Development of the Future Rail Freight System to Reduce the Occurrences and Impact of Derailment

D-RAIL

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Future Rolling Stock breakdown to 2050

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Abbreviation/Acronym	**Definition**
BTKM	Billion tonne Kilometre
EC	European Commission
EU	European Union
GDP	Gross domestic product
NUTS	Nomenclature of Units for Territorial Statistics
NSTR	Nomenclature uniforme des marchandises pour les statistiques de transport
REF	Reference Scenario
TEN	Trans-European transport network
WPL	White Paper Low
WPH	White Paper High
WP	Work Package

Executive Summary

The deliverable ‘D2.2 Future rolling stock breakdown to 2050’ focused on the derivation of a range of traffic volume forecasts based on NSTR (Nomenclature uniforme des marchandises pour les statistiques de transport) commodity groups (0-9) produced in D2.1 a Rail freight forecast to 2050 using TRANS-TOOLS modelling tool. These forecasts were based on three scenarios: Reference Scenario, White Paper Low Scenario and White Paper High Scenario. In the Reference Scenario there is no policy change whereas the other two scenarios assume a partial (30%) and a full (50%) shift of freight from road to rail as per the goals set by the EU 2011 White paper on Transport for modal shift. Since in general, particular wagon types are used to transport a particular goods type (commodity) it is possible to explore the wagon type of the future by forecasting the goods that are likely to be transported by rail in the future. Given that the link between a particular commodity and rail freight wagon is not absolutely definitive, a primary and secondary wagon type will be proposed.

The projected traffic volumes were reviewed for those with the greatest potential for growth and modal shift to rail. In addition those commodities with the greatest aggregate volume activity were also identified. In both cases originating tonnage and a production measure (billion tonne kilometre -BTKM) was derived. These were then assigned to an origin-destination matrix to identify the major traffic corridors and traffic flows. The other significant flows within the geographic scope of the project where rail’s volume performance can be anticipated to grow and new wagon technologies will be required should not be overlooked. The authors are also inherently aware that national domestic flows are likely to be significantly greater than cross border international traffic.

When considering commodity types with the greatest projected average annual growth - there are changes in the type of goods anticipated to be transported by rail. Foodstuffs in particular show very significant potential growth between 2010 and 2050 with an estimated yearly growth of over 5% on average - if the full aims and objectives of the White Paper be realised, i.e. White Paper High Scenario.

When considering net growth i.e. goods moved in BTKM, it is observed that goods which feature heavily at present are still prominent in rail freight transportation up to 2050. This is typically the transportation of bulk goods for which rail freight has traditionally relied upon and shown strength in (in terms of market share). Rail transportation of fuel will also continue to be influenced by developments in the European power generation sector and decisions relating to use of coal

It has been demonstrated that full realisation of the 2011 White Paper objectives (White Paper High Scenario), when compared to the Reference and White Paper Low Scenarios does not alter the top three NST/R commodity types: “solid mineral fuels”, “crude, manufacturing and building materials” and “machinery and transport equipment” commodity types. However in the final, full White Paper High Scenario,

other (which includes container traffic) is estimated to have the greatest volume of goods moved in BTKM where previously it had been crude, manufacturing and building materials.

The NSTR nomenclature is such that category 9 (machinery and transport equipment) also includes the transport of containers. It is apparent from previous EC funded research projects (such as RETRACK, CREAM) that intermodal and co-modal services involving rail are likely to figure much more in the overall portfolio of services offered. These will probably be a mix of container, swap body and trailer carrying trains. This in turn suggests a trend towards increased numbers of flat wagons or more intensive use of existing ones.

There are concerns that the commodity projections and their subsequent conversion into traffic flows and wagon types may be understated. The impact of growing volumes of international container traffic originating/terminating outside the EU could generate a much higher demand for inter-modal capable wagons.

Unfortunately the lack of data made available by rail freight operators and wagon owners in relation to rolling stock has impacted negatively on this report. Obtaining existing data on wagon fleet typology and future fleet size and type projections proved challenging.

Given the importance of the focus on future rail development in the EU, the absence of formal, robust future projections of cargo flow, commodity types and related wagon fleet types to support the anticipated growth by the rail sector at a European level, is a major rail industry weakness and concern to be addressed.

Despite this, the adoption and implementation of appropriate methodologies and EC developed tools such as TRANS-TOOLS has ensured the forecast and subsequent report adhere to and use common EU forecasting tools and methodologies.

1 Introduction

The D-RAIL project aims to identify the root causes of derailment with particular reference to rail freight vehicles. Freight vehicles typically have a wider range of operating parameters than their passenger counterparts. This is largely due to a significant range in loads, speeds, duty cycles, ownership and the quality of maintenance programmes.

D-RAIL analyses how isolated minor faults combine to cause more significant impact and possible derailment of the vehicle. The study is extended to include expected demand on the rail freight system by the year 2050.

WP2 of the project assesses the future trends of freight transport by rail predominantly from an economic standpoint up to the year 2050. Building on freight projections developed as part of deliverable D2.1, the aim of D2.2 is to identify the future rolling stock requirements and the likely wagons of the future. This will allow subsequent work packages to focus their analysis.

D2.2 relies heavily on the input from D2.1 so it is worth summarising the outputs of D2.1 and their relevance.

Deliverable D2.1 focused on analysing and describing future levels of transport demand in three different scenarios: the Reference Scenario - with no policy change from the current rail system, and two White Paper Scenarios (High and Low), which describe how rail freight demand might develop by implementing the objectives of the 2011 White Paper for Transport (which assumes both a full and partial modal shift from road to rail). Parameters for each scenario were identified by studying of a number of reports on rail freight development. The 2011 White Paper policy options were applied to the Reference Scenario, deriving the freight demand for all three scenarios.

Results were analysed from a demand, modal split and commodity perspective. The Reference and White Paper Low Scenarios demonstrated similar results in terms of growth and modal split, as the White Paper Low Scenario increased the demand in 2050 by less than 20%. With regard to the White Paper High Scenario, results were significantly different, as the additional demand almost doubled up to 2050.
It is the commodity forecast that contributes significantly in determining the wagon(s) of the future.

1.1 Objective

D2.2, entitled ‘Future Rolling Stock Breakdown to 2050’ aims to present a forecast of future rolling stock and breakdown by typology, up to the year 2050. Based on the commodity types forecasts presented in the Reference Scenario, White Paper Low Scenario and White Paper High Scenario, D2.2 predicts likely wagon type(s) of the future as well as providing an estimate of the total number of wagons in the EU27 in 2050.

1.2 Structure of the report

The report describes the methodology adopted and assumptions that have been made. The methodology includes details of the conversion of the rail freight forecast in to rolling stock using NSTR commodity types and corresponding wagon types for the three Scenarios used (See Table 3). It is hoped the report results will be endorsed at a validation workshop. A general overview of this workshop and the bodies and organisations expected to be involved are described in section 3.2.

Sections 3 presents an analysis of the future wagon type by NSTR commodity in terms of goods lifted (tonnes) and goods moved (tonne.km) and for a number of origin destination pairs.

Section 4 of the report explores some of the technological changes envisaged up to the year 2050. Incorporating these technological changes section 5 estimates the anticipated rolling stock requirements in terms of fleet size for the EU27 up to the year 2050 based on earlier forecasts and input from supplementary literature.

Section 6 of this report explores examines particular origin destination pairs for Europe's largest cross border flows and estimates the wagon type associated with these corridors.

Finally section 7 draws the necessary conclusions and discusses some of the limitations of the study.

2 Methodology

The rolling stock breakdown up to year 2050 is largely dependent on a number of sources including: rolling stock breakdown from the freight forecast up to 2050 (in section 3); the influence of productivity or the level of the usage of the rolling stock (in section 4) ; and the current rolling stock fleet size (in section 5).

2.1 Conversion of rail freight forecast into rolling stock

The first step was to convert the rail freight forecast up to 2050, conducted in D.21, into rolling stock requirements.

The rail freight forecast up to 2050 was produced from the freight demand model in TRANS-TOOLS (essentially a mathematical model, primarily used for transport demand forecasting between regions in the EU 27 for all transport modes). It uses a sequential trade module and traffic module to predict freight demand and a module with multiple inputs for passenger transport.
Other inputs consist of infrastructure developments and transport policy (mainly in the form of charging costs for transport), There is also the potential to evaluate external scenarios.

Outputs are given on Nomenclature of Territorial Units for Statistic NUTS II – consisting of 1303 region levels for freight transport (and NUTS III for passenger). NUTS is a geographical code standard for referencing the subdivisions of European countries for administrative and statistical purposes. The standard is developed and regulated by the European Union, and thus only covers the member states of the EU in detail. The Nomenclature of Territorial Units for Statistics is instrumental in the European Union's Structural Fund delivery mechanisms and encompasses the following areas:

Transport data (this gives tonne-km, vehicle-km etc.);

Modal split (the distribution of transport demand per modality); and

Load on corridors (aggregated results for multiple regions).

One important output of TRANS-TOOLS is the origin destination (O/D) matrices. These contain the predicted transport demand from an Origin towards a Destination for a certain NUTS level and for a certain commodity.

The TRANS-TOOLS model can be seen as well-established in terms of its representation in a “four stage transportation model” (trip generation, trip distribution, mode choice and assignment). The model provides a trend extrapolation based on developments such as economy and transport policy.

As the model relies upon trend extrapolation it is less capable of taking into account trend-breaks unless these are fully specified in advance. “Normal use” of models such as TRANS-TOOLS implicitly assumes that there are no trend-breaks in the future; unless exogenously.

To convert the freight forecast into a rolling stock forecast and breakdown a number of assumptions were made - principally the wagon type used to transport a particular commodity. These are detailed in Table 1.

2.2 Validation workshop

The last step of this deliverable is to validate results by means of a workshop. The workshop will be attended by infrastructure system managers represented by UNIFE, The International Union of Private Wagons and wagon leasing companies such as VTG, AAE and TRANSWAGGON and a variety of freight wagon manufacturers.

3 Rolling Stock Breakdown by Commodity

This section presents three commodity based assessments that aim to determine the future rail freight wagon type of 2050.

Commodity based assessments are as follows:

- Wagon type by commodity – cargo types with the highest anticipated growth
- Wagon type by commodity – cargo types with the highest net volumes
- Wagon type by commodity – top 10 origin destination relations (routes)

It should be noted that the D2.1 commodity forecasts were presented for the years 2030 and 2050. However, the assessments presented in D2.2 will be based primarily on the commodity forecast for 2050.

It is the commodity forecast that will form the first step in determining the wagon type of the future.

3.1 NSTR Commodity Nomenclature

The nomenclature used for the classification of transported goods by road in the D-Rail report is NSTR1. NSTR1 consists of ten goods types listed from 0-9 covering a comprehensive range of goods types such as foodstuffs, metal products and chemicals.

Transportation of goods by road using NSTR commodity types is collected by individual EU member states (except Malta) and reported to the commission where it is aggregated and made available through the Eurostat database.

NSTR1 has subsequently been replaced by a more detailed nomenclature NST 2007. However, the TRANS-TOOL modelling software
reports still use the previous system (NSTR1) and as such it is the NSTR1 goods categories that are used in this report.

Table 1 provides a description of the ten NSTR1 goods types (0-9) which forms the basis of this study.

Table 1: NSTR1 Commodity Types and Description

	NSTR Commodity	Description
0	Agricultural products	Products of agriculture, hunting, and forestry; fish and other fishing products
1	Foodstuffs	Food products, beverages and tobacco
2	Solid mineral fuels (Coal)	Coal and lignite; crude petroleum and natural gas
3	Petroleum products	Coke and refined petroleum products
4	Ores and metal waste	Metal ores and other mining and quarrying products; peat; uranium and thorium
5	Metal products	Basic metals; fabricated metal products, except machinery and equipment

6	Crude, manufacturing, building materials	Crude, manufacturing raw and semi-finished products, building materials such as cement, rod, sand
7	Fertilizers	Chemical and natural fertilizer minerals
8	Chemicals	Chemicals, chemical products and manmade fibers; rubber and plastic products; nuclear fuel
9	Other (inc containers)	Machinery, transport equipment (automobile industry parts) and products not falling in previously defined groups + **containers**

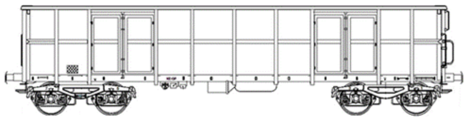
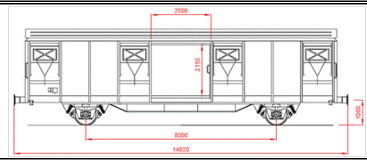
3.2 Wagon Type Assignment

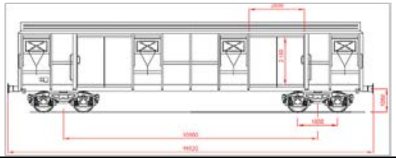
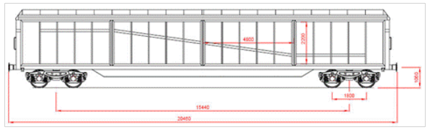
Given the nature of this commodity based forecast of the future wagon types, it is important that a relevant wagon type is assigned to each commodity type. Supporting literature for the commodity/wagon type assumptions shown in Table 2 below were difficult to find. Conclusions were therefore formed following consultation with D-Rail project partners and other relevant sources such as Wikipedia, http://www.slo-zeleznice.si/en/freight/wagons and UIC leaflets (e571X1, e571X2, e571X3, e571X4) which provide definitions and descriptions of wagon types etc.

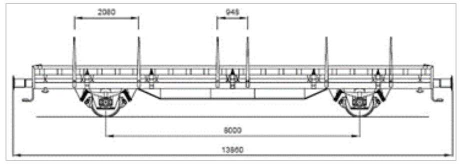
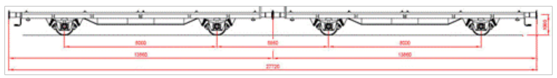
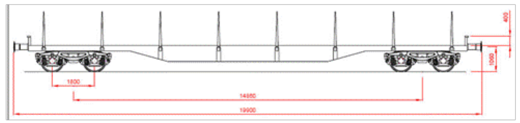
It has become apparent during the course of this study that there is no single standard or common terminology used as a generalised description for freight wagons. With this in mind, Table 2 has been produced in order to clearly define the wagon type being analysed.

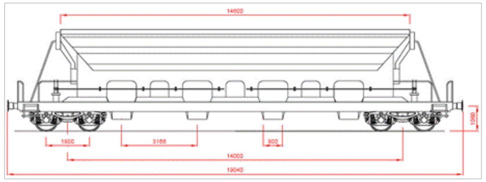
Table 3 has been produced in order to demonstrate the link between those wagon types described in Table 2 with the commodity types described in Table 1

Table 2: Description of freight wagon types

No	Wagon Type (English)	Wagon Type (Alternatives)	Description	UIC standard class / leaflet	Picture	Specific commodities (NSTR1)
1	***Open Wagon***	Open Top Wagons, Gondola (US).	Open wagons are designed primarily for rail freight transport of bulk goods that are not moisture-retentive and can usually be tipped, dumped or shovelled. The Open wagons form a significant part of a railway companies' wagon fleets; for example, forming just under 40% of the Deutsche Bahn's total goods wagon stock in Germany.	**Class E** Es - Ordinary open high-sided wagons two axles, UIC 571-1		Open wagons are applicable for, among others, : granular materials, wood, products of engineering industry, steel constructions, vehicles
				Class E Ea(o)s - Ordinary open high-sided wagons four axles, UIC 571-2		
2	***Covered Wagon***	Van, Boxcar (US), (others?)	Covered wagon can be defined as a large wagon covered with an	**Class G** Gbs –Covered wagon type 1, UIC 571-1 ….		Covered wagon with the ventilation flaps can b applicable for,

			arched canvas top. The arched canvas or cover is used to protect the cargo from spilling over, weather related problems or other threats.	**Class G** Gas - …………		among others,: single pieces of goods, goods on palettes, furniture, glass, china, electronics, various shapes etc.
				Class H Hbfs - …………		
				Class H Habiss – Covered bopgie wagon with sliding walls type 1, UIC 571-3…………		
3	***Covered Hopper Wagon***		2-axle wagon with bilateral controlled top unloading by gravity. This wagon is specially intended for the conveyance of goods vulnerable to dampness	UIC Type 2 wagon with opening roof (Tds)		

			Bogie wagons with bilateral bulk unloading by gravity. This wagon is specially intended for the conveyance of goods vulnerable to dampness	UIC Type 2 wagon with opening roof (Talns)		
4	***Flat wagon***	Platform Wagon, Flatcar (US), (others?)	A flat wagon is a piece of railway rolling stock that consists of an open, flat deck on four or six wheels or a pair of bogies. The deck of the wagon can be wood or steel, and the sides of the deck can include pockets for stakes or tie-	Flat Wagon K - , Flat Wagon Kgs		Flat wagons are applicable for goods which do not require the protection against the weather includes, among others: single pieces of goods, larger volume and lower weight, metallurgical products, steel constructers, containers, raw
				Flat wagon L - Laags		
				Flat Wagon R- Regs Rgs		

			down points to secure loads. Flat wagons designed for carrying machinery have sliding chain assemblies recessed in the deck. They are used for loads that are too large or cumbersome to load in other wagons such as covered wagons. They are also used to transport intermodal containers (shipping containers) or trailers as part of intermodal freight transport shipping.	Flat wagon S - Sgns Sgs		and sawn wood, steel constructions, large and heavy machinery, vehicles and containers etc.
				Flat wagon T Tadds		
5	***Tank wagon UIC***	UIC Tank Wagon US Tank car	A tank wagon is a type of rolling stock designed to transport liquid and gaseous commodities.	Tank wagon		

6	***ISO Tank Container***	ISO Tank Container	A tank container, also known as ISO tank, is a specialized type of container designed to carry bulk liquids, such as chemicals, liquid hydrogen, gases and food grade products. Both hazardous and non hazardous products can be shipped in tank containers.			

Table 3: NSTR1 Categories and Associated Primary and Alternative Wagon Types

	NSTR Commodity	Primary Wagon Type	Alternative Wagon Type
0	Agricultural products	Covered Hopper Wagons	Open top wagons for some products
1	Foodstuffs	Covered Wagon	Flat Wagon (Refrigerated Container)/tanker
2	Solid mineral fuels (Coal)	Open Top Wagons	Covered hoppers
3	Petroleum products	Tank Wagon	Container flats for tank containers
4	Ores and metal waste	Open Top Wagons	Covered hoppers
5	Metal products	Flat Wagons	Covered wagons
6	Crude, manufacturing, building materials	Open Top Wagon	Flat Wagon, Covered Wagon, Tank Wagon
7	Fertilizers	Covered Hopper Wagons	Tank or hopper wagons for granules/powders/liquids
8	Chemicals	Tank Wagon	Flat wagons for container tanks hoppers for granules, powders
9	Machinery, transport equipment	Flat Wagon	Flat Wagon (Specials), Car carriers/hi cube vans

Table 3 shows the typical wagon type used to transport each of the NSTR1 cargo types. This assumption will be applied to the commodity forecasts produced as part of D2.1. It is important to note however that it is not always possible to categorically state an associated wagon type for each of the commodities as the commodity types are somewhat aggregated in terms of the goods they cover. Therefore an alternative wagon type has also been identified and proposed.

3.3 Wagon type(s) by commodity

The assessment of the future wagon types examines the commodity types for the three scenarios developed throughout Work Package 2: Reference Scenario, White Paper Low Scenario and White Paper High Scenario.

Presented in this section are a number of tables that forecast, for the EU27+, [1] the transport volume in **tonnes** and **tonne kilometres** by NSTR1 commodity type between 2010 and 2050.

For each of the three scenarios and associated tables, discussion will focus on both those products demonstrating the highest potential for growth as we advance toward 2050, and, those commodity types with the highest net (or absolute) volumes in billion tonne kilometres (BTKM).

By examining the commodities with the highest potential for growth we are able to identify those goods, which will form an increasingly important part of the rail freight market up to 2050 and even beyond, demonstrated by the change in commodity types transported between 2010 and 2050. It is important however that attention be drawn to the number of billion tonne km for each of the commodity types. In many instances this will differ from those with the highest potential for growth. However, since the D-Rail project focuses on wagon derailment, it is perhaps those commodities and associated wagon types that travel the greatest distance, hence the greatest number of billion.tonne.km (BTKM) (statistically) that are more likely to suffer from derailment.

At the end of this section a summary of the most significant commodity types is presented. This acts as a quick reference and shows the most important commodities and associated wagon types for each of the three 2050 scenarios by forecast average annual growth, forecasted volume in BTKM and net (absolute) growth in BTKM.

Beyond this, an analysis of the top 10 origin and destinations pairs was conducted enabling us to explore the anticipated wagon type of the future along several of Europe's main corridors.

3.3.1 Reference Scenario

The Reference Scenario assumes no major policy change. Burgess et al., (2008 p.45) suggested that the Reference Scenario is a 'Business as usual' scenario i.e. it will assume that the evolution of the freight transport system is an extension of

[1] EU27+ includes Norway (NO) and Switzerland (CH)

current trends. Thus the definition of the reference scenario will include projections of Gross Domestic Product GDP (which is a relevant element for the generation of freight trips); autonomous changes in transport cost (i.e. due to more expensive oil prices); and transport network changes due to completed TEN-T projects. Additional network changes not due to the TEN-T could also form part of the reference scenario according to available data (e.g. from national infrastructure plants). Thus it is primarily based on an extrapolation of existing trends affecting the transport of goods by rail.

3.3.1.1 Commodities with highest forecasted goods moved in BTKM in 2050

Table 4 below presents the forecast volume for the Reference Scenario between 2010 and 2050 in BTKM for each of the commodity types.

From this and Table 1 we can conclude that three commodity types feature most prominently for forecast goods moved by freight volume in BTKM in 2050 - namely: solid mineral fuels; crude, manufacturing and building materials; and machinery and transport equipment.

Solid mineral fuels are typically transported by **Open top wagons**. Or alternatively: **Covered hoppers** or hoppers with top raves to prevent spillage and dust swirl in transit. Crude, manufacturing and building materials are also typically transported by Open top wagon with the option of alternative wagon types: Flat wagon, Covered wagon and Tank wagon. The machinery and transport equipment are transported by Flat wagon with the option of alternative wagons: Special Flat wagon and Car carriers.

Table 4: EU27 NSTR Commodity Types – Forecast Volume, Net Growth per annum in billion tonne km and Average Growth percentage (Reference Scenario) Source: D2.1

Commodity Type	**Forecast Volume 2010-2050 (BTKM)**				**Ave Growth Pa %**	**Net Growth (b – a)**
	2010 (a)	2020	2030	2050 (b)		
Agricultural products	22.5	25.4	30.0	35.6	1.16%	13.1
Foodstuffs	4.2	4.6	5.1	6.1	0.92%	1.9
Solid mineral fuels	48.1	61.4	80.8	95.7	**1.73%**	**47.6**
Petroleum products	11.9	14.3	17.8	21.1	**1.44%**	9.2
Ores and metal waste	32.6	37.1	43.8	52.0	1.17%	19.4
Metal products	24.5	27.0	30.9	36.7	1.02%	12.2
Crude,	81.9	94.4	113.4	134.5	1.25%	**52.6**

manufacturing, building materials						
Fertilizers	19.6	23.2	28.7	34.0	**1.39%**	14.4
Chemicals	22.4	24.5	27.8	33.1	0.98%	10.7
Machinery, transport equipment (inc containers)	55.3	60.8	69.3	82.2	1.00%	**26.9**

3.3.1.2 Commodities with highest forecast average annual percentage growth per annum

It is demonstrated in Table 4 for the Reference Scenario (i.e. no change in EU transport policy) that three NSTR commodity types: solid mineral fuels (1.73%); petroleum products (1.44%); and fertilisers (1.39%) are the most significant as they are anticipated to show the greatest average percentage growth between 2010 and 2050.

From this and the previous Table 1, we can conclude that Open top wagons and Tank wagons are most likely to feature in 2050 rail freight transport - considering the Reference Scenario. Other alternative wagons types are: Covered hoppers, Container flats for tank containers and Flat or hopper wagons for granules/power/liquid.

3.3.1.3 Commodities with the highest net growth in BTKM

Net growth is defined as the difference in forecast volumes per commodity between 2010 and 2050. For the example of solid mineral fuels in Table 4 above this would result in 95.7 BTKM in 2050 minus 48.1 BTKM in 2010 equating to a Net Growth of 47.6 BTKM.

When considering commodities in terms of net growth in BTKM for the Reference Scenario in 2050 we observe a different set of commodities and associated wagon types compared to the average annual percentage growth.

For net growth in BTKM it is apparent that three NSTR commodity types: solid mineral fuels; crude, manufacturing and building materials; and machinery and transport equipment are the most significant commodity types. The growth of inter-modal traffic which falls into the latter category may prove to be understated if maritime and international inter-modal traffic from/to non-EU countries is included.
From this and Table 1 we can conclude that open top wagons and Flat wagons are most likely to feature in 2050 rail freight transport services when considering the Reference Scenario. Other alternative wagons types are: Covered hopper, Tank wagon, Covered wagon, Special Flat wagon and Car carriers

3.3.2 2011 White Paper Low Scenario

For the White Paper Low Scenario it is assumed that 30% of road freight for distances greater than 300 km shifts to rail and waterborne transport. This is in keeping with the 2011 White Paper objectives.
Similarly to Table 4 above, Table 5 below presents the anticipated growth by NSTR commodity type between 2010 and 2050.

3.3.2.1 Commodities with highest forecasted goods moved in BTKM in 2050

Similarly as observed in the Reference Scenario, three commodity types feature in the forecasted goods moved by freight volume in BTKM in 2050: solid mineral fuels; crude, manufacturing and building materials; and machinery and transport equipment.

Solid mineral fuels are typically transported by Open top wagons with the option of alternative wagon type: Covered hoppers. Crude, manufacturing and building materials are also typically transported Open top wagon with the option of alternative wagon type: Flat wagon, Covered wagon and Tank wagon. The machinery and transport equipment are transported by Flat wagon with the option of alternative wagon: Special Flat wagon and Car carriers.

Table 5: EU27 NSTR Commodity Types – Forecast Volume, Net Growth per annum in billion tonne km and Average Growth percentage (2011 White Paper Low Scenario) Source: D2.1

Commodity Type	**Forecast Volume 2010-2050 (BTKM)**				**Ave Growth Pa %**	**Net Growth**
	2010	**2020**	**2030**	**2050**		
Agricultural products	22.5	25.4	35.3	45.4	**1.78%**	23.0
Foodstuffs	4.2	4.6	8.1	11.6	**2.56%**	7.4
Solid mineral fuels	48.1	61.4	81.3	**96.7**	1.76%	**48.6**
Petroleum products	11.9	14.3	18.8	22.9	1.65%	11.0
Ores and metal waste	32.6	37.1	45.6	55.3	1.33%	22.7
Metal products	24.5	27.0	33.5	41.3	1.32%	16.9
Crude, manufacturing, building materials	81.9	94.4	126.5	**158.7**	1.67%	**76.8**
Fertilizers	19.6	23.2	29.0	34.7	1.44%	15.1

Chemicals	22.4	24.5	33.1	42.7	1.63%	20.3
Machinery, transport equipment (inc containers)	55.3	60.8	86.1	**113.2**	**1.81%**	**57.9**

3.3.2.2 Commodities with highest forecast average percentage annual growth per annum

It can be seen from Table 5 that three NSTR commodity types: agricultural products; foodstuffs; machinery and transport equipment (including containers) feature prominently as they show strong annual percentage growth up to 2050. Agricultural products are expected to grow 1.78% on average per annum while machinery and transport equipment including containers are expected to grow by a 1.81% on average per annum.

In this instance however it is foodstuffs that are expected to show the strongest growth between 2010 and 2050. On average foodstuffs are expected to grow by an average of 2.56% per annum.

This is explained by the influence of the White Paper objectives up to 2030. By transferring 30% of road freight for distances greater than 300km to rail, rail is able to capture freight markets where traditionally it has made little impact so far. Whether it can realistically do this using existing conventional wagon designs and the way in which they are managed as assets is open to question. Rail freight will have to significantly enhance its productivity in relation to wagons if it is to be competitive with road freight and capture the market share anticipated by the EU. The wagons will need to be operated much more intensively with minimum dwell times for loading, discharge and maintenance together with appropriate planning and operational regimes which maximises service deployment. Inter-modal wagons are used intensively in the railway domain within Europe and operating practices used to support this could be transferred to other categories of wagons and traffic/commodities.

Foodstuffs are traditionally transported by covered wagon – generally considered to be one of the most versatile wagon types. They are typically loaded from the side and used to carry general freight. Considering the diversity of foodstuffs including sugar, molasses and milk products alternative wagon types may include Flat wagon (Refrigerated container/tanker) or specialist tankers. Covered Hopper wagons may feature for agriculture commodity types in 2050 with the option of alternative wagon types: Open top wagon. Flat wagons may feature for machinery and transport equipment commodity types in containers or swap bodies with the option of alternative wagons: Special Flat wagons and Car carriers for finished vehicles and also for parts for vehicle assembly.

3.3.2.3 Commodities with the highest net (absolute) growth in BTKM

As was the case in with the Reference Scenario the White Paper Low Scenario demonstrates a change of NSTR commodity type. The three most prominent

commodity types are: solid mineral fuels; crude, manufacturing and building materials; and machinery and transport equipment.
Solid mineral fuels are typically transported by Open top wagons with the option of an alternative wagon type: Covered hoppers. Crude, manufacturing and building materials are also typically transported in Open top wagons with the option of alternative wagon type: Flat wagon, Covered wagon and Tank wagon. The machinery and transport equipment are transported by Flat wagon with the option of alternative wagon: Special Flat wagons and Car carriers for finished vehicles and components.

3.3.3 2011 White Paper High Scenario

For the White Paper High Scenario the full objectives of the 2011 White Paper are realised. The ultimate objective of the 2011 White Paper is to achieve a modal shift of 50% from road freight to rail and waterborne transport for distances greater than 300km.

3.3.3.1 Commodities with highest forecasted goods moved in BTKM in 2050

As in the Reference and Low Scenario, three commodity types feature by forecasted freight volume in BTKM in 2050: solid mineral fuels; crude, manufacturing and building materials; and machinery and transport equipment.

Crude, manufacturing and building materials are also typically transported Open top wagon with the option of alternative wagon type: Flat wagon, Covered wagon and Tank wagon. The machinery and transport equipment are transported by Flat wagon with the option of alternative wagon: Special Flat wagon and Car carriers.

Table 6: EU27 NSTR Commodity Types – Forecast Volume, Net growth and Average Growth per annum in billion tonne km (2011 White Paper High Scenario) Source: D2.1

Commodity Type	**Forecast Volume 2010-2050 (BTKM)**				**Ave Growth Pa %**	**Net Growth**
	2010	**2020**	**2030**	**2050**		
Agricultural products	22.5	25.4	63.1	96.7	**3.72%**	**74.2**
Foodstuffs	4.2	4.6	41.2	72.5	**7.38%**	68.3
Solid mineral fuels	48.1	61.4	82.6	**99.0**	1.82%	50.9
Petroleum products	11.9	14.3	23.6	31.8	2.48%	19.9
Ores and metal waste	32.6	37.1	49.4	62.3	1.63%	29.8
Metal products	24.5	27.0	46.4	65.3	2.48%	40.8

Crude, manufacturing, building materials	81.9	94.4	164.3	**228.3**	2.60%	**146.5**
Fertilizers	19.6	23.2	31.4	39.0	1.74%	19.4
Chemicals	22.4	24.5	53.4	80.2	3.24%	57.9
Machinery, transport equipment	55.3	60.8	155.3	**240.8**	**3.74%**	**185.4**

3.3.3.2 Commodities with highest forecast average percentage annual growth per annum

Table 6 shows the full effect of realising the 2011 White Paper ambitions. In terms of average percentage annual growth foodstuffs are once again most prominent at 7.38% on average per annum. This is a significant increase from the forecast growth of the partial White Paper (ie Low Scenario) objectives as more goods traditionally transported by road freight are transferred to rail freight. This would involve major changes in rail freight services to meet market and commodity/shipper imposed requirements and expectations in terms of logistics if it is to achieve this sort of market penetration.

Agricultural products and machinery and transport equipment now also show very positive signs of growth with 3.72% and 3.74% on average per annum respectively.
It has been noted previously that **foodstuffs** are generally transported by covered wagon with the option of alternative wagon type: Flat wagon (refrigerated container) and tanker. However it should be noted that foodstuffs captured from road freight (as the White Paper Scenario suggests, are likely to be finished products and refrigerated goods transported by refrigerated containers. These are likely to require higher transit speed requirements, which in turn would have implications for the propensity to de-rail and hence influencing the design survivability of the cargo module/wagon structure and contents.

Agricultural products are generally transported by Covered hopper wagon with the option of Open top wagons. These can in some cases be classed as self-discharging wagons. This type of wagon can be emptied using flaps or cargo doors in the base of the wagon to allow the cargo contents to fall under gravity into suitable reception hoppers. This type of wagon can be discharged whilst stationary or on the move at very low speeds using wagon and trackside interfaces to open and close the bottom doors. The design of the flaps or doors can vary and include air operated equipment. The shutters are normally closed even when the wagon is empty to minimise the risk of the equipment fouling the track or other infrastructure.

Machinery and transport equipment is typically transported by Flat wagon including container flats or trailer carrying wagons with the option of alternative wagon type: Special Flat wagon and Car carriers.

3.3.3.3 Commodities with the highest net growth in BTKM

Three commodity types feature in net growth in BTKM in 2050: agriculture products; foodstuffs; and machinery and transport equipment as well as crude, manufacturing and building materials.

It is already noted that foodstuffs are traditionally transported by covered wagons. Considering the diversity of foodstuffs including sugar, molasses, milk products; alternative wagon types may include Flat wagon (Refrigerated container/tanker). Covered Hopper wagons may feature for agriculture commodity types in 2050 with the option of alternative wagon types: Open top wagon. Flat wagon may feature for machinery and transport equipment commodity type with the option of alternative wagons: Special Flat wagon and Car carriers.

Interestingly however the ranking (by net growth in BTKM) of these commodity types changes when compared to the Reference and 2011 White Paper Low Scenarios with Machinery and transport equipment now having the highest net growth in BTKM value.

3.4 Summary of wagon types by commodity (growth potential and highest BTKM)

Table 7 below briefly summarises the findings of this chapter. It shows the wagon type associated with each of the scenarios in terms of anticipated growth but also the highest forecast volume (BTKM) values. When referencing the wagon type it is the primary wagon type as listed previously in Table 1 that is considered.

Table 7: Summary table showing top 3 commodity types for each 2050 scenario (goods lifted)

		Ave Forecast Growth Pa			Highest Absolute Values			Net Increase 2010-2050		
Commodity	**Typical Wagon Type (UIC)**	**REF 2050**	**WPL 2050**	**WPH 2050**	**REF 2050**	**WPL 2050**	**WPH 2050**	**REF 2050**	**WPL 2050**	**WPH 2050**
Agricultural products	Covered Hopper Wagons		☐	☐						☐
Foodstuffs	Covered Wagon		☐	☐						
Solid mineral fuels (Coal)	Open Top Wagons	☐			☐	☐	☐	☐	☐	
Petroleum products	Tank Wagon	☐								
Ores and metal waste	Open Top Wagons									
Metal products	Flat Wagons									
Crude, manufacturing, building materials	Flat Wagons or Covered Wagon				☐	☐	☐	☐	☐	☐
Fertilizers	Covered Hopper Wagons	☐								
Chemicals	Tank Wagon									
Machinery, transport equipment	Flat Wagon		☐	☐	☐	☐	☐	☐	☐	☐

3.5 Conclusion

The reference scenario assumes no major policy change - an evolution of freight transport as an extension of current trends.

With this in mind it would appear logical and as presented in Table 7 above, that those goods traditionally transported by rail will remain rail freights strength up to 2050 - since rail is unlikely to capture new markets using existing methods. It is therefore anticipated that solid mineral fuels, crude, manufacturing and building materials and machinery transport equipment (including containers) will continue to be the staple goods of the rail freight market.

The forecast for the reference scenario therefore presents **open top, flat or covered wagons** as the most prominent up to 2050.

The White Paper low scenario assumes that 30% of road freight for distances over 300km will shift to rail and waterborne transport. This is a significant shift in cargo volumes to rail. In order to capture a significant share of this increase, rail will have to transport new types of goods that are normally transported by road (e.g. high value, time sensitive goods).

Despite this it can be seen in Table 7 above that **open top, flat or covered wagons** once again feature most prominently, particularly for the highest absolute and net increase forecasting methods. However, referring to the average percentage forecast growth per annum forecasting method, a change in anticipated wagon type is observed – **covered hopper** wagons and **covered wagons** become prominent in 2050. This suggests that the implementation of the White Paper low scenario will mean rail increasingly transports high value goods such as agricultural products and foodstuffs, however they are still likely to form a small part of the overall rail freight market in terms of BTKM.

The White Paper high scenario realises the full objectives of the EC 2011 White Paper. The White Paper high scenario aims to achieve a modal shift of 50% from road freight to rail and waterborne transport for distances greater than 300km. This is a very significant increase in the volume of goods transported by rail.

For this scenario results vary between forecasting methods. Container traffic and crude, manufacturing and building materials once again feature prominently in the highest absolute and net increase forecasting scenarios. This translates to **open top, flat or covered wagons.**

When considering the average percentage forecast growth per annum scenario **covered hopper wagon, covered wagon and flat wagons** become most prominent. Once again this suggests that new commodity types will be captured by rail freight, however, they remain less than the traditional rail freight goods of crude, manufacturing and building materials and machinery and transport equipment including containers.

Taking the nine scenarios into account **Flat Wagons, Open top Wagons and Covered Wagons** are presented as the wagon of the future and for further analysis in the D-Rail project.

4 Influence of Productivity Changes on Rolling Stock Breakdown

This section of the report explores the likely drivers behind the anticipated increase in productivity of rolling stock.

Several aspects are considered to relate to and indeed influence the future productivity of rail freight rolling stock. Capacity and speed are considered as the overarching parameters - each with associated technology, operational and regulatory aspects. These aspects will be used to structure this section of the report, as demonstrated in Figure 1.

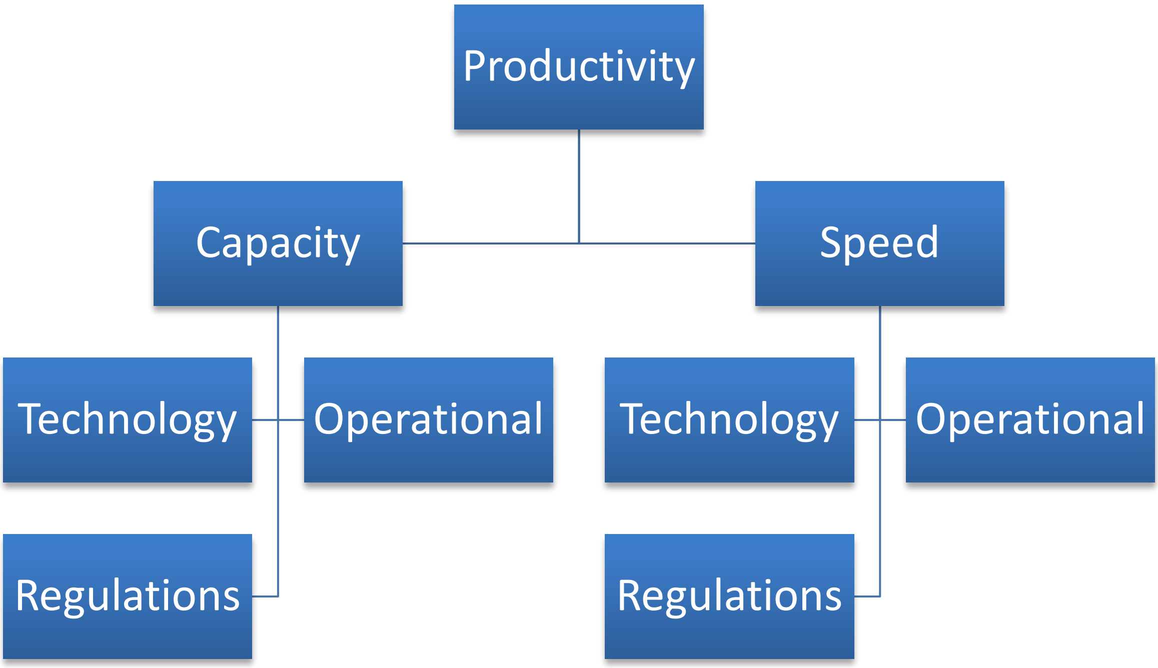


Figure 1: Productivity Influences

4.1 Capacity

Capacity can be described as better utilising the capacity of the rail network. This extends beyond additional trains in the timetable to carrying greater volumes of cargo and hence increasing capacity without additional services. Capacity may also be increased through the better utilisation of existing vehicles, for example by reducing the time present at terminals or marshalling yards.

4.1.1 Technology

The current fleet of wagons in the EU27 are, generally speaking, of relatively high tare weight, meaning that rail freight can carry proportionally lower net freight – when compared to a vehicle with a lower tare weight.

It is anticipated that in the future, toward 2050, a **reduction in the tare weight** of the vehicles will be achieved resulting in an increased payload.

For some commodities the key is not the absolute weight limit of the wagon but the ability to offer the maximum cargo volume. This is especially true for goods with a lower density than those bulk cargoes traditionally transported by rail. It should be noted that in the USA there are already some innovations (e.g. WABASH National) in this line. By reducing tare weight, the net weight to gross weight ratio will be improved substantially to accommodate both weight and volume parameters.

It is envisaged that a reduction in tare weight will be achieved through the trend toward light-weighting of the vehicle. It is thought this will be achieved through the use of more ‘modern’ and ‘innovative’ materials.

Much attention is increasingly given to the operation of freight trains with higher axle loads for bulk traffic up to 30 tonnes. This is not a widespread upper bound but has implications for track and structure strength to accommodate this weight level on a routine basis.

Existing and commonly used vehicle bogies mean dynamic properties associated with higher axle loads contribute significantly to infrastructure damage. Advances in rail vehicle bogie and general rail vehicle dynamics through better suspension characteristics are envisaged to reduce the direct damage to track and allow for the permission of increasingly high axle loads.

Presently rail freight wagons have a relatively long life span (25 years or more), certainly when compared to rail’s main competitor road transport. Whilst operators of such wagons will most probably point to a desire to increase this life cycle and therefore reduce the capital cost associated with the purchase of new equipment – it is considered by the authors that this desire is likely to have a detrimental effect on the overall productivity of the fleet. The comparatively short life cycle of road transport (typically <7 years for trucks) means the fleet continually benefits from product development. The fleet operators also naturally benefit from the reduced maintenance costs associated with a new vehicle.

Current wagon fleets in the EU27 are stiff and non-flexible. To improve the load factor and ultimately to achieve higher productivity, the development of **modular designs of wagons** is expected to contribute to the solution of this problem by providing much greater flexibility. Such wagons can be used for a wide variety of commodity types ranging from bulk traffics to inter-modal with options to change application through the life of the wagons. It is noted that this is an innovative step forward and the rail sector is required to take radical steps in design and certification if it is likely to achieve such ambitious goals. However, through the use of modular design it is not considered impossible to incorporate a range of cargo loading/discharge options in terms of apertures/door designs and cargo loading/securing systems. Commodity and application dependency need to be considered as part of the design process to maximise commercial competitiveness.

The future operation of rail freight might also aim to ensure transit security by the incorporation of security equipment. There will be a need to link to track and trace and also fleet monitoring to maximise the wagon in service productivity (up to 24/7 target). Part of the design process should aim to minimise the incidence of wagon overloading and imbalanced loading leading to potential derailment.

Rail operation needs to differentiate between major generic traffic types (bulk/inter-modal/general/tanker/hazardous). It is already noted in section 7.1 that there can be a common core design of wagon to fulfil future requirements for most commodity categories and the transfer of more general cargo into inter-modal where required. Access to information on train services, schedules, available space and weight, pricing, terminal times and any pre/end haulage is vital. There will be suitable service information systems to maximise commercial in-service time. There will be positive implications for wagon fleet size, type and asset management.

4.1.2 Operational

Empty running is a very significant barrier to high productivity. This is applicable to both rail and road transport and has received attention from both.

It is anticipated that there will be fleet management models and operations planning to maximise **load factor** and thus higher revenue (e.g. fewer wagons used much more intensively, reducing empty running). This is likely to require significant changes in the measures of productivity and key performance indicators (KPIs) (e.g. loaded tonne km per annum/hours in service, hours available but not used/empty running, round trips per annum).

It is hoped that changes in operational patterns, aiming toward (24/7) and higher frequency between trains will lead to an increase in productivity. At present this is rarely achieved since this operational pattern is expected to lead to the wholesale integration of freight and passenger rail services. Presently, priority and therefore higher quality train paths are given to passenger services by the infrastructure manager.

Should such barriers be removed in part, rail freight is likely to be able to provide a much more reliable and punctual service.

The integration of freight and passenger rail services however, requires significant changes to the current methods of timetable planning by infrastructure managers. Conversations with infrastructure managers, Network Rail (UK), Trafikverket (Sweden) and TCDD (Turkey) in the SPECTRUM project have suggested the typical lead time from inception to implementation of a new timetable takes between 1.5 and 2 years. This is clearly unresponsive and does not meet the needs of modern manufacturing techniques and supply chain management.

4.1.3 Regulatory

There is a developing regime for certification covering the design, manufacture, commissioning and deployment of new wagons and rolling stock in the EU. Moves towards harmonization under **interoperability** should, theoretically allow designs to be capable of operation in pan European and domestic services. In reality this regime still produces anachronisms in terms of acceptance and free circulation that constrain freight service development and commercial exploitation. Within domestic spheres of operation, control and influence, there are specific situations where wagons are tailored to a particular duty or service application and not allowed to deviate from this.

It is also worth noting that at present there is little incentive for rail freight operators and wagon owners to invest in potentially expensive wagon technologies (advanced suspension systems) that may for instance preserve or extend the life of rail infrastructure such as the track. Track access charges should be adapted to reflect the detrimental effect a rail vehicle is likely to have. With this in mind, if rail is to explore markets currently unexploited such as the transport of lower density high value goods where capacity is filled by volume rather than weight, changes are required to charging methods to facilitate lighter vehicles. Unfortunately while some EU states (such as the UK and Switzerland) have comprehensive track access charging models, others do not. With this in mind a wagon owner will not operate a non-compliant wagon in a country with a comprehensive charging system. Rather they are likely to continue to operate and subsequently impact negatively on the infrastructure of the state with less comprehensive track access charging models.

4.2 **Speed**

4.2.1 Technology

It is envisaged that, generally speaking, vehicle performance is likely to increase toward 2050. It is thought that performance will increase in terms of overall top speed as well as acceleration and deceleration.

The light-weighting of vehicles has previously been mentioned as a method by which payload may be increased. Further to this, light-weighting of rail vehicles will also impact positively on the ability of the vehicle to increase top speed, acceleration and deceleration properties.

It is anticipated that there will have to be significant improvement in rail vehicle **braking systems**, for example, through the usage of disc brakes to minimise noise and enhance braking performance. The cost of this type of braking technology is such that the possibility to retrofit to existing wagons may not be attractive and that any use of disc brakes should be considered for new-build vehicles. The SPECTRUM project is planned to look at the braking system for both quicker acceleration and deceleration (SPECTRUM, 2012). The higher acceleration and potentially top speed of trains requires a compensating capability to slow to a stop including full emergency braking under maximum load conditions. Another improvement in braking systems can be the possible transition away from pneumatic braking to alternative technologies including full electric braking. Pneumatic braking technology is now out-dated and relatively slow compared to electro-pneumatic and full electric braking. The higher cost of electric brakes can be offset by the requirement for reduced maintenance over the potential life of the vehicle asset. There is also the potential to incorporate brake and train control lines into the wagons at construction for short haul and push pull fixed formation train operations if this operational method is required for some traffic applications. This can be a useful retrofit for short fast train formations allowing bi-directional operations with no shunting or re-arrangement of the train formation in transit (see Innovatrain).

It is likely that in 2050 there will be **reduced rolling resistance** through the complete usage of roller bearings and minimal requirements axle box for lubrication over the vehicle life. An extension of maintenance intervals can be achieved through design and component capability. Under this system, the maintenance costs of wagons could be identified and lowered by intelligent design, selection of materials and coatings plus the identification of wagons as a vital and expensive asset base to be managed intensively.

There will be usage of track friendly (low track force) bogies and suspension. These are currently more expensive than the traditional three piece bogie. The latter is however an old design and has major known deficiencies particularly at higher speeds. LTF bogies may offer (where applicable) significant benefits in terms of track access charges and also comparable ride qualities to road freight for those commodities that mandate better ride qualities as part of a broader service and product package. . The freight train will be in operation at **higher speeds** for inter-modal and **high value time sensitive** traffic. The SPECTRUM (2012) project is exploring this aspect as well.

4.2.2 Operational

Operational speed is paramount to the success of rail freight in the future, whilst increasing attention is given to technological changes that allow for faster point to point speeds. However if the overall operational time/speed is not reduced, advances in this area are likely to be mitigated. Operational speed should therefore extend to times and access to terminals where it is hoped innovative transhipment techniques will reduce the time spent at terminals and hence the overall operational speed.

There are pressures to increase the axle load of certain types of wagons, particularly those employed in bulk traffic applications and any increases may be on specific lines or routes and not part of a general increase in axle weight ratings across the entire network. The corresponding requirement to enhance coupler strength and braking to accept the new higher gross weight ratings will need to be accommodated at the design phase.

4.2.3 Regulatory

There will be large scale rail loading gauge enhancements (high cube) to maximise wagon and container size.

The anticipated desire to increase speeds and vehicle performance toward 2050 is likely to have significant implications in terms of regulation. Currently there exist more stringent regulations for passenger vehicles, clearly in place with the safety of passengers in mind. However, as the anticipated rail freight vehicle speed (toward passenger standard) increase is realised more stringent regulations are likely to follow. High performance freight vehicles are expected to have to adhere to passenger regulations.

4.3 Other

Here a number of measures are considered which do not necessarily fall within the categories of capacity or speed.

There will be increasing commercial and emissions limits on road transport together with access limits relating to time, size, weight and fuel type together with rising fuel cost. Rail is also under pressure on some of these particularly in relation to fuel although this is mitigated by electrification. Noise constraints are also an issue rail will need to address through design and the replacement of noise generating components such as brakes. Such inputs will create a much bigger market opportunity for rail in sectors and commodity flows in 2050 but rail cannot rely on the discomfiture of its primary competition in the vague hope that shippers will use it as a default.

4.4 Conclusion – Productivity Influence on Rolling Stock

The aims and objectives of the European Commission in relation to modal shift toward rail and waterway have been stated on a number of occasions throughout the course of this paper. If these ambitious targets are to be realised then rail freight must adapt new vehicle technologies and operational methods. Many of these have been described in the preceding sections and can be summarised as follows:

- Light-weighting of vehicles leading to a reduction in tare-weight and increase in payload
- Increased axle loads for transport of bulk cargo
- Modular wagon design leading to more versatile wagons for the transport of various cargo types
- Increased security and the more readily available track and trace systems in line with road transport
- Improved fleet management leading to more intensely used rolling stock and reduced empty running
- Changes in operational patterns moving toward 24/7 operation
- Real time timetabling methods leading to a more responsive and flexible services
- Increased vehicle performance in terms of speed, acceleration and deceleration through lighter more powerful vehicles and improved braking systems
- Regulatory changes to bring rail freight more in line with passenger regulations as a result of rail freight vehicle performance increases

It is anticipated that should some or all of these measures be taken or technologies implemented toward 2050, rail freight is likely to increase its productivity and therefore market share.

A report providing an overview of America's rail roads demonstrated the increase in freight volume since regulator change (Staggers) in 1981. Figure 2 also shows the relationship between volume, productivity, revenue and rates.

It can be seen that volume and productivity are intrinsically linked suggesting an increase in productivity will produce an equal increase in freight cargo volume.

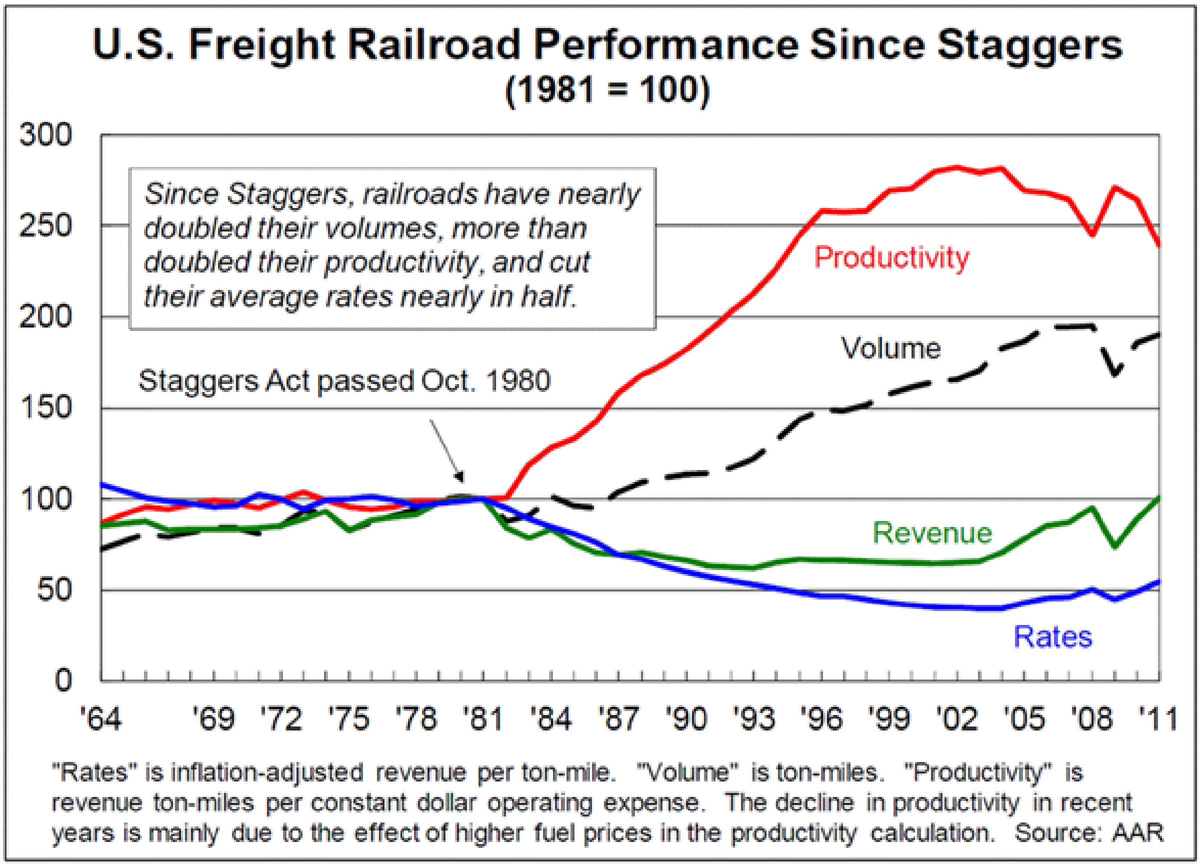


Figure 2: U.S. Freight Railroad Performance since "Staggers" in 1981

5 Rolling Stock – Fleet Size 2050

As part of deliverable D2.2 there is a requirement to estimate the number of rail freight vehicles/wagons in operation in the year 2050.

Data relating to the number of freight wagons in operation have been extremely difficult to obtain and data that has been obtained has been of questionable reliability.

In order to estimate the number of rail freight wagons up to the year 2050 a number of sources (such as Eurostat Database, Railway Directory and DNV Report) have been investigated with varying degrees of success.

5.1 Review of Literature

5.1.1 Eurostat Database

Firstly, the euro stat database was examined. Specifically data was obtained through the following search:

Transport > Railway Transport > Railway Transport Equipment > Number of wagons, by status of enterprise

This search query returned the results shown in Table 8 for the years 2002 to 2010.

Table 8: Number of rail freight wagons operating in the EU (Source Eurostat)

GEO/TIME	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Belgium	19,719	20,312	20,101	18,782	17,077	15,544	15,730	15,854	12,821	:
Bulgaria	22,925	14,537	13,505	12,317	:	:	:	:	11,812	11,124
Czech Reput	52,427	49,150	48,158	47,500	47,172	47,680	47,659	46,925	35,436	35,077
Denmark	1,746	1,378	:	:	:	192	153	0	:	:
Germany (inc	118,415	111,852	:	:	102,778	:	:	:	:	:
Estonia	6,122	7,531	17,433	18,924	18,376	18,376	16,781	19,643	18,284	17,575
Ireland	1,817	:	:	:	:	:	:	:	:	:
Greece	3,539	3,535	3,473	3,497	3,204	3,166	3,568	4,763	:	:
Spain	25,987	25,041	:	32,658	22,658	13,817	14,311	13,718	13,218	12,966
France	109,770	107,033	103,833	99,372	95,238	:	:	:	:	:
Italy	:	:	56,155	54,528	45,660	46,371	41,398	40,740	30,319	30,331
Latvia	8,105	7,911	7,952	8,706	8,871	8,848	8,891	8,796	9,493	9,033
Lithuania	12,509	12,391	12,144	13,134	13,192	13,393	13,564	13,918	13,792	13,352
Luxembourg	:	:	:	:	:	3,450	3,650	3,650	:	:
Hungary	22,983	21,695	20,189	19,783	16,027	:	:	12,240	10,683	:
Netherlands	:	:	:	:	:	:	:	:	:	:
Austria	18,519	18,441	:	:	:	:	20,787	:	:	21,015
Poland	96,741	119,308	111,532	107,315	103,234	103,527	104,982	101,528	95,462	89,270
Portugal	4,366	4,092	:	:	:	:	:	3,043	:	:
Romania	93,187	86,786	:	60,964	58,951	55,503	54,713	47,420	45,505	43,311
Slovenia	5,981	5,774	4,770	4,627	4,465	4,508	4,501	4,476	4,374	3,627
Slovakia	24,587	24,796	23,973	24,936	25,515	25,989	27,538	20,820	14,534	15,260
Finland	12,259	11,842	11,627	11,738	11,216	11,024	10,848	10,992	10,524	10,464
Sweden	17,910	17,674	16,909	16,832	16,637	16,407	15,896	15,735	14,797	15,166
United Kingd	:	:	:	:	:	:	:	:	:	:
Norway	2,631	:	:	:	:	:	:	:	:	:
Switzerland	:	:	:	:	:	:	:	:	:	:
Croatia	9,456	8,774	7,920	7,376	7,330	6,813	6,781	6,632	6,644	6,674
Total	691,701	679,853	479,674	562,989	617,601	394,608	411,751	390,893	347,698	334,245

It should be noted that privately owned vehicles are not included in these statistics although a significant number of wagons are being handled by specific private initiatives and are continuously increasing (such as UIP, basically represented by OLTIS in D-RAIL)

Table 8 also shows that the total number of wagons reported varies greatly between 2002 and 2010. Variation is likely to be caused by a number of factors, namely: a lack of consistency in reporting by EU27 countries year on year and no private wagons included in the data.

Finally the global economic downturn of 2008 is expected to have impacted negatively on the total number of wagons reported. However this should not have had any influence any statistical or reporting errors.

Examining 2009 data (the most comprehensive dataset) shows a total of 347,698 wagons. However there are a couple of very noticeable absentees from this list, not least, Germany, France and the UK.

Populating these cells using a very simplistic linear interpolation produces the following Table 9.

Table 9: Number of rail freight wagons operating in the EU - including forecast values (modified from Eurostat)

GEO/TIME	2001	2002	2003	2004	2005	2006	2007	2008	2009
Belgium	19,719	20,312	20,101	18,782	17,077	15,544	15,730	15,854	12,821
Bulgaria	22,925	14,537	13,505	12,317	:	:	:	:	11,812
Czech Reput	52,427	49,150	48,158	47,500	47,172	47,680	47,659	46,925	35,436
Denmark	1,746	1,378	:	:	:	192	153	0	:
Germany (inc	118,415	111,852	:	:	102,778	:	:	:	87,549
Estonia	6,122	7,531	17,433	18,924	18,376	18,376	16,781	19,643	18,284
Ireland	1,817	:	:	:	:	:	:	:	:
Greece	3,539	3,535	3,473	3,497	3,204	3,166	3,568	4,763	3,996
Spain	25,987	25,041	:	32,658	22,658	13,817	14,311	13,718	13,218
France	109,770	107,033	103,833	99,372	95,238	:	:	:	81,014
Italy	:	:	56,155	54,528	45,660	46,371	41,398	40,740	30,319
Latvia	8,105	7,911	7,952	8,706	8,871	8,848	8,891	8,796	9,493
Lithuania	12,509	12,391	12,144	13,134	13,192	13,393	13,564	13,918	13,792
Luxembourg	:	:	:	:	:	3,450	3,650	3,650	3,783
Hungary	22,983	21,695	20,189	19,783	16,027	:	:	12,240	10,683
Netherlands	:	:	:	:	:	:	:	:	:
Austria	18,519	18,441	:	:	:	:	20,787	:	21,558
Poland	96,741	119,308	111,532	107,315	103,234	103,527	104,982	101,528	95,462
Portugal	4,366	4,092	:	:	:	:	:	3,043	2,852
Romania	93,187	86,786	:	60,964	58,951	55,503	54,713	47,420	45,505
Slovenia	5,981	5,774	4,770	4,627	4,465	4,508	4,501	4,476	4,374
Slovakia	24,587	24,796	23,973	24,936	25,515	25,989	27,538	20,820	14,534
Finland	12,259	11,842	11,627	11,738	11,216	11,024	10,848	10,992	10,524
Sweden	17,910	17,674	16,909	16,832	16,637	16,407	15,896	15,735	14,797
United Kingd	:	:	:	:	:	:	:	:	:
Norway	2,631	:	:	:	:	:	:	:	:
Switzerland	:	:	:	:	:	:	:	:	:
Croatia	9,456	8,774	7,920	7,376	7,330	6,813	6,781	6,632	6,644
Total	691,701	679,853	479,674	562,989	617,601	394,608	411,751	390,893	548,450

It can be seen that the revised (forecast total) is equal to 548,450 wagons. Considering the uncertainty in this approach it was considered important to investigate alternative data sources.

Whilst Eurostat should be considered the official source for European statistics it is quite clear that in this instance the reporting methods are inadequate and lacks the consistency required to be used as a base of evidence for this report.

5.1.2 Railway Directory

Railway Directory is the international rail industry reference work, covering operators, statutory bodies, manufacturers, suppliers and services. The first edition was published in 1895. The current website was redeveloped in early 2009 and went live in September 2009 – although the content is updated most days.

The directory allows organisations and bodies with the appropriate subscription to access a variety of data including freight and passenger operating data.

With this in mind a thorough review of rail freight operators and their rolling stock was conducted.

Specifically, data:

- Ranged from 2003-2011
- Did not include data for Cyprus, Estonia and Malta
- Provided data for wagons, electric locos, diesel locos and shunters
- Included 369 companies and organisations
- Was not classified by year for 187 of the 369 organisations

The railway directory indicated **463,626** wagons were present in the EU27 except Cyprus, Estonia and Malta where data were not present.

Unfortunately – as was the case with the Eurostat data – data were inconsistent.

It is the range of years that provided most cause for concern regarding the reliability of the dataset. As mentioned previously, 187 of the organisations did not have a corresponding year. This equated to 22092 wagons with no associated year.

5.1.3 DNV Report

The DNV report entitled “Assessment of freight train derailment risk reduction measures: Part B Final Report” was published in October 2011 on behalf of the European Railway Agency, 120 rue Marc Lefrancq, 59300 Valenciennes, France.

The study was divided into two distinct research stages: Parts A and B.

Part A aimed to identify all prevention and mitigation measures that exist today or could be implemented within the short term (before 1st of January 2013) or medium term (ready to be voluntarily applied or to be introduced in EU regulation within 5 to 10 years).

Part B had the objective of analysing the measures identified in Part A with a view to identifying those that were the most efficient. Part B included all prevention measures but was limited to mitigation measures based on derailment detection.

The scope was directed towards identifying preventive and mitigation measures related to freight train operation. Shunting or marshaling operations were not considered to the same degree as such operations have a lower consequence potential.

The geographical scope for this work considered the EU-27 countries plus the 3 candidate countries (Turkey, Macedonia and Croatia) and Norway and Switzerland. In addition, the USA and Japan were considered in the scope of safety measure identification, but limited to the most commonly used safety measures and to the foreseeable innovations at medium term.

As part of the DNV report a comprehensive review of mitigation measures was conducted. The review included the development of a cost model and economic assessment of these measures.

With reference to mitigation measure M1 – derailment detection, detailed in Figure 3 below it can be seen that the report identifies a total 718,000 rail freight wagons for the year 2009 within the geographical scope described previously.

M1- Derailment Detection	€2000 per wagon All Freight: Total installation cost for 718,000 wagons = €1436 million All DG: Total installation cost for 98,000 wagons = €196 million RID scope: Total installation cost for 15,500 wagons = €31 million	Negligible, but has 6 year maintenance requirement (1 hour per wagon assumed) All freight (6 year) : €36 million All DG (6 year) : €5 million RID Scope (6 year) : €775,000	N/A	95% effective in detecting a derailment

Figure 3: DNV Report - Cost Benefit for mitigation measure M1 to be applied to 718,000 wagons

This figure (718,000) is also referenced in the 2012 European Railway Agency (ERA) Final Report entitled “Prevention and mitigation of freight train derailments at short and medium terms”.

Recognising that freight train derailments remained a safety and operational concern, and following a request made by the European Commission, ERA commissioned further work, which aimed to carry out an exhaustive analysis of all prevention and mitigation measures which could reduce the risks related to freight train derailments.

Considering all of the above the authors consider the DNV report to be a suitable source of information for this report.

5.2 Methodology

5.2.1 Rolling Stock Forecast Assumptions

This section of the report aims to assess and estimate the total EU27 rolling stock fleet size in 2050 based on the commodity forecasts developed as part of deliverable D2.1.

Attention should be drawn to several assumptions that have been made as part of this analysis.

Presently it is thought that much of the current European rolling stock is either under or over utilised. That is to say, much rolling stock is used exclusively while others are used infrequently.

For the purposes of this analysis it is assumed that all rolling stock is utilised and used consistently. This assumption allows an average tonne kilometre per wagon value to be applied to the commodity forecast.

As an average a load factor of 60% is used. This assumes the wagon is on average 60% full. This load factor is therefore the starting point for the sensitivity testing, which assumes that increased load factors and improvements in wagon efficiency will result in the future. Assuming a fixed load factor we assume a doubling in the transport of goods by rail will result in a doubling of the wagon fleet size.

As has been the case with previous analysis certain commodity groups are assumed to be transported by certain wagon types. This link has not changed and is demonstrated in Table 1.

5.2.2 Approach

For each of the scenarios the growth rates (percentage annual growth in BTKM) shown in Figure 4 were applied to the starting figure of 718,000.

Rail Demand per scenario (in btonne-km)	2010	2020	2030	2050	pa growth
Reference	316	365	439	521	1.26%
White Paper Low	316	365	488	611	1.66%
White Paper High	316	365	699	1000	2.92%

Figure 4: Commodity Growth Rates for Ref, White Paper Low and White Paper High Scenarios

Based on an examination of trends and a thorough and comprehensive modelling process it is anticipated that there will be very significant increases in demand for rail freight services should the European Commission meet its targets for modal shift from road to rail and inland waterways.

Readers are advised to take note of the average annual growth figures (percentage annual growth in BTKM) presented in in Figure 4 above, for the reference, White paper low and White paper high scenarios as described earlier in this report.

The application of these growth rates resulted in a total required rolling stock fleet size for 2050.

Simply put, the anticipated average annual growth rates for reference, white paper low and white paper high, are applied to the original fleet size starting value of 718,000

The results of this process are presented further in section 5.3 below.

5.3 Results

Having explained the approach adopted during the course of this analysis the overall results (in terms of predicted 2050 wagon fleet size) are now presented.

Table 10: Wagon numbers for up to 2050 assuming a load factor of 60%

	REF 2010	REF 2050	2050 WP Low	2050 WP High
Total	718,000	1,095,963	1,283,168	2,100,247

The three 2050 scenarios are of utmost importance to the D-Rail project when we consider the project horizon year is also 2050.

Specifically it estimated the EU27 and CH will consist of a total of:

- 1,095,963 wagons in 2050 assuming “business as usual”

- 1,283,168 wagons in 2050 assuming the EC 2011 White paper objectives are partially implemented
- 2,100,247 wagons in 2050 assuming the EC 2011 white paper objectives are fully met

Readers are reminded that these figures assume no change in efficiency or load factors (60%) for rail freight between 2010 and 2050.

5.3.1 Impact of increased productivity on overall fleet size

It has been described in section 4.4 of this report that a number of technological, operational and regulatory changes are likely to take place between now and 2050 and thereby influence the efficiency and usage of rail freight wagons up to 2050.

With this in mind this report explores the effect of significant (5%-25%) changes in productivity to the number of wagons in operation. The first step in the sensitivity testing is to examine the effect of changes to the load factor (currently assumed 60%) to the total rolling stock number for 2050. The results of these tests can be seen in Table 11 below for the three scenarios used throughout this report.

Table 11: Total EU27 Rolling Stock with increased load factors

	Increased productivity factor by				
	5%	**10%**	**15%**	**20%**	**25%**
REF 2050	1,041,165	986,367	931,569	876,770	821,972
WPL2050	1,219,009	1,154,851	1,090,693	1,026,534	962,376
WPH 2050	1,995,235	1,890,222	1,785,210	1,680,198	1,575,185

As mentioned previously the load factor on which analysis has previously been conducted was assumed to be 60%. The sensitivity test demonstrates the influence of the load factor on the overall European wagon fleet size.

6 Geographic Rail Freight and Rolling Stock Breakdown

Consideration will follow in relation to the pan-European links which transport the greatest volume of goods. This allows us to determine the possible wagon type of the future based on the examination of a number of important EU corridors.
This section begins with a broad geographical analysis of the top 50 origin destination flows for each of the three 2050 scenarios on which this report has so far been developed.

In this report European cross border transport reflects movement between 2 distinct countries without detail of originating and destination points within those countries so therefore analysis does not include the major national transport chains. It should be noted however that national flows form an integral part of the commodity forecast and so are incorporated into the wagon of the future analysis accordingly in previous sections.

Previous forecasting work undertaken as part of deliverable D2.1 and refined in this analysis has allowed the identification of the top 50 origin destination flows for the reference, WPL and WPH scenarios. These are presented in Table 12, Table 13, Table 14 and summarised in Table 15.

Table 12: Top 50 Origin Destination Flows (BTKM) - REF 2050

Rank	**REF 2050**			**Rank**	**REF 2050**		
	Origin	**Dest**	**BTKM**		**Origin**	**Dest**	**BTKM**
1	PL	DE	9.6	**26**	LV	IT	2.6
2	DE	IT	9.5	**27**	FR	BE	2.6
3	CZ	DE	8.6	**28**	NO	SE	2.6
4	NL	DE	7.9	**29**	DE	DK	2.5
5	DE	AT	5.5	**30**	DE	PL	2.5
6	IT	DE	4.8	**31**	SK	CZ	2.4
7	FR	IT	4.8	**32**	PL	CZ	2.3
8	DE	NL	4.4	**33**	CZ	SK	2.3
9	CR	RO	4.4	**34**	SK	AT	2.3
10	BE	IT	3.9	**35**	CR	AT	2.2
11	AT	DE	3.9	**36**	FR	NL	2.0
12	PL	AT	3.6	**37**	DE	ES	1.9
13	PL	RO	3.6	**38**	CZ	PL	1.8
14	BE	DE	3.6	**39**	DK	DE	1.8
15	BE	FR	3.5	**40**	IT	BE	1.7
16	DE	FR	3.2	**41**	RO	PL	1.7
17	DE	CH	3.1	**42**	SI	AT	1.7
18	DE	CZ	3.0	**43**	DE	CR	1.7
19	DE	BE	2.8	**44**	RO	CR	1.7
20	SE	NO	2.8	**45**	AT	CR	1.7
21	CZ	AT	2.7	**46**	NL	IT	1.7
22	SE	DE	2.7	**47**	CZ	CR	1.6
23	LV	FI	2.7	**48**	CZ	RO	1.6
24	NL	FR	2.7	**49**	IT	FR	1.6

25	AT	IT	2.6	**50**	SE	FI	1.5

Table 13: Top 50 origin Destination Flows (BTKM) - WPL 2050

Rank	**WPL 2050**			**Rank**	**WPL 2050**		
	Origin	**Dest**	**BTKM**		**Origin**	**Dest**	**BTKM**
1	DE	IT	11.2	**26**	DE	CZ	3.3
2	PL	DE	10.6	**27**	DE	DK	3.2
3	NL	DE	9.5	**28**	AT	IT	3.0
4	CZ	DE	9.0	**29**	SE	NO	3.0
5	FR	IT	7.5	**30**	LV	FI	2.9
6	DE	AT	6.9	**31**	CZ	AT	2.8
7	DE	NL	6.5	**32**	FR	NL	2.8
8	BE	FR	6.1	**33**	LV	IT	2.8
9	IT	DE	5.4	**34**	NO	SE	2.7
10	FR	BE	4.9	**35**	DK	DE	2.6
11	AT	DE	4.8	**36**	SK	CZ	2.4
12	BE	DE	4.7	**37**	PL	CZ	2.4
13	BE	IT	4.5	**38**	SK	AT	2.3
14	CR	RO	4.4	**39**	DE	ES	2.3
15	NL	FR	4.1	**40**	CZ	SK	2.3
16	DE	FR	4.0	**41**	CR	AT	2.2
17	DE	CH	4.0	**42**	SE	DK	2.2
18	DE	BE	3.9	**43**	FR	ES	2.1
19	NL	IT	3.8	**44**	DE	CR	2.0
20	SE	DE	3.7	**45**	IT	BE	2.0
21	DE	PL	3.7	**46**	CZ	PL	1.9
22	PL	AT	3.7	**47**	SE	IT	1.8
23	PL	RO	3.6	**48**	FR	DE	1.8
24	IT	NL	3.5	**49**	RO	PL	1.8
25	IT	FR	3.3	**50**	DE	SK	0.4

Table 14: Top 50 Origin Destination Flows (BTKM) - WPH 2050

Rank	**WPH 2050**			**Rank**	**WPH 2050**		
	Origin	**Dest**	**BTKM**		**Origin**	**Dest**	**BTKM**
1	DE	IT	19.3	**26**	AT	IT	5.8
2	NL	DE	16.7	**27**	DE	DK	5.6
3	PL	DE	15.5	**28**	DE	CH	5.5
4	FR	IT	14.8	**29**	IT	ES	5.5
5	IT	DE	13.9	**30**	DE	CZ	5.4
6	CZ	DE	11.8	**31**	ES	IT	5.2
7	DE	AT	11.2	**32**	PT	ES	5.2
8	FR	ES	11.1	**33**	DK	DE	4.9
9	DE	FR	11.0	**34**	FR	NL	4.8
10	DE	NL	10.9	**35**	CR	RO	4.7

11	IT	FR	10.9	**36**	ES	PT	4.4
12	ES	FR	10.3	**37**	SE	DE	4.2
13	BE	FR	9.7	**38**	PL	AT	3.9
14	DE	ES	9.0	**39**	PL	RO	3.9
15	FR	DE	8.4	**40**	SE	NO	3.7
16	AT	DE	8.4	**41**	NO	SE	3.4
17	BE	DE	8.3	**42**	DE	CR	3.2
18	DE	PL	8.3	**43**	CZ	AT	3.1
19	FR	BE	8.1	**44**	IT	BE	3.0
20	ES	DE	7.8	**45**	RO	DE	3.0
21	NL	FR	7.2	**46**	LV	FI	3.0
22	DE	BE	6.7	**47**	BE	ES	3.0
23	NL	IT	6.4	**48**	SK	CZ	2.9
24	IT	NL	5.9	**49**	PL	CZ	2.9
25	BE	IT	5.9	**50**	LV	IT	2.9

Table 15: Summary of top 10 origin destination flows for each 2050 scenario

REF 2050			**WPL 2050**			**WPH 2050**		
Origin	**Dest**	**BTKM**	**Origin**	**Dest**	**BTKM**	**Origin**	**Dest**	**BTKM**
PL	DE	9.6	DE	IT	11.2	DE	IT	19.3
DE	IT	9.5	PL	DE	10.6	NL	DE	16.7
CZ	DE	8.6	NL	DE	9.5	PL	DE	15.5
NL	DE	7.9	CZ	DE	9.0	FR	IT	14.8
DE	AT	5.5	FR	IT	7.5	IT	DE	13.9
IT	DE	4.8	DE	AT	6.9	CZ	DE	11.8
FR	IT	4.8	DE	NL	6.5	DE	AT	11.2
DE	NL	4.4	BE	FR	6.1	FR	ES	11.1
CR	RO	4.4	IT	DE	5.4	DE	FR	11.0
BE	IT	3.9	FR	BE	4.9	DE	NL	10.9

This analysis has allowed the identification of 10 origin destination pairs.

6.1 Greatest Volume Origin Destination Pairs

Work conducted previously as part of D2.1 has allowed the identification of the ten most prominent origin destination pairs on a tonnes lifted basis - as shown in Table 16 below.

Table 16: Top 10 Origin Destination Pairs

Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Origin	NL	PL	CZ	DE	DE	BE	DE	CZ	SK	FR
Destination	DE	DE	DE	IT	NL	FR	AT	AT	CZ	BE

It can be seen from Table 16 Germany (DE) features six times in the top ten 10 origin destination pairs including the most important corridor (merging all transport between NL and DE), and in terms of tonnes lifted has its origin in the Netherlands. The reverse, origin in Germany and destination in the Netherlands is 5th in the ranking. The smallest of these flows is between France and Belgium.

With this in mind let us further explore these origin destination pairs in terms of the commodity types typically transported along them.
As in the previous section we examined 3 scenarios; Reference, 2011 White Paper Low and 2011 White Paper High up to the year 2050.

6.1.1 Reference Scenario - 2050

Figure 5 below shows the commodity breakdown for each origin destination pair for the Reference Scenario. (Surprisingly there is a low container flow between NL and DE). Details of Figure 5 can be found in the appendix, Table 19

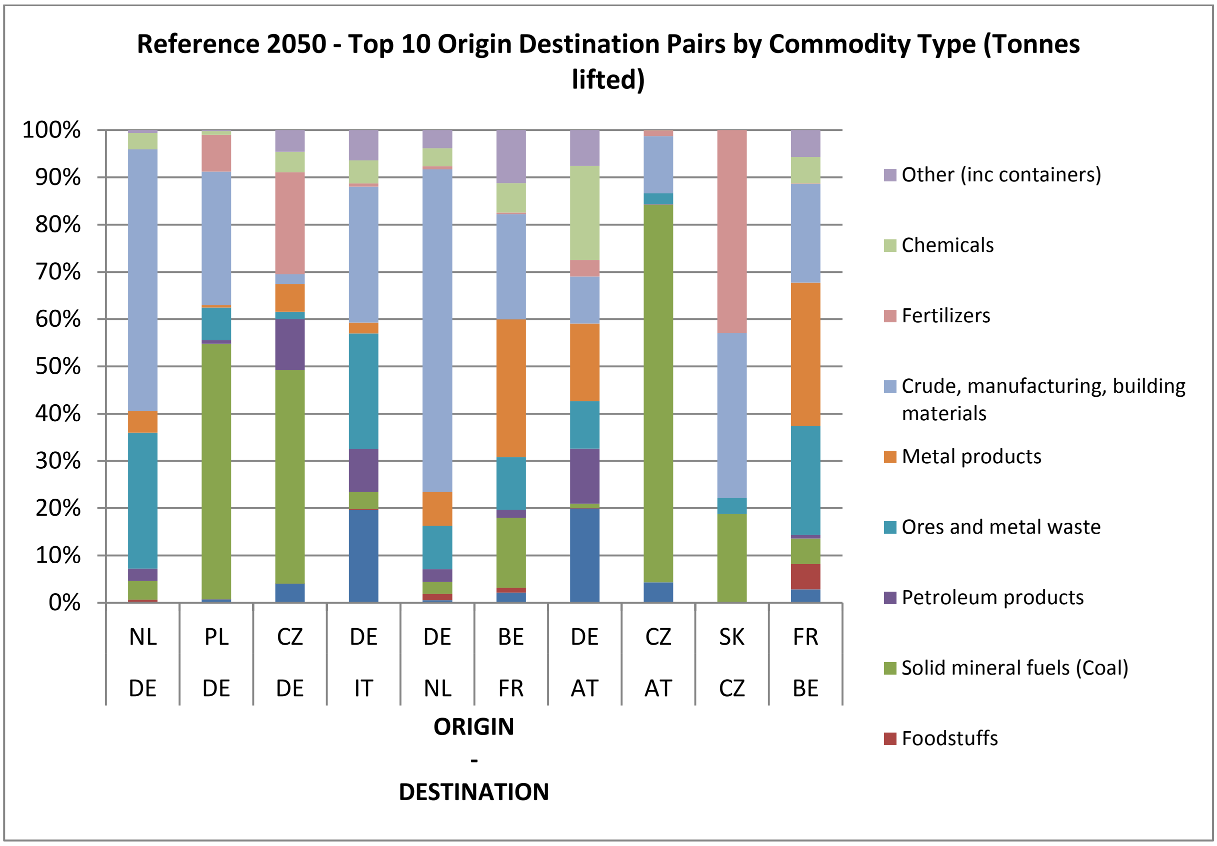


Figure 5: Reference Scenario 2050 - Top 10 Origin Destination Pairs (thousand tonnes) by Commodity Type.

It is clear to see that two (The Netherlands to Germany and Germany to The Netherlands) out of the ten corridors are predominantly, crude, manufacturing and building materials. Solid mineral fuels feature as the most prominent commodity type in three of the ten corridors. Interestingly, between the Czech republic and Austria solid mineral fuels account for 80% of goods lifted by rail freight. Corridors from Poland to Germany and Czech Republic to Germany also predominantly consist of solid mineral fuels. Container traffic may be considered a slight anomaly, or at least under-represented in this figure since the contents and therefore mass of containers is likely to be significantly less than a full train containing coal or crude, manufacturing or building materials.

For the ten origin destination pairs considered above, crude, manufacturing and building materials represent **42,980,000** tonnes lifted.
Solid mineral fuels for the five corridors presented above represent **34,199,000** tonnes lifted.

6.1.2 2011 White Paper Low Scenario – 2050

Figure 6 below shows the commodity breakdown for each origin destination pair of the White Paper Low Scenario.

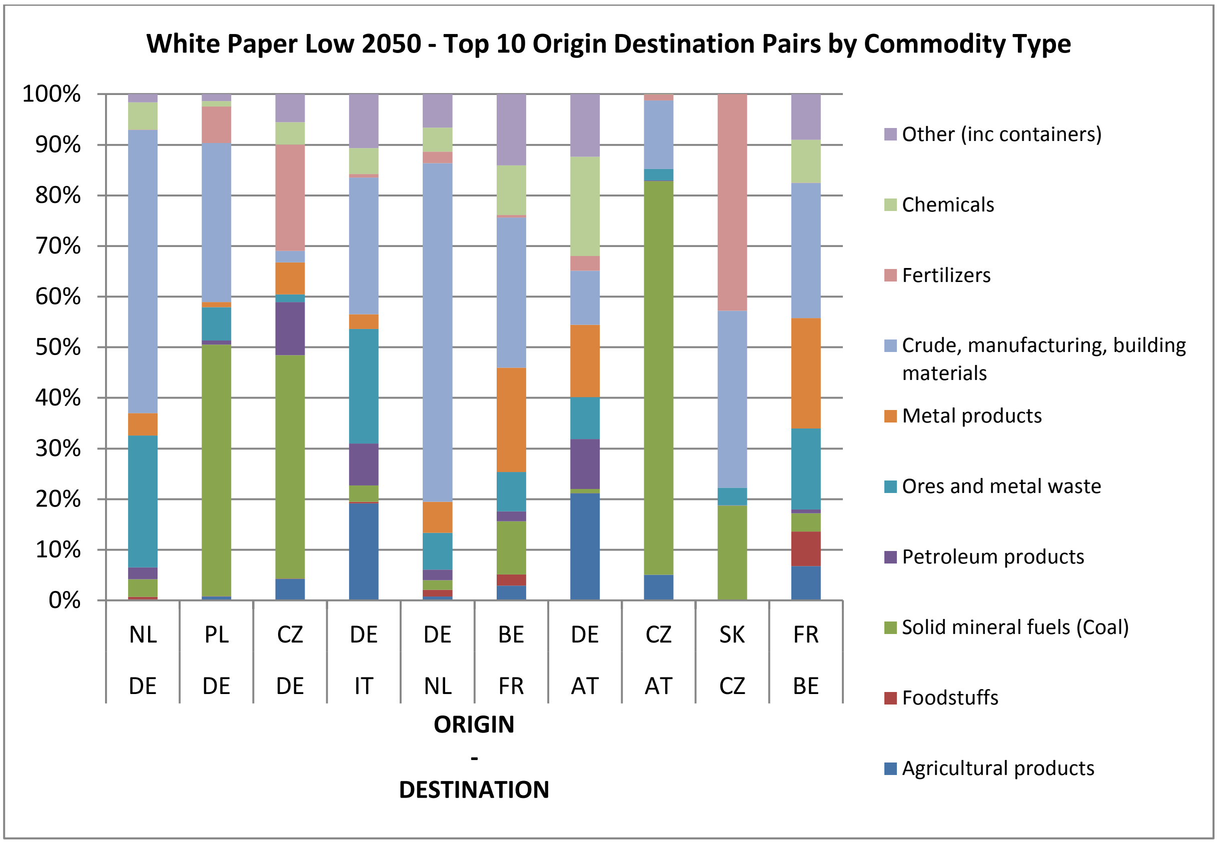


Figure 6: White Paper Low 2050 - Top 5 Origin Destination Pairs (thousand tonnes) by Commodity Type. See appendix table 14 for further details.

As was the case in the 2050 Reference Scenario, crude, manufacturing and building materials are most prominent along the Netherlands to Germany, Germany to Italy, Germany to Netherlands, Belgium France and France Belgium corridors.

Origin destination pairs of Poland to Germany and Czech Republic to Germany, again, mostly consist of the transportation of solid mineral fuels.

For the ten origin destination pairs considered above, crude, manufacturing and building materials represent **53,854,000** tonnes lifted.

Solid mineral fuels for the ten corridors presented above represent **34,401,000** tonnes lifted.

Further information supporting Figure 6 can be found in Table 20 located in the appendices.

6.1.3 2011 White Paper High Scenario – 2050

Figure 7 below shows the commodity breakdown for each origin destination pair of the White Paper High Scenario.

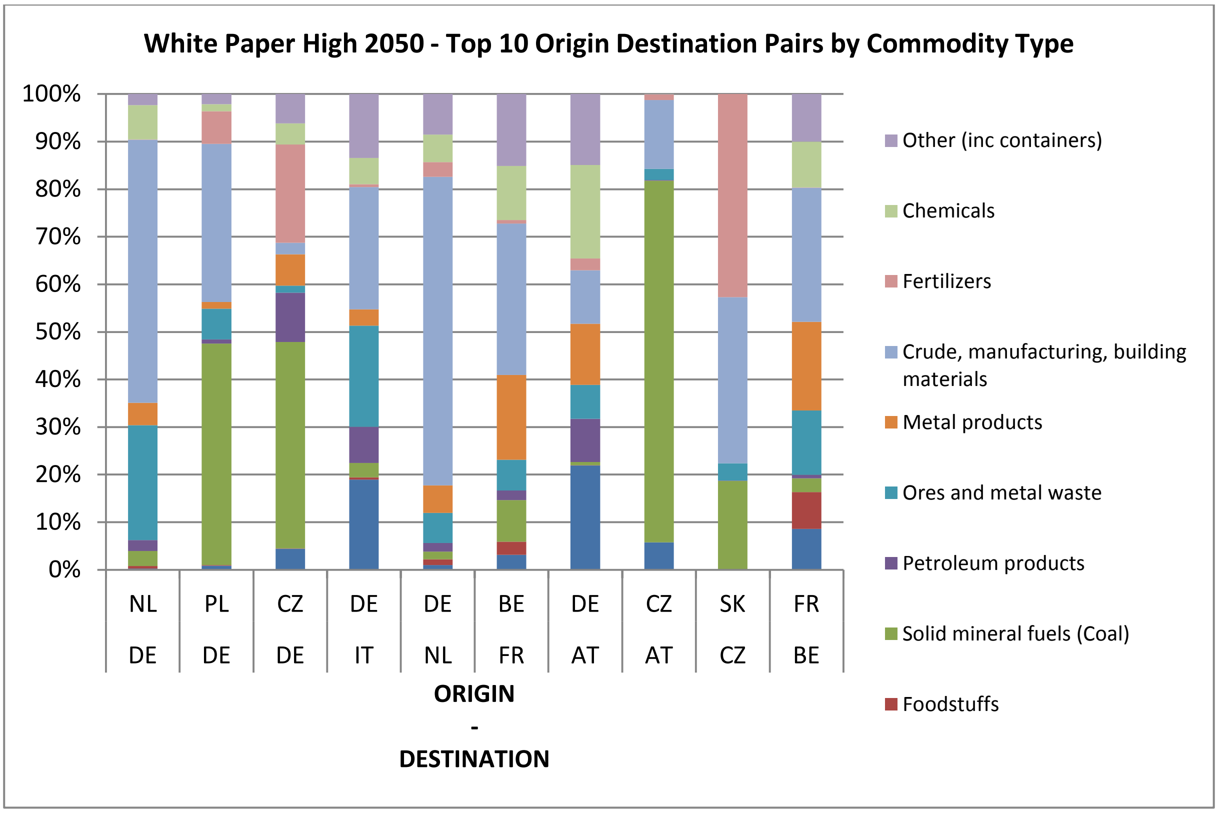


Figure 7: White Paper High 2050 - Top 10 Origin Destination Pairs (thousand tonnes) by Commodity Type. See appendix table 15 for further details.

Following a similar pattern to that observed previously - the 2011 White Paper High Scenario estimates crude, manufacturing and building materials to be most prominent along the Netherlands to Germany, Germany to Italy, Germany to Netherlands, Belgium to France and France to Belgium.

Origin destination pairs of Poland to Germany and Czech Republic to Germany, again, mostly consist of the transportation of solid mineral fuels.

For the ten origin destination pairs considered above, crude, manufacturing and building materials represent **61,538,000** tonnes lifted.

Solid mineral fuels for the ten corridors presented above represent **34,587,000** tonnes lifted.

Further information supporting Figure 7 can be found in Table 21 located in the appendices.

6.2 Primary Wagon Types corresponding to NSTR Commodity Type for Top Origin Destination Pairs

Table 17 below summarises the finding of the previous section which analysed the commodity types being lifted along ten origin and destination pairs, namely: The Netherlands to Germany, Poland to Germany, The Czech republic to Germany, Germany to Italy, Germany to The Netherlands, Belgium to France, Germany to Austria, The Czech Republic to Austria, Slovakia to The Czech Republic and France to Belgium.

Table 17: Summary of corridor primary wagon type analysis by commodity (2050)

		NL	PL	CZ	DE	DE	BE	DE	CZ	SK	FR
Commodity	**Primary Wagon Type**	DE	DE	DE	IT	NL	FR	AT	AT	CZ	BE
Agricultural products	Covered Hopper Wagons							☐			
Foodstuffs	Covered Wagon										
Solid mineral fuels (Coal)	Open Top Wagons		☐	☐					☐		
Petroleum products	Tank Wagon										
Ores and metal waste	Open Top Wagons										
Metal products	Flat Wagons										
Crude, manufacturing, building materials	Flat Wagons or Covered Wagon	☐			☐	☐	☐				☐
Fertilizers	Covered Hopper Wagons									☐	
Chemicals	Tank Wagon										
Machinery, transport equipment	Flat Wagon										

It can be seen that open top wagons and flat wagons feature most prominently, as they did in previous EU wide analyses found earlier in this report.
On the basis of the corridor analysis presented in the previous section, the following wagon types are put forward for further investigation in forthcoming chapters of the D-Rail project:

- **Open Top Wagons**
- Flat Wagons
- Covered Wagons

Table 18 below summarises the finding of the previous section which analysed the commodity types being transported along ten origin and destination pairs as shown in Table 16. Associated alternative wagon types are listed at the beginning of the report in Table 3.

Table 18: Summary of corridor alternative wagon type analysis by commodity (2050)

		NL	PL	CZ	DE	DE	BE	DE	CZ	SK	FR
Commodity	**Alternative Wagon Type**	DE	DE	DE	IT	NL	FR	AT	AT	CZ	BE
Agricultural products	Open top wagons							x			
Foodstuffs	Flat Wagon (Refrigerated Container)/tanker										
Solid mineral fuels (Coal)	Covered hoppers		x	x					x		
Petroleum products	Container flats for tank containers										
Ores and metal waste	Covered hoppers										
Metal products	Covered wagons										
Crude, manufacturing, building materials	Flat Wagon, Covered Wagon, Tank Wagon	x			x	x	x				x
Fertilizers	Tank or hopper wagons for granules/powders/liquids									x	
Chemicals	Flat wagons for container tanks hoppers for granules, powders										
Machinery, transport equipment	Flat Wagon (Specials), Car carriers										

Based on the findings presented in Table 18 above the following wagons are most prominent:

- **Covered Hoppers**
- **Flat, covered or tank wagons**

7 Summary and Conclusions

This report has presented a number of rail freight wagon types to be considered for further analysis as part of the D-Rail project.

The posing of such wagon types has been primarily built upon commodity forecasts (in D-RAIL deliverable D2.1 Rail Freight Forecast up to 2050) up to the year 2050. The year 2050 was chosen in line with the projects' future year horizon. It should be noted however that by definition a future forecast will never be wholly accurate, especially given a forecast period up to 2050. Despite this, by adhering to standard forecasting techniques such as EU developed standard forecasting tools - TRANS-TOOL - we can be assured that the forecast is as accurate as can be expected for such an ambitious forecasting period.

Also by incorporating a form of sensitivity testing we are able to examine results should the forecast vary slightly.

When considering commodity types with the greatest projected average annual growth per annum we see a change in the type of goods anticipated to be transported by rail. Foodstuffs in particular show very significant growth between 2010 and 2050 with an estimated yearly growth of over 5% on average should the full aims and objectives of the White Paper be realised.

When considering goods moved, that is commodities in terms of BTKM (**highest absolute values**) it is observed that goods which feature heavily in present rail freight transportation also feature largely in 2050. This is typically the transportation of bulk goods for which rail freight has traditionally relied heavily upon and has shown strength (in terms of market share). Rail is likely to be heavily influenced by developments in the European power generation (e.g. usage of coal) sector. It has been demonstrated that full realisation of the 2011 White Paper objectives (White Paper High Scenario), when compared to the Reference and White Paper Low Scenarios does not alter the top three commodity types: solid mineral fuels, crude, manufacturing and building materials and machinery and transport equipment commodity types.

However it is worth noting that in the final, full White Paper Scenario, machinery and transport equipment (including containers) now show the greatest number of goods moved (BTKM) where previously it had been crude, manufacturing and building materials.

The NSTR nomenclature is such that category 9 (machinery and transport equipment) also includes the transport of containers. It is apparent from previous EC funded research projects (such as RETRACK, CREAM) that intermodal and co-modal services involving rail for a component of a freight transit are likely to figure much more in the overall portfolio of services offered. These will probably be a mix of container, swap body and trailer carrying trains. This suggests a trend toward increased numbers of flat wagons or more intensive use of existing flat wagons.

The move to higher speeds and lighter rail wagons will need to be tempered with assurances that the service performance will not lead to a growing number of derailments. The drive to reduce the weight of wagons (i.e. less tare weight by making wagon from light materials) and an increasing amount of lighter weight but higher value/time-sensitive traffic raises significant issues in relation to safety management and asset management.

To forecast and breakdown the future rolling stock it was important to determine the current rolling stock fleet in the EU27 to analyse age, number, axle load, tare weight, and other operational characteristics. With this in mind, efforts were taken to collect data on the existing rolling stock by reviewing available literature. A number of organisations, governing bodies and institutes were also approached during this work. However, barriers to such attempts were often met. In general these barriers are best described as a lack of readily available public information. Unlike other sectors, rail freight operators and relevant authorities maintain a restrictive regime for a variety of reasons, most of which are quite probably valid commercial reasons.

Subsequently, the data template form was sent to the railway authorities in all European countries. So far only the Czech Republic, Latvian and Slovakian authorities have replied. This limited data was analysed and incorporated into the general forecast and synthesis.

The trends in freight rolling stock which were identified and analysed within this report are relevant to predict the future developments in terms of types of vehicles, innovations and new technologies to be implemented. These predictions are the starting point for further work in D-RAIL technical work packages (such as WP3, 4 and 5), which will have to take into consideration the specific technical characteristics and features relevant to the derailments issue, for each type of freight wagon, but in particular for those which were identified as priorities by this deliverable. Further work will have to identify, analyse and discuss the main characteristics relevant to derailments, with respect to the trends of future freight rolling stock, such as:

- General characteristics determining the vehicle dynamics (tare, maximum payload, loading gauge, etc.)
- Loading/unloading and fixing features
- Maximum speed and braking parameters
- Aerodynamics, etc.

It has been demonstrated that should the EU come close to achieving its objectives as set out in the Transport White Paper 2011 there will be significantly greater demand on the rail freight infrastructure and rolling stock with a large and significant increase in the number of wagons in operation and a much anticipated increase in productivity and asset utilisation.

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SUSTRAIL D1.3 (2011) Overview of Common Freight Wagon Vehicles and Economic Data, 20th November

The DNV report entitled "Assessment of freight train derailment risk reduction measures: Part B Final Report" was published in October 2011 on behalf of the European Railway Agency

Appendices

REF 2050

Destination	**DE**	**DE**	**DE**	**IT**	**NL**	**FR**	**AT**	**AT**	**CZ**	**BE**	Sum (tonnes)
Origin	**NL**	**PL**	**CZ**	**DE**	**DE**	**BE**	**DE**	**CZ**	**SK**	**FR**	
Agricultural products	0.16%	0.71%	4.01%	19.61%	0.51%	2.16%	19.97%	4.32%	0.00%	2.82%	6,799
Foodstuffs	0.47%	0.03%	0.00%	0.18%	1.39%	1.03%	0.00%	0.00%	0.00%	5.36%	965
Solid mineral fuels (Coal)	3.92%	54.08%	45.24%	3.58%	2.50%	14.82%	0.99%	79.95%	18.75%	5.38%	34,199
Petroleum products	2.64%	0.75%	10.79%	9.16%	2.72%	1.66%	11.62%	0.11%	0.07%	0.79%	6,086
Ores and metal waste	28.78%	6.89%	1.51%	24.45%	9.16%	11.11%	10.04%	2.22%	3.35%	22.96%	18,331
Metal products	4.62%	0.51%	5.94%	2.26%	7.22%	29.16%	16.47%	0.00%	0.00%	30.44%	11,436
Crude, manufacturing, building materials	55.38%	28.24%	2.02%	28.77%	68.19%	22.26%	9.90%	12.15%	34.94%	20.92%	42,980
Fertilizers	0.01%	7.84%	21.56%	0.72%	0.67%	0.37%	3.57%	1.22%	42.89%	0.05%	10,975
Chemicals	3.47%	0.79%	4.32%	4.87%	3.83%	6.24%	19.89%	0.03%	0.00%	5.63%	6,294
Other (inc containers)	0.56%	0.17%	4.60%	6.39%	3.82%	11.20%	7.54%	0.00%	0.00%	5.65%	5,030
CHECK	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Total	23,900	20,809	20,265	14,252	13,624	10,622	10,027	9,921	9,922	9,753	143,095

Table 19: REF 2050: Top 10 Origin Destination Pairs (Tonnes Lifted)

WP LOW 2050

Destination	DE	DE	DE	IT	NL	FR	AT	AT	CZ	BE	Sum (tonnes)
Origin	NL	PL	CZ	DE	DE	BE	DE	CZ	SK	FR	
Agricultural products	0.20%	0.76%	4.27%	19.14%	0.76%	2.92%	21.16%	5.05%	0.00%	6.80%	8,867
Foodstuffs	0.52%	0.09%	0.05%	0.34%	1.33%	2.20%	0.02%	0.00%	0.00%	6.79%	1,802
Solid mineral fuels (Coal)	3.46%	49.66%	44.11%	3.25%	1.91%	10.52%	0.82%	77.80%	18.69%	3.62%	34,401
Petroleum products	2.35%	0.86%	10.51%	8.25%	2.08%	1.97%	9.88%	0.11%	0.07%	0.74%	6,364
Ores and metal waste	26.04%	6.54%	1.49%	22.62%	7.24%	7.77%	8.29%	2.28%	3.52%	16.02%	18,925
Metal products	4.40%	1.04%	6.35%	2.91%	6.14%	20.62%	14.26%	0.00%	0.00%	21.77%	12,544
Crude, manufacturing, building materials	56.00%	31.37%	2.27%	27.03%	66.91%	29.62%	10.67%	13.52%	34.96%	26.71%	53,854
Fertilizers	0.02%	7.27%	21.00%	0.65%	2.30%	0.55%	2.92%	1.19%	42.76%	0.05%	11,378
Chemicals	5.40%	1.06%	4.40%	5.16%	4.70%	9.76%	19.60%	0.04%	0.00%	8.48%	9,505
Other (inc containers)	1.61%	1.35%	5.54%	10.65%	6.63%	14.09%	12.37%	0.00%	0.00%	9.02%	9,867
CHECK	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Total	27,164	22,744	20,826	15,831	17,850	16,071	12,359	10,213	9,954	14,497	167,508

Table 20:WP Low: Top 10 Origin Destination Pairs (Tonnes Lifted)

WP HIGH 2050

Destination	**DE**	**DE**	**DE**	**IT**	**NL**	**FR**	**AT**	**AT**	**CZ**	**BE**	Sum

Origin	NL	PL	CZ	DE	DE	BE	DE	CZ	SK	FR	(tonnes)
Agricultural products	0.26%	0.85%	4.44%	18.96 %	0.96%	3.12%	21.91 %	5.73%	0.00%	8.60%	10,689
Foodstuffs	0.54%	0.15%	0.08%	0.45%	1.27%	2.76%	0.04%	0.00%	0.00%	7.70%	2,519
Solid mineral fuels (Coal)	3.16%	46.53 %	43.40 %	3.01%	1.62%	8.74%	0.70%	76.06 %	18.65 %	2.93%	34,587
Petroleum products	2.28%	0.91%	10.33 %	7.61%	1.76%	2.05%	9.09%	0.12%	0.07%	0.71%	6,672
Ores and metal waste	24.15 %	6.43%	1.48%	21.27 %	6.35%	6.46%	7.14%	2.34%	3.63%	13.57 %	19,528
Metal products	4.71%	1.42%	6.61%	3.42%	5.81%	17.82 %	12.87 %	0.00%	0.00%	18.62 %	13,847
Crude, manufacturing, building materials	55.31 %	33.25 %	2.43%	25.75 %	64.85 %	31.79 %	11.23 %	14.51 %	34.98 %	28.17 %	61,538
Fertilizers	0.07%	6.83%	20.64 %	0.60%	3.07%	0.78%	2.49%	1.16%	42.67 %	0.05%	11,728
Chemicals	7.21%	1.48%	4.45%	5.51%	5.82%	11.35 %	19.62 %	0.05%	0.00%	9.63%	12,570
Other (inc containers)	2.32%	2.14%	6.14%	13.41 %	8.49%	15.12 %	14.92 %	0.01%	0.00%	10.02 %	13,687
CHECK	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Total	29,926	24,402	21,210	17,181	21,178	20,275	14,651	10,460	9,975	18,106	187,364

Table 21: WP High: Top 10 Origin Destination Pairs (Tonnes Lifted)