38 The three main impacts estimated from the Calculator for the core scenario are:

- Direct and indirect GVA impacts, resulting from the direct efficiency savings following an operational improvement. These savings are subsequently reinvested, generating indirect GVA impacts throughout the economy based on the Input-Output multipliers;
- Direct and indirect employment impacts - we estimate a number of direct jobs as the equivalent number of FTEs (full time equivalents) that would be needed to deliver the GVA impacts calculated above, and then estimate indirect jobs based on the input-output multipliers; and
- External benefits, resulting from modal shift from road to rail, given an assumption about diversion of passenger and tonne-km (emissions, noise and safety/accidents).

### Results

6.39 The Net Present Value (NPV) of impacts resulting from the core scenario for the EU26 is €32 billion of direct GVA, €31 billion of indirect GVA and €75 million of external benefits, for the period 2015-2030. Figure 6.3 shows the GVA results by cluster. Cluster C has the highest direct impacts, driven by the potential efficiency savings materialising in Bulgarian, Czech, Hungarian and Romanian railway systems. The direct impacts in clusters B and D are smaller, but the indirect GVA is expected to be proportionately larger given the size of the rail multipliers identified in these economies.

6.40 Figure 6.4 shows the resulting effects on job creation. The increase in rail activity resulting from reinvesting the operating surpluses is expected to generate 1,600 jobs across the EU, the greatest share of which are in cluster C. These will give rise to a broadly equivalent number of indirect jobs over the period 2015-2030. These numbers are relatively small as the focus of our analysis is on capital productivity improvements. Should efficiency estimates be derived based on a more balanced distribution of capital and labour impacts, the employment effects could be greater.

6.41 External benefits are estimated to have an NPV of €75 million. The magnitude of the external benefit estimates is a function of the assumption that all additional railway outputs that are provided as a consequence of reinvestment of cost savings are met with an equivalent increase in demand for passenger and rail freight. In line with standard practice, we assume that approximately 20% of all new rail traffic is abstracted from private car or road freight traffic, thus reducing external costs for travel by road[36].

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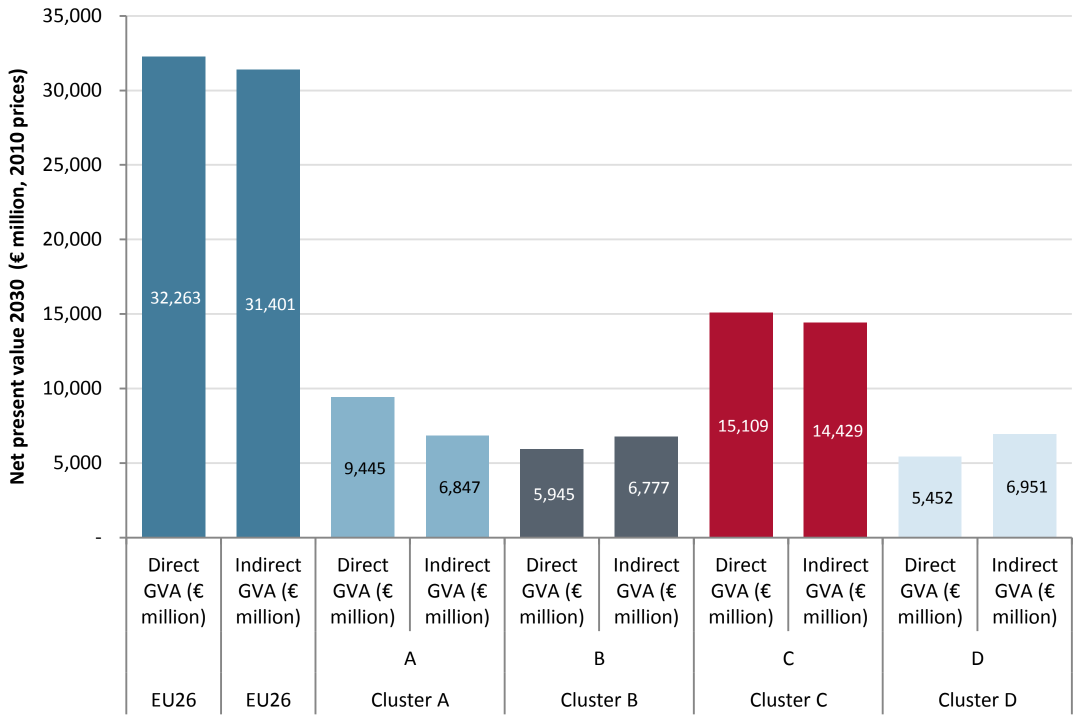
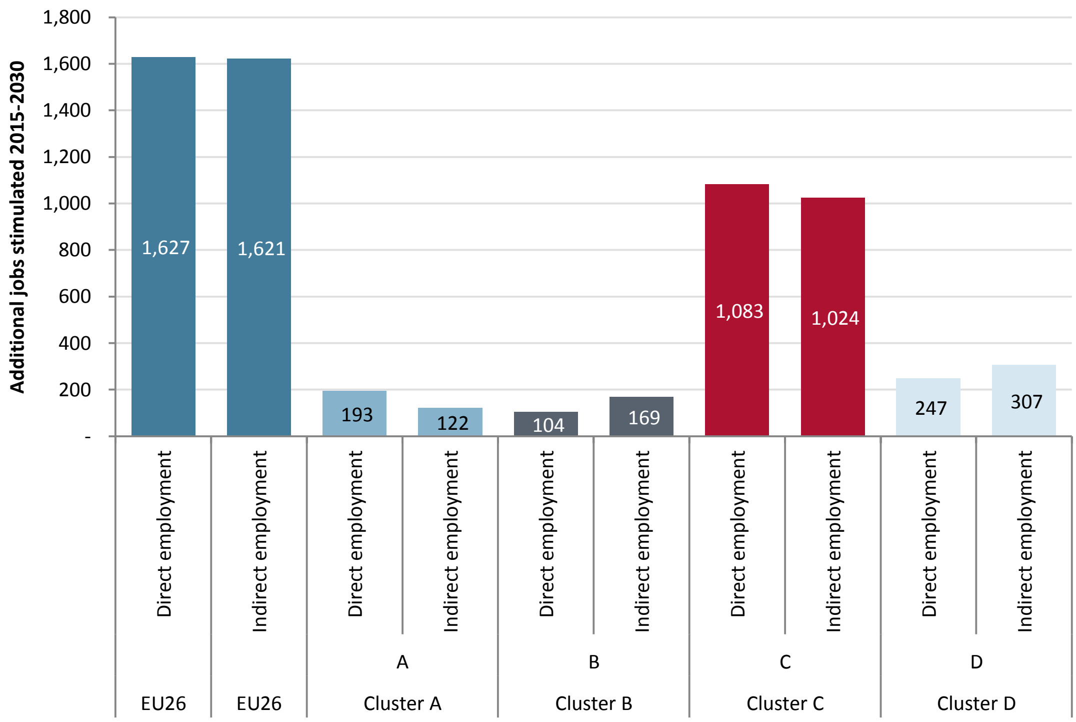
[36] The external benefit for cluster B is estimated to be negative because the dis-benefit of additional emissions, noise and accidents exceeds the benefits from the reduction in these external impacts from the assumed reduction in road use. Since all of the Member States within cluster B are large, higher-

**Figure 6.3: NPV of GVA impacts 2015-2030 (core scenario)**



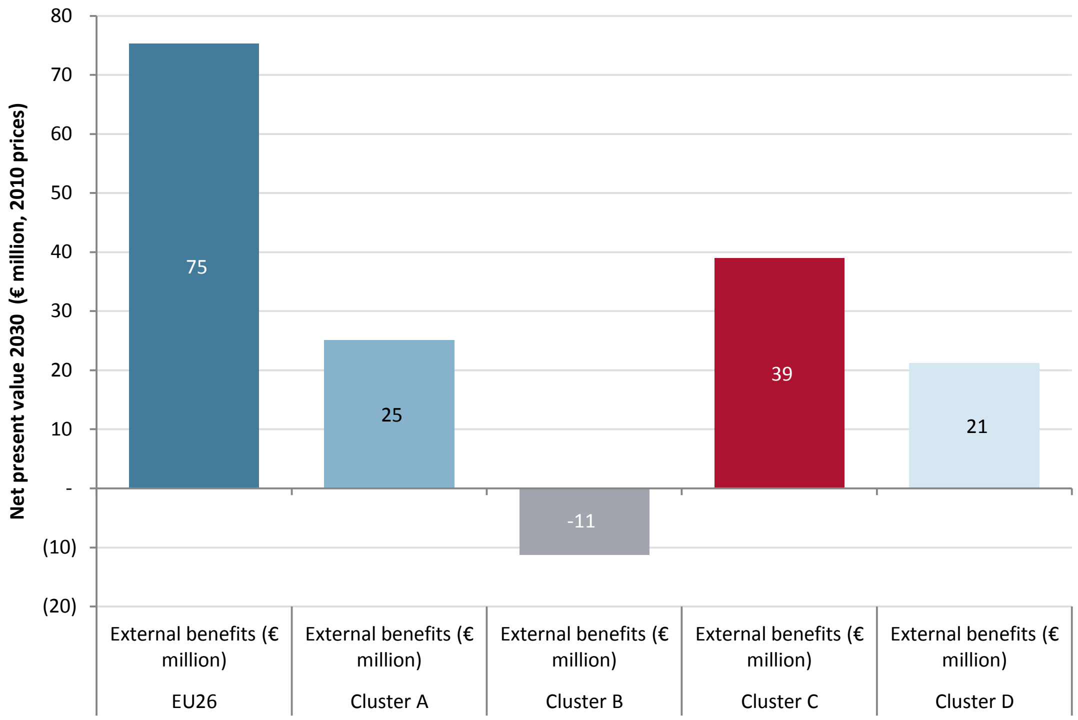

Steer Davies Gleave analysis

**Figure 6.4: Estimate of employment impacts 2015-2030 (core scenario)**




income countries they will have higher values for the reduction of externalities compared to other clusters, which exacerbates the scale of the negative impact.

**Figure 6.5: NPV of external benefits 2015-2030 (core scenario)**




Steer Davies Gleave analysis

6.42 We have similarly estimated the impacts of a persistent improvement in efficiency up to 2050. The NPV of these impacts for the period 2015-2050 is €121 billion for direct GVA, €118 billion for indirect GVA and €740 million for external benefits. More than 10,000 jobs would be created across the EU and a further 10,000 jobs would be supported indirectly.

### Summary of impacts

6.43 The following table consolidates the core scenario results, for the EU26, for the period 2015-2030.

**Table 6.4: Summary of scenario results and impacts (2010 prices, 2010 PV)**

| Impact | Value |
|---|---|
| Direct GVA (€m PV) | 32,300 |
| Indirect GVA (€m PV) | 31,400 |
| Direct employment | 1,630 |
| Indirect employment | 1,620 |
| External benefits (€m PV) | 75 |
| Increase in passenger km in 2030 (million) | 200,000 |
| Increase in tonne km in 2030 (million) | 260,000 |

Source: Steer Davies Gleave analysis; Net Present Values expressed in million euros (2010 prices, 2010PV) for the period 2015-2030. Employment is expressed in full-time equivalent (FTE) units. Figures may not tally due to rounding.

## Supplementary scenario analysis

### Background

6.44 The supplementary scenario analysis has been developed to assess changes in relative prices between transport modes, given that the main model developed to capture the impacts of productivity improvements does not include an assessment of price dynamics. To this end, we have produced an off-model calculation that assesses the impact of a change in road costs on modal shift and estimates the additional rail demand that would result if the price of road transport were to increase.

### Methodology

6.45 In carrying out the supplementary scenario analysis we have:

- Estimated cross price elasticities between road costs and rail usage (for freight and passenger traffic separately);
- Assumed a one-off shock to motoring costs in 2015;
- Calculated the knock-on impact of the shock on rail demand; and
- Compared the increase in rail demand caused by the shock, with the increase in rail supply delivered in the core scenario.

*Estimating cross elasticities*

6.46 First, we have reviewed the existing literature on own price elasticities for road, rail, passenger and freight transport, focusing on the following sources:

- Price sensitivity of European road freight transport – towards a better understanding of existing results (Significance, 2010);
- Transit Price Elasticities and Cross Elasticities (VTPI, 2015)[37];
- Understanding Transport Demands and Elasticities (VTPI, 2013);
- Passenger Demand Forecasting Handbook v5.1 (ATOC, 2013);
- Road Traffic Demand Elasticities (RAND Europe, 2014); and
- Long Run Trends in Car Use (OECD, 2013).

6.47 Our review of the literature identified that most studies base the estimation of elasticities on the demand response to changes in fuel prices (own price demand elasticity). Where possible we have sought to identify long-run price elasticities which, ceteris paribus, tend to be higher than short-run elasticities. Key conclusions from our review are as follows:

- It is reasonable to assume the fuel cost own price elasticity falls within a fairly narrow range of -0.1 to -0.5, but some trips are more elastic depending on distance and purpose.
- Transit ridership elasticities (mainly from US data samples) are typically in the range -0.6 to -0.9, although this varies considerably between peak and off peak, and by distance.
- There is little evidence on differences in fuel price elasticities for urban and non-urban journeys, and we are therefore not able to remove the effect of urban journeys from our sample.
- There is some consistency in the own price elasticity of freight demand, with values in the range -0.1 to -0.6.

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[37] In reviewing the literature we have isolated bus fares from wider definitions of “transit” which may include some rail systems, light rail systems and metro systems. European evidence has been given greater weight than studies from North America.

6.48 In contrast, evidence on cross-elasticity values shows they are unstable and depend heavily on the current market share between modes. Therefore we make use of the following relationship between own price elasticities, market share and diversion factors in order to derive cross elasticities. This is a standard relationship between own and cross elasticities that is true by definition and which is extensively reported within the literature (see Dodgson, 1986)[38].

$$e_{AB} = |e_{BB}|.(V_B/V_A).\delta_{BA}$$

where $e_{AB}$ is the cross elasticity of demand for A to the price of B, $e_{BB}$ is B's own price elasticity, $V_B/V_A$ is the relative volume share of B to A, and $\delta_{BA}$ is the proportion of the change in demand for B that diverts to/from A (a 'diversion factor').

6.49 We have adopted the following assumptions in order to populate the formula above and estimate the additional rail demand from a change in road costs:

- The evidence from the literature review has informed our own elasticity values for road transport (-0.3 for passengers and -0.4 for freight journeys);
- Separate market shares for passenger and freight transport are derived at the Member State level based on our database for this study;
- A diversion factor is the proportion of the change in demand for a mode (as a result of cost changes) that comes from or goes to another mode. In calculating the external benefits of the core scenario we assumed a value of 20% (i.e. 20% of road demand would divert to rail) and for consistency we adopt the same value in this analysis.
- For the purpose of this exercise a 5% uniform increase in road transport costs is assumed[39]. This might come from an increase in fuel prices, the application of tolls or an increase in private car and truck purchase / maintenance costs[40].

6.50 The resulting cross-elasticities by Member State are reported in Table 6.5 below.

**Table 6.5: Road Price Cross Elasticities of Demand for Rail by Member State**

| Member State | Road Price Cross Elasticity (Rail Passenger) | Road Price Cross Elasticity (Rail Freight) |
|---|---|---|
| Austria | -0.39 | -0.14 |
| Belgium | -0.60 | -0.41 |
| Bulgaria | -1.14 | -0.46 |
| Czech Republic | -0.48 | -0.28 |
| Germany | -0.57 | -0.22 |
| Denmark | -0.45 | -0.55 |
| Estonia | -2.13 | -0.06 |
| Greece | -4.01 | -3.65 |

[38] Dodgson, J. S. (1986) Benefits of Changes in Urban Public Transport Subsidies in the Major Australian Cities. Economic Record 62, pp.224-235

[39] Given the variation in existing road transport costs across Member States, the variations at Member State level may differ.

[40] Recent trends suggest that the cost of passenger transport by rail is rising compared to road transport. Between 2005 and 2014 rail passenger prices rose by 41% (EU28 excluding Malta and Cyprus) while the cost of passenger motoring rose by 36% (Harmonised Indices of Consumer Prices – Eurostat). This suggests that the scale of price shock is reasonable and could be interpreted as a reversal of the trends observed over the past decade.

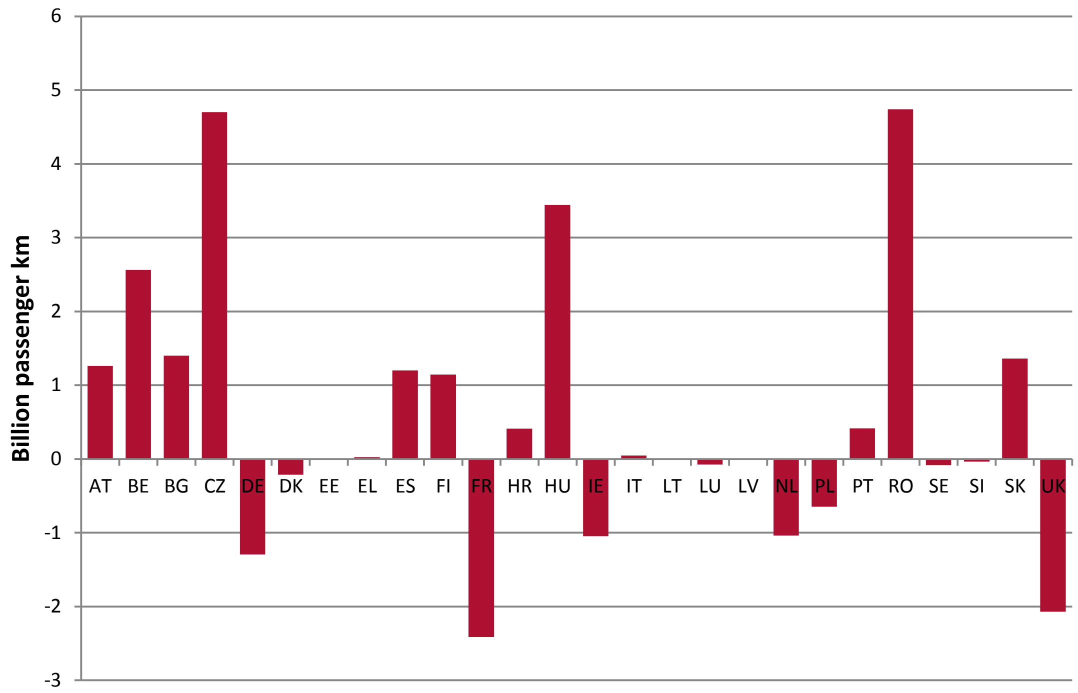
| | | |
|---|---|---|
| Spain | -0.75 | -1.69 |
| Finland | -0.85 | -0.23 |
| France | -0.44 | -0.40 |
| Croatia | -0.85 | -0.27 |
| Hungary | -0.38 | -0.28 |
| Ireland | -1.61 | -10.03 |
| Italy | -0.84 | -0.68 |
| Lithuania | -4.22 | -0.11 |
| Luxembourg | -1.09 | -3.22 |
| Latvia | -1.14 | -0.05 |
| Netherlands | -0.56 | -1.04 |
| Poland | -0.90 | -0.38 |
| Portugal | -1.15 | -1.17 |
| Romania | -0.68 | -0.19 |
| Sweden | -0.51 | -0.12 |
| Slovenia | -1.53 | -0.34 |
| Slovakia | -0.66 | -0.24 |
| United Kingdom | -0.63 | -0.58 |
| Maximum | -4.22 | -10.03 |
| Minimum | -0.38 | -0.05 |
| Mean | -1.10 | -1.03 |
| Median | -0.80 | -0.36 |

6.51 These elasticities are applied to the increase in road costs in order to estimate the increase in rail demand resulting from modal shift. The increase in road costs is assumed to take place during 2015, causing a shock to rail demand. After that, we assume that demand will grow in line with the EU Reference Scenario 2030 values.

**Key results**

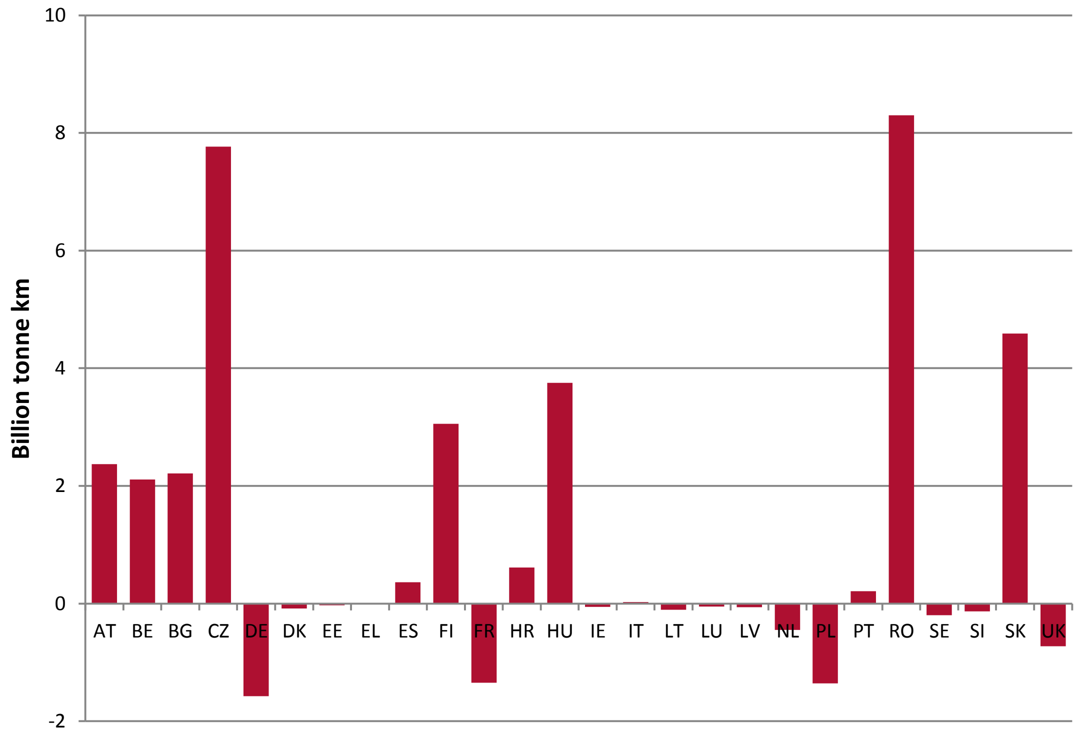
6.52 The results of the analysis are presented for the year 2030. In the figure below, we compare the additional demand from the assumed change in relative prices to the additional supply delivered in the core scenario for both passenger and freight.

**Figure 6.6: Comparison of outputs (rail passenger km) between the core scenario and supplementary scenario analysis in 2030**




Source: Steer Davies Gleave analysis (note that positive values suggest that the additional outputs delivered by the core scenario are greater than the additional demand generated by the supplementary scenario analysis)

**Figure 6.7: Comparison of outputs (rail tonne km) between the core scenario and supplementary scenario analysis in 2030**




Source: Steer Davies Gleave analysis (note that positive values suggest that the additional outputs delivered by the core scenario are greater than the additional demand generated by the supplementary scenario analysis)

6.53 The charts should be interpreted with some care. For those Member States on the efficient frontier, the total quantity of outputs generated in 2030 by the core scenario is simply the level projected by the EU Reference Scenario 2013 (i.e. there are no efficiency gains to be delivered). By contrast, for those Member States currently operating away from the efficient frontier, additional rail outputs over-and-above the EU Reference Scenario 2013 are delivered as a result of the re-investment of cost savings achieved through efficiency improvements.

6.54 In most cases in which a Member State is currently operating inefficiently (i.e. away from the efficient frontier), the additional demand that can be accommodated by reinvesting the efficiency savings is broadly in line with the additional demand generated by a change in relative prices. In practice, while some investment expenditure is likely to be required (e.g. to upgrade junctions and signalling) our analysis suggests that the additional demand could be served through better deployment of current rolling stock and infrastructure assets.

6.55 In other Member States, primarily where no productivity improvements have been modelled (e.g. France), the increase in rail demand from modal shift would need to be accommodated by further investment which, in turn, would require additional funding. Our analysis does not attempt to quantify the exact threshold beyond which national rail systems would need extra investment.

6.56 When results are aggregated by the Member State clusters reported in the rest of the study we find that in all clusters except Cluster B, the additional demand generated by the motoring cost shock is less than the additional capacity supplied in the core scenario (i.e. the additional demand can be accommodated without further investment expenditure). However, for Cluster B, where the potential for productivity improvements is lowest, a considerable amount of excess demand would need to be accommodated and this might require further investment.

6.57 At the European level, the additional rail demand resulting from a change in relative prices would be lower than the additional demand that could be accommodated by reinvesting the efficiency savings under the core scenario.

**Table 6.6: Comparison between the supplementary scenario analysis and the core scenario by cluster**

| Cluster | Passenger km (million) from supplementary scenario analysis vs core scenario | Tonne km (million) from supplementary scenario analysis vs core scenario |
|---|---|---|
| A | 2,600 | 6,900 |
| B | -4,600 | -3,500 |
| C | 13,600 | 20,700 |
| D | 2,200 | 5,100 |

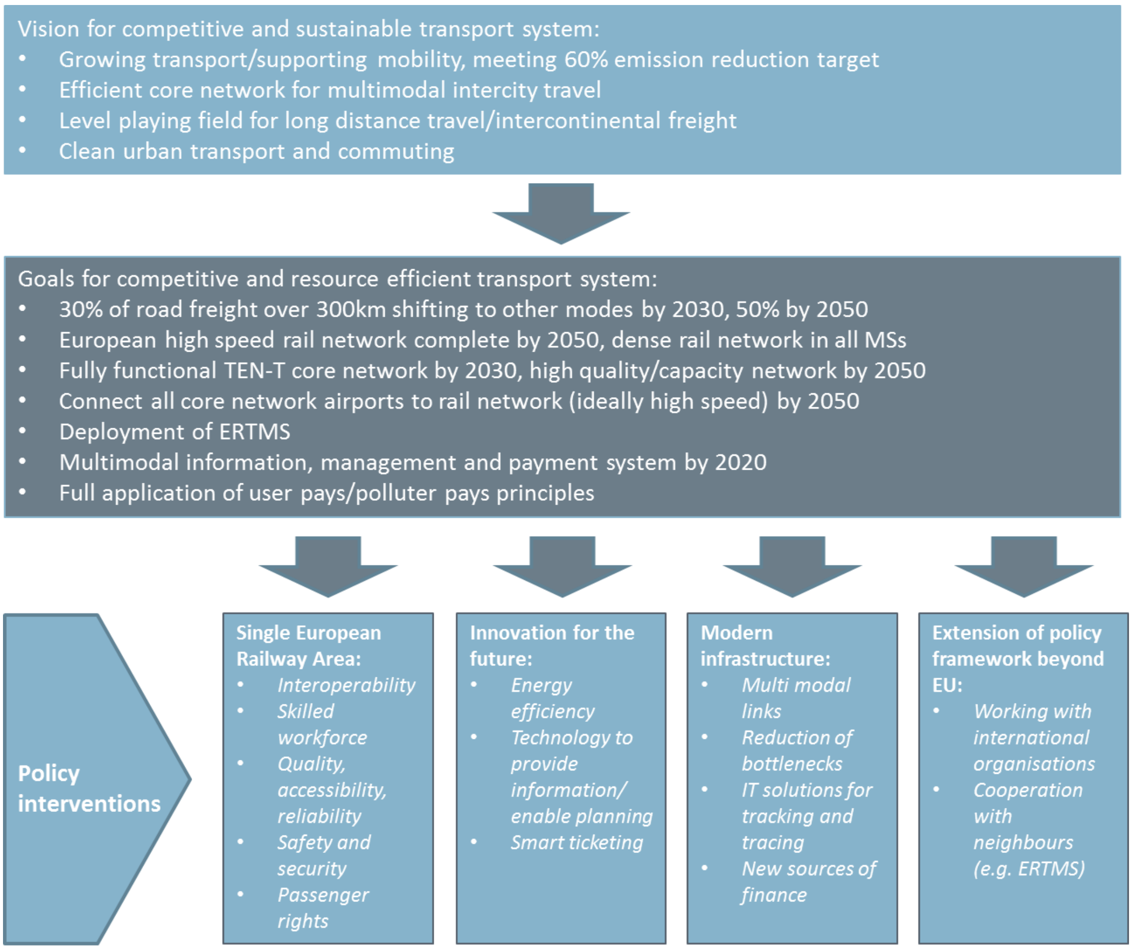
Steer Davies Gleave analysis. Positive figures indicate that the additional demand from the core scenario is higher than that from the core scenario.

# 7 Policy implications

## The current policy context

7.1 As noted in Chapter 1, the 2011 White Paper, *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*, sets out a vision for the European transport sector in which rail transport plays a much greater role than at present. Rail's share of both passenger and freight movements is expected to increase significantly as a result of the generation of new traffic and a switch of existing traffic from other modes, in particular from road. This, in turn, will require a substantial improvement in rail's competitiveness, delivered through a range of policy interventions covering infrastructure and operations. The policy framework described in the White Paper is summarised in the figure below.

**Figure 7.1: The EU policy framework for the rail sector**



7.2 This framework includes policy interventions designed to address a number of general issues arising across the sector with the ultimate aim to improve the quality and efficiency of rail services. This study has demonstrated that enhancing the productivity of both the rail network and rolling stock can deliver significant cost savings. Current EU policies, such as TEN-T and rail freight corridors, interoperability measures and market opening aim to transition from the patchwork of national railways to a network of EU railways, and thus enhance productivity and cost efficiency of rail transport.

7.3 This study has nevertheless demonstrated the need to consider additional country-specific constraints and weaknesses that are currently undermining rail industry efficiency and competitiveness. In particular, we note that:

- Some Member States, including several in Eastern Europe, have legacy networks that were developed to serve a different profile and distribution of economic activity from that observed today, with the result that their rail industries require substantial restructuring and investment to realign both passenger and freight services with current economic needs;
- Others, primarily among the EU 15, have already undertaken substantial investment in new infrastructure and rolling stock, but their networks continue to be subject to major capacity constraints that will need to be relieved through further enhancements; at the same time there are countries where network utilisation rates can significantly improved;
- While the majority of Member States experience relatively low levels of passenger train utilisation, often reflecting inflexible capacity and service frequency requirements in public service contracts, some still achieve significantly higher average load factors than others; and
- Some Member States have been more successful than others in balancing the performance of passenger and freight rail.

7.4 In addition, although there is a general concern about the overall financial sustainability of the sector across Europe, financial constraints have taken different forms in different countries. For example, in Bulgaria the industry's financial position deteriorated to the point where it could no longer cover operational expenditure, prompting the introduction of a major reform programme supported by the World Bank in 2011. By contrast, in the UK, the financing of operations has been on a stable footing for some years, with premiums paid by some passenger franchisees now broadly balancing the subsidies paid to others, but some industry commentators have nevertheless suggested that Network Rail's ongoing accumulation of debt to fund enhancements will prove unsustainable in the long-run.

7.5 Against this background, the interaction between EU and national rail policy requires careful coordination. On the one hand, it is important that necessary restructuring and network consolidation at the national level does not undermine the further development of an EU single market in rail services. On the other key European policy initiatives, for example support for TEN-T projects from the Connecting Europe Facility and research funded by the Shift$^2$Rail Joint Undertaking, will need to be implemented in a coordinated manner with national policy measures to improve efficiency. In the following paragraphs, we consider a number of implications for the development of both EU and national rail policies, drawing on the results of the analysis described in previous chapters.

## The need for industry restructuring

7.6 Arguably, the most important area of policy interaction relates to industry restructuring among Member States in Eastern Europe, in particular Bulgaria, the Czech Republic, Hungary and Romania (included in cluster C in the analysis reported in Chapter 4). The results of the DEA reported in Chapter 5 suggest that these countries must achieve substantial improvements in efficiency if they are to catch up with Poland, the most productive Member State in cluster C, which, after adjusting for scale effects, has one of the most productive railways in Europe[41]. Reflecting this, if all four countries were to achieve this improvement based upon 2012 outputs and operating costs, the resulting rail sector cost savings would be €4.4bn - €5.1bn per annum, some 23% - 41% of the total annual cost savings estimated across the 26 Member States modelled.

7.7 Our scenario analysis is necessarily simplified for the purposes of modelling, and is not intended to simulate precisely the effects of the restructuring programme needed to raise the efficiency of the rail industry in each country. However, the scope for efficiency improvements and associated cost savings indicated by our analysis are broadly in line with the aims of the industry reform measures being implemented in Bulgaria with the support of the World Bank. We note, for example, that the programme includes a number of measures intended to improve the efficiency of resource use as well as others focused on securing a more efficient scale of operations, not least:

- Optimisation of business units and staff, with associated cost reductions;
- Disposal of businesses that are not related to railways;
- Suspension of operations on railway lines that do not have any traffic, but which incur costs;
- Appointment of qualified, competent staff and management who are accountable to Bulgarian citizens; and
- Training of railway managers and workers.

7.8 We anticipate that elements of the programme, suitably modified to take account of different national industry characteristics, could be transferred to other countries, and note that the new Rail Reform Authority in Romania has already been charged with managing a similar streamlining exercise. More generally, experience in Bulgaria suggests that the implementation of major restructuring programmes is a realistic prospect, and that the level of improvement in efficiency assumed for the purposes of the scenario analysis, while challenging, is considered achievable by industry stakeholders. We also note that significant improvements in efficiency have already been achieved in countries such as the United Kingdom, Italy, Germany, Austria and Sweden as a result of the full liberalisation of rail freight markets and the introduction of competition, albeit more limited, in rail passenger markets.

7.9 At the same time, we consider that caution should be exercised in the development and implementation of programmes of this kind for a number of reasons:

- First, reductions in the size of the asset base (for example, as a result of a reduction in the size of the operational infrastructure network or the national rolling stock fleet) may be necessary to ensure better targeting of existing resources in conditions of financial constraint. At the same time, reductions in the asset base do not always result in proportionate cost savings. By way of illustration, closure of an existing line may result in only limited savings in maintenance costs in the short term, since it may not be cost effective to isolate track, signalling, electrification and communications equipment until it

[41] It has to be noted however that while showing high capital productivity rates, the quality of rail infrastructure and rail services in Poland is relatively poor

has deteriorated to the point where a major intervention is needed, which may take several years. In these circumstances, substantial reductions in costs may only be possible in the long-run. This highlights the limitations of analysis based on physical measures of efficiency, which can overstate the potential for cost savings, at least in the short to medium term.

- Second, reductions in the size of the network, while they may deliver both efficiency improvements and significant cost savings, may also prove inappropriate in the long term. In the UK, the size of the national network decreased by 40% between 1960 and 1980. While this undoubtedly led to significant cost savings, and reflected the general decline in rail traffic resulting from a growth in road transport over the same period, it has made it more difficult to accommodate the substantial increase in both passenger and freight traffic since the mid-1990s. In the event, capacity previously removed has recently been reinstated, for example on the Cotswold and Swindon to Gloucester lines where capacity has been increased from one track to two on each route. Elsewhere, the disposal of railway land has further constrained the ability of the industry to respond to increasing demand through infrastructure enhancements, since reinstatement of infrastructure would involve costly acquisition of land and change of land use, e.g. again in the UK on the proposed Bedford to Cambridge route.
- Finally, excessive rationalisation of infrastructure capacity could discourage or even prevent competitive entry into the rail market, whether inadvertently or by design. For example, between 1999 and 2010 Deutsche Bahn removed capacity, preventing access to large sections of its peripheral rail network, while at the same time increasing the density of traffic on its core network. Consequently, the availability of paths, and therefore the scope for market entry, was reduced.

7.10 Taken together, these considerations suggest that there is some risk that sector rationalisation, although necessary, will not deliver all of the anticipated cost savings, and/or that it may hinder subsequent development of the industry in terms of capacity and service offer. This highlights a need for long term planning and coordination at EU level, reliable information on costs, capacity provision and outputs, and careful consideration of the impact of individual restructuring programmes.

## Potential policy development

### Industry reporting and monitoring

7.11 The collection and consolidation of EU rail sector data was a key part of this study, and we have prepared a database including information on costs, inputs and outputs for all Member States, differentiating between infrastructure management and train operation and between freight and passenger services wherever possible. However, this exercise has highlighted various deficiencies in the available data tending to limit the potential for analysis and hence the information used to inform policy both at national and EU level. These deficiencies are described in more detail in Appendix A, but here we note that they include:

- presentation of consolidated accounts which often combine modes and/or markets which may straddle Member States;
- omission of individuals who work for sub-contractors or agencies from employment data, and the lack of consistency in reporting employee data according to total staff numbers or full-time-equivalents;
- lack of clarity regarding the definition of public subsidy as stated in each operator’s regulatory accounts, which may not include indirect public subsidy such as that provided through capital programmes or tax relief.

- limited availability of net debt data, which is not widely reported in regulated accounts; and
- difficulties associated with obtaining consistent time-series data for the period 2003-2013, during which there has been considerable market liberalisation and consolidation.

7.12 This issue could be addressed through the introduction of a more prescriptive framework for the collection of data on infrastructure management. The Commission Implementing Regulation on rail market monitoring, reports of regulatory bodies and railway indicators developed by ERA are first steps in this direction[42]. However, following the air navigation precedent[43], the information collected would be limited to that available within the infrastructure managers (i.e. the monopoly suppliers of network infrastructure services) and could not be expected to include the costs and revenues of train service providers, some of which operate in competitive markets. It is a general characteristic of liberalised markets that commercially sensitive information of this kind is often not published (at least below a high level of aggregation) and/or may not be prepared on a consistent basis across operators. It follows that strengthening the framework of data collection in the way outlined above would not resolve all of the data issues identified in the course of this study[44].

**Ensuring optimal rail capacity**

7.13 We have noted the potential for rationalisation of rail infrastructure to have an adverse effect on the availability of capacity, including capacity that might otherwise be used by new entrant rail service providers, and the need to consider possible long-term rail market requirements when undertaking major restructuring. However, while the possibility of excessive rationalisation is a general concern, potentially applying to any programme of restructuring in Member States across the EU, whether or no specific proposals for capacity reduction are appropriate or not will depend on the part of the network in question and the markets that it serves (or may serve in the future). For example, it may be possible to demonstrate that closure of a line or a marshalling yard will effectively foreclose new entry, but it may nevertheless be the case that:

- The new entrant is not able to pay non-discriminatory access charges designed to cover the direct costs of the infrastructure (i.e. the line is genuinely commercially unviable); and/or
- The wider benefits of the new service, including environmental benefits and other externalities, are insufficient to cover ongoing maintenance, renewal and other costs (i.e. there is no existing economic case for continuing to operate the infrastructure, although such a case might be made in the future).

7.14 This demonstrates the need for case-by-case appraisal of proposals for rationalisation, drawing on the powers of rail sector regulators and competition authorities as necessary,

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[42] Commission Implementing Regulation (EU) No 2015/1100 of 7 July 2015 on the reporting obligations of the Member States in the framework of rail market monitoring

[43] In the European air navigation industry national service providers are subject to detailed reporting requirements covering both the cost information required to calculate charges and more general information relating to safety, capacity, efficiency and environmental impacts

[44] In the case of data for rail freight operations, there may be parallels to the annual Rail Waybill dataset for the United States which includes shipment data from a stratified sample of rail waybills submitted by freight operators to the Surface Transportation Board

where operators or other stakeholders raise concerns. More general regulatory provisions seeking to preserve defined levels of capacity, whether at the EU or national level, are unlikely to ensure economically optimal outcomes in which possible future capacity needs are balanced against more immediate potential for cost savings.

7.15 Nevertheless, given the risk that major restructuring programmes designed to achieve substantial cost savings can lead to excessive rationalisation, it is important to ensure that stakeholders (including relevant transport authorities, representatives of passengers and existing and potential operators) have the opportunity to express their views on the closure of lines, stations, freight yards and other facilities. There is therefore a general need to ensure that Member States and infrastructure managers, when developing rail infrastructure development strategies and business plans as foreseen in Article 8 of Directive 2012/34/EU, would consider thoroughly future mobility needs and give an opportunity to all existing and potential users to express their views on closure of lines.

7.16 It may therefore be appropriate to develop a framework for ensuring that stakeholders are properly consulted on the effects of rail rationalisation, to be implemented through either legislation or guidance. In either case, consultation procedures will need to reflect the legal, institutional and cultural environment prevailing in individual Member States, and specific consultations will need to be tailored according to the proposals in question. Any framework must therefore provide for flexibility, allowing Member States to balance the need for open and transparent consultation on the one hand with effective and timely decision-making on the other.

**Exchange of experience and good practice**

7.17 Our analysis has demonstrated that rail industries across the EU vary considerably in terms of the economic and demographic environments in which they operate, their relative stages of development, the relative importance of different markets (e.g. passenger and freight) that they serve and the levels of efficiency that they achieve. At the same time, the clustering analysis in Chapter 4 and the DEA in Chapter 5 have highlighted important similarities between national rail industries within individual clusters. Against this background, we consider that the exchange of experience and good practice, including in relation to management and operational practice as well as policy implementation, is likely to yield significant benefits.

7.18 To some degree, this kind of exchange of information is already supported through existing institutional arrangements, for example the framework for developing Technical Specifications for Interoperability (TSIs) overseen by the European Railway Agency, and the work of several pan-European rail organisations. Recently new structures have been created, such as the European Network of Rail Regulatory Bodies (ENRRB), the Platform of Rail Infrastructure Managers in Europe (PRIME) and Rail Undertakings' Dialogue. These forums shall continue to encourage the dissemination of good practice in areas such as forecasting future capacity needs and management of network rationalisation, driving productivity improvements, opening markets, industry consultation, application of the results of new research (including those arising from the work of Shift$^2$Rail).

## Recommendations for further work

7.19 In light of the experience gained in completing this study, it is clear that there is considerable scope to better understand the relative efficiency of rail systems across Europe. While any further analysis is likely to face similar data constraints to those identified in this report, we have highlighted three areas which we consider to be promising areas for further work. They include work to:

- Investigate scale effects to understand the optimal size of rail networks and agents;
- Explore trade-offs between factors of production (including labour) simultaneously; and
- In addition to assessment at national level, consider European rail efficiency within a wider geographic and temporal context.

*Economies of scale*

7.20 The results of the data envelopment analysis described in Chapter 5 suggest that further work to investigate the optimal size of rail networks may provide insights on the mechanisms and policy levers through which greater efficiency can be achieved. In the presence of diseconomies of scale there may be a case for horizontal and/or vertical separation.

7.21 These observations are supported by Sánchez, Monsálvez and Martínez (2008) who find that the process of vertical separation has had a positive effect on the efficiency of European railway systems[45]. These gains are larger when horizontal separation has also been completed. By contrast, no significant gains are observed in productivity or efficiency when only operations are reformed, but the vertically integrated structure of the industry is maintained.

7.22 Other studies, however, suggest a more mixed response to vertical separation. For example, Growitsch and Wetzel (2009) find that vertical separation raises costs while Cantos et al (2011) find vertical separation to be statistically insignificant[46]. Others such as Friebel et al (2010) find that reforms can improve efficiency, but only where they are delivered sequentially and not part of a package, and Mizutani and Uranashi (2013) find that the impact of vertical separation depends upon the level of traffic density on the rail network[47].

*Total factor productivity*

7.23 Given the range of policy levers available to the European Commission to influence and encourage the efficiency of the rail sector, this study deliberately focused upon capital productivity. However, either by including additional factors of production, or by disaggregating efficiency measures according to broad categories of rail-related activities, it may be possible to shed further light on the drivers of efficiency. Further work may include:

- Exploiting disaggregate (ideally company-level) data to decompose total factor productivity between different activities performed by railway agents e.g. provision of locomotive power, operation of carriages and wagons, provision of permanent way and working of traffic (see Dodgson, 2011).
- Gathering data on employment within the rail sector to better understand and benchmark labour market characteristics including working conditions, market constraints, capital-labour substitution rates etc. For example, this could build upon AECOM (2011) which shows that average staff costs were about 20% higher in the UK than in Germany and

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[45] See Sánchez, Monsálvez and Martínez, *Vertical and Horizontal Separation in the European Railway Sector: Effects on Productivity*

[46] See Growtisch and Wetzel, *Testing for Economies of Scope in European Railways: An Efficiency Analysis* and Cantos et al, *Evaluating European Railway Deregulation Using Different Approaches*

[47] See Friebel et al, *Railroad (De)Regulation – A European Efficiency Comparison* and Mizutani and Uranishi, *Does Vertical Separation Reduce Cost? An Empirical Analysis of the Rail Industry in European and East Asian OECD Countries.*

Sweden, though about 25% less in Britain than in the Netherlands (allowing for currency differences and PPP).

*Extending the scope of analysis*

7.24 The majority of the analysis presented in this report considers the relative performance of European railway systems at a single point in time. While we attempted to explore trends in efficiency through time, the temporal dimension of our dataset is small when compared to the number of cross-sectional observations and therefore provides limited insights. In practice, however, the accumulation of capital will have an impact on the technology available to the rail sector and hence the capital-labour substitution ratio would be expected to change through time. Understanding the evolution of performance through time would allow the development of more sophisticated, dynamic efficiency scenarios.

7.25 In addition to furthering our understanding of efficiency trajectories through time, we consider that there may be value in extending the sample of international benchmarks beyond the European Union. European railways may not, necessarily, represent the best benchmarks in all cases and across all rail-related activities. As a consequence it is implicit in the findings of this study that those Member States currently operating on the efficiency frontier cannot improve any further given the current technological mix. In practice, this is unlikely to be the case.

# Appendices

# A Data collection – Member State notes

A.1 In addition to the generic issues described in paragraphs ? to ?, we also encountered a number of country specific issues and gaps in data covering the years 2007 to 2012. These are summarised by Member State below:

**Austria (AT)**

- The passenger revenue dataset was inflated using RMMS market size data to reflect the fact that not all operators were captured in our study. This adjustment could not be made to the operating cost and staffing datasets as the data reported by this Member State is not disaggregated between the Infrastructure Manager and the operator.

**Czech Republic (CZ)**

- No subsidy data was available for 2008 from the UIC Database. We were able to identify data from the principal Operator's Annual Report and Accounts for the *"Settlement of losses from passenger transportation from the State/regional budget(s) including the grant for student fares*" and for *"securing railway routes"*. We have assumed that these items are a subsidy, although this assumption may not be directly comparable to the assumption underpinning UIC data for 2007 and 2009-12.
- The passenger revenue, operating cost and staffing datasets were inflated using RMMS market size data to reflect the fact that not all operators were captured in our study.

**Denmark (DK)**

- We were unable to account for Arriva Denmark's incomes and expenditure, as their accounts were not presented at a sufficiently disaggregated level. We have used RMMS data to adjust the passenger revenues, operating costs and staffing datasets to reflect this gap.
- It should be noted that staffing figures for the Infrastructure Manager (Banedanmark) were provided as employees and not as Full Time Equivalents. However, in one set of accounts both figures were given and they were within 1% of each other. We therefore believe that the total staffing figures for this Member State are accurate.

**Estonia (EE)**

- We have been unable to obtain passenger fare income, operating cost and staffing data for the Operator AS GoRail, which is the international operator in Estonia. We have, however, been able to obtain data for the domestic passenger operator, the Infrastructure Manager and the principal freight operator.

- Please note that this data was provided to us by a third party, who undertook currency conversion calculations themselves. It is possible that slightly different conversion rates were used.

**France (FR)**

- SNCF Group does not disaggregate its domestic income and costs from those incurred by its subsidiaries (including those operating outside France). It also does not provide a clear breakdown of its revenue between fares and subsidies/public service contracts. We have had to make a number of assumptions to produce estimates for the breakdown of SNCF revenues.
- In particular, we have assumed that the following items are considered to be subsidies:
  - Public Service Orders for train operations (excludes RFF PSOs)
  - Operating Grants
  - Payments received for concession financial assets
  - Investment grants relating to intangible assets
- Any income derived from the state for Capital expenditure has not been considered as a subsidy.
- The revenue arising from fares has had to be estimated, as SNCF does not provide a breakdown for its revenues at a Group Level. It does, however, provide figures for fares revenue for its divisions. In order to estimate fares revenue, we have assumed the following:
  - For 2003-09: the revenues generated by SNCF in France are the sum of the revenues generated by Voyages and Proximités minus the estimated subsidy.
  - For 2010-13: the revenues generated by SNCF in France are calculated by following the same formula as set out above, then deflated by 25%. This deflationary factor has been introduced to account for the income generated by SNCF's overseas interests. We chose this value as this was the difference between the figure generated by our estimate and the (single) revenue figure provided by the RMMS.
  - Freight revenues are equal to the income of Géodis (SNCF's freight division).
  - Income raised by SNCF Infra and Gares & Connections are considered out of scope.

**Finland (FI)**

- No Infrastructure Manager data was available for 2007 and 2008.
- It should also be noted that the principal operator's passenger revenue has been calculated by taking away the public subsidy to passenger services from passenger revenue. This may not be a completely accurate representation of actual fare income. However, we believe that it provides a reasonable estimate.

**Greece (EL)**

- No infrastructure income data was available for 2007 and 2008.
- Public subsidy data was only available for 2011-13.
- Staffing figures for 2007-08 may be incomplete. However, the trend in staffing levels is very clear (there has been a significant reduction during the period 2007-13).

**Italy (IT)**

- Data for this Member State were sourced from a relatively large number of sources. It is possible that not all sources will be directly comparable. However, we believe that the totals for this Member State are generally accurate.

### Latvia (LV)

- It was not possible to disaggregate the income data for the principal operator Pasažieru Vilciens. We were also unable to obtain staffing data for this operator.
- Please note that this data was provided to us by a third party, who undertook currency conversion calculations themselves. It is possible that slightly different conversion rates were used.

### Lithuania (LT)

- No major issues have been identified.

### Netherlands (NL)

- We were unable to account for Arriva Netherland's incomes and expenditure, as their accounts are not presented at a sufficiently disaggregated level. We have used RMMS data to adjust the passenger revenue, operating costs and staffing datasets to reflect this gap.

### Poland (PL)

- It should also be noted that Passenger and Infrastructure revenue were calculated by taking away the passenger and infrastructure portion of the public subsidy respectively.
- The passenger revenue dataset was inflated using RMMS market size data to reflect the fact that not all operators were captured in our study. This adjustment could not be made to the operating cost and staffing datasets as the data reported by this Member State is not disaggregated between the Infrastructure Manager and the operator. That said, it was possible to adjust the staffing data for 2012.

### Portugal (PT)

- Data for the passenger operator are presented at a group level, as disaggregated figures were not available for most of the period 2003-13. It is therefore possible that non-rail interests have been captured in our figures.
- Values for depreciation and amortisation are very different in size between CP and the infrastructure manager REFER. We are therefore not convinced that this data is consistent and comparable.
- The passenger revenue, operating cost and staffing datasets were inflated using RMMS market size data to reflect the fact that not all operators were captured in our study.

### Romania (RO)

- Data on the many smaller operators is incomplete and, for this reason, have not at all been included in the final dataset.
- It should also be noted that Passenger and Infrastructure revenue were calculated by taking away the passenger and infrastructure portion of the public subsidy respectively.
- The passenger revenue, operating cost and staffing datasets were inflated using RMMS market size data to reflect the fact that not all operators were captured in our study.

### Slovakia (SK)

- The passenger revenue, operating cost and staffing datasets were inflated using RMMS market size data to reflect the fact that not all operators were captured in our study.

**Slovenia (SI)**

- No debt data was available.
- As UIC International Railway Statistics are not yet available for 2013, we were unable to access data for this year.

**Spain (ES)**

- We were unable to obtain income data (passenger, freight and subsidy) for 2003 and 2004.
- We were unable obtain employee data for 2003.
- There are some further gaps in data for minor operators/infrastructure managers, but we do not believe these have a material impact.
- Debt data was only available for 2009-12.

**Sweden (SE)**

- The data collection process for Sweden has been complicated a number of issues:
  - There are a large number of operators that do not report to the UIC or produce annual accounts in a consistent format
  - In 2010 the rail Infrastructure Manager, Banverket, was amalgamated with a number of other transport agencies to create the organisation Trafikverket. This organisation (a government body) does not report its accounts on a modal basis. It has therefore been impossible to obtain disaggregated data for infrastructure revenue, costs, debt and staff.
  - The Freight operator only reported complete data to the UIC in 2009.
  - No market share data is available from the RMMS. This means that we are unable to scale up our data based on the market share of the operators that we are able to account for.
- We have been able to obtain reasonably complete data for 2007-08 and 2012. This may enable some analysis, but not over the timeline covered by this study.

**United Kingdom (UK)**

- All financial data for regulatory accounts are presented by UK Financial Year (April 1$^{st}$ to March 31$^{st}$) and not by calendar year. We have converted this data into Calendar Years by calculating a weighted average of each consecutive pair of years.
- Staffing data comes from multiple sources, which may not be directly comparable.
- In one year (2010) it was necessary to interpolate 2009 and 2011 data to provide an estimate for operator employees in this year.
- Revenues and public subsidies for Northern Ireland railways are included, whereas operating costs for Northern Ireland Railways (which were not provided by DRDNI) are not included. We estimate that Northern Ireland Railways accounts for less than 1% of the total operating costs for the UK rail sector, and so this omission is unlikely to undermine the total figure.
- Total public subsidy is provided by the Office for Road and Rail (ORR). We have been able to identify the proportion of this subsidy that is paid to the Infrastructure Manager (Network Rail) and franchised operators; however, we have not been able to identify which organisations receive the remaining public funding. For the purposes of this study, we are only presenting the total public subsidy provided by the ORR and the Department for Regional Development in Northern Ireland (DRDNI).

- Operating cost data for UK train operators is available via the ORR data portal but the data series commences in 2008. We were, however, able to locate a benchmarking study, published by ORR in 2012, that included data for the revenues and costs of franchised train operators covering the period 2003 to 2008. This data was presented in 2010/11 prices, and therefore have been adjusted (by applying a ratio determined by comparing ORR nominal revenue data with the revenue data provided in this study) in order to provide an estimate for operating costs over the 2003 to 2008 period.

# B Data tables

B.1 The data tables presented in this Appendix report:

- High-level indicators for each Member State over the period 2007-2012 (Tables B.1 to B.9)
- Primary KPIs over the period 2007-2012 (Tables B.10 to B.12)
- Primary and secondary KPIs for 2012 (Table B.13)

**Table B.1: Freight Rolling Stock by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 100.8 | 81.5 | 73.8 | 73.8 | 73.8 |
| Bulgaria | 100.0 | 103.3 | 95.1 | 94.6 | 132.5 | 133.5 |
| Czech Republic | 100.0 | 98.5 | 74.4 | 57.5 | 57.3 | 56.8 |
| Denmark | 100.0 | 100.0 | 100.0 | 100.0 | 99.8 | 99.7 |
| Germany | 100.0 | 118.8 | 121.6 | 116.3 | 118.8 | 116.1 |
| Estonia | 100.0 | 100.0 | 93.1 | 89.5 | 90.0 | 90.4 |
| Ireland | 100.0 | 100.0 | 78.8 | 56.3 | 56.3 | 56.3 |
| Greece | 100.0 | 133.5 | 133.5 | 88.5 | 88.5 | 88.5 |
| Spain | 100.0 | 96.5 | 80.2 | 92.4 | 88.5 | 91.1 |
| France | 100.0 | 102.0 | 93.9 | 99.4 | 95.7 | 92.2 |
| Croatia | 100.0 | 97.8 | 98.0 | 98.4 | 89.4 | 89.4 |
| Italy | 100.0 | 98.4 | 73.1 | 73.1 | 68.7 | 53.4 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | 100.0 | 99.5 | 115.0 | 114.9 | 116.6 | 120.2 |
| Lithuania | 100.0 | 101.7 | 100.8 | 97.4 | 97.1 | 96.1 |
| Luxembourg | 100.0 | 108.8 | 110.5 | 110.5 | 110.5 | 110.5 |
| Hungary | 100.0 | 100.4 | 99.8 | 99.8 | 99.8 | 99.8 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 107.2 | 114.4 | 121.6 | 128.8 | 136.0 |
| Austria | 100.0 | 165.2 | 147.0 | 154.8 | 94.3 | 98.0 |
| Poland | 100.0 | 100.6 | 98.3 | 92.1 | 88.0 | 85.5 |
| Portugal | 100.0 | 103.0 | 103.0 | 108.2 | 107.3 | 107.3 |
| Romania | 100.0 | 87.4 | 87.4 | 135.4 | 129.2 | 135.5 |
| Slovenia | 100.0 | 98.5 | 98.1 | 80.7 | 79.0 | 78.4 |
| Slovakia | 100.0 | 96.8 | 95.2 | 93.6 | 95.6 | 94.6 |
| Finland | 100.0 | 101.3 | 97.5 | 97.0 | 96.0 | 91.0 |
| Sweden | 100.0 | 99.0 | 93.1 | 95.4 | 94.0 | 92.5 |
| United Kingdom | 100.0 | 98.0 | 94.1 | 88.1 | 85.8 | 83.5 |

Note: Results are only provided if data for the entire time series is available

**Table B.2: Passenger Rolling Stock by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 97.7 | 104.2 | 104.2 | 100.5 | 100.5 |
| Bulgaria | 100.0 | 103.2 | 103.4 | 88.3 | 114.6 | 114.6 |
| Czech Republic | 100.0 | 99.9 | 99.7 | 98.9 | 97.7 | 96.8 |
| Denmark | 100.0 | 103.4 | 117.9 | 88.7 | 78.4 | 68.0 |
| Germany | 100.0 | 106.5 | 106.1 | 105.9 | 101.8 | 101.2 |
| Estonia | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Ireland | 100.0 | 111.7 | 101.9 | 101.9 | 101.9 | 101.9 |
| Greece | 100.0 | 101.5 | 101.5 | 91.9 | 91.9 | 91.9 |
| Spain | 100.0 | 104.4 | 108.1 | 116.6 | 104.1 | 101.7 |
| France | 100.0 | 102.5 | 104.2 | 106.5 | 106.2 | 104.8 |
| Croatia | 100.0 | 100.2 | 94.7 | 94.7 | 94.0 | 94.0 |
| Italy | 100.0 | 96.6 | 122.6 | 122.5 | 105.6 | 98.7 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Lithuania | 100.0 | 85.8 | 80.4 | 79.7 | 63.4 | 61.9 |
| Luxembourg | 100.0 | 97.9 | 97.9 | 112.0 | 109.9 | 109.9 |
| Hungary | 100.0 | 96.5 | 91.1 | 93.0 | 86.9 | 91.5 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 97.6 | 87.7 | 97.9 | 98.9 | 102.1 |
| Austria | 100.0 | 101.1 | 100.6 | 99.9 | 96.0 | 95.3 |
| Poland | 100.0 | 99.6 | 95.7 | 95.5 | 92.2 | 82.5 |
| Portugal | 100.0 | 99.2 | 98.4 | 91.0 | 89.9 | 92.5 |
| Romania | 100.0 | 95.7 | 95.7 | 87.7 | 80.1 | 72.5 |
| Slovenia | 100.0 | 97.1 | 96.5 | 95.2 | 95.2 | 95.2 |
| Slovakia | 100.0 | 96.5 | 92.9 | 86.4 | 88.6 | 85.6 |
| Finland | 100.0 | 101.1 | 100.9 | 104.6 | 107.6 | 110.4 |
| Sweden | 100.0 | 111.0 | 111.0 | 110.0 | 101.9 | 105.9 |
| United Kingdom | 100.0 | 105.7 | 107.8 | 107.8 | 111.5 | 112.3 |

**Table B.3: Employees by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 98.0 | 101.4 | 101.8 | 99.9 | 96.9 |
| Bulgaria | 100.0 | 97.8 | 91.3 | 84.1 | 72.2 | 68.4 |
| Czech Republic | 100.0 | 103.1 | 85.2 | 80.7 | 76.6 | 64.9 |
| Denmark | 100.0 | 100.6 | 112.1 | 103.4 | 107.9 | 97.5 |
| Germany | 100.0 | 86.0 | 98.4 | 96.6 | 99.6 | 105.4 |
| Estonia | 100.0 | 63.7 | 56.2 | 55.2 | 58.0 | 58.0 |
| Ireland | 100.0 | 98.4 | 93.7 | 88.9 | 84.2 | 81.3 |
| Greece | 100.0 | 94.6 | 87.2 | 79.7 | 57.5 | 46.9 |
| Spain | 100.0 | 99.0 | 112.7 | 112.3 | 110.1 | 99.4 |
| France | 100.0 | 98.4 | 97.5 | 95.3 | 94.3 | 94.3 |
| Croatia | n/a | n/a | n/a | n/a | n/a | n/a |
| Italy | 100.0 | 95.1 | 90.9 | 85.7 | 79.9 | 76.3 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | 100.0 | 99.4 | 90.5 | 88.0 | 85.8 | 89.9 |
| Lithuania | 100.0 | 101.7 | 99.7 | 98.9 | 99.7 | 100.6 |
| Luxembourg | 100.0 | 102.6 | 101.0 | 100.1 | 98.8 | 96.9 |
| Hungary | 100.0 | 71.1 | 63.0 | 86.1 | 84.4 | 85.6 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 103.8 | 118.3 | 97.7 | 99.8 | 117.6 |
| Austria | 100.0 | 98.5 | 105.3 | 102.9 | 99.3 | 96.9 |
| Poland | 100.0 | 98.5 | 91.6 | 86.3 | 81.8 | 129.8 |
| Portugal | 100.0 | 100.7 | 81.0 | 80.3 | 76.5 | 75.9 |
| Romania | 100.0 | 99.2 | 92.5 | 86.5 | 80.3 | 81.3 |
| Slovenia | 100.0 | 100.9 | 99.4 | 94.1 | 112.0 | 109.0 |
| Slovakia | 100.0 | 98.1 | 95.6 | 92.7 | 87.6 | 81.9 |
| Finland | 100.0 | 100.1 | 99.5 | 96.3 | 90.0 | 81.6 |
| Sweden | 100.0 | 107.9 | 201.6 | 159.5 | 154.3 | 152.3 |
| United Kingdom | 100.0 | 102.5 | 110.4 | 109.0 | 107.6 | 104.3 |

Note: Results are only provided if data for the entire time series is available

**Table B.4: Train kilometres by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 100.3 | 93.4 | 95.4 | 102.6 | 102.6 |
| Bulgaria | 100.0 | 97.3 | 87.9 | 83.4 | 85.1 | 75.7 |
| Czech Republic | 100.0 | 99.9 | 105.6 | 104.1 | 104.4 | 104.9 |
| Denmark | 100.0 | 101.7 | 116.4 | 116.4 | 116.3 | 116.3 |
| Germany | 100.0 | 102.3 | 111.5 | 114.9 | 115.7 | 115.4 |
| Estonia | 100.0 | 75.5 | 38.8 | 47.1 | 41.0 | 34.9 |
| Ireland | 100.0 | 84.7 | 84.7 | 100.5 | 100.5 | 94.5 |
| Greece | 100.0 | 106.3 | 89.9 | 78.6 | 63.0 | 61.6 |
| Spain | 100.0 | 104.3 | 110.1 | 106.3 | 103.7 | 91.6 |
| France | 100.0 | 101.2 | 105.2 | 98.4 | 101.4 | 103.9 |
| Croatia | 100.0 | 99.9 | 95.4 | 87.3 | 84.0 | 81.8 |
| Italy | 100.0 | 97.4 | 96.7 | 96.8 | 92.2 | 91.9 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | 100.0 | 101.9 | 100.8 | 90.7 | 103.4 | 104.4 |
| Lithuania | 100.0 | 105.5 | 93.5 | 97.2 | 103.6 | 99.1 |
| Luxembourg | 100.0 | 98.3 | 111.5 | 112.9 | 121.5 | 119.6 |
| Hungary | 100.0 | 89.7 | 79.3 | 78.7 | 83.1 | 83.8 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 101.1 | 132.3 | 132.3 | 135.9 | 135.9 |
| Austria | 100.0 | 102.4 | 98.8 | 102.2 | 99.2 | 99.2 |
| Poland | 100.0 | 97.2 | 125.4 | 110.1 | 113.4 | 106.4 |
| Portugal | 100.0 | 102.5 | 102.1 | 99.3 | 95.5 | 89.8 |
| Romania | 100.0 | 95.3 | 98.1 | 101.3 | 107.2 | 104.4 |
| Slovenia | 100.0 | 101.7 | 98.5 | 95.4 | 99.0 | 95.8 |
| Slovakia | 100.0 | 97.8 | 95.4 | 100.1 | 96.3 | 95.7 |
| Finland | 100.0 | 101.3 | 95.1 | 97.0 | 97.1 | 96.8 |
| Sweden | 100.0 | 104.8 | 109.6 | 107.6 | 114.6 | 119.0 |
| United Kingdom | 100.0 | 112.7 | 109.2 | 119.8 | 120.9 | 118.2 |

Note: Results are only provided if data for the entire time series is available

**Table B.5: Rail passenger kilometres by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 104.7 | 105.2 | 106.4 | 105.1 | 103.7 |
| Bulgaria | 100.0 | 96.4 | 88.5 | 86.7 | 85.3 | 77.4 |
| Czech Republic | 100.0 | 98.6 | 94.3 | 95.5 | 97.3 | 105.3 |
| Denmark | 100.0 | 101.7 | 99.6 | 102.8 | 107.0 | 109.3 |
| Germany | 100.0 | 104.3 | 104.0 | 106.1 | 107.6 | 111.8 |
| Estonia | 100.0 | 100.1 | 91.1 | 90.5 | 88.8 | 85.9 |
| Ireland | 100.0 | 98.5 | 83.9 | 83.6 | 81.6 | 78.6 |
| Greece | 100.0 | 85.7 | 73.2 | 69.2 | 49.6 | 43.0 |
| Spain | 100.0 | 109.7 | 105.9 | 102.4 | 104.3 | 102.8 |
| France | 100.0 | 106.2 | 105.3 | 105.3 | 109.1 | 109.2 |
| Croatia | 100.0 | 112.4 | 113.9 | 108.1 | 92.2 | 68.5 |
| Italy | 100.0 | 99.5 | 96.7 | 94.8 | 94.1 | 89.6 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | 100.0 | 96.7 | 76.9 | 76.2 | 75.4 | 74.2 |
| Lithuania | 100.0 | 97.3 | 87.3 | 91.2 | 95.1 | 98.5 |
| Luxembourg | 100.0 | 109.2 | 105.4 | 109.8 | 110.4 | 118.4 |
| Hungary | 100.0 | 94.8 | 92.2 | 87.9 | 89.2 | 89.2 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 98.5 | 99.1 | 99.1 | 108.1 | 110.0 |
| Austria | 100.0 | 113.1 | 111.2 | 112.1 | 113.5 | 118.2 |
| Poland | 100.0 | 101.7 | 93.8 | 90.2 | 91.5 | 89.8 |
| Portugal | 100.0 | 105.7 | 104.1 | 103.1 | 103.9 | 95.4 |
| Romania | 100.0 | 93.1 | 82.0 | 72.7 | 67.7 | 60.9 |
| Slovenia | 100.0 | 102.7 | 103.4 | 100.1 | 95.2 | 91.3 |
| Slovakia | 100.0 | 106.1 | 104.6 | 106.7 | 112.3 | 113.6 |
| Finland | 100.0 | 107.3 | 102.6 | 104.8 | 102.8 | 106.8 |
| Sweden | 100.0 | 108.6 | 110.3 | 108.7 | 110.9 | 114.9 |
| United Kingdom | 100.0 | 105.6 | 105.2 | 111.3 | 116.8 | 121.5 |

Note: Results are only provided if data for the entire time series is available

**Table B.6: Rail tonne kilometres by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 96.4 | 68.8 | 80.8 | 82.0 | 78.6 |
| Bulgaria | 100.0 | 89.5 | 60.0 | 58.5 | 62.8 | 55.5 |
| Czech Republic | 100.0 | 94.7 | 78.5 | 84.5 | 87.8 | 87.5 |
| Denmark | 100.0 | 104.9 | 95.6 | 125.9 | 147.0 | 127.6 |
| Germany | 100.0 | 100.9 | 83.6 | 93.6 | 98.9 | 96.0 |
| Estonia | 100.0 | 70.5 | 70.5 | 78.7 | 74.4 | 60.8 |
| Ireland | 100.0 | 79.8 | 61.2 | 71.3 | 81.4 | 70.5 |
| Greece | 100.0 | 94.1 | 66.1 | 73.5 | 42.2 | 33.9 |
| Spain | 100.0 | 97.6 | 70.6 | 82.0 | 86.7 | 88.6 |
| France | 100.0 | 95.1 | 75.4 | 70.3 | 80.2 | 76.4 |
| Croatia | 100.0 | 92.7 | 73.9 | 73.3 | 68.2 | 65.2 |
| Italy | 100.0 | 94.2 | 70.4 | 73.6 | 78.3 | 80.1 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | 100.0 | 106.9 | 102.2 | 93.8 | 116.9 | 119.4 |
| Lithuania | 100.0 | 102.6 | 82.7 | 93.4 | 105.0 | 98.6 |
| Luxembourg | 100.0 | 48.6 | 34.8 | 56.3 | 50.2 | 42.0 |
| Hungary | 100.0 | 98.3 | 76.4 | 87.7 | 90.7 | 91.9 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 96.8 | 77.3 | 82.1 | 88.4 | 85.3 |
| Austria | 100.0 | 102.5 | 83.1 | 92.8 | 95.2 | 91.2 |
| Poland | 100.0 | 95.9 | 80.1 | 89.8 | 99.1 | 90.1 |
| Portugal | 100.0 | 98.6 | 84.1 | 89.4 | 89.8 | 93.6 |
| Romania | 100.0 | 96.7 | 70.4 | 78.5 | 93.4 | 85.5 |
| Slovenia | 100.0 | 97.7 | 78.2 | 94.9 | 104.1 | 96.3 |
| Slovakia | 100.0 | 96.4 | 72.2 | 84.0 | 82.5 | 78.7 |
| Finland | 100.0 | 103.3 | 85.0 | 93.4 | 90.0 | 88.9 |
| Sweden | 100.0 | 98.6 | 87.7 | 100.9 | 98.3 | 94.8 |
| United Kingdom | 100.0 | 99.1 | 90.2 | 87.4 | 98.6 | 100.8 |

Note: Results are only provided if data for the entire time series is available

**Table B.7: Passenger revenue by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 107.3 | 109.5 | 113.0 | 114.5 | 114.9 |
| Bulgaria | 100.0 | 109.2 | 100.8 | 96.1 | 98.4 | 96.1 |
| Czech Republic | 100.0 | 107.9 | 106.4 | 113.2 | 121.8 | 124.8 |
| Denmark | 100.0 | 103.5 | 96.4 | 98.8 | 127.0 | 108.9 |
| Germany | 100.0 | 107.2 | 106.9 | 107.5 | 109.5 | 128.0 |
| Estonia | 100.0 | 116.2 | 118.0 | 114.1 | 117.3 | 108.3 |
| Ireland | 100.0 | 102.0 | 93.8 | 86.7 | 83.0 | 89.1 |
| Greece | 100.0 | 99.0 | 102.6 | 109.8 | 91.2 | 103.3 |
| Spain | 100.0 | 125.7 | 136.4 | 139.7 | 148.6 | 145.8 |
| France* | 100.0 | 124.5 | 150.6 | 166.5 | 189.9 | 192.9 |
| Croatia | n/a | n/a | n/a | n/a | n/a | n/a |
| Italy | 100.0 | 104.6 | 107.3 | 109.9 | 114.0 | 113.0 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | 100.0 | 26.1 | 27.0 | 26.3 | 25.1 | 5.9 |
| Lithuania | 100.0 | 109.2 | 101.9 | 117.0 | 130.0 | 137.7 |
| Luxembourg | 100.0 | 104.6 | 107.7 | 117.2 | 119.7 | 123.6 |
| Hungary | 100.0 | 12.4 | 169.1 | 180.1 | 190.4 | 187.0 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 102.9 | 107.3 | 110.6 | 117.8 | 120.2 |
| Austria | 100.0 | 113.6 | 111.7 | 89.8 | 90.6 | 94.9 |
| Poland* | 100.0 | 154.6 | 178.6 | 209.6 | 175.6 | 409.9 |
| Portugal | 100.0 | 107.2 | 107.2 | 109.2 | 111.5 | 112.3 |
| Romania | 100.0 | 97.9 | 74.9 | 71.0 | 78.1 | 73.9 |
| Slovenia | 100.0 | 105.3 | 104.6 | 104.3 | 111.2 | 119.3 |
| Slovakia | 100.0 | 115.4 | 111.9 | 113.9 | 125.3 | 139.5 |
| Finland | 100.0 | 110.9 | 110.6 | 113.9 | 113.5 | 120.7 |
| Sweden | 100.0 | 103.5 | 87.6 | 95.0 | 87.3 | 90.2 |
| United Kingdom | 100.0 | 102.3 | 96.1 | 105.2 | 111.2 | 130.0 |

Note: Results are only provided if data for the entire time series is available (* Passenger revenue in Poland is considerably higher in 2012 when compared to previous years and is a result of improved coverage of our dataset in 2012 compared to previous time periods)

**Table B.8: Operating costs (operator and infrastructure manager) by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 105.3 | 110.5 | 123.5 | 112.9 | 111.9 |
| Bulgaria | 100.0 | 111.1 | 95.6 | 86.1 | 82.8 | 88.3 |
| Czech Republic | 100.0 | 128.6 | 120.6 | 120.1 | 115.9 | 125.2 |
| Denmark | 100.0 | 104.2 | 111.5 | 122.7 | 130.7 | 123.0 |
| Germany | 100.0 | 101.6 | 99.9 | 102.0 | 101.9 | 117.8 |
| Estonia | n/a | n/a | n/a | n/a | n/a | n/a |
| Ireland | 100.0 | 105.0 | 96.0 | 90.6 | 80.0 | 78.6 |
| Greece | 100.0 | 101.2 | 104.8 | 92.8 | 140.8 | 69.2 |
| Spain | 100.0 | 109.9 | 118.8 | 119.1 | 138.7 | 128.0 |
| France | 100.0 | 102.0 | 109.7 | 126.9 | 132.5 | 129.6 |
| Croatia | n/a | n/a | n/a | n/a | n/a | n/a |
| Italy | 100.0 | 101.2 | 93.9 | 83.9 | 84.3 | 83.8 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | n/a | n/a | n/a | n/a | n/a | n/a |
| Lithuania | 100.0 | 118.3 | 99.3 | 108.5 | 120.6 | 130.7 |
| Luxembourg | 100.0 | 103.0 | 101.0 | 175.1 | 191.9 | 196.9 |
| Hungary | 100.0 | 130.7 | 71.7 | 72.6 | 74.7 | 78.2 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 105.8 | 93.6 | 103.0 | 102.8 | 113.6 |
| Austria | 100.0 | 118.0 | 123.7 | 129.2 | 129.2 | 127.9 |
| Poland | 100.0 | 128.6 | 95.9 | 108.7 | 126.8 | 98.7 |
| Portugal | 100.0 | 104.8 | 101.8 | 102.1 | 116.4 | 105.5 |
| Romania | 100.0 | 100.1 | 80.2 | 111.9 | 130.2 | 138.3 |
| Slovenia | 100.0 | 110.0 | 105.4 | 113.8 | 150.5 | 137.8 |
| Slovakia | 100.0 | 121.9 | 125.2 | 120.1 | 116.8 | 115.4 |
| Finland | 100.0 | 102.6 | 105.3 | 100.5 | 103.3 | 97.6 |
| Sweden | 100.0 | 105.9 | 105.8 | 109.2 | 154.0 | 166.9 |
| United Kingdom | 100.0 | 101.7 | 90.9 | 94.3 | 96.1 | 114.5 |

Note: Results are only provided if data for the entire time series is available

**Table B.9: Rail subsidies by Member State (2007 = 100)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 100.0 | 102.7 | 140.3 | 142.7 | 139.2 | 140.9 |
| Bulgaria | 100.0 | 122.1 | 167.9 | 175.7 | 169.0 | 169.0 |
| Czech Republic | 100.0 | 63.7 | 71.4 | 73.2 | 79.9 | 74.5 |
| Denmark | 100.0 | 97.1 | 105.6 | 108.4 | 125.6 | 117.3 |
| Germany | 100.0 | 99.5 | 101.0 | 102.5 | 104.0 | 105.6 |
| Estonia | n/a | n/a | n/a | n/a | n/a | n/a |
| Ireland | 100.0 | 102.4 | 86.3 | 88.0 | 91.2 | 88.4 |
| Greece | n/a | n/a | n/a | n/a | n/a | n/a |
| Spain | 100.0 | 100.9 | 103.5 | 101.8 | 102.8 | 29.5 |
| France | 100.0 | 91.1 | 116.5 | 94.3 | 88.3 | 88.6 |
| Croatia | n/a | n/a | n/a | n/a | n/a | n/a |
| Italy | 100.0 | 102.9 | 97.7 | 82.8 | 78.4 | 80.0 |
| Cyprus | n/a | n/a | n/a | n/a | n/a | n/a |
| Latvia | n/a | n/a | n/a | n/a | n/a | n/a |
| Lithuania | 100.0 | 582.5 | 394.8 | 27.0 | 25.8 | 31.7 |
| Luxembourg | 100.0 | 103.1 | 109.9 | 122.8 | 127.0 | 134.2 |
| Hungary | 100.0 | 147.9 | 129.1 | 154.9 | 147.4 | 166.4 |
| Malta | n/a | n/a | n/a | n/a | n/a | n/a |
| Netherlands | 100.0 | 106.4 | 70.5 | 81.1 | 76.3 | 110.0 |
| Austria | 100.0 | 107.0 | 114.4 | 123.3 | 126.5 | 134.9 |
| Poland | 100.0 | 83.7 | 107.7 | 141.6 | 252.2 | 0.0 |
| Portugal | 100.0 | 107.8 | 121.0 | 118.5 | 122.0 | 125.0 |
| Romania | 100.0 | 102.6 | 87.6 | 91.8 | 109.5 | 135.5 |
| Slovenia | 100.0 | 95.9 | 117.8 | 110.7 | 109.6 | 108.8 |
| Slovakia | 100.0 | 189.0 | 211.7 | 215.8 | 295.7 | 296.8 |
| Finland | 100.0 | 108.0 | 110.4 | 109.8 | 113.5 | 115.3 |
| Sweden* | n/a | n/a | n/a | n/a | n/a | n/a |
| United Kingdom | 100.0 | 83.6 | 76.3 | 74.8 | 72.9 | 73.1 |

Note: Results are only provided if data for the entire time series is available (*there is a break in the time series data for Sweden. While we have confidence in the subsidy data available for 2011 and 2012, we have not been able to reconcile the this with data for the period prior to the series break in 2010)

**Table B.10: Track utilisation by Member State (total train kilometres/track kilometres)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 29,243 | 28,159 | 25,748 | 26,271 | 28,273 | 28,273 |
| Bulgaria | 8,862 | 8,623 | 7,778 | 7,478 | 7,673 | 6,830 |
| Czech Republic | 16,049 | 16,213 | 17,148 | 16,920 | 16,959 | 17,045 |
| Denmark | 21,440 | 21,794 | 24,949 | 24,949 | 25,105 | 25,114 |
| Germany | 26,537 | 27,171 | 29,737 | 30,662 | 30,986 | 30,959 |
| Estonia | 11,183 | 7,499 | 3,849 | 5,461 | 4,724 | 4,021 |
| Ireland | 8,771 | 7,428 | 7,428 | 8,819 | 8,819 | 8,286 |
| Greece | 7,803 | 8,293 | 7,014 | 6,130 | 4,908 | 4,800 |
| Spain | 12,915 | 13,471 | 14,425 | 13,484 | 13,071 | 11,556 |
| France | 16,462 | 16,676 | 17,331 | 16,228 | 16,422 | 16,740 |
| Croatia | 10,842 | 10,836 | 10,341 | 9,469 | 9,102 | 8,870 |
| Italy | 20,653 | 19,889 | 19,574 | 19,579 | 18,620 | 18,549 |
| Latvia | 7,853 | 8,009 | 9,516 | 8,503 | 9,861 | 9,983 |
| Lithuania | 8,489 | 8,961 | 7,935 | 8,243 | 8,786 | 8,409 |
| Luxembourg | 26,287 | 25,851 | 29,313 | 29,676 | 31,931 | 31,440 |
| Hungary | 15,719 | 14,182 | 12,545 | 12,443 | 13,118 | 13,286 |
| Netherlands | 37,952 | 38,267 | 48,125 | 48,125 | 49,452 | 49,452 |
| Austria | 24,140 | 25,387 | 25,897 | 28,483 | 27,744 | 28,464 |
| Poland | 10,086 | 9,701 | 12,428 | 10,950 | 11,263 | 10,620 |
| Portugal | 13,722 | 14,046 | 13,998 | 13,603 | 13,318 | 13,769 |
| Romania | 8,569 | 8,164 | 8,403 | 8,678 | 9,185 | 8,946 |
| Slovenia | 16,093 | 16,366 | 15,856 | 15,345 | 16,180 | 15,667 |
| Slovakia | 12,991 | 12,720 | 12,409 | 13,035 | 12,525 | 12,557 |
| Finland | 8,913 | 8,998 | 8,451 | 8,616 | 8,592 | 8,562 |
| Sweden | 11,165 | 11,635 | 12,050 | 11,808 | 12,524 | 13,086 |
| United Kingdom | 28,851 | 32,510 | 31,627 | 34,641 | 34,457 | 33,675 |

**Table B.11: Passenger train utilisation by Member State (passenger kilometres/passenger train kilometres)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 3,033 | 3,250 | 3,063 | 3,096 | 3,172 | 3,131 |
| Bulgaria | 1,563 | 1,460 | 1,338 | 1,534 | 1,163 | 1,056 |
| Czech Republic | 1,511 | 1,492 | 1,428 | 1,460 | 1,504 | 1,644 |
| Denmark | 4,193 | 4,123 | 3,542 | 4,857 | 5,726 | 6,739 |
| Germany | 4,510 | 4,419 | 4,423 | 4,519 | 4,768 | 4,982 |
| Estonia | 1,447 | 1,448 | 1,318 | 1,310 | 1,286 | 1,243 |
| Ireland | 3,454 | 3,045 | 2,843 | 2,834 | 2,767 | 2,666 |
| Greece | 2,475 | 2,090 | 1,783 | 1,862 | 1,334 | 1,159 |
| Spain | 4,497 | 4,723 | 4,404 | 3,951 | 4,504 | 4,546 |
| France | 5,142 | 5,328 | 5,199 | 5,086 | 5,284 | 5,356 |
| Croatia | 2,918 | 3,273 | 3,509 | 3,331 | 2,863 | 2,127 |
| Italy | 4,893 | 5,041 | 3,858 | 3,784 | 4,361 | 4,441 |
| Latvia | 2,002 | 1,937 | 1,540 | 1,525 | 1,509 | 1,485 |
| Lithuania | 967 | 1,096 | 1,050 | 1,107 | 1,451 | 1,538 |
| Luxembourg | 1,654 | 1,845 | 1,781 | 1,621 | 1,662 | 1,781 |
| Hungary | 2,595 | 2,549 | 2,628 | 2,453 | 2,663 | 2,529 |
| Netherlands | 5,387 | 5,434 | 6,085 | 5,453 | 5,889 | 5,800 |
| Austria | 3,217 | 3,600 | 3,557 | 3,610 | 3,803 | 3,988 |
| Poland | 2,737 | 2,796 | 2,684 | 2,587 | 2,717 | 2,977 |
| Portugal | 3,761 | 4,009 | 3,981 | 4,260 | 4,347 | 3,881 |
| Romania | 2,159 | 2,100 | 1,850 | 1,790 | 1,825 | 1,812 |
| Slovenia | 2,177 | 2,304 | 2,333 | 2,290 | 2,177 | 2,089 |
| Slovakia | 1,222 | 1,343 | 1,375 | 1,509 | 1,549 | 1,622 |
| Finland | 3,689 | 3,915 | 3,752 | 3,697 | 3,523 | 3,568 |
| Sweden | 12,956 | 12,680 | 12,879 | 12,807 | 14,100 | 14,055 |
| United Kingdom | 4,605 | 4,603 | 4,490 | 4,751 | 4,826 | 4,983 |

**Table B.12: Freight train utilisation by Member State (freight tonne kilometres/freight train kilometres)**

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Belgium | 589 | 563 | 497 | 644 | 654 | 627 |
| Bulgaria | 422 | 366 | 266 | 261 | 200 | 175 |
| Czech Republic | 342 | 329 | 361 | 502 | 524 | 527 |
| Denmark | 809 | 848 | 773 | 1,018 | 1,191 | 1,035 |
| Germany | 776 | 659 | 533 | 625 | 646 | 642 |
| Estonia | 429 | 303 | 325 | 378 | 355 | 289 |
| Ireland | 145 | 116 | 113 | 183 | 209 | 181 |
| Greece | 234 | 165 | 116 | 194 | 111 | 90 |
| Spain | 724 | 733 | 638 | 642 | 710 | 704 |
| France | 566 | 528 | 455 | 400 | 475 | 469 |
| Croatia | 527 | 499 | 398 | 392 | 402 | 385 |
| Italy | 610 | 584 | 587 | 614 | 694 | 914 |
| Latvia | 3,484 | 3,745 | 3,099 | 2,845 | 3,495 | 3,460 |
| Lithuania | 1,515 | 1,529 | 1,243 | 1,454 | 1,638 | 1,555 |
| Luxembourg | 163 | 73 | 51 | 83 | 74 | 62 |
| Hungary | 857 | 839 | 656 | 753 | 779 | 789 |
| Netherlands | 2,844 | 2,567 | 1,922 | 1,920 | 1,952 | 1,784 |
| Austria | 1,157 | 718 | 654 | 693 | 1,168 | 1,077 |
| Poland | 733 | 699 | 597 | 715 | 826 | 773 |
| Portugal | 876 | 838 | 714 | 724 | 732 | 764 |
| Romania | 294 | 325 | 237 | 170 | 212 | 185 |
| Slovenia | 906 | 898 | 721 | 1,065 | 1,194 | 1,112 |
| Slovakia | 533 | 530 | 404 | 478 | 460 | 443 |
| Finland | 967 | 986 | 843 | 932 | 907 | 945 |
| Sweden | 1,463 | 1,457 | 1,378 | 1,547 | 1,531 | 1,498 |
| United Kingdom | 669 | 676 | 641 | 663 | 769 | 808 |

**Table B.13: Summary of KPIs (2012)**

| Member State | Tkm / Track km | Pkm / Track km | Tonne km / Track km | Pkm / RSP | Tonne km / RSF | Tkm / Opex | Tkm / Subsidy | Tkm / FTE | Pkm / Passenger opex | Pkm / Subsidy | Pkm / FTE | Tkm / RSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Belgium | 28,273 | 2,875,489 | 2,032,384 | 3,130,699 | 626,938 | 0.03 | 0.06 | 2,863 | 3.18 | 5.72 | 291,150 | 30,782 |
| Bulgaria | 6,830 | 460,934 | 714,251 | 1,055,712 | 175,374 | 0.10 | 0.18 | 1,188 | 6.76 | 12.34 | 80,140 | 15,644 |
| Czech Republic | 17,045 | 767,209 | 1,506,706 | 1,643,969 | 527,119 | 0.08 | 0.19 | 4,331 | 3.75 | 8.62 | 194,940 | 36,524 |
| Denmark | 25,114 | 2,569,254 | 863,775 | 6,738,523 | 1,035,149 | 0.04 | 0.09 | 6,017 | 4.10 | 9.05 | 615,514 | 65,868 |
| Germany | 30,959 | 2,638,097 | 3,284,640 | 4,982,247 | 641,816 | 0.08 | 0.15 | 10,423 | 6.89 | 12.48 | 888,153 | 58,469 |
| Estonia | 4,021 | 296,717 | 6,476,010 | 1,243,386 | 288,681 | 0.12 | 0.16 | 1,773 | 8.71 | 11.46 | 130,846 | 16,852 |
| Ireland | 8,286 | 822,303 | 47,421 | 2,665,541 | 181,275 | 0.06 | 0.06 | 3,923 | 5.98 | 6.11 | 389,341 | 26,858 |
| Greece | 4,800 | 325,764 | 110,807 | 1,158,774 | 89,614 | 0.01 | 0.08 | 3,604 | 0.72 | 5.62 | 244,562 | 17,075 |
| Spain | 11,556 | 1,411,619 | 625,361 | 4,546,076 | 703,774 | 0.05 | 0.11 | 6,489 | 5.70 | 12.90 | 792,582 | 37,217 |
| France | 16,740 | 2,911,997 | 1,064,452 | 5,356,176 | 469,157 | 0.02 | 0.09 | 3,248 | 3.33 | 15.22 | 565,031 | 30,791 |
| Croatia | 8,870 | 405,584 | 856,723 | 2,127,168 | 384,628 | | | | | | | 46,522 |
| Italy | 18,549 | 2,614,127 | 1,186,635 | 4,441,490 | 914,363 | 0.05 | 0.09 | 4,313 | 6.68 | 13.14 | 607,854 | 31,515 |
| Latvia | 9,983 | 391,935 | 11,756,452 | 1,484,725 | 3,459,968 | 0.11 | | | 4.42 | | | 37,819 |
| Lithuania* | 8,409 | 228,070 | 8,020,374 | 1,538,168 | 1,555,312 | 0.08 | 4.22 | 1,404 | 2.14 | 114.36 | 55,106 | 56,714 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Luxembourg | 31,440 | 1,360,000 | 876,364 | 1,780,952 | 61,874 | 0.02 | 0.05 | 1,402 | 0.99 | 2.14 | 38,015 | 41,171 |
| Hungary | 13,286 | 990,990 | 1,171,766 | 2,529,497 | 788,889 | 0.08 | 0.12 | 2,667 | 5.75 | 8.85 | 115,361 | 33,913 |
| Netherlands | 49,452 | 5,674,743 | 2,043,478 | 5,799,864 | 1,784,262 | 0.03 | 0.05 | 2,683 | 3.22 | 5.57 | 200,144 | 50,543 |
| Austria | 28,464 | 2,313,649 | 3,984,266 | 3,988,376 | 1,077,055 | 0.04 | 0.06 | | 2.98 | 5.09 | | 49,067 |
| Poland | 10,620 | 908,702 | 2,492,889 | 2,977,451 | 772,938 | 0.10 | 0.20 | 4,407 | 8.30 | 16.71 | 505,701 | 34,796 |
| Portugal | 13,769 | 1,496,655 | 952,774 | 3,880,612 | 763,722 | 0.04 | 0.47 | 3,353 | 4.21 | 50.63 | 272,561 | 35,700 |
| Romania | 8,946 | 422,195 | 1,250,070 | 1,812,027 | 185,468 | 0.06 | 0.24 | 1,300 | 2.95 | 11.12 | 111,270 | 38,394 |
| Slovenia | 15,667 | 613,482 | 2,870,141 | 2,089,296 | 1,112,179 | 0.10 | 0.43 | 5,564 | 3.99 | 16.77 | 604,778 | 53,355 |
| Slovakia | 12,557 | 684,386 | 2,112,719 | 1,622,032 | 442,753 | 0.05 | 0.10 | 1,877 | 2.88 | 5.18 | 88,599 | 29,761 |
| Finland | 8,562 | 678,836 | 1,560,397 | 3,567,639 | 944,790 | 0.05 | 0.36 | 2,190 | 4.21 | 28.16 | 85,765 | 44,996 |
| Sweden^ | 13,086 | 1,058,908 | 1,979,436 | 14,054,827 | 1,498,442 | 0.08 | 0.23 | 1,630 | 6.14 | 18.93 | 88,819 | 173,695 |
| United Kingdom | 33,675 | 3,712,111 | 1,305,730 | 4,983,162 | 807,524 | 0.04 | 0.11 | 6,175 | 4.32 | 12.58 | 489,625 | 45,205 |

Source: SDG analysis (TKm = train kilometres; Pkm – passenger kilometres; RSP = passenger rolling stock; RSF = freight rolling stock; Opex = total operating costs; Passenger opex = passenger operating costs; FTE = full time equivalent employees) * Subsidy data for Lithuania appear volatile over time and therefore Tkm/subsidy and Tkm/subsidy figures may be over-stated ^ Passenger rolling stock quantities for Sweden appear very small compared to the size of the rail network (this is consistent through time)

# C Clustering methods

C.1 In determining our approach to clustering, we considered three distinct yet complementary methodologies that appeared promising but which were ultimately discarded. These were:

- Regression modelling;
- Hierarchical partitioning; and
- Expert review.

**Regression modelling**

C.2 Our first approach to clustering used regression modelling in which a normalised measure of performance (e.g. passenger-kilometre per capita) was used as the dependent variable of a regression model. The exogenous factors identified above were then treated as independent variables that have an influence on performance. In performing this analysis we:

- Obtained factor-specific coefficients by way of a OLS/logit regression;
- Used these coefficients as inputs into a modelled function for each Member State
- Used outturn data for the exogenous variables to estimate the expected value of the dependent variable[48];
- Ranked Member States based on those scores; and
- Allocated Member States to clusters according to the frequency with which they were ranked in a given quartile across models.

C.3 Regression modelling is more data-driven and potentially more objective than other methods, but the results are based on the assumption that the main exogenous determinants of key performance have been included in the analysis.

**Hierarchical partitioning**

C.4 Our second approach involved hierarchical clustering by way of partitioning. Exogenous factors were ranked in terms of their statistical significance using outputs from the regression analysis[49]. We then constructed a tree diagram based on thresholds that are set at the mean value for each of the exogenous factors. For instance, Member States were first divided into two groups depending on whether their GDP per capita (identified as the most important

[48] Either as an absolute number (from the OLS regression) or as a probability score (from the logit regression)

[49] GDP per capita was the most important variable, followed by population density, track density, and number of ports linked by rail. High-speed rail network length was not included in the partitioning in order to reduce the number of branches created.

influence on rail performance) was above or below the average GDP per capita for the EU26. Next, the group of wealthier Member States was split according to whether the population density (the second most important influence on performance) was above or below the average.

C.5 Hierarchical partitioning is more flexible and gives greater weight to the exogenous factors that are deemed to be most important, such as GDP per capita. However, it requires assumptions about the thresholds underpinning each partition and led to a greater level of disaggregation than was required for the analysis.

**Expert review**

C.6 The third approach relied heavily on expert judgement. While broadly comparable to the method of hierarchical clustering, this approach built clusters from the bottom-up. We created 13 pairs of Member States based on a review of exogenous factors, and consideration of similarities and differences in rail markets from previous studies. Having identified the pairs of 'most similar' Member States, we then aggregated those pairs into larger groups based on the similarities between pairs. This was based on an inspection of the available data on exogenous factors, as well as knowledge of other systems of classification adopted by EU institutions. For example, the Cohesion Funding Framework 2014-2020 indicates which countries are eligible for EU funds based on an index of socio-economic indicators and allows groupings according to classifications such as 'more developed' or 'transition' Member States. The Global Competitiveness Index prepared by the World Economic Forum similarly provided useful information on the quality of perceived transport infrastructure. While the approach allows greater flexibility, it is clearly subjective and therefore particularly open to challenge.

# D Clustering outputs

D.1 Table C.1 reports the results of the nine clustering model specifications described in Table 4.3. The results are presented against a 'five-cluster' specification. While models 4 and 8 were identified as our preferred models from a passenger and freight perspective, it should be noted that further professional experience and judgement was applied in order to determine the final clusters used in subsequent phases of the analysis.

**Table D.1: Detailed clustering outputs**

| | Passenger | | | | | Freight | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| BE | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BG | 4 | 2 | 2 | 5 | 2 | 2 | 2 | 4 | 2 |
| CZ | 4 | 2 | 2 | 5 | 2 | 2 | 2 | 4 | 2 |
| DK | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| DE | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 |
| EE | 4 | 1 | 1 | 5 | 1 | 1 | 1 | 4 | 1 |
| IE | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 |
| EL | 5 | 2 | 2 | 5 | 2 | 2 | 2 | 5 | 2 |
| ES | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 |
| FR | 1 | 5 | 5 | 3 | 5 | 5 | 5 | 1 | 5 |
| HR | 4 | 1 | 1 | 5 | 1 | 1 | 1 | 4 | 1 |
| IT | 5 | 3 | 3 | 4 | 3 | 3 | 3 | 5 | 3 |
| LV | 4 | 1 | 1 | 5 | 1 | 1 | 1 | 4 | 1 |
| LT | 4 | 1 | 1 | 5 | 1 | 1 | 1 | 4 | 1 |
| LU | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 1 |
| HU | 4 | 2 | 2 | 5 | 2 | 2 | 2 | 4 | 2 |
| NL | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| AT | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 |
| PL | 4 | 3 | 3 | 5 | 3 | 3 | 3 | 4 | 3 |
| PT | 5 | 2 | 2 | 5 | 2 | 2 | 2 | 5 | 2 |
| RO | 4 | 3 | 3 | 5 | 3 | 3 | 3 | 4 | 3 |
| SI | 5 | 1 | 1 | 5 | 1 | 1 | 1 | 5 | 1 |
| SK | 4 | 1 | 1 | 5 | 1 | 1 | 1 | 4 | 1 |
| FI | 1 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 3 |
| SE | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 |
| UK | 1 | 3 | 3 | 4 | 3 | 3 | 3 | 1 | 3 |

D.2 Dendrograms for each specification of the clustering analysis are provided in the following figures. A dendrogram is a tree diagram frequently used to illustrate the arrangement of the clusters produced by hierarchical clustering. A simple example and explanation is provided in Figure 4.2.

**Figure D.1: Dendrogram for clustering model specification 1**

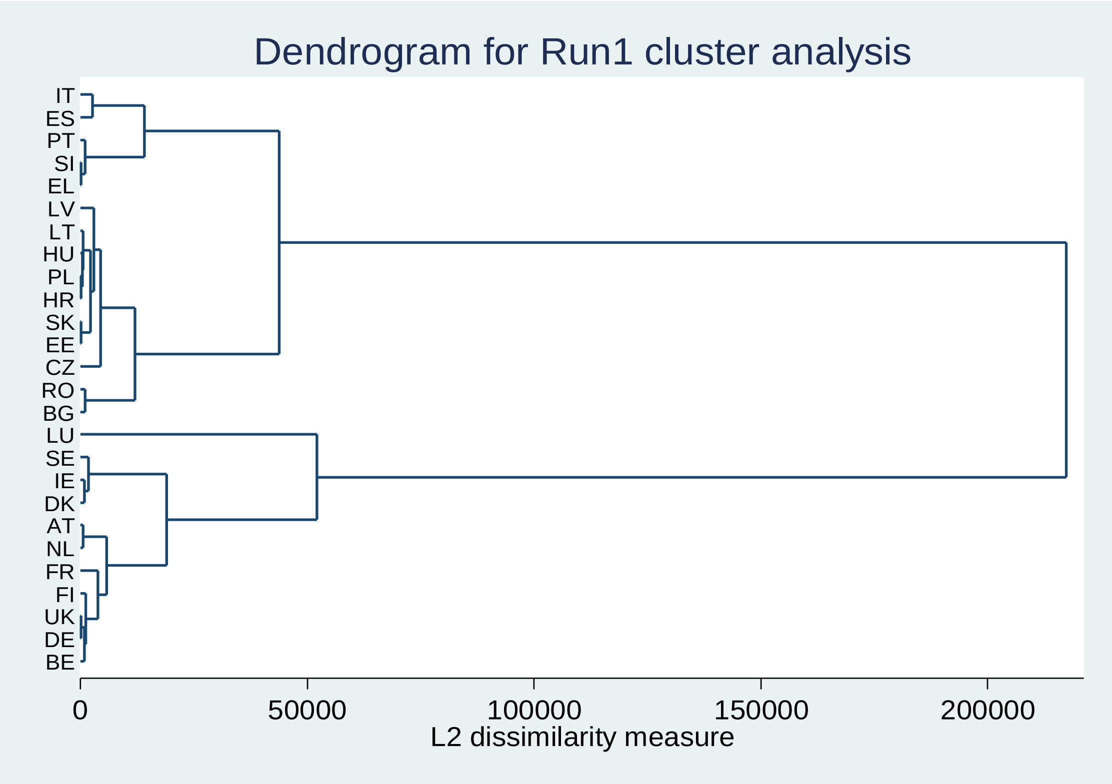


**Figure D.2: Dendrogram for clustering model specification 2**

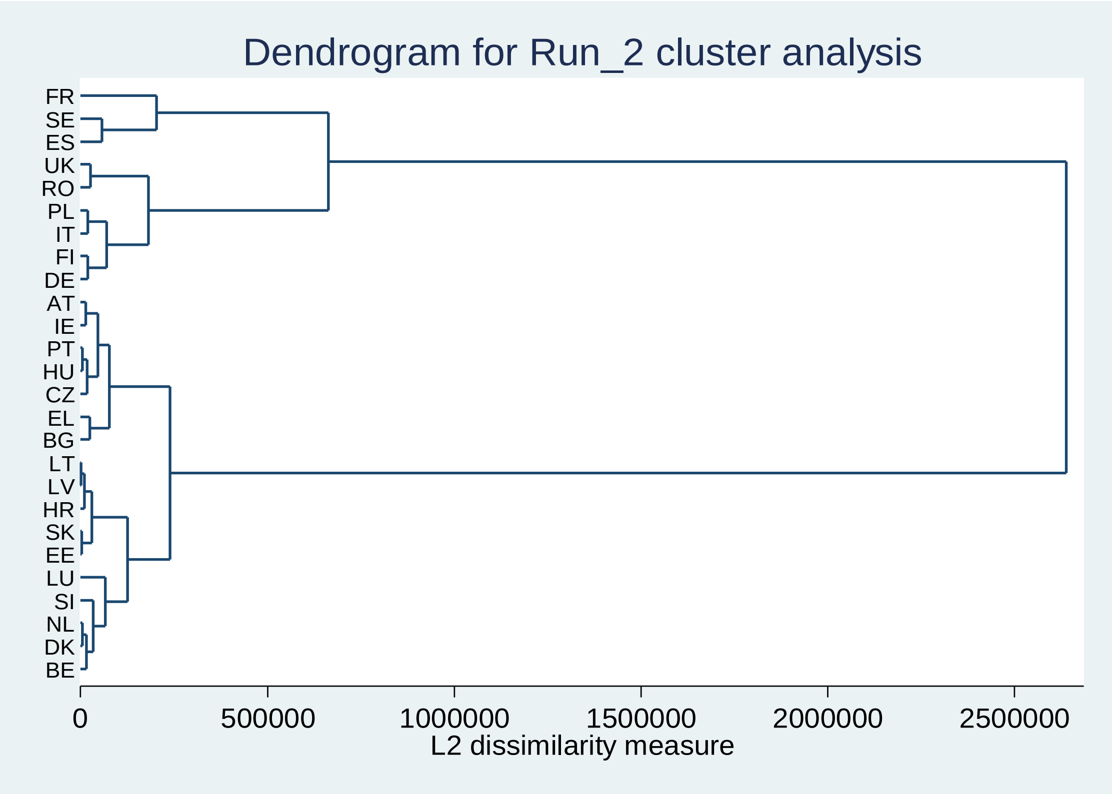



**Figure D.3: Dendrogram for clustering model specification 3**

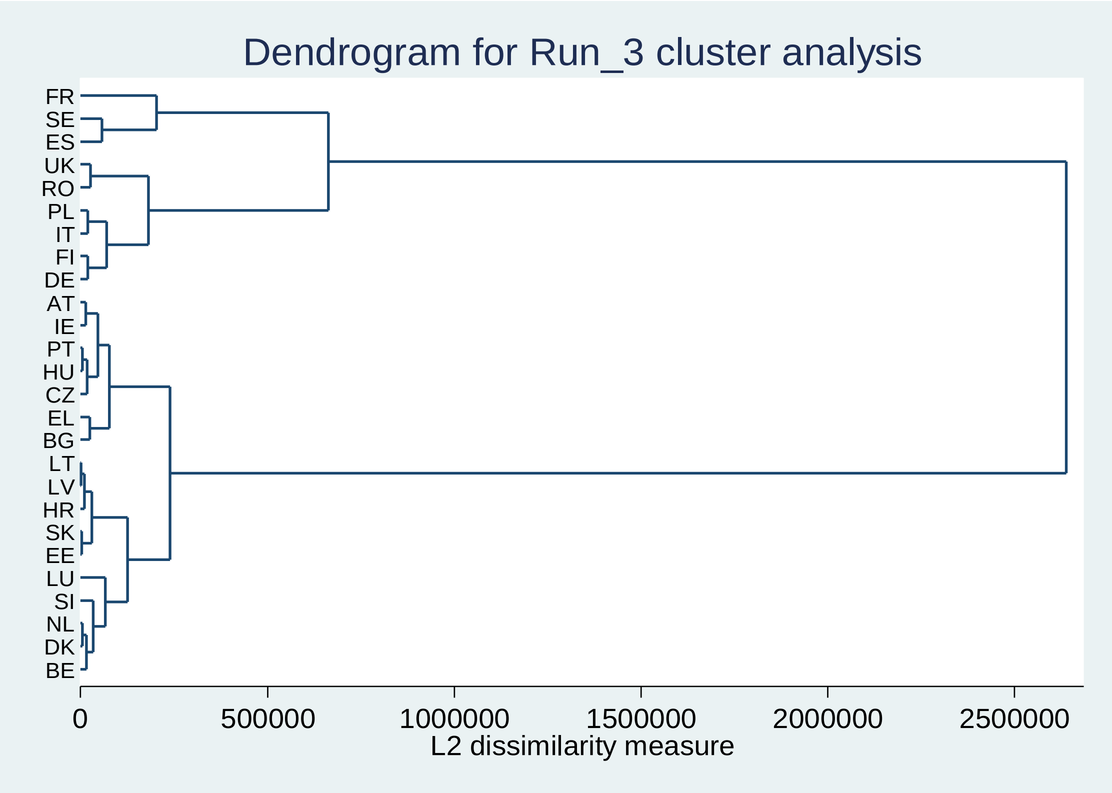


**Figure D.4: Dendrogram for clustering model specification 4**

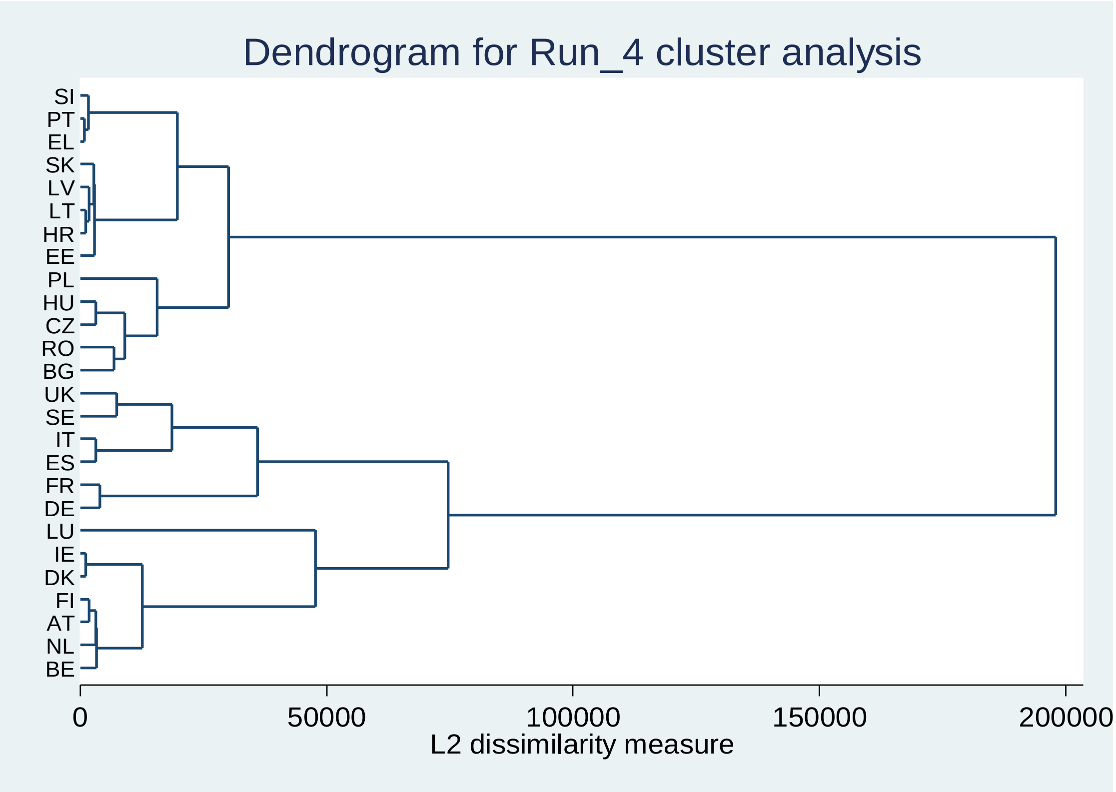



**Figure D.5: Dendrogram for clustering model specification 5**

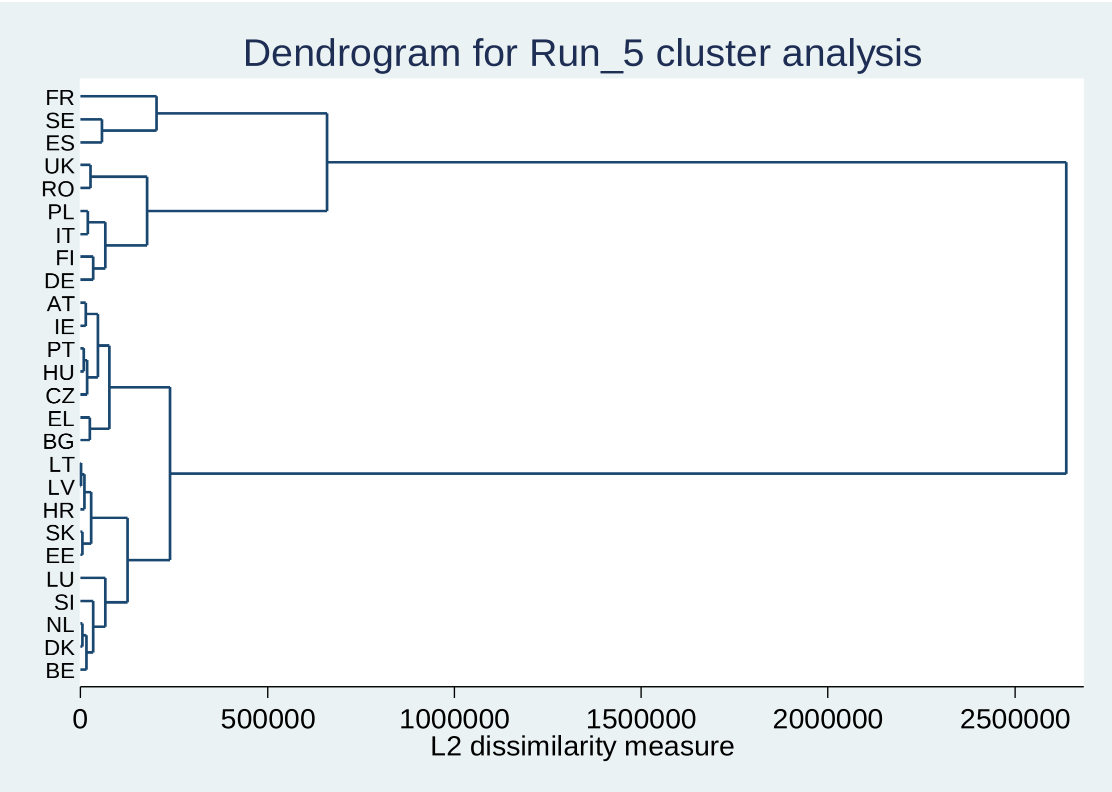


**Figure D.6: Dendrogram for clustering model specification 6**

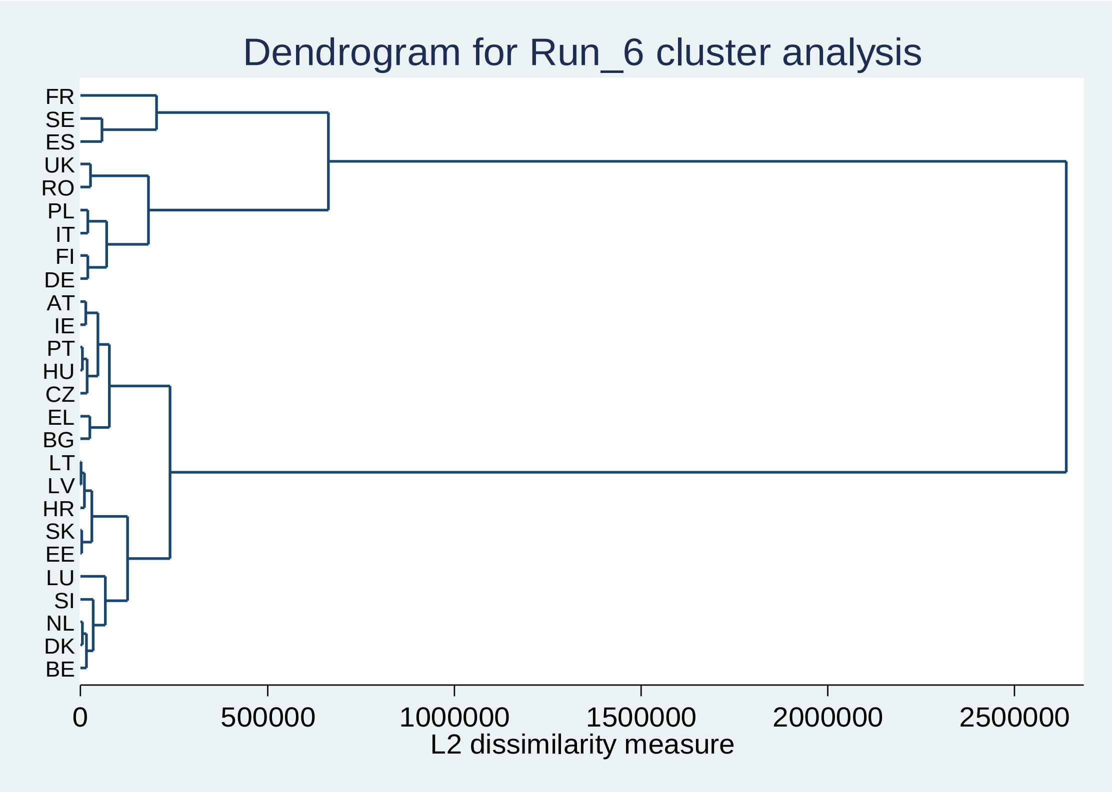



**Figure D.7: Dendrogram for clustering model specification 7**

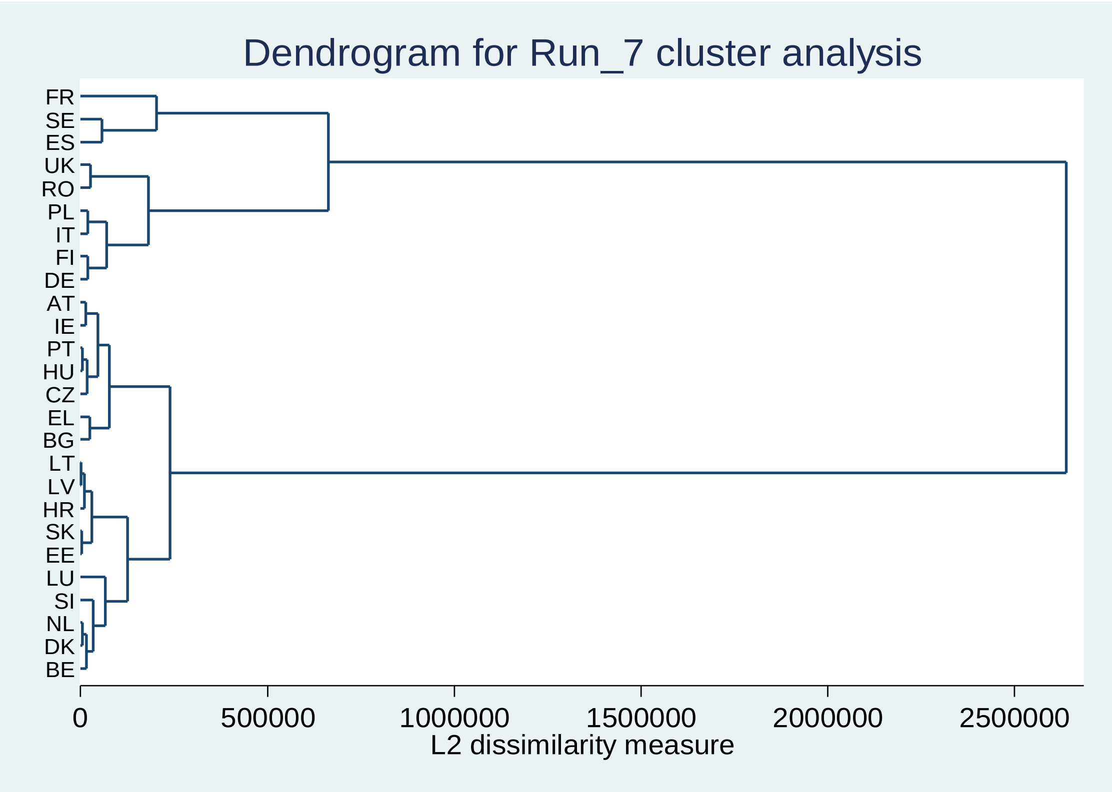


**Figure D.8: Dendrogram for clustering model specification 8**

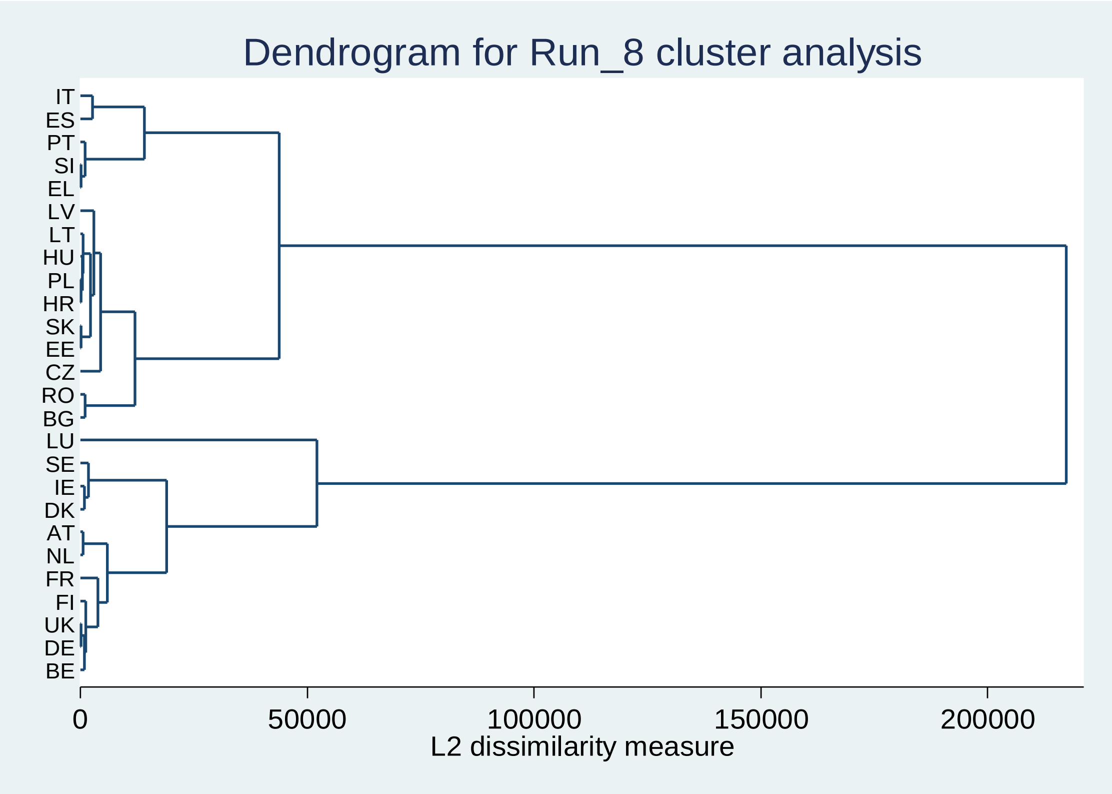
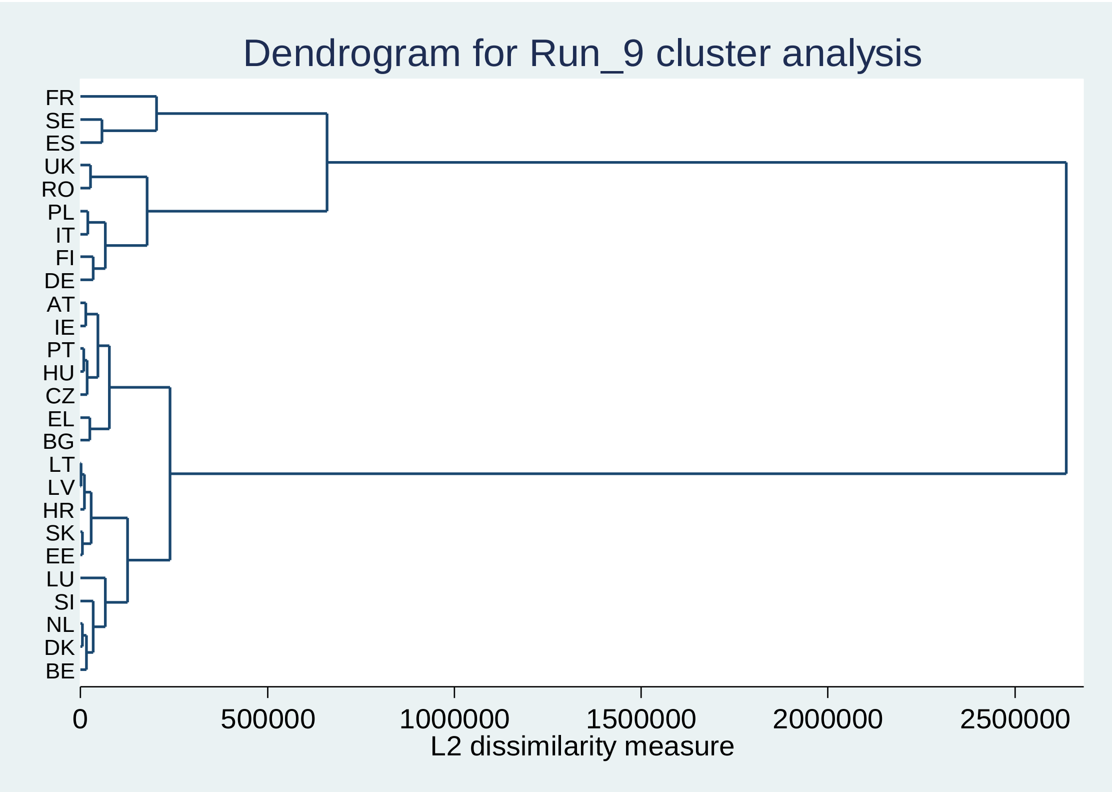



**Figure D.9: Dendrogram for clustering model specification 9**



# E Data envelopment analysis models

E.1 Given the flexibility of DEA to incorporate measures of inputs and outputs across multiple dimensions, we followed a systematic but iterative approach to analyse the efficiency of national railway systems. The following pages present results for a sample of the DEA models tested and as described in Table 5.1, under both constant and variable returns to scale assumptions.

**Table E.1: Data envelopment analysis outputs – variable returns to scale (mean)**

| | Total capital productivity (static) | Total capital productivity (dynamic) | Passenger only | Freight only | Track utilisation | Train utilisation |
|---|---|---|---|---|---|---|
| DEA model | **1** | **2** | **3** | **4** | **5** | **6** |
| Cluster A | 0.85 | 0.85 | 0.74 | 0.61 | 0.62 | 0.79 |
| Cluster B | 0.95 | 0.94 | 0.90 | 0.42 | 0.73 | 0.95 |
| Cluster C | 0.44 | 0.46 | 0.30 | 0.33 | 0.28 | 0.40 |
| Cluster D | 0.79 | 0.81 | 0.57 | 0.66 | 0.50 | 0.78 |
| **EU26** | 0.78 | 0.78 | 0.64 | 0.53 | 0.54 | 0.75 |

**Table E.2: Data envelopment analysis outputs – variable returns to scale (standard deviation)**

| | Total capital productivity (static) | Total capital productivity (dynamic) | Passenger only | Freight only | Track utilisation | Train utilisation |
|---|---|---|---|---|---|---|
| DEA model | **1** | **2** | **3** | **4** | **5** | **6** |
| Cluster A | 0.20 | 0.20 | 0.25 | 0.30 | 0.32 | 0.26 |
| Cluser B | 0.10 | 0.10 | 0.13 | 0.30 | 0.32 | 0.10 |
| Cluster C | 0.30 | 0.31 | 0.09 | 0.32 | 0.18 | 0.32 |
| Cluster D | 0.24 | 0.24 | 0.23 | 0.26 | 0.31 | 0.26 |
| **EU26** | 0.27 | 0.27 | 0.28 | 0.30 | 0.32 | 0.30 |

**Table E.3: Data envelopment analysis outputs – variable returns to scale (direct results)**

| | | Total capital productivity (static) | Total capital productivity (dynamic) | Passenger only | Freight only | Track utilisation | Train utilisation |
|---|---|---|---|---|---|---|---|
| **Cluster** | **DEA model** | **1** | **2** | **3** | **4** | **5** | **6** |
| A | Belgium | 0.60 | 0.62 | 0.55 | 0.33 | 0.60 | 0.44 |
| | Denmark | 1.00 | 1.00 | 1.00 | 0.66 | 0.50 | 1.00 |
| | Ireland | 1.00 | 1.00 | 0.54 | 1.00 | 0.25 | 1.00 |
| | Luxembourg | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Netherlands | 1.00 | 1.00 | 1.00 | 0.63 | 1.00 | 1.00 |
| | Austria | 0.79 | 0.78 | 0.64 | 0.34 | 0.77 | 0.59 |
| | Finland | 0.54 | 0.55 | 0.46 | 0.31 | 0.24 | 0.54 |
| B | Germany | 1.00 | 1.00 | 0.93 | 1.00 | 1.00 | 1.00 |
| | Spain | 0.76 | 0.77 | 0.68 | 0.22 | 0.31 | 0.76 |
| | France | 1.00 | 1.00 | 1.00 | 0.38 | 1.00 | 1.00 |
| | Italy | 0.92 | 0.86 | 0.81 | 0.27 | 0.70 | 0.92 |
| | Sweden | 1.00 | 1.00 | 1.00 | 0.44 | 0.38 | 1.00 |
| | United Kingdom | 1.00 | 1.00 | 1.00 | 0.23 | 1.00 | 1.00 |
| C | Bulgaria | 0.24 | 0.27 | 0.22 | 0.21 | 0.17 | 0.23 |
| | Czech Republic | 0.30 | 0.28 | 0.26 | 0.18 | 0.24 | 0.25 |
| | Hungary | 0.41 | 0.43 | 0.37 | 0.25 | 0.25 | 0.39 |
| | Poland | 0.96 | 1.00 | 0.42 | 0.90 | 0.59 | 0.96 |
| | Romania | 0.30 | 0.31 | 0.25 | 0.12 | 0.17 | 0.18 |
| D | Estonia | 1.00 | 1.00 | 1.00 | 0.80 | 0.80 | 1.00 |
| | Greece | 0.61 | 0.61 | 0.32 | 0.54 | 0.13 | 0.61 |
| | Croatia | 0.62 | 0.67 | 0.47 | 0.43 | 0.19 | 0.62 |
| | Latvia | 1.00 | 1.00 | 0.45 | 1.00 | 1.00 | 1.00 |
| | Lithuania | 1.00 | 1.00 | 0.76 | 0.73 | 0.73 | 1.00 |
| | Portugal | 0.74 | 0.83 | 0.63 | 0.60 | 0.36 | 0.72 |
| | Slovenia | 1.00 | 1.00 | 0.63 | 0.95 | 0.46 | 1.00 |
| | Slovakia | 0.38 | 0.36 | 0.31 | 0.26 | 0.30 | 0.30 |

**Table E.4: Data envelopment analysis outputs – variable returns to scale (re-based outputs results)**

| | | Total capital productivity (static) | Total capital productivity (dynamic) | Passenger only | Freight only | Track utilisation | Train utilisation |
|---|---|---|---|---|---|---|---|
| **Cluster** | **DEA model** | **1** | **2** | **3** | **4** | **5** | **6** |
| A | Belgium | 0.60 | 0.62 | 0.55 | 0.33 | 0.60 | 0.44 |
| | Denmark | 1.00 | 1.00 | 1.00 | 0.66 | 0.50 | 1.00 |
| | Ireland | 1.00 | 1.00 | 0.54 | 1.00 | 0.25 | 1.00 |
| | Luxembourg | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Netherlands | 1.00 | 1.00 | 1.00 | 0.63 | 1.00 | 1.00 |
| | Austria | 0.79 | 0.78 | 0.64 | 0.34 | 0.77 | 0.59 |
| | Finland | 0.54 | 0.55 | 0.46 | 0.31 | 0.24 | 0.54 |
| B | Germany | 1.00 | 1.00 | 0.93 | 1.00 | 1.00 | 1.00 |
| | Spain | 0.76 | 0.77 | 0.68 | 0.22 | 0.31 | 0.76 |
| | France | 1.00 | 1.00 | 1.00 | 0.38 | 1.00 | 1.00 |
| | Italy | 0.92 | 0.86 | 0.81 | 0.27 | 0.70 | 0.92 |
| | Sweden | 1.00 | 1.00 | 1.00 | 0.44 | 0.38 | 1.00 |
| | United Kingdom | 1.00 | 1.00 | 1.00 | 0.23 | 1.00 | 1.00 |
| C | Bulgaria | 0.25 | 0.27 | 0.52 | 0.23 | 0.28 | 0.24 |
| | Czech Republic | 0.32 | 0.28 | 0.61 | 0.19 | 0.40 | 0.25 |
| | Hungary | 0.42 | 0.43 | 0.88 | 0.28 | 0.42 | 0.41 |
| | Poland | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Romania | 0.31 | 0.31 | 0.59 | 0.13 | 0.28 | 0.19 |
| D | Estonia | 1.00 | 1.00 | 1.00 | 0.80 | 0.80 | 1.00 |
| | Greece | 0.61 | 0.61 | 0.32 | 0.54 | 0.13 | 0.61 |
| | Croatia | 0.62 | 0.67 | 0.47 | 0.43 | 0.19 | 0.62 |
| | Latvia | 1.00 | 1.00 | 0.45 | 1.00 | 1.00 | 1.00 |
| | Lithuania | 1.00 | 1.00 | 0.76 | 0.73 | 0.73 | 1.00 |
| | Portugal | 0.74 | 0.83 | 0.63 | 0.60 | 0.36 | 0.72 |
| | Slovenia | 1.00 | 1.00 | 0.63 | 0.95 | 0.46 | 1.00 |
| | Slovakia | 0.38 | 0.36 | 0.31 | 0.26 | 0.30 | 0.30 |

**Table E.5: Data envelopment analysis outputs – variable returns to scale efficiency gap (re-based outputs results)**

| | | Total capital productivity (static) | Total capital productivity (dynamic) | Passenger only | Freight only | Track utilisation | Train utilisation |
|---|---|---|---|---|---|---|---|
| **Cluster** | **DEA model** | **1** | **2** | **3** | **4** | **5** | **6** |
| A | Belgium | 40% | 38% | 45% | 67% | 40% | 56% |
| | Denmark | 0% | 0% | 0% | 34% | 50% | 0% |
| | Ireland | 0% | 0% | 46% | 0% | 75% | 0% |
| | Luxembourg | 0% | 0% | 0% | 0% | 0% | 0% |
| | Netherlands | 0% | 0% | 0% | 37% | 0% | 0% |
| | Austria | 21% | 22% | 36% | 66% | 23% | 42% |
| | Finland | 46% | 45% | 54% | 69% | 76% | 46% |
| B | Germany | 0% | 0% | 7% | 0% | 0% | 0% |
| | Spain | 24% | 23% | 32% | 78% | 69% | 24% |
| | France | 0% | 0% | 0% | 62% | 0% | 0% |
| | Italy | 8% | 14% | 19% | 74% | 30% | 8% |
| | Sweden | 0% | 0% | 0% | 56% | 62% | 0% |
| | United Kingdom | 0% | 0% | 0% | 77% | 0% | 0% |
| C | Bulgaria | 75% | 74% | 48% | 77% | 72% | 76% |
| | Czech Republic | 68% | 72% | 39% | 81% | 60% | 75% |
| | Hungary | 58% | 57% | 12% | 72% | 58% | 59% |
| | Poland | 0% | 0% | 0% | 0% | 0% | 0% |
| | Romania | 69% | 69% | 41% | 87% | 72% | 81% |
| D | Estonia | 0% | 0% | 0% | 20% | 20% | 0% |
| | Greece | 39% | 39% | 68% | 47% | 87% | 39% |
| | Croatia | 38% | 33% | 53% | 57% | 81% | 38% |
| | Latvia | 0% | 0% | 55% | 0% | 0% | 0% |
| | Lithuania | 0% | 0% | 24% | 27% | 27% | 0% |
| | Portugal | 26% | 17% | 37% | 40% | 65% | 28% |
| | Slovenia | 0% | 0% | 37% | 5% | 54% | 0% |
| | Slovakia | 62% | 64% | 69% | 74% | 70% | 70% |

## DEA model 1 results

**Figure E.1: DEA model 1 results – constant returns to scale (2012)**

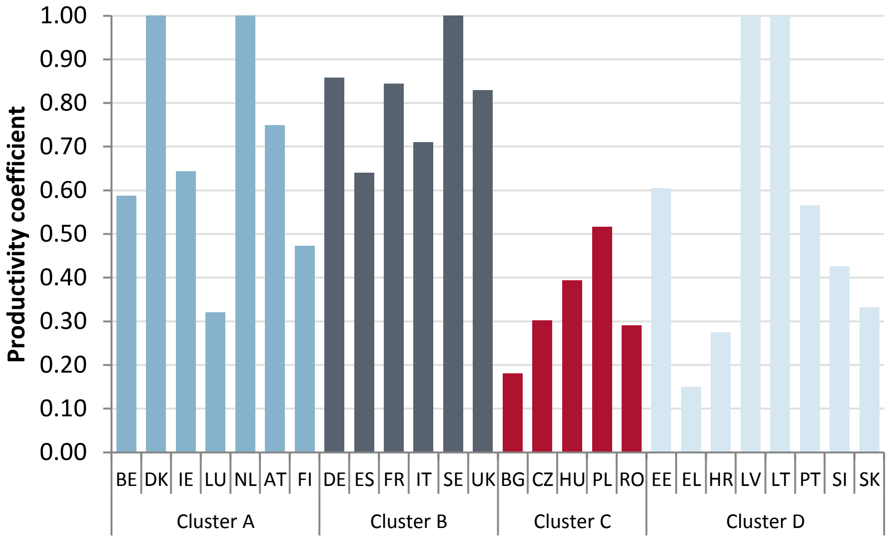
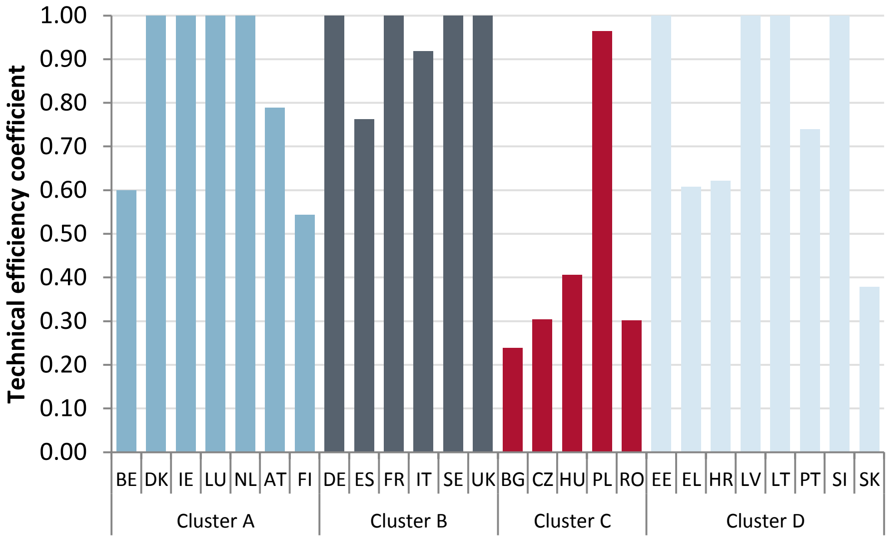



**Figure E.2: DEA model 1 results – variable returns to scale (2012)**



### DEA model 2 results

E.2 Model 2 has the same inputs and outputs as Run 1, but is modelled over a 3 year period. This allows for the comparison of efficiency scores over time as well as across the sample.

**Figure E.3: DEA model 2 results – variable returns to scale (2012)**

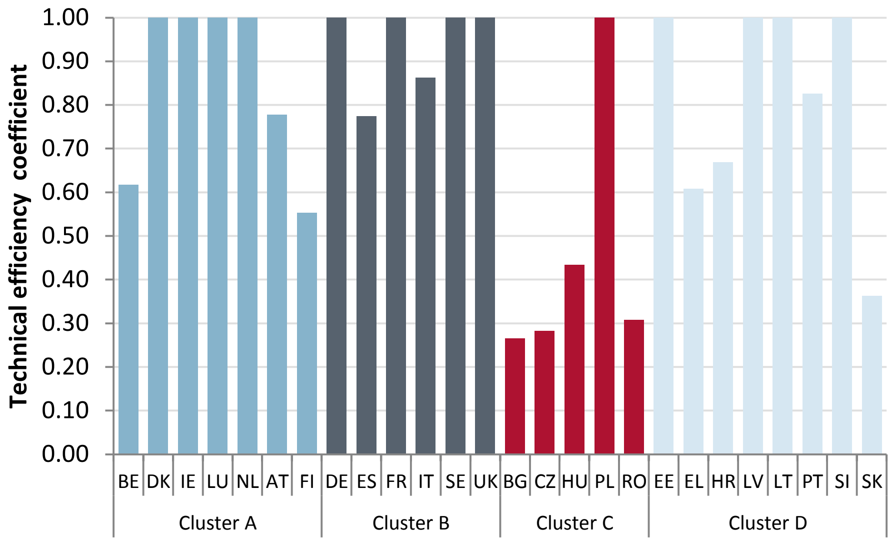
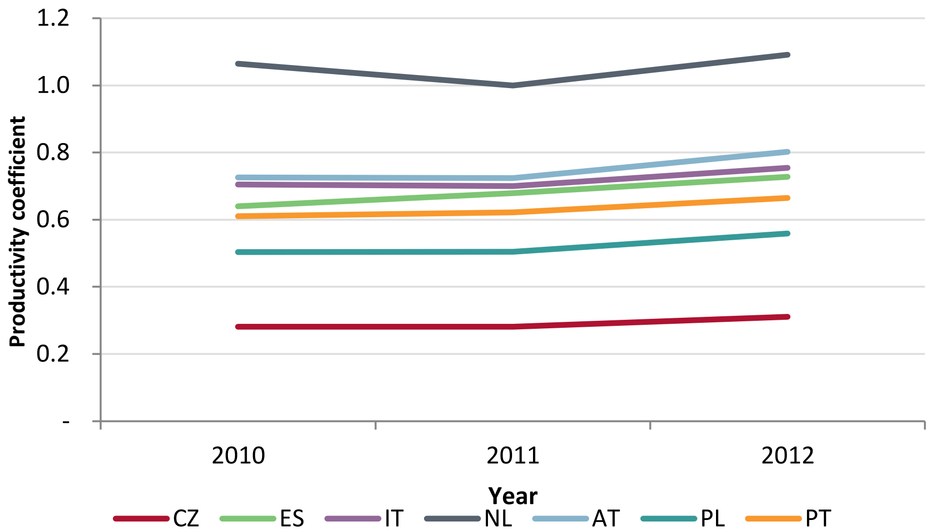



**Figure E.4: DEA model 2 results – constant returns to scale over time (sample of Member States)**



## DEA model 3 results

**Figure E.5: DEA model 3 results – constant returns to scale (2012)**

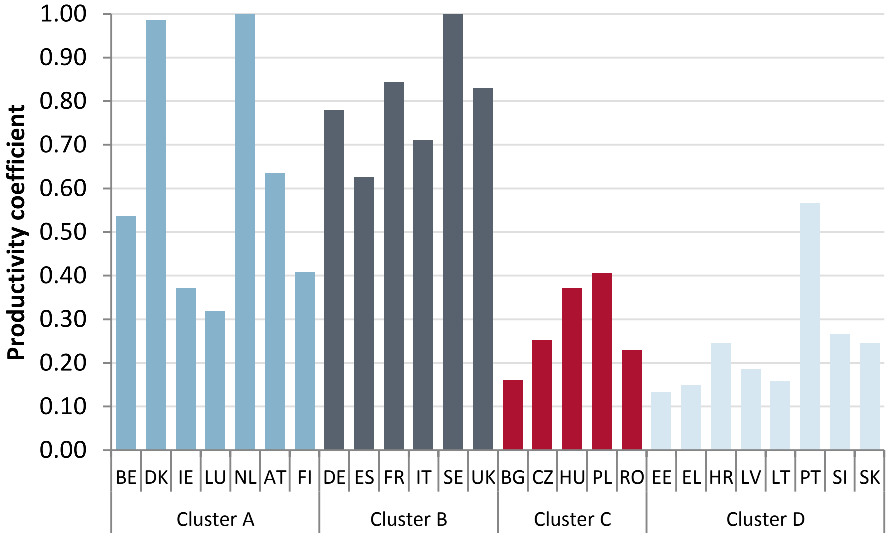
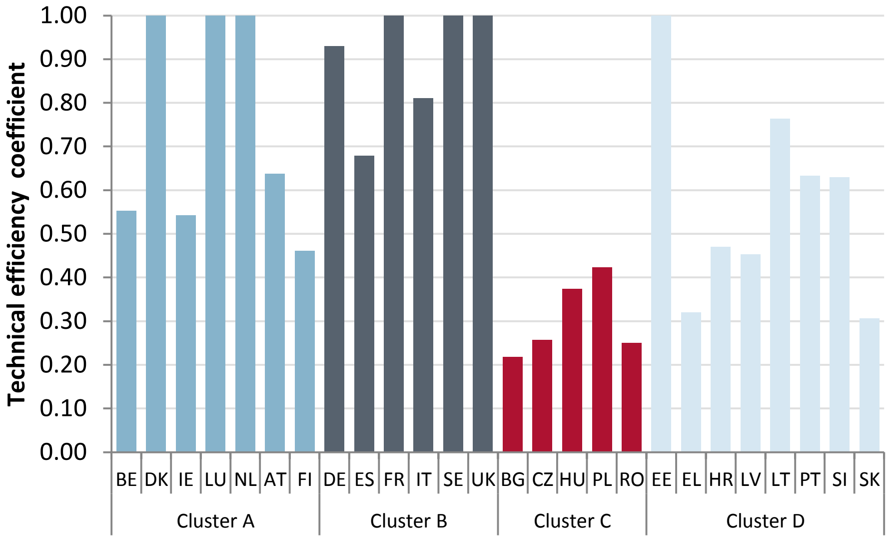



**Figure E.6: DEA model 3 results – variable returns to scale (2012)**



## DEA model 4 results

**Figure E.7: DEA model 4 results – constant returns to scale (2012)**

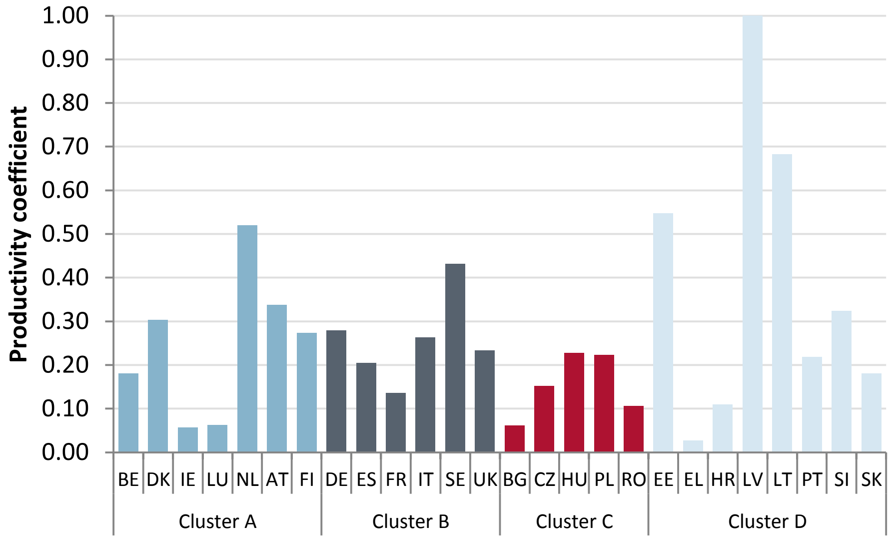
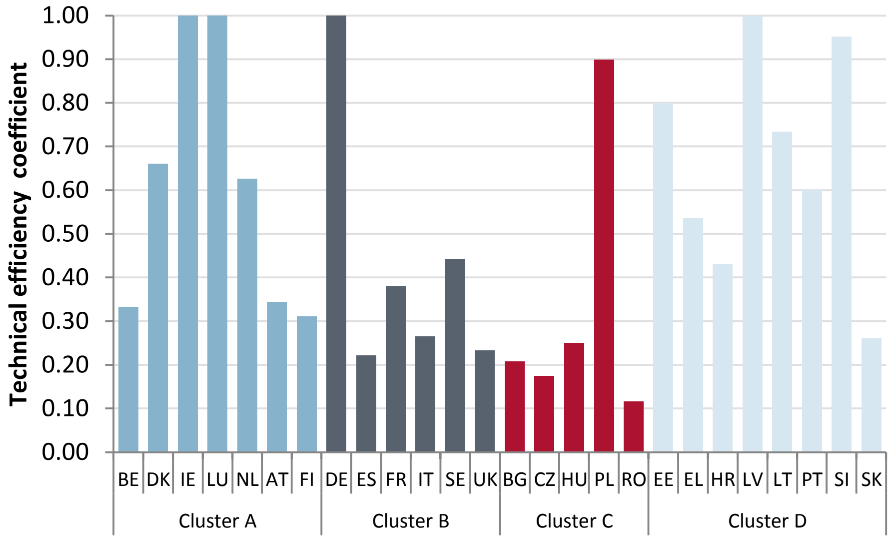



**Figure E.8: DEA model 4 results – variable returns to scale (2012)**



### DEA model 5 results

**Figure E.9: DEA model 5 results – constant returns to scale (2012)**

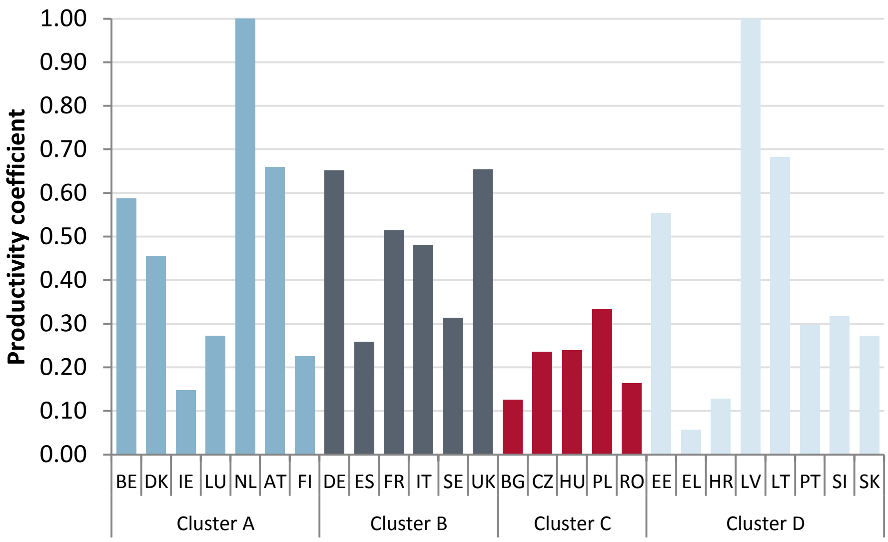
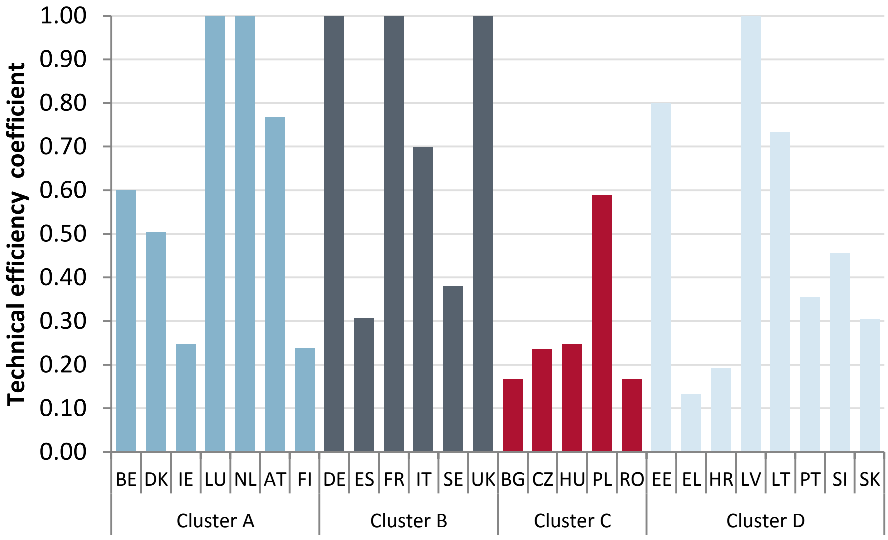



**Figure E.10: DEA model 5 results – variable returns to scale (2012)**



## DEA model 6 results

**Figure E.11: DEA model 6 results – constant returns to scale (2012)**

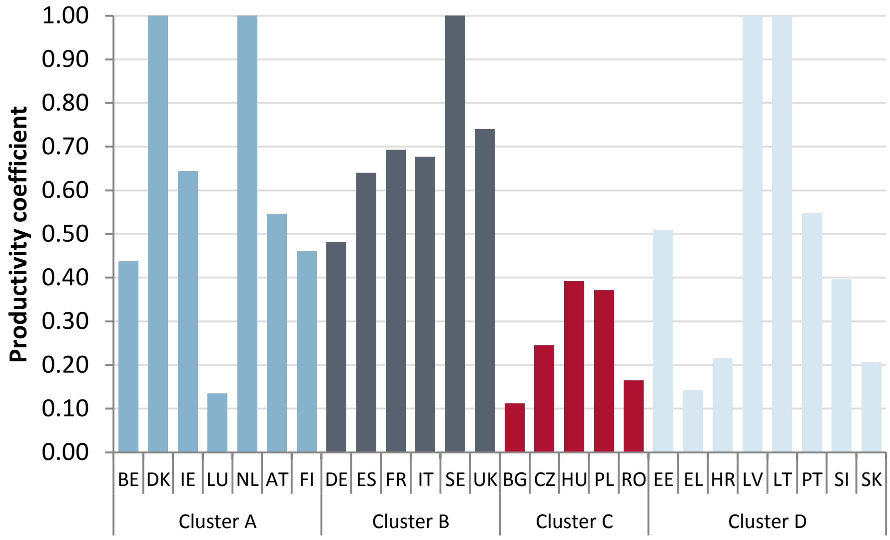
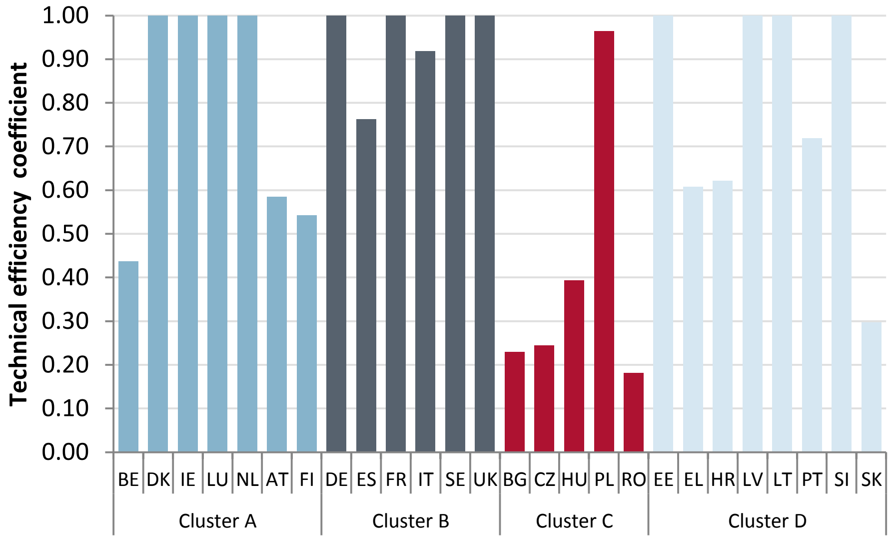



**Figure E.12: DEA model 6 results – variable returns to scale (2012)**



# F Scenario modelling tool – record of assumptions

## Base Case

**Outputs**

F.1 For all output data, the Reference scenario 2013 results are available for the years 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045 and 2050. Data between these years has been interpolated and assumed to grow at a constant rate. Outputs include:

- Rail passenger kilometres (the sum of conventional and high speed rail);
- Freight rail tonne kilometres;
- Road passenger kilometres; and
- Road freight tonne kilometres.

**Emissions**

F.2 For all emissions data, the Reference scenario 2013 results are available for the years 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045 and 2050. Data between these years has been interpolated and assumed to grow at a constant rate. Data include:

- Rail passenger $CO_2$ emissions;
- Freight rail $CO_2$ emissions;
- Road passenger $CO_2$ emissions; and
- Road freight $CO_2$ emissions;

**Rolling Stock**

F.3 Passenger rolling stock numbers are taken from the input data gathered from UIC datasets and national sources for years 2010, 2011, 2012. The figures for subsequent years are based on the growth rates from the PRIMES-TREMOVE Transport Model 'stock' section for 'Rail Transport-Passenger'.

F.4 Freight rolling stock numbers are taken from the input data gathered from UIC datasets and national sources for years 2010, 2011, 2012. The figures for subsequent years are based on the growth rates from the Reference scenario 2013 results.

**Inputs**

Track km

F.5 Track km for the years 2010, 2011 and 2012 are taken from the input data gathered from UIC datasets and the EU Statistical Pocketbook. For subsequent years, track km is assumed to remain constant at the 2012 level.

Operating Costs (Opex)

F.6 Operating costs for the years 2010, 2011 and 2012 are taken from the input data gathered from UIC datasets and national sources. These costs have been deflated to 2010 prices using Eurostat Annual average HICP data.

F.7 For subsequent years, operating costs per unit are assumed to remain constant at the average (mean) value of 2010 – 2012. Total operating costs rise in line with passenger and freight outputs.

**Exogenous Variables**

F.8 The exogenous variable data is available for the years 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045 and 2050 data between these years has been interpolated and assumed to grow at a constant rate.

- GDP data projections is taken from the EPC/ECFIN Ageing Report 2012.
- Population data is taken from Eurostat - EUROPOP2010 population projections.

## Scenario test

**Step one – reduce operating costs**

F.9 Based upon the expected efficiency level for a given Member State in a given year (as defined by its efficiency score and efficiency trajectory), we calculate the operating cost savings that can be achieved. This results in a reduction in total costs for a given level of output (i.e. unit costs fall).

F.10 Efficiency savings are assumed to affect freight and passenger rail in equal measure and therefore cost savings are distributed between the provision of freight and passenger services according to the share of total costs attributable to delivering freight and passenger services.

**Step two – increase output**

F.11 The total cost saving achieved in year t (e.g. 2015) is reinvested in year t+1 (e.g. 2016) to deliver additional passenger and freight outputs. The unit cost for any additional output in year t+1 is taken from the calculation described in paragraph F.9 for year t[50].

F.12 The quantity of additional outputs that can be generated from cost savings is calculated separately for freight and passenger outputs.

**Step three – economic benefits**

F.13 By reducing the quantity of inputs needed to deliver a given level of outputs, when considered in isolation the results of 'step one' can be considered as an increase in operating surplus or value added. Alternatively, they can be thought of as an intermediate baseline against which the increase in output estimated through 'step two' can be compared. By increasing the outputs delivered by (and therefore expenditure of) the rail sector at a given unit cost, we would expect there to be second and third-round effects on other sectors of the economy.

[50] For example, in the counterfactual scenario Member State A generates outputs of 10 billion passenger kilometres at a cost of €10 million (i.e. 1,000 passenger kilometres/€). In the efficiency scenario, its total costs fall to €8 million in year t. In year t+1 the €2 million saved is re-invested to generate additional rail outputs at the more efficient cost per unit of 1,250 passenger kilometres/€. Output increases by 2.5bn passenger kilometres (€2 million x 1,250 passenger kilometres/€).

Therefore, in addition to the direct increase in output and employment within the rail sector, indirect impacts need to be estimated through output and employment multipliers.

F.14 For those Member States where we have a direct estimate (Austria, Netherlands, Italy, UK , Czech Republic, Poland, Portugal, Slovakia), their specific output and employment multipliers have been applied to the total operating cost savings/additional expenditure. For those Member States where no direct estimate is available, an arithmetic mean of the multipliers for those countries in their cluster has been applied.

**Step four – externalities**

F.15 In order to estimate the net impact of additional rail outputs upon external factors ($CO_2$ emissions, noise and safety) it is necessary to make two assumptions. First, we assume that all of the additional supply generated by the rail industry is taken up with additional demand i.e. there is latent demand that is not fulfilled within the counterfactual scenario. Second, we assume that 20% of all additional rail passenger and freight kilometres are abstracted from the road network. The scenario assessment calculator has the facility to allow us to amend these assumptions.

F.16 Finally, using values taken from the *Update of the Handbook on External Costs of Transport*, we have calculated the net marginal impact of a reduction in road use (by both freight and passenger traffic) and a corresponding increase in rail use. For example, the reduction in road passenger/vehicle kilometres is multiplied by the relevant value of a marginal change in usage to generate a gross reduction in highway externalities, from which the equivalent value of externalities generated by an increase in rail passenger/vehicle kilometres is subtracted to estimate a net overall figure.

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