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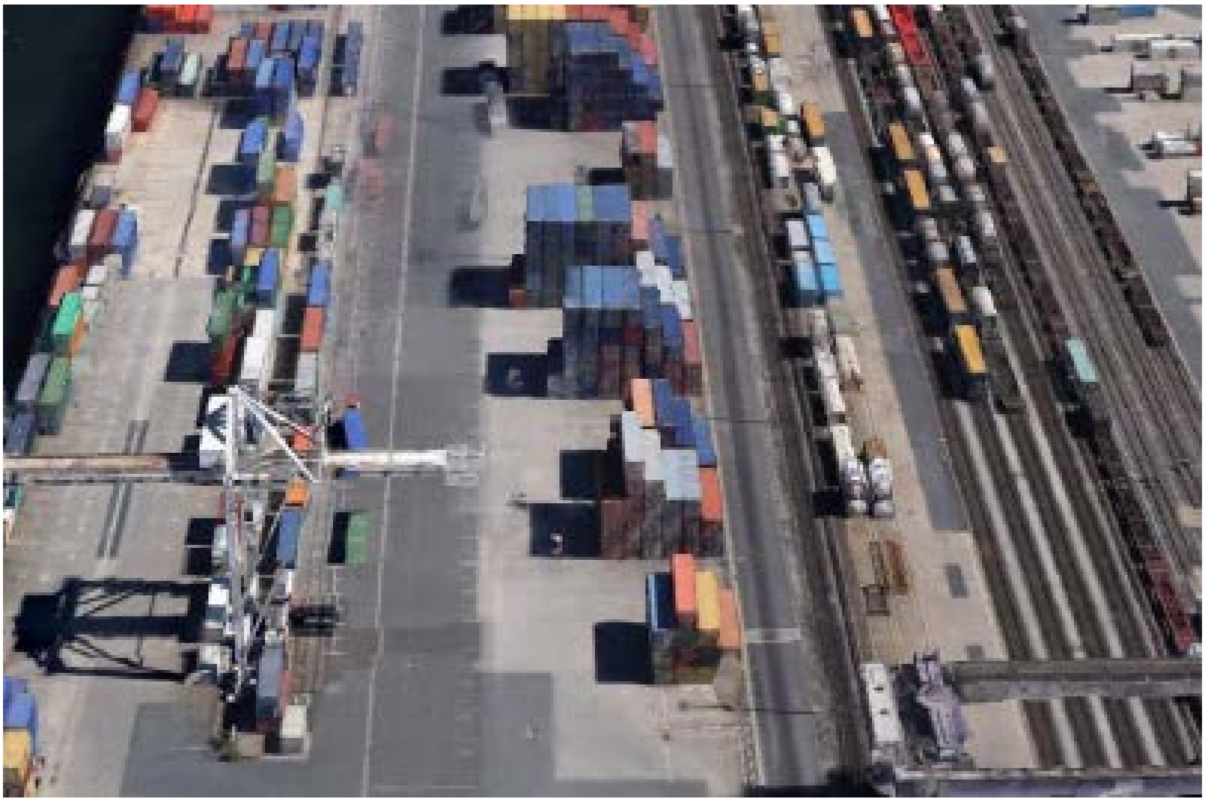

CEDR Call 2015: Freight and Logistics in a Multimodal Context

FALCON Handbook

Understanding what influences modal choice

November 2017

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Abbreviations

AIS	Automatic Identification System (for vessels)
ANPR	Automated Number Plate Recognition
BASt	Federal Highway Research Institute
B2B	Business-to-business
B2C	Business-to-consumer
CBA	Cost-Benefit Analysis
CFS	Commodity Flow Survey
CO_2	Carbon Dioxide
Eurostat	Statistical Office of the European Union
HCT	High Capacity Transport
HCV	High Capacity Vehicles
HGV	Heavy Goods Vehicle
ICT	Information and Communication Technologies
IoT	Internet of Things
ITS	Intelligent Transport System
ITU	Intermodal Transport Unit
IWW	Inland waterways
KPI	Key Performance Indicators
LSP	Logistics service provider
NRA	National Road Administration
NRDB	National Road Data Base
NST	Standard goods classification for transport statistics
NUTS	Classification of Territorial Units for Statistics
PBS	Performance Based Standards
PI	Physical Internet
SCM	Supply Chain Management
SIAP	Smart Infrastructure Access Policy
STA	Swedish Transport Administration
STEEP	Society, Technology, Economy, Environment and Politics
TEU	Twenty-foot Equivalent Unit
TEN-T	Trans-European Transport Network
WIM	Weigh in motion
3PL	Third-Party Logistics Provider
4PL	Fourth-Party Logistics Provider

Glossary

Cabotage	The national carriage of goods for hire or reward carried out by non-resident hauliers on a temporary basis in a host Member State in the EU.
Consolidation	A process where consignments from one shipper or different shippers are grouped together to a single, large shipment. Normally organized by forwarders.
Drayage	The transport of goods over a short distance, often as part of a longer overall move, such as moving goods from a ship into a warehouse.
Intermodal transport	The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes.
Intermodality	A system of transport whereby two or more modes of transport are used to transport the same loading unit or truck in an integrated manner, without loading or unloading, in a [door to door] transport chain.
Logistics Service Providers	Firms who provide management over the flow of goods and materials between points of origin and destination.
Third party logistics providers (3 PL)	Firms who solely focus on the distribution logistic to the consumer and offer value-added services such as commissioning, warehousing, packaging or after-sales-services.
Fourth party logistics providers (4 PL)	Firms who organize the whole supply chain which includes also e.g. the procurement logistics.
Modal split	The percentage share of each mode of transport in total transport, typically expressed in tonne-kilometres or tonnes.
Modal shift	The growth in demand of a transport mode at the expense of another.
Multimodal transport	Carriage of goods by two or more modes of transport.
Physical Internet (PI)	A system in which goods are encapsulated in smart containers, transported, handled and stored within a 'Logistics Web' like data in the Internet.
Shipper	Manufacturers, retailers and wholesalers who send goods for shipment.
Sub-modes	Different versions of a transport mode, according to capacity, size dimension or some other characteristic.
Supply chain	The network of organizations, people, activities, information and resources and technology involved in the production and distribution of a commodity. A supply chain covers the logistics chain(s) and the transport chain(s).
Synchromodality	A system in which cargos are allocated to different modes and routes in a flexible and continuous manner under the direction of a logistics service provider.
Transport chain	A series of transport legs involving one or several (sub) modes.
Unimodal transport	The movement of goods in a single transport mode without any transhipment.

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Executive Summary

A solid understanding of the freight sector is a key input in a well-functioning and competitive transport system that is reducing its negative external effects. The objective of this Handbook is to describe developments in the transport sector with emphasis on optimal use of infrastructure and transport modes to give a review of the factors influencing firms' modal choice and describe the data and tools needed to analyse the impacts of trends and policy measures.

In chapter 2, it is concluded that there are ongoing trends towards higher freight transport demand and higher logistical requirements which are expected to continue to year 2030 and beyond. This leads to higher requirements on firms that provide logistics services, vehicles/vessels, energy sources as well as the physical and digital infrastructure. It also poses a challenge for reaching the European Union's targets on energy efficiency and a 30% reduction of the greenhouse gases by 2030.

Various technological developments and policies are likely to improve the efficiency of the transport system. Some technologies are already in use in some countries (high capacity vehicles), some are ready to be used on a larger scale (alternative fuels) and some are under development (automation of vehicles, Internet of things and Physical Internet). Several policy- and infrastructure-related requirements must be fulfilled before new technologies can be implemented at a larger scale (e.g. sensors for autonomous vehicles).

In chapter 3 we derive several lessons regarding firms' modal choice. We show that shipment attributes (e.g. commodity, value, weight) and trip distance impose restrictions on the firms' ability to choose between transport solutions. Some shippers are captive to a single transport solution and the degree of modal competition will depend on the distance class and commodity mix.

We show that transport cost is the most important choice criterion for firms, provided that sufficiently high requirements on time and reliability are met. But cost sensitivity varies considerably across market segments and the relative competitive positions of the modes explain much of the variation. Cost sensitivity also depends on whether the shipper or receiver bears the cost.

Road transport is the most common choice due to its cost advantage as well as the customers' last-minute requests and demand for short lead-time. The possibility to use other modes than road increases with larger shipment sizes and volumes, receivers accepting longer lead times and typically with consolidation of flows within and between firms. This illustrates the connection between the mode choice and other logistics decisions.

In chapter 4 we discuss the importance of terminals for modal competition and conclude that transhipment cost and waiting time for drivers is a significant part of the cost in multimodal chains. Measures to reduce transhipment cost include subsidizing transhipments directly and funding land acquisition, infrastructure and transhipment equipment. Measures to reduce waiting time in terminals include controlling approaching road traffic at an early stage and using technologies to predict trucks' time of arrival and waiting more accurately. In addition, dry ports can reduce congestion and waiting time. We also highlight how modes can be complements rather than competing alternative. Improving the conditions for the road will most certainly increase its attractiveness for door-to-door road transports, but it can also benefit transport chains where pre- and post-haulage by road is included.

Chapter 5 discusses which data are needed for national road administrations (NRAs) to incorporate the findings in chapter 3 and 4 in their analysis of the transport sector. We conclude that there is a gap between what kind of data NRAs need and what kind of data they have access to. All NRAs have

adequate access to aggregated data that describe the level of freight activity and traffic. But there is a shortage of disaggregated data describing variables that affect firms' mode choice, including shipment characteristics (e.g., weight, value, commodity class), modal attributes (e.g., transit times, delivery reliability) and terminal structure. Better access to these disaggregated data allows better evaluations how trends and transport policies affect the freight transport sector and modal choice. In addition, there is a need for more data describing load factors and the cubic volume of freight moved, making it easy to analyse the impact of high capacity transport and the efficiency of freight transports.

In chapter 6 we present national transport models that can be used to study the impact of trends and transport policies. There is sometimes a trade-off between using a simple model that can answer simple questions fast and a complex model that requires more effort and gives more detailed answers. We provide guidelines on how to conduct a first impact assessment using these models.

Based on the findings from chapter 2-6 we offer NRAs our recommendations of measures that are related to collaboration, digitalisation and data as well as new technologies and infrastructure:

1. Collaboration
    - Increase collaboration between transport authorities responsible for different modes.
    - Increase collaboration between transport authorities and private sector
    - Formulate an international strategy for the continental combined transport**.**
    - Push the collaboration between the market partners.

2. Digitalization and data
    - Increase NRAs' access to reliable data by pushing the development towards the equipment of load units and vehicles/vessels with tracking and tracing devices.
    - Increase the scope of data collection in the freight sector. Commodity flow surveys could be used in a larger extent, possibly including firms' logistics structure, volumetric measures, scheduling variables and/or vehicle/vessel utilization.
    - Improve existing transport models and the possibility of sharing transport models.
    - Organize a round-robin where suppliers/users of national transport models are requested to analyse a specific representative transport problem.

3. New technologies and infrastructure
    - Assess infrastructure requirements that come with an increased use of autonomous vehicles, electrification of vehicles and high capacity vehicles.
    - Increase the use of Smart Infrastructure Access Policies (SIAP) and performance-based standards (PBS).
    - Initiate cross-company logistics clusters at the urban periphery for freight centres to enable multistage distribution systems.

1. Introduction

Freight transport with all modes plays a crucial role for the functioning of economies while simultaneously being responsible for negative external effects such as congestion, noise and various forms of pollution. The need for an efficient and competitive transport system that is also reducing its negative social effects is on top of many policy-makers' lists. A case in point is the White Paper on Transport by the European Commission (2011), in which it recognizes transport's fundamental role to the economy and society while underlining the need for a sustainable transport system. The transport system consists of the firms that provide logistics and transport services, their personnel, the different vehicles and energies used and the transport- and ITS-infrastructure.

The challenge is to achieve a sustainable transport system that can cope with increasing freight transport volumes. Total freight transport activity (in tonne-km) is projected to increase by about 58% (1.2% annually) between 2010 and 2050 (European Commission, 2016). Another challenge is to contribute to the goals of the European Union regarding energy efficiency, green-house gas emissions and air pollution/clean air[1], as well as fulfilling the 30% improvement of end-to-end logistics performance by 2030 set out by the European Technology Platform Alice (ETP-Alice 2017)[2]. A well-functioning freight transport system that is also reducing its negative external effects requires optimal use of the infrastructure and the transport modes. Knowledge about the overall freight transport system is needed as an efficient and sustainable system requires high utilization of the modes one by one and in combination.

A key input for striving towards such a system is policy-makers' and transport authorities' solid understanding of the freight transport sector in general, and the influences on the choice of transport solutions and modes in particular. In the light of this, the objective of this handbook is to provide a detailed review of the factors influencing modal choice, describe developments in the transport sector and the data and tools needed to analyse the impacts of trends and policy measures.

The handbook is aimed towards authorities responsible for transport and infrastructure in Europe. Focus is on national road administrations (NRAs), which are organized in different ways in different countries. In some countries, like the Netherlands and Sweden, a single public agency is responsible for the main national infrastructure facilities. In other countries, like Germany, France and Norway, the responsibilities are spread out over several executive agencies. In this handbook, we refer to these organizations as NRAs for simplicity.

Most of the content of the handbook is based on results from European countries. It is important to note that there is wide range of commodity, firm and commercial/logistics characteristics across

[1] European Commission (2013). A Clean Air Programme for Europe COM (2013) 918 final. Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. European Commission (2014). A policy framework for climate and energy in the period from 2020 to 2030 COM (2014) 15 final.

[2] "A truly integrated transport system for sustainable and efficient logistics" has been developed within the European project SETRIS and approved by the technology platforms ACARE (Advisory Council for Aviation Research and Innovation in Europe), ALICE (Alliance for Logistics Innovation through Collaboration in Europe), ERRAC (The European Rail Research Advisory Council), ERTRAC (European Road Transport Research Advisory Council) and WATERBORNE (European Maritime Industries Advisory Research Forum). The purpose of the SETRIS-project is to deliver a coordinated approach to research and innovation strategies of all modes in Europe.

different freight market segments in Europe. These differences will be investigated and similarities and differences between countries will be highlighted.

The handbook is focused on long-distance domestic and cross-border transports, where all modes are used and mode choice matters most. The modes considered in this handbook are road, rail, air, maritime/sea and inland waterway transport (IWW). The two latter categories will sometimes be referred to as waterborne transport. Except for an analysis of the trend towards larger vehicles and vessels there is no specific focus on the choice of vehicle/vessel type and size. The "sister project" FLUXNET (Freight and Logistics Using eXtended Network Empowerment Tools – multimodality integrated with land use, freight and logistics) focuses on the urban and regional scale and the connection between land use and infrastructure planning (Paul et al. 2017). FLUXNET plans to derive recommendations based on best practises and test beds.

Two features guide our definition of modal choice. First, there are various ways in which transport modes are combined. These types of transports are discussed more in detail in chapter 3 and 4. The alternatives for firms choosing a transport solution include unimodal options and various combinations of modes. Second, firms may be using several transport solutions for different routes. This implies that the modal choice is a selection of a transport solution, which entails a choice of how intensive different modes are to be used in a transport chain, rather than choosing one mode or the other for a whole transport chain. It also shows that transport modes may compete or complement each other.

The content of this handbook spans several academic disciplines and is derived using a range of methods. For most parts, we have conducted desk reviews of existing research, grey literature and current conditions of the freight markets and public administrations in the transport sector. We therefore compile existing results and evidence, rather than provide new findings of our own. Examples are mainly taken from European countries.

The outline of the handbook is as follows. Chapter 2 sets the scene for an analysis of freight markets by compiling and describing trends that affect freight transports. Chapter 3 and 4 aims to provide a solid understanding of what influences firms' choice of transport solutions and logistic strategies. Chapter 3 reviews the academic and grey literature to identify factors that determines firms' mode choice and describes real world cases to derive firms' mode choice and planning at the strategic and the operational level. Chapter 4 examines the role of terminals when it comes to competition between unimodal road transports and multimodal transports. It discusses how costs related to transhipment and pre- and post-haulage as well as waiting time for truck drivers and trucks matters for the choice between transport chains. Altogether, these two chapters describe how firms make their decision on mode choice and the environment surrounding these decisions.

Chapter 5 and 6 show which data and assessment tools are needed for NRAs to incorporate the findings in chapter 3 and 4 in their analysis of the transport sector. Chapter 5 examines the data needs of the transport authorities and the availability and nature of the data on freight transports on the European and national level. It identifies different data sources and describes the available variables. It also reviews different data collection methods applied in European countries. Chapter 6 presents different national transport models that can be used to study the impact of trends and transport policies. It gives an overview of different national transport models and what kind of questions can be answered with these models. Finally, chapter 7 compiles the lessons learned in chapter 2 to 6 and derives recommendations for the transport authorities.

2. Trends

2.1. Introduction

Infrastructure planning and building – especially for long distance transports through one or several countries – are usually done with a long-term perspective and for specific transport forecasts and infrastructure requirements. Future developments, within the logistics sector, influence the requirements on the infrastructure and other parts of the transport system. These trends are described in this chapter.

The first part describes the general framework consisting of social, technological, economic, ecological and political developments – the so called Mega Trends. The second part describes possible future trends within the logistic sector that ensue from the Mega Trends or arise due to other developments. The trends are identified by a desk research and described in the literature. The main sources for the Mega Trends are JRC (2015), PWC (2014) and Klaus et al. (2011).

2.2. Mega Trends

The transport system is embedded in an overall framework of social, technological, economic, ecological and political circumstances, which are called 'Mega Trends' (see Figure 2-1).

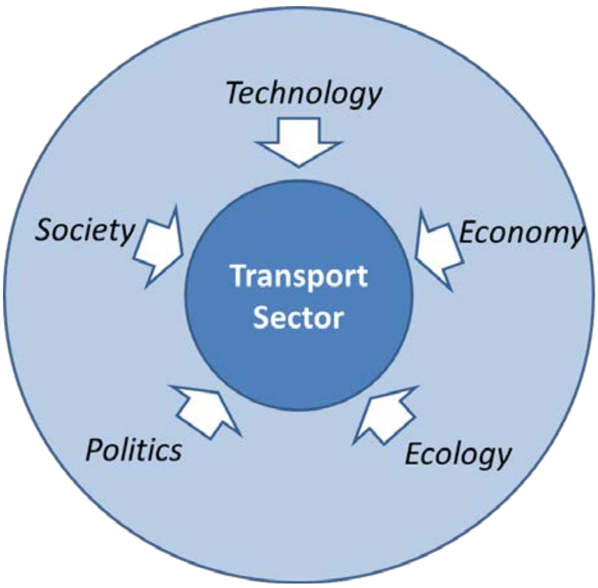


Figure 2-1. Connection between the Mega Trends and Trends. Source: DLR

The Mega Trends typically work on the global level. The five factors Society, Technology, Economy, Ecology and Politics (STEEP) provide a framework for the analysis of trends in the transport sector. They are depicted in Table 2-1.

	Mega Trend	Description
Society	Demographic development	Low fertility rates, aging populations and a growing number of migrants change the demographic structure in Europe (Hoßmann et al. 2008). At least in the near future the overall trend towards an increasing population in Europe is assumed to continue.
	Consumerism and post-industrial society	The customers have an increasing influence on product diversity. It is expected, that requirements of the customers regarding the on-time punctuality, speed, resiliency and flexibility of logistic services increase further.
	Urbanisation	About 72 % of the European population live in urban areas and the share is expected to continue. The freight transport demand and traffic flows concentrate in these regions. An adequate connection to the long-haul transport network is required.
Technology	Technological progress	The development of a smart and digital world, the automation of vehicles and processes or alternative energies enables new opportunities for the logistic sector to reduce emissions and costs and to raise their productivity. Research and development fosters this development and is expected to continue.
Economy	Globalisation	Worldwide economic areas with international trade relations have emerged. The rising liberalization led to an open European Transport Market with hardly no restrictions or barriers. Protectionist trade policies in the EU and the US may break with the globalisation trend.
	Business organisation	Rationalisation has previously led to resource-intensive processes like transports being outsourced to subcontractors. New business models, mostly developed by startups, offer shipping or storage space for a shared use (Sharing Economy). But there are also first approaches to reintegrate transport process to ensure short-time deliveries, mainly from a few major e-commerce companies.
Ecology	Climate Change and pollution	The EU has set up goals regarding energy efficiency, green-house gas emissions and air pollution. New mobility concepts and alternative fuels are being developed to reach these goals. Extreme weather conditions pose challenges for transport and infrastructure.
	Social and environmental awareness	With the concept of product stewardship, companies have a responsibility for the society, environment, health and social compatibility of their products. The Dow Jones industrial average uses these criteria as assessment criteria for companies.
	Resource depletion	Limited natural resources are components of key technologies in electrical engineering and require efficient recycling processes. Due to higher prices of limited fossil energy resources, energy prices are also rising.
Politics	European policy	The aim of the European transport policy is to create a single European Transport Area towards a competitive and resource efficient system. Remaining issues, especially in the rail sector, are planned to be solved.
	Standardisation	European and global standardisation facilitates international freight transports. There are still incompatibilities, e.g. between European countries and modes.
	Infrastructure Priorities	The development of the Trans-European Networks for transport (EU 2013), telecommunications networks (EC 2011) and energy (EU 2006) support the development of transnational logistics services.

Table 2-1: Overview of Mega Trends that influence the transport sector. Source: DLR

2.3. Trends within the logistics sector

Related to the Mega Trends, there are trends specific to the logistics sector that influence the transport system in general and the infrastructure. The main sources for the trends in the logistic sector are DHL (2016), Bundesvereinigung Logistik (2013) and PWC (2009). These trends are categorized into four groups in Figure 2-2:

1. Demand and production: The requirements of firms and households on logistics and transport services.
2. Logistics: The improvement of existing logistic concepts or development of new concepts to fulfil the requirements of the firms and households in 1.
3. Technology: The technological development that allows or facilitates the improvement or development of the logistic concepts in 2.
4. Transport policy: The transport policies that facilitate the implementation of existing technologies or foster the development of new technologies.

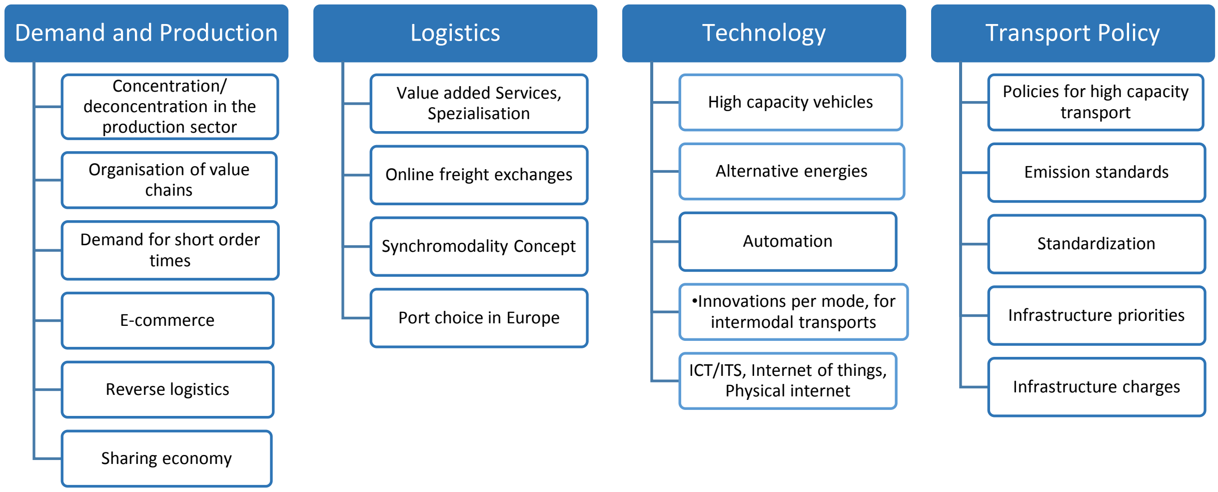


Figure 2-2. Overview over major trends affecting road and intermodal transport. Source: DLR

The following sections describe those trends that are expected to have an impact on

- the volume and the structure of the traffic (measured in vehicle-kilometres)
- route choice that influences traffic flows and density within the mode specific networks
- modal choice and change demand of infrastructure
- other infrastructure requirements (e.g. carrying capacity)

In Table 2-2 we link the trends (related to all modes) to each of these four aspects. The table also comprises expert judgements of the project team regarding the importance of trends short-term (in the next couple of years) medium-term *(*before 2030) or long-term *(*before 2050), column 5 Table 2-2. The table shows that mainly trends in technology, but also transport policy influence the infrastructure requirements. The importance of the trends differs between different countries with different conditions regarding geography, topography, population density etc. The Synchromodality concept is for example more relevant and has larger impacts on route and mode choice in the Netherlands than in Sweden.

		Traffic volume	Route choice	Modal choice	Infrastructure requirements	Time horizon
1. Demand and production	Concentration/ deconcentration in production	x				Short, medium
	Organisation of value chain	x	x			Short, medium
	Demand for short order times	x		x		Short, medium
	E-commerce	x	x	x		Short, medium
	Reverse logistics	x				Short, medium
	Sharing economy	x				Short, medium
2. Logistics	Value added services, specialisation	x		x		Short, medium
	Online freight exchanges			x		Short, medium, long
	Synchromodality concept		x	x		Short, medium
	Port choice in Europe		x			Short, medium
3. Technology	High capacities vehicles			x	x	Short, medium
	Alternative energies (electrification of roads)		x	x	x	Short, medium, long
	Automation of vehicles		x	x	x	Medium, long
	Innovations per mode and for intermodal transports			x	x	Medium, long
	ICT/ITS, Internet of things, Physical internet	x	x		x	ICT (short) IoT and PI (medium, long)
4. Transport policy	Policies for high capacity transport	x	x	x	x	Short, medium
	Emissions, regulations			x		Short, medium
	Standardization			x		Short, medium, long
	Infrastructure priorities		x	x		Short, medium
	Infrastructure charges		x	x	x	Short, medium, long

Table 2-2. Impact of Trends on Infrastructure (own estimations)

Some of the trends like the automation and innovations for intermodal transport work on a medium or long time horizon. Still, the agreement about standards needs to be started on a short time horizon. It can also be stated, that most of the listed trends are seen for a short and medium time horizon. Changes in traffic volume, route and modal choice are possible and probably require a short time strategy to react.

The trends are described in detail below. For an estimation of the effect of the trends, a specific influence on the model parameter is crucial. In chapter 6 we provide impact assessments of selected trends (port choice in Europe, automation of trucks, permission of longer/heavier vehicles and innovations in the rail freight sector). The impacts of selected trends are quantified where studies are available and the impact on model parameters can be described.

2.3.1. Demand and production

All trends in demand and production cited in Figure 2-2 are expected to have an impact on transport demand and therefore the traffic volume. The production sector, e.g. the markets for automotive or household appliance, is characterized by a concentration to a few large firms. The rising competitive constraints have led to a rationalisation within the firms and to a reduction of the real net output ratio. This changed the organization of value chains in two ways: outsourcing of the production sites to foreign countries and outsourcing of transportation processes to subcontractors (see Logistics). This leads to more transports and the trend is assumed to continue.

The outsourcing of the production sites from Western and Northern European countries to East European countries and Asia has been observed since 1980 [Pedersini 2006]. Since a few years, companies e.g. in Germany and United Kingdom re-shore their production back [Fraunhofer 2012, Bailey and De Propris 2014]. The re-shoring trend is assumed to continue due to higher flexibility and better quality regarding the fulfilment of customers' needs (Fraunhofer 2012). Other reasons for firms re-shoring are decreasing wage differences between countries or shorter lead times. Increasing consumer demand in Eastern Europe and Asia may on the other hand make it more profitable to allocate production to these regions.

A study addressing the food supply chain structures in Germany shows, that centralisation of supply chains may reduce freight transport performance under the precondition, that locations of production or warehouses and commodity flows are chosen in order to minimize the freight transport performance – otherwise an increase of the freight transport performance is expected (Ottemöller and Friedrich 2017).

The last mile delivery (B2B or B2C) require small shipment sizes and short-term-deliveries (e.g. over-night-services, same-day-delivery). Customers' demand and expectations regarding supply chain management increase (Bundesvereinigung Logistik 2013, DHL 2016). Additionally, the share of firms in Europe that make use of e-commerce increased from 13 % in 2008 to 20 % in 2015 (Eurostat 2016). This share is expected to increase further. The high share of small and frequent shipments favours the air and road mode.

The retailing strategies of companies changed in the past decade from a stationary retail to a multi-channel retailing e.g. through the online channel, mobile channel and social media (Verhoef et. al 2015). Furthermore, Verhoef et. al 2015 introduce the concept of omni-channel retail, where consumers simultaneously seek information online and buy the products offline. The raising importance of multi-channel retailing increases the importance of e-commerce in general. The European average amount of companies selling their products online is about 20 %. In 2015, there was a wide variation between the share of companies making e-sales in 2015 among the European Countries. While 28 % of the companies in Germany and Sweden sell their products online, only 7 %

practice e-commerce in Romania. Among others, Sweden, France, Netherlands, Norway and Germany have an amount of e-sales above that European average. Over the last years, the share of companies in Europe making e-commerce is increasing from 13 % in 2008 to 20 % in 2015 (Eurostat 2016). This trend is expected to continue in the coming years as further product categories will probably be included and the population access to the internet will increase.

Regarding reverse logistics; the EU launched Directive 2012/19/EU on waste electrical and electronic equipment with the purpose to contribute to a sustainable production and efficient use of resources and the retrieval of secondary raw materials (EU 2012). All operators involved in a life cycle of electronic products, e.g. producers, distributors and consumers, are asked to re-use or recycle products. This basically means for producers and distributors the redemption of old electronic products and the feed to the recycling process with the help of the reverse logistics. This entails, everything else being equal, additional transports to dispose old electronic products and to recycle them.

In the past, the market transparency for shippers increased by upcoming online freight exchanges. Therefore, complex structures of subcontractors emerged and contemporary, inefficient working companies diminished. The shared use of capacity of trucks and trains may increase the utilization if price and availability of free capacity meet the requirements of shippers. This effect is difficult to estimate, because free capacity doesn't mean, that it will be used by another logistic service provider.

2.3.2. Logistics

The scope of logistic services has increased in the last decades (Baumgarten 2008) and is expected to increase further. The transport services were outsourced to third- or fourth-party-logistics providers. Third party logistics providers (3 PL) solely focus on the distribution logistic to the consumer and offer value-added services like commissioning, warehousing, packaging or after-sales-services compared to forwarding agents. However, fourth party logistics providers (4 PL) organize the whole supply chain which includes also e.g. the procurement logistics. The 3 PL and 4 PL are huge companies which are able to fulfil the demand for a periodic and high transport volume of the industry and enable a periodic transport between the logistics centres as well as production sites and logistics centres all over Europe. Subsequently, the amount of tonne and vehicle-kilometres increased. This development is judged to continue.

The use of online freight exchanges leads tentatively to a better market transparency and a more efficient use of the vehicles. The shared use of capacity of e.g. trucks and trains increases the utilization if price and availability of free capacity meet the requirements of shippers. The actual use of the freight exchanges is motivated by the attraction of online auctioning to shippers and the marketing of online platforms.

The European Ports registered a growth in the gross weight of handled goods over the last ten years from 2005 to 2015 from about 2.6 % (Eurostat 2017a). But some of the European Ports recorded an above the average growth. They are depicted in Table 2-3.

It can be stated, that the gross weight of the ARA ports (Antwerpen, Rotterdam, Amsterdam) increased. Still, Mediterranean ports like Peiraias, Trieste, Valencia or Sines are also increasing their transhipment volume, even if they are still on a lower level compared to the ARA ports. The importance of these ports is due to the expansion of the Suez Canal, which educed the sailing between Southern and Eastern Europe and e.g. Asia. This has given the Mediterranean ports e.g. in Koper (Slovenia), Piräus (Greece), Genua (Italy) or Marseille (France), that are generally smaller than the Northern/Central European ports incentives to expand. Investments have been carried out and further investments are planned until 2020. This means that the Mediterranean ports can be an attractive solution, regarding transport costs and the environmental impact, at least for shippers and receivers in destinations in Southern and Eastern Europe.

Ports	**Gross Weight of Goods handled in Ports [1000 Tons]**		**Growth rate from 2005 – 2015 [%]**
	2005	2015	
Antwerpen	145,835	190,107	30.4
Bremerhaven	33,728	49,753	47.5
Peiraias	18,688	38,322	105.1
Algeciras	55,186	79,374	43.8
Valencia	34,990	57,557	64.5
Trieste	43,355	49,137	13.3
Riga	24,421	39,362	61.2
Amsterdam	69,304	98,776	42.5
Rotterdam	345,819	436,942	26.3
Sines	24,929	41,218	65.3
Top 20 ports	1,521,730	1,723,358	13.2
EU ports	3.742,774	3,840,488	2.6

Table 2-3 Growth rate of European Ports from 2005 to 2015. Source: Eurostat 2017a

There are two, to a certain part competing, developments for transports between Europe and the rest of the world. One is that the trend towards larger container ships has favoured the large container ports, e.g. in the Hamburg Le Havre Range, that have comparative advantages in form of high capacity, fast loading/unloading and well-developed Hinterland transport etc. (See also "Larger vehicles, development" in section 2.3.3). There is also the increased use of ports in Southern Europe due to the extension of the Suez Canal.

The synchromodality concept aims to combine several modes (road, rail, inland waterway and short sea shipping) when planning a container shipment to a given destination. In the case of a synchromodal transport consignment, modes, routes and schedules may be switched at any given moment according to local conditions (especially transport availability and time restriction on the consignment). This makes synchromodal transport more complex than regular intermodal operations, but the flexibility it creates leads to higher utilization of barges and trains. This helps to deliver higher efficiencies and more environmental benefits at lower transport costs. The Synchromodality concept requires the implementation of new technologies (see section 2.3.3). A serious game has been developed for creating a mind shift in transport planning (Buiel et al, 2015). A detailed description of the Synchromodality concept is given in Appendix A.

The Synchromodality concept has been developed in the Netherlands to cope with the increasing volumes of hinterland transports to and from the container terminals e.g. in the port of Rotterdam. The concept aims to enhance the flexibility in the transport chain, resulting in a more robust network, lower total transport costs and a better environmental performance through a viable alternative to the unimodal road transport (Behdani et al, 2016). Synchromodality also aims at creating the most efficient and sustainable transportation plan for all orders in an entire network of different modes and routes, by using the available flexibility (van Rissen et al, 2015). The concept is likely to improve transport service level, capacity utilization, and modal shift, but not to reduce delivery costs (Zhang and Pel, 2016). An implementation of synchromodal transport requires a form of multimodal planning in which the best possible combination of transport modes is selected for every transport order (Mes and Iacob, 2016) at the level of service provider.

Figure 2-3. Synchromodality concept - Flexibility options for multimodal transport

2.3.3. Technology

In the past, there has been a trend to use high capacity vehicles in all modes; which means that the costs per tonne-kilometre could be reduced by exploiting economies of scale. The high capacity vehicles also contribute to a cost/CO_2 reduction compared to conventional trucks. The carrying capacity of container vessels increased from about 800 TEU (Twenty-foot Equivalent Unit) in the 1950ties to about 18,000 TEUs today (Rodrigue 2017). Only a few ports in Europe can handle the today largest container vessels and there are indications that economies of scale can turn to diseconomies of scale. Rodrigue (2017) sees limitations for vessels with a carrying capacity of more than 8,000 TEU, because some ports cannot provide the infrastructure that is required and do not have the throughput that is needed. International Transport Forum (2015) state that further increases in vessel size could increase the handling costs in the ports and the costs for the hinterland transports disproportionally.

Regarding freight trains, the European project Make Rail The Hope for protecting Nature (MARATHON 2017) has for example developed a 1 500 meters long train. The objective was to generate additional capacity by transporting double volumes using the same train path.

For the future, the development of technological innovation is judged to be different between urban and non-urban transportation (see Figure 2-4). In urban transportation, noise and greenhouse gas emissions reach a dimension, where immediate reaction is needed in order to reduce the negative effects on health and environment. Therefore, for example the electrification of the vehicles and suitable multistage urban distribution concepts are required (FLUXNET-project, see Paul et al. (2017)). The developing approaches for automation of transports will probably take longer time compared to non-urban-transportation, because of the intense interactions with other traffic participants in urban areas.

Regarding the non-urban (long-distance) transportation, the automation is seen as a development until 2030 and is currently discussed for all modes. So far there has been most progress for road transport which gives tentatively comparative advantages for road transports before the other modes catch up. In Sweden, there is a government investigation on autonomous road vehicles with a focus on passenger transport that will be finalized at the end of 2017 (Regeringen 2015). Also, the Federal Ministry of Transport and Digital Infrastructure in Germany start to promote the automation of vehicles (BMVI 2015).

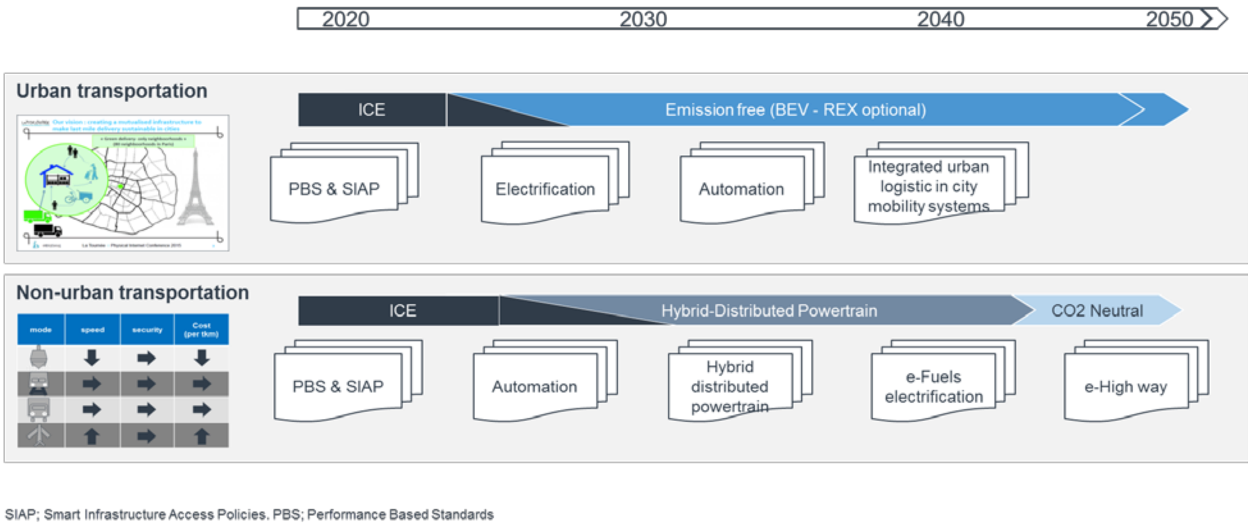


Figure 2-4: Expected innovation in urban and non-urban transportation. Source: MAN

Current innovations like the Mercedes Future Truck or autonomous Volvo-Truck tested in a mine aim for a high-grade automation of the driving process. The potential of autonomous trucks is seen in

- Reduced transport costs due to reduced driver and fuel costs (PWC 2016, Berger 2016). The driver is not needed or can carry out other work during the trip, which also may ease the truck driver shortage in several European countries. Especially on long distances, the trucks can be used more efficient as there is no need to plan for rests.
- Increased safety, system efficiency, energy efficiency and quality (ERTRAC 2015, DHL 2016).
- Increased infrastructure capacity (Friedrich 2015).
- Changes of logistic processes on a medium term (see section 2.3.2).

Truck platooning can give additional benefits. Janssen et al. (2015) find that truck Platooning reduces fuel use by the leading and following vehicles by 10%, with corresponding costs reductions. Sophisticated estimates for labour cost reductions are currently not assessable, because further legislative regulations about the drivers' task while driving in a platoon are needed.

Beside the required technological development, legal regulations must be adopted and infrastructure must be equipped with sensors and communication systems. Large-scale use of autonomous trucks is probably still a long way ahead. In Sweden, experts estimated that the share of autonomous trucks in long distance traffic would be around 10-20% in 2030 and around 50% in 2050 (Kristoffersson et al. 2017).

The development of more energy efficient solutions and alternative energies is seen on a mid-term-perspective until 2035. It is needed to reach environmental and climate goals and not directly related to the transport authorities. One exception is the electrification of parts of the rail network or the road network. Electrification of the long-haul freight transport is challenging because of higher power and energy demands of freight vehicles compared to light duty vehicles for last mile logistics in urban areas and therefore a battery-powered electric vehicle is an unlikely option (Nicolaides et al 2017). For the application of electric vehicles for long-haul freight transport, the electricity has to be provided to the vehicles while they are in motion. First, there is the Inductive Power Transfer technique, where the road infrastructure transfers energy wirelessly to the moving road vehicles. This technology is technically and economically feasible for passenger cars, but the use in trucks is rarely tested (Nicolaides et al 2017). A second option is the catenary technology, where trucks need an electric overhead line. Today, a couple of prototypical sections are built (in Sweden and the USA) or under construction (in Germany), where the use of these hybrid trucks (diesel/electric) is tested. The existence and development of competing solutions, indicate that a larger scale implementation of this technology in the short and medium time perspective is unrealistic.

Within rail freight, there are also first approaches of automation. One example is that shunting locomotive drivers control the locomotive by radio remote control, which increases the safety during the shunting process. Another example are driverless metros in some cities. The automation of the maritime transports is also subject of research projects (e.g. MUNIN 2016).

The private-public partnership Shift2Rail is driving different types of innovations (EC 2014). Their budget is € 920 million for the period 2014-2020. Shift2Rail provides a platform for cooperation that will drive research and innovation activities in support of the achievement of the "Single European Railway Area" and improve the attractiveness and competitiveness of the "European rail system". Activities are organised around (1) cost-efficient and reliable trains, (2) advanced traffic management and control systems; (3) cost-efficient and reliable high capacity infrastructure, (4) IT Solutions for Attractive Railway Services and (5) Technologies for Sustainable & Attractive European Freight. The founding members are the European Union, eight representatives of the rail industry and rail infrastructure managers from the UK (Network Rail) and Sweden (Swedish Transport Administration).

The overall result of a recently performed government commission in Sweden (Swedish Maritime Administration, 2017) is that the potential for domestic inland waterway transports in Sweden is moderate. However, a large potential is seen for international IWW-transport based on loops that tie together Swedish inland and sea ports with other European ports. These types of transports require a new type of small vessel that can go along the coast and has not been developed so far.

The technical development of communication systems facilitates online and mobile data communication. This digitalisation, in form of improved information and communication technologies (ICT) and intelligent transport systems (ITS), is a key for the development of improved logistics- and transport services (e.g. track and tracing) and to develop new digital services e.g. mobile payment systems, cloud services and sharing platforms. It is expected that further technologies like big data analysis or Internet of Things (see below) will increase the digitalisation of logistics processes and driving new business models (DHL 2016). Even today, digital technologies are used in warehouses (e.g. smart container, intelligent shelves or warehouse robots) or for 3-d printing (Rohleder 2017). The improved communication systems establish also the basis for the Physical Internet concept (see below). But digitalisation also comes with challenges for the transport sector, such as high requirements regarding data security and privacy.

The interconnection of physical objects with each other and goods with the logistic system is a quite new aspect. It has to be distinguished between a) the Internet of Things (IoT) and b) the Physical Internet (PI). The Internet of Things (IoT) that was developed in the 2000s and is described 'as the networked connection of physical objects' (DHL 2015). This means, that every object can send, receive, process and store information – for example within logistics processes (DHL 2016). As a result, the transparency and reliability of logistics operations can be increased and costs can be reduced, due to an automating decision making (DHL 2016). In addition, Peeters and Baeck (2016) see also environmental sustainability possibilities like saving resources and energy. But there are also challenges, which have to be managed for a broad implementation of this concept. For example, for a secure supply chain some data and security issues have to be ensured (DHL 2016) before a broad implementation of this concept. Still, Peeters and Baeck (2016) see the transportation sector as an early adopter of the IoT, because it may help to increase its productivity.

In the Physical Internet concept, goods are transported, handled and stored within a 'Logistics Web' like data in the Internet (Crainic and Montreuil 2015). Goods are encapsulated in smart containers, which are routed across logistic centres and several shipments are coupled into multiple segments between these centres. The PI needs the technology of IoT to enable connectivity between the PI-containers and the PI-system (Montreuil 2012). The PI can share transportation and distribution networks and therefore may increase the utilization of vehicles. To develop a European strategy for research and innovation concerning the PI, the European Technology Platform ALICE was established (ALICE 2017). The platform ALICE is based on the recognition of the need for an overarching view on logistics and supply chain planning and control, in which shippers and logistics service providers closely collaborate to reach efficient logistics and supply chain operations. ALICE will support and assist the implementation of the European research program HORIZON 2020.

2.3.4. Transport policy

Policy measures are related to all modes. Regarding road transports, the European Commission allows the use of trucks up to 25.25 meter and 60 tonnes gross weight for national and international road freight transport on a specific positive net (EU 2015). Spain, Belgium, Netherland and Luxemburg uses trucks with these parameters. In Germany, trucks with a gross weight up to 44 t are allowed within the combined transport and longer truck combinations ('Lang Lkw') are permitted on a positive net. But there are also exceptions. In Finland trucks, up to 76 tonnes are permitted. Sweden allows trucks up to 64 tonnes and has decided to allow trucks up to 74 tonnes on roads with high carrying capacity. Other things being equal, the increase of the weight and/or weight of trucks favours road transports in relation to the other modes. But there are also developments towards high capacity vehicles also for trains and vessels (see section 2.3.3).

In the course of the development of a European Economic Area and international transport relations it is necessary to connect the national networks in order to improve transportation and the competitiveness of companies and nations. Therefore, the Trans-European Networks (TEN), containing transportation (TEN-T), energy and telecommunication, were created by the European Union with the objective to construct the main important infrastructure within the EU until 2030. For the transport sector, nine core corridors were defined, which represent the main long-haul-relations within Europe. The member states are committed to coordinate their infrastructure construction and to finance it. These corridors are also used for piloting new aspects like platooning or IT-guidance.

Regarding the transport infrastructure, the completion of the TEN-T core network (2030) and the comprehensive network (2050) is projected to benefit rail and IWW (inland navigation) and to lead to lower external costs. Within the TEN-T network for rail freight transport, the maximum train length of 750 metres and a maximum of 22.5 tonnes per axle are determined for the year 2030 (European Commission 2011b). To facilitate international rail freight transport, technological barriers like different train control systems need to be addressed as well. Three European guidelines are in force on interoperability of the railways in order to open the rail network to international rail freight services.

Standardization is important in different parts of the transport system, i.e. for vehicle dimensions, containers and other loading units, physical objects and self-routing shipments, data interfaces and a smart infrastructure. Different forms of standardization are possible; performance based standards are one example (Kharrazi et al. 2015).[3] With the implementation of standards, reliable framework

[3] Regulatory principles differ significantly in terms of how quantified and specific they are. At one end, "principle-based regulation" do not include quantified limits and are specified in broad objectives (OECD 2005). At the other end, prescriptive regulations outline specifically how a target should be met with explicitly defined and quantified mandates. Performance-based standards (PBS) lie between the two approaches and typically includes specific performance criteria/measures with quantified required level of performance (Kharazzi et al. 2015).

conditions are given to e.g. manufactures and operators of vehicles (Lemmer 2016). Missing standards can delay or obstruct the implementation of efficient technologies.

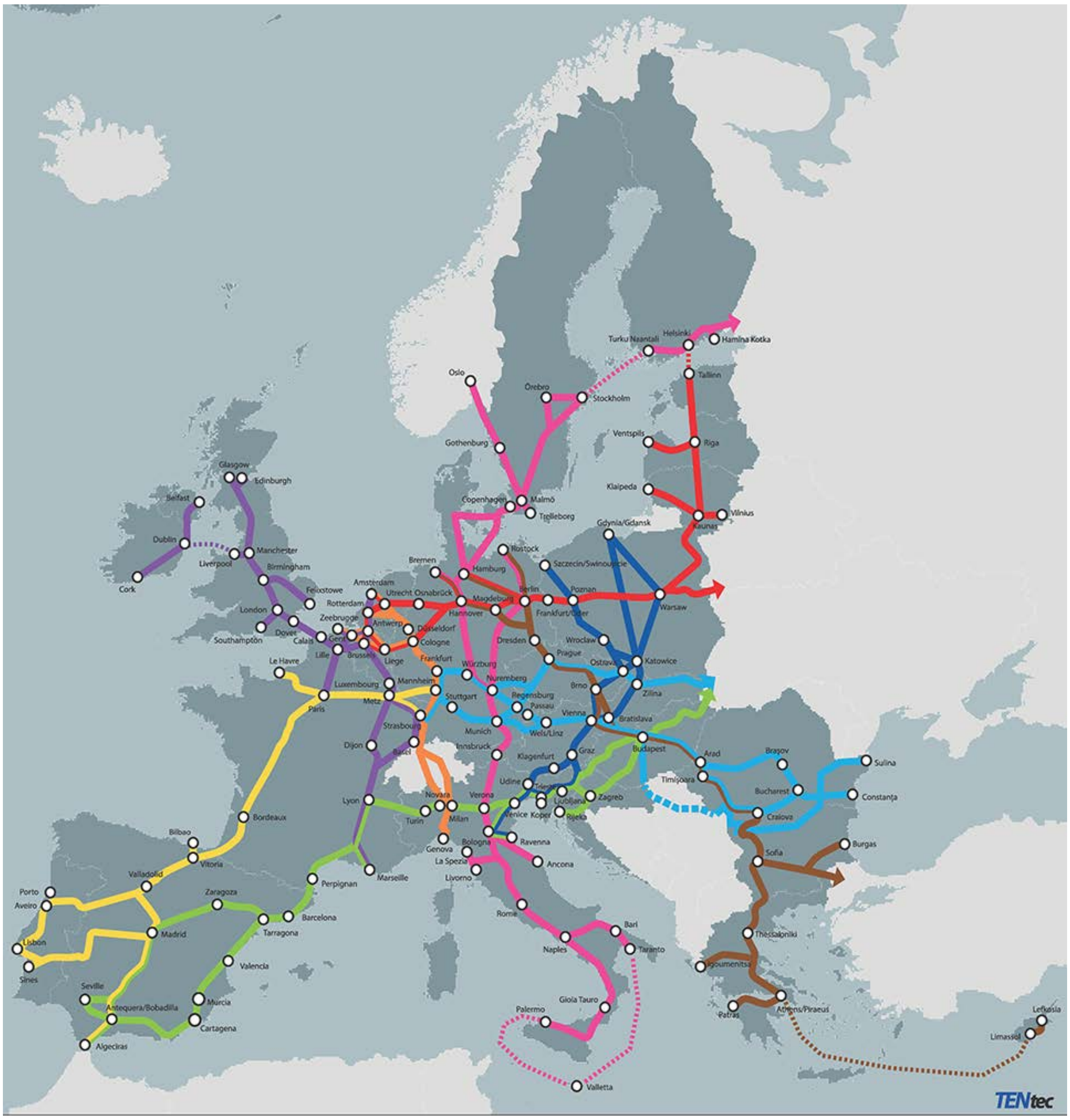


Figure 2-5. TEN-T core network corridors. Source: European Commission (2017)

The introduction of environmental classes (EURO-classes) for trucks in the 1990s has led to a large reduction of the air pollution caused by trucks. Recently, similar regulations have been implemented for the reduction of the SOx emissions (IMO 2017a) and the NOx emissions (IMO 2017b) caused by sea transports. This implies, at least short term, cost increases for sea transports and the possibility of modal shifts from sea to road transport. Both for road and sea transports the use of alternative fuels is a way to reduce greenhouse gases. Different solutions are developed in different countries resp. regions and it is probably not possible to develop fuel distribution infrastructures for all these.

A further internalization of the external costs caused by the freight transports will generally lead to increased transport costs. Infrastructure charges for trucks are regulated in the EU directive 1999/62/EG; every member state is allowed to charge the use of roads by trucks over 12 tonnes gross vehicle weight. In 2006, the directive was revised and included trucks over 3.5 tonnes gross vehicle weight. The introduction of distance based road user charges for heavy trucks in more European countries will increase the costs for road transports, especially in those countries, among others Sweden and the Netherlands that have time-based infrastructure charges today. A standardization of road tolling systems for trucks appears desirable.

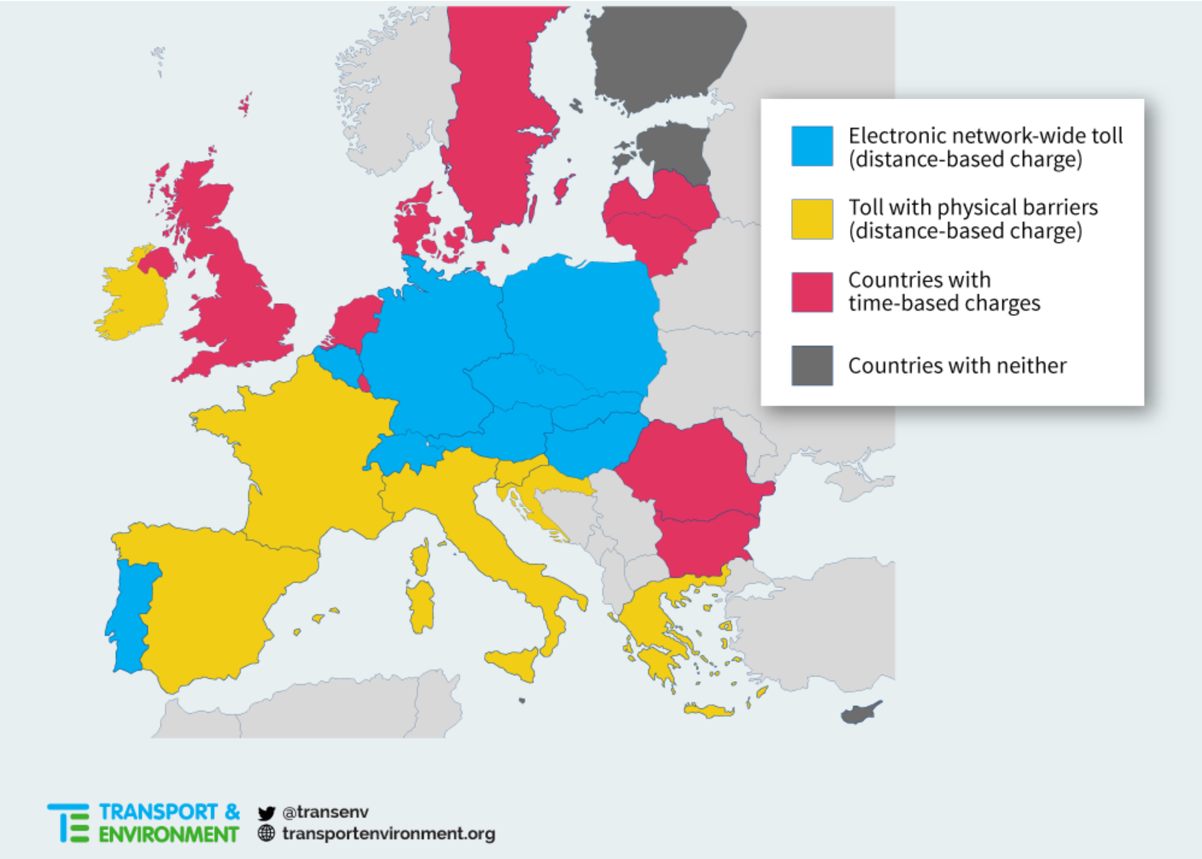


Figure 2-6. Charging Heavy Goods Vehicles in the EU. Source: Transport & Environment (2017)

2.4. Conclusions

In section 2.2 we described that the ongoing trends towards higher transport demand and higher logistical requirements from the different types of customers are expected to continue till 2030 resp. 2050. This is due to an increased population, more international trade, solutions like E-commerce that make shopping easier as well as higher requirements to recycle products. Regarding international trade, the re-shoring of production from overseas to Europe, BREXIT and the increased consumption of regional products and sharing products and services lead to less international trade and transports. However, these factors are assumed to be of minor importance at least in the short term.

As shown in section 2.3 the developments above lead to increased requirements on the transport system, namely the firms that provide logistics and transport services, their personnel, the different vehicles and energies used and the transport- and ITS-infrastructure. The main developments in the coming years are seen in: 1) Changing demand for logistics like shorter order times, need for high flexibility of transports, small shipment sizes, increasing need for reverse logistics, 2) Emerging new logistic concepts and requirements like E-Commerce, Freight exchanges and the specialisation of Logistics, 3) Upcoming IT-related technical solutions, which foster the supply of logistic services and 4) Intensified orientation of the European Transport Policy towards a sustainable multimodal transport.

Already today there are bottlenecks in parts of the infrastructure that cause congestion and waiting time for passenger- and freight transports. Today's transports cause also external costs in form of greenhouse gases, air pollution, noise, accidents etc. These costs increase, other things being equal, when transport demand increases. Online freight exchanges are a tool that can be used to achieve a high degree of utilisation of all vehicles. Technical solutions for the Internet of Things and Physical Internet may change the supply of logistic services on a longterm horizon until 2040 to 2050.

The transport system has large challenges in the coming years. Different technical solutions are already used in some countries (longer/heavier trucks) or ready to use (certain alternative energies, digitalization) or under development (automation of vehicles, Internet of Things, Physical Internet etc.).

The review of the trends shows that it is necessary that several requirements are fulfilled before e.g. a new technology is implemented at a larger scale. The use of autonomous trucks requires e.g. investments in the infrastructure (sensors etc.) and digitalization to be able to develop new logistics concepts. Often policy measures are needed to achieve desired solutions.

The size of the trucks, trains, barges and vessels is expected to increase further. Typically, larger vehicles put higher requirements on the infrastructure. On the other hand, the use of larger vehicles can lead to a more efficient use of the infrastructure (fewer larger trains need fewer slots) and less external costs per tonne-km. This development is however questioned for container vessels as they may have reached their maximum.

The exploitation of economies of scale for container vessels has contributed to a concentration of the overseas ports in Northern/Central Europe and in some cases to capacity problems in the hinterland connections. The Synchromodality concept system that has been developed for the port of Rotterdam and is now finding wider application, uses all available modes and can be adapted in other ports. Increased use of sea transports can also be used to reduce infrastructure and external costs; the extension of the Suez Channel has led to investments in South European ports that will influence port choice and transports on hinterland connections in Europe.

Especially for long distance transports, it is obvious that all modes are needed - one by one and in combination. The efficiency of the rail transports is improved permanently; major innovations of EU's Shift2rail initiative (2014-2020) are probably in place after 2020.

3. Firms' Mode Choice

3.1. Introduction

This chapter contains a literature survey and a set of case studies to give an overview of the factors influencing firms' choice of transport solution and mode. The survey covers grey literature and peer-reviewed articles and is focused on recent evidence from European countries.[4] The case studies consist of in-depth interviews with freight agents. It is useful to start with a brief description of the logistics process and the considerations that must be taken when analysing this topic.

When considering firms' modal choice, it is important to note that there are various ways in which transport modes can be combined. In this handbook, we therefore treat the mode choice as a selection of transport solution that involves the choice between different unimodal options and various combination of modes. In the latter case, the choice entails a decision on how intensive (e.g. in tonnes, tonne-km or the number of legs) the different modes are to be used in a transport chain. Box 3.1 provides the terminology for various transport solutions.

Box 3.1 Terminology of transport solutions

Unimodal transport simply refers to the situation where a single transport mode is used (without any transshipment). Sub modes (i.e. small and large trucks) can be used and goods can be consolidated in terminals. **Multimodal transport** is defined as "carriage of goods by two or more modes of transport."

Intermodal transport is defined as "the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes." Intermodal transport can therefore be said to be a particular version of multimodal transports.

Co-modality refers to the efficient use of different modes on their own and in combination.

Source: UNECE (2001), EC (2006)

Because supply chains involve several stake holders, it is not always evident from outside who is responsible for selecting the transport solution. The decision-makers that can be involved in the movement of goods include shippers, freight forwarders, third- and fourth party logistics providers, carriers (or hauliers) and receivers of the goods. Shippers are producers of the goods that need to be delivered to the receivers, who in turn use the goods for processing, final sale or consumption. Shippers may perform their transports in-house (on own account) or contract out either their transport operations or all their logistics activities to service providers. These companies include freight forwarders as well as third- and fourth party logistics providers.[5] Carriers (or hauliers) are contracted by shippers, freight forwarders or logistics service providers (LSPs) to haul cargo from an origin to a destination (e.g. from a terminal to the receiver of the goods). They include maritime shipping companies, IWW-operators, rail operators and trucking companies.

These firms set requirements to be met in the logistics process, including conditions for delivery, handling, shipment size, frequency, service quality and freight rates. Surveys show that the party

[4] Research on freight modal split has a long history. For reviews of earlier work, see e.g., McKinnon (1987).

[5] Typically, the term third-party logistics provider (3PL) is devoted to firms offering multiple, bundled services, rather than solely transport or warehousing activities (Leahy et al., 1995), while fourth-party logistics providers (4PL) offer supply chain co-ordination rather than operational services (van Hoek and Chong, 2001). However, the literature offers different and sometimes conflicting definitions of these terms.

determining the transport solution varies between agreements (Lammgård 2007; Lammgård et al. 2013; Andersson et al. 2016). The choice of transport solution and mode can therefore be thought of as being determined by the interactions between freight agents, and the conditions and requirements that they set. The aim of this chapter is to identify and describe these factors and their influence on mode choice. It is crucial to understand that the importance of these factors varies greatly across firms and depends on several aspects, including commodity class, trip distance and geographical conditions. We will highlight these differences through-out the chapter.

Figure 3-1 summarizes the content of this chapter. Section 3.2 investigates the importance of shipment attributes. In section 3.3 we look at mode choice from a process perspective at both the strategic and the operational level. This section presents the results from in-depth interviews of shippers and logistics service providers, which shows the influence of organizational and managerial practices within firms. Section 3.4 examines the influence of modal characteristics (cost and transport service quality). It provides set of measures showing the average demand responses of these factors, which can be applied by NRAs in forecasts and other analyses. Section 3.5 briefly reviews additional choice criteria.

SECTION 3.2 Shipment characteristics	SECTION 3.3 Firm organization and management	SECTION 3.4 Modal characteristics	SECTION 3.5 Other choice criteria
•Value •Weight •Volume •Time-sensitivity •Transport distance •Regularity	•Management •Organization •Habits •Attitudes	•Cost •Time •Reliability •Service frequency •Damage risk	•Environmental impact •Customer service •Security

Figure 3-1. Factors that influence firms' choice of transport solution and modes.

3.2. Importance of shipment attributes

It is useful to begin by analysing the importance of shipment attributes and transport distance, as these factors impose restrictions on firms' ability to choose between transport solutions. The importance of these factors stems from the intrinsic qualities of each transport mode. The starting place for the analysis is therefore to review the advantages and disadvantages of the modes.

Surveys of shippers and logistics service providers in Europe repeatedly find that trucks are considered to have an advantage in terms of service frequency, reliability, flexibility and safety compared to rail and waterborne transports (Eurogroup Consulting 2014; Grønland et al. 2014; Ludvigsen 1999; Grue and Ludvigsen 2006). This is confirmed in behavioural studies showing that road transport is more likely to be chosen by the logistics operators, shippers and transport managers that value these factors the most (Beuthe and Bouiffioux 2008; Bergantino et al. 2013; Feo et al. 2011; Jiang et al. 1999). The attractiveness stems from the virtually limitless ability of trucks to reach almost every customer and to adjust to sudden variations in traffic and demand. The alternative modes can be restrained by pre-determined schedules and rail transport often has fixed capacity (Reis 2014; Tavasszy and Meijeren 2011). In addition, country-wide surveys consistently find a low satisfaction with rail transport infrastructure and service in European countries (Arvis et al. 2016).

Rail and waterborne transports have superior vessel and vehicle capacity and are the most competitive when economies of scale are realized and transport cost is reduced. The additional advantage of waterborne transport, especially short sea shipping, is that it is typically not restricted by network capacity (as rail transport is). Air transport is safe and fast but usually the most expensive transport mode. Table 3-1 summarizes the advantages and disadvantages of each transport mode.

	Road	Air	Rail	Waterborne
Speed	Medium-high	High	Medium	Low
Load capacity	Low-medium	Low	Medium-high	High
Damage risk	Low	Low	Medium-high	Medium-high
Flexibility	High	Medium	Low	Low
Reliability	High	Medium	Low	Medium

Table 3-1. Comparative advantages of transport modes. Source: STA (2012)

The comparative advantages favour certain commodity types. Road and air transports tend to attract time-sensitive goods and products with high value-to-weight ratio (Eurostat, 2017b). These products are associated with higher cost of storage and damage and will favour fast, flexible and reliable modes. Rail and waterborne transport dominate the market for heavy bulk goods such as coal, petroleum and natural gas (Dionori et al., 2015). These items make it easier to realize economies of scale and are less sensitive to time and damage.

The capacity differences of the vehicle/vessel types within the modes mean that shipment size (in terms of volume and/or weight) is a determining factor in mode choice. A long stream of articles has recognized the importance of shipment size and show that the mode choice entails a simultaneous decision on how much to ship and which modes to use (McFadden et al. 1986; Inaba and Wallace 1989; Abdelwahab and Sargiuos 1992; Holguin-Veras 2002; Johnson and de Jong 2011; Combes 2012; Abate et al., 2016). Small shipments are typically transported by road or air and large shipments by rail or waterborne transports (Tavasszy and de Jong 2014). Waterborne and rail transports are not considered competitive options for small shipments unless they are consolidated (Garcia-Menendez and Feo-Valero 2009; Feo-Valero et al. 2011a).[6]

Figure 3-2 illustrate these findings by showing the modal share of inland transport (road, rail and inland waterways) for the EU-27 in 2012. Road transports completely dominate transports of food products, machinery and equipment, mail and parcels, furniture, textiles and textile products. Rail and inland waterway transport have sizeable market shares for metal ores, coke and refined petroleum products, coal, crude petroleum and natural gas. Sea transport is excluded from these figures but generally attract similar type of goods as rail and IWW (Transport Analysis 2016).

The comparative advantages are also distance dependent. The additional transhipment and loading cost associated with waterborne and rail transport cannot be compensated for by lower transport cost if the transport distance is too short. Similarly, the speed of air transport cannot be utilized on shorter distances. This means that road transport is the dominant mode on shorter distances (below some 300 kilometres) (as indicated in de Jong 2003; Beuthe et al. 2001; Beuthe et al. 2014; Notteboom 2011; Rich et al. 2011; EC 2011). This can be short door-to-door road transports in unimodal road chains (potentially involving consolidation in a road terminal), or transports to and from terminals in multimodal chains. Conversely, rail and waterborne transport are generally only competitive alternatives for longer distances, except for large and regular freight volumes (McKinnon 2015).

[6] Consolidation means that consignments from one shipper or different shippers are grouped together to a single, large shipment, and is normally organized by forwarders.

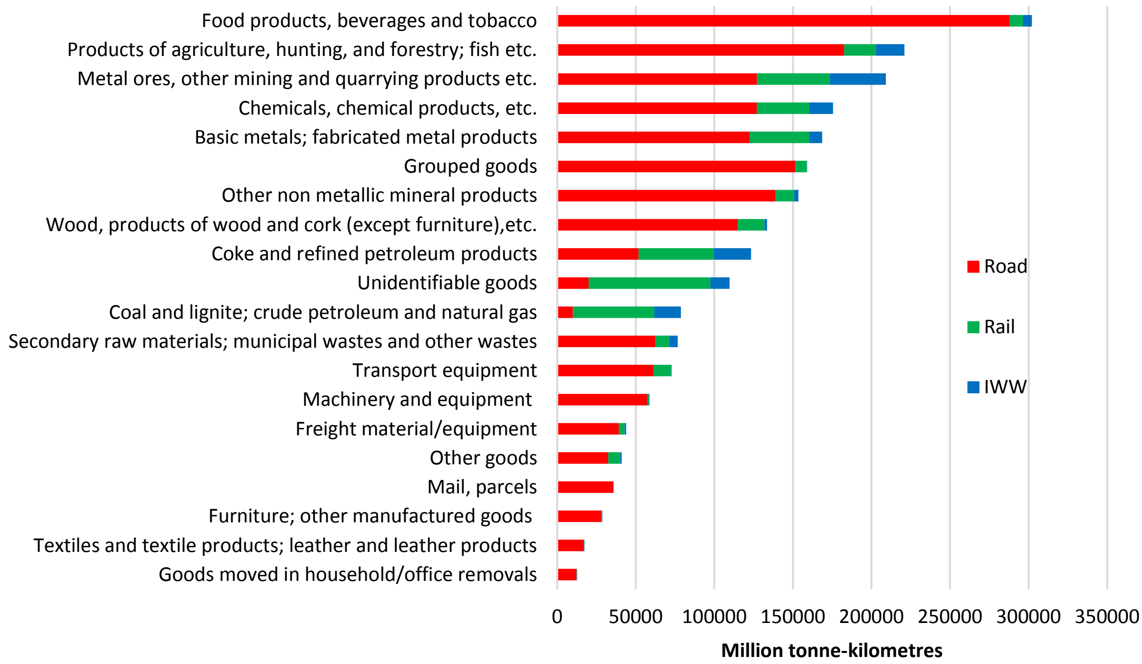
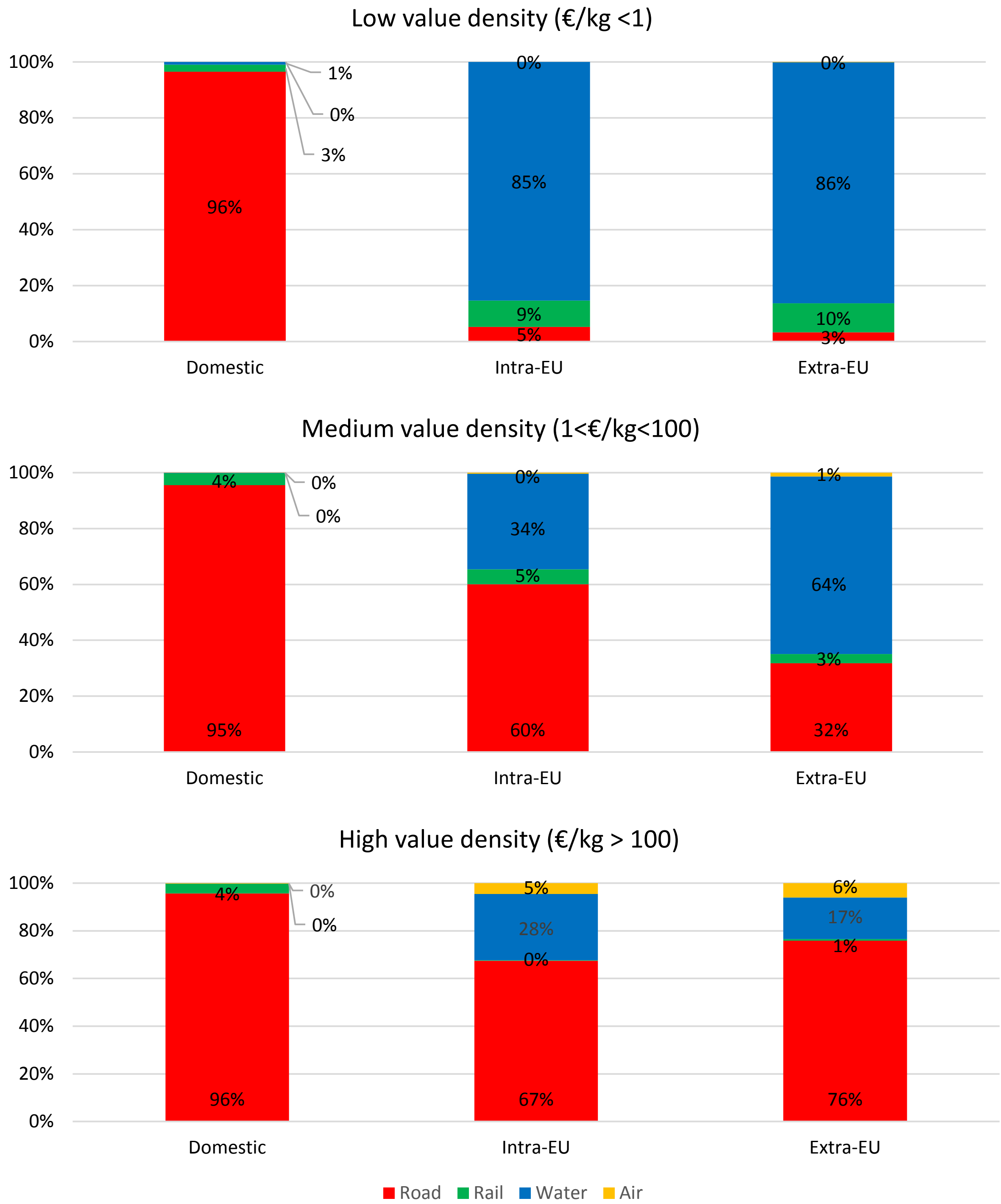


Figure 3-2. EU27 modal share of inland transport in 2012, by commodity. Source: Eurostat (2017b)

Figure 3-3 show modal shares in tonnes for different categories of value density and regions in which the transport took place (domestic, intra-EU and extra-EU). The figures are based on the shipments in the 2009 Swedish Commodity Flow Survey. It has not been possible to derive corresponding information from the CFS 2016 (that has been published 29 June 2017, www.trafa.se/varufloden/).

The figure is informative of the degree of competition between the modes within the different market segments. In comparison to Figure 3-2, it accounts for both product characteristics (value density) and transport region. Figure 3-3 shows that trucks are widely dominating for domestic transport, irrespective of value density. Rail transports are used for low density products, both for domestic and international shipments (intra- and extra-EU). Waterborne transports are used for international shipments, particularly for low- and medium value density products. Air transports are used for international shipments of high-value products. It should be noted that the data are taken from Swedish companies from certain sectors (forestry and logging, crop production, manufacturing, wholesale and retail trade) which may limit the generalization to other settings (Transport Analysis 2011).[7]

[7] See Savy (2009) for a similar discussion about modal competition on the European level.



Note: Value is defined excluding VAT and transport cost, weight is defined net of packaging. SEK converted to EUR through rate 1 SEK = 0,1 EUR. Domestic = origin and destination within Sweden, Intra-EU = origin or destination in another EU country, Extra-EU = origin or destination in country outside EU. A mode is considered as being selected if it is part of a transport chain or the only mode used for the transport.

Figure 3-3. Modal shares (in tonnes) in Sweden by value density and region. Source: CFS 2009

Table 3-2 summarizes these results by showing the dominating distance classes and shipment characteristics for each mode.[8] Numerical values for the intervals can be found in Appendix D. There are three main implications of these findings. First, for some transports, the distances class and shipment attributes are such that firms are captive to a single transport solution and have limited possibility and incentives to substitute to other solutions. Determinants of mode choice such as transport cost and time will then have limited, if any, impact on the transport decision. Firms who can substitute between transport solutions make up the contestable market in which the modes compete.

Second, the degree of competition between modes (including combination of modes) is different depending on the distance class and shipment characteristics. For instance, sea transport may only compete with air transport for shipments between Europe and China, but face competition from road, rail and barge transport over intra-EU-shipments.

Third, differences in the commodity mix and transport distances explain some of the country-differences in modal split (see Figure 5.1 below) and modal competition. To the extent that international transports are taking place on longer distances compared to domestic transports, there will be more favourable conditions for rail, waterborne and air transport in exporting and/or importing countries. Countries in which shippers are transporting heavier and less time-sensitive commodities are also more likely to benefit rail and waterborne transports. As will be shown in section 3.4, shipment attributes and transport distance also influence how much weight firms assign to cost and transport service quality.

	Road	Air	Rail	Waterborne
Value density	Medium-high	High	Medium-low	Low-medium
Weight	Low-medium	Low	Medium-high	High
Volume	Small-medium	Small	Medium-large	Large
Time sensitivity	Medium-high	High	Medium-low	Low
Distance class	<300 km	>300 km	>300 km	>300 km

Table 3-2. Dominating distance and shipment attributes by mode. Source: Brogan et al (2012)

3.3. Importance of firm organization and management

In this section, we look at mode choice from a process perspective at both the strategic and the operational level. We develop a framework of organizational and behavioural mode choice processes and then apply it to six case studies conducted for this handbook. The case studies consist of in-depth interviews with logistic and general managers and planners from shippers and logistic service providers (LSPs). We analyse how the mode choice is made, whether sustainability is considered in the choice process and how firms think public authorities influence the mode choice.

3.3.1. Framework of organizational and behavioural mode choice processes

On an individual level, any making of a decision always has its restrictions to a certain degree, either in terms of the availability of a limited number of alternatives of choices, *cognitive* limitations of an individuals' mind, or limited time to decide (Simon, 1972). Human behaviour can be said to be regulated by i) behavioural beliefs which produce an *attitude* towards the behaviour, ii) normative beliefs which result in a *subjective norm* and iii) control beliefs which give rise to *perceived behavioural*

[8] Table 3-2 should serve as a rule-of-thumb over the segments for which different modes tend to dominate. There are of course instances where modes are being used in segments where another mode dominates.

control. The combination of these lead to the formation of a behavioural *intention* (Ajzen, 1991), which may be overruled by habits that lead to automatic behaviour (Aarts and Dijksterhuis, 2000).

On a company level, organizations develop a company mission, vision and strategy that helps the company to go in the direction that suits its characteristics, features and network demands. The company strategy will be translated into a supply chain management (SCM) strategy, which again will be translated into goals, which are made measurable with key performance indicators (KPIs). This idea of translating a company strategy into measurable KPIs can also be found in the balanced scorecard developed by Kaplan and Norton (1992), see Figure 3-4.

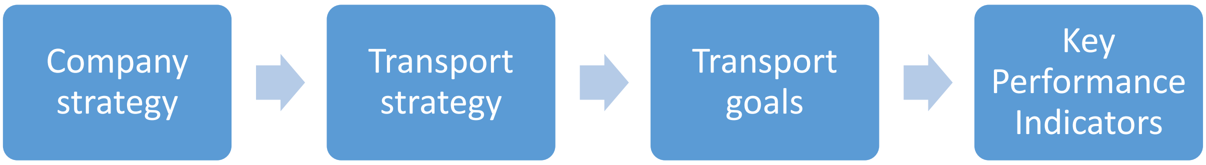


Figure 3-4. Strategy deployment

In other words, here we consider mode choice as the result of a behavioural choice process from an individual (with attitudes, beliefs, habits and limited rationality) and that an organization is expected to influence their employees to act in line with its strategy. These two processes (organizational and personal) occur at both the strategic and the operational level. The framework in Figure 3-5 puts the two processes and levels together and will be used to analyse our case studies.

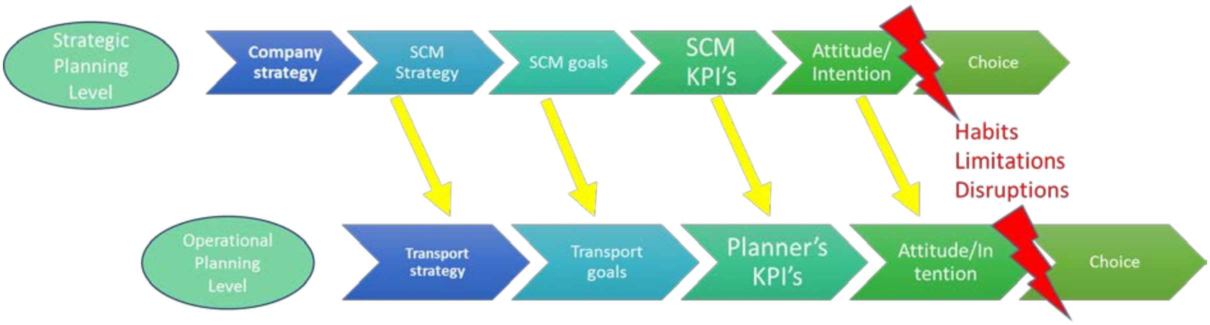


Figure 3-5. Framework of mode choice process

3.3.2. Case studies

Seven people employed by international operating shippers (4) and LSPs (3) in the Netherlands were asked about i) how the choice of transport solution was made, ii) the presence of an organizational strategy for sustainable mode choice and iii) their view on how public authorities influence the choice of multimodal transports. These companies were selected because they represent a mix of large and small sized companies, LSPs and shippers, active and more passive in their mode choice and, obviously, willing to cooperate with this research.

Shipper A

Shipper A is a manufacturer of fast-moving consumer goods in the Netherlands and serves its customers (mainly retailers) in the Benelux countries and the Scandinavian market. The respondent in the case study is a supply chain analyst for operational and strategical issues.

Shipper A organizes the transport for some of its shipments. They most often opt for trucks, which is very much governed by the way the company has been operating in the past. It is also experimenting with using barge for inbound shipments to the port of Rotterdam. The shipper also contracts LSPs to perform the transport for some of its shipments. In these cases, the shipper specifies the load locations, destination and required service level and selects the LSP that can offer a solution that fits the requirements to a reasonable price. The modes being used are of little importance to the shipper as long as the requirements are met.

The company has a strategy on sustainability that includes reducing their carbon emissions by at least 20%, and aims to achieve this by combining inbound and outbound flows. The respondent thinks public authorities should inform shippers of their plans pro-actively and bring together the shippers when they develop new plans.

Shipper B

Shipper B is a large European manufacturer of frozen fast-moving consumer goods that supplies restaurants and supermarkets. The company has inbound flows of raw material and outbound flows of temperature-controlled products. The production logistics and physical distribution is organized from the Netherlands and they contract over 50 LSPs. The respondent is a transport manager.

Shipments within Europe are mainly transported by road. Shipper B is considering intermodal transports for shipments to the UK but their volumes are not large enough for the company to set up an intermodal solution by itself. For this reason, the company and its LSPs are investigating how they can combine flows with other producers in the areas that Shipper B is located in. Shipments to Sweden used to go by road until Shipper B sat down with one of the LSPs and requested their shipments to be transported by rail. This was a shift in the mentality and habits of the LSP and required that Shipper B and LSP set up a system of rail transports three days a week.

Barge is used for some of the shipments going to destinations outside Europe. This was made possible because of increasing volumes to non-European markets and because the company was assisted by the “Bureau Voorlichting Binnenvaart”, a Dutch information agency that acts as an intermediary for all questions concerning inland waterway transport. The respondent thinks the biggest challenge for intermodal solutions is that they require high volumes. Shipper B is therefore looking for ways to bundle flows and considers combining their shipments with those of other shippers. However, the respondent worries about gain sharing and possible violation of competition law and thinks that more potential lies in Chross Chain Control Centres (4C), platforms where companies meet, share technological expertise and get involved in a range of supply chain planning activities.

Shipper B has a sustainability strategy and a goal to raise the share of shipments sent by barge from 20 % to 60-70 %. The company also takes part of a “Lean & Green”-programme[9] that brings together shippers and LSPs and challenge them to consolidate loads and use multimodal solutions. The respondent aims to use intermodal solutions for trip distances above 700 kilometres. He thinks it is not only a challenge to convince employees and LSPs about new transport solutions, it can also be difficult to convince the customers. Some are open to intermodal solutions with longer lead time and see the advantage of planning ahead. Others are used to receiving the delivery the day after ordering

[9] Lean & Green Europe is an international community of organizations working on solving complex sustainability challenges in logistics. Carbon dioxide reduction targets are achieved through data analytics, innovation collaboration and elimination of inefficiencies.

it and oppose longer lead time because they want to keep their stock levels low. For these customers, he reasons, changes must come gradually and not from one day to the other.

The respondent thinks public authorities should include environmental costs in the pricing of transport modes, preferably on European level. This would push people to use more sustainable transports, he reasons, because transport is all about the cost and money is the strongest incentive.

Shipper C

Shipper C is a manufacturer of high-tech materials used in the construction and wind power industries. Its products are distributed from the factory in the Netherlands to countries in and outside Europe. The respondent is responsible for outgoing transports.

The modal choice is made by the LSPs that the company contracts. Shipper C specifies the delivery requirements and information about the shipment and the LSPs in turn offer a transit time and rate. To Shipper C, the transport solutions being used is of little importance as long as the conditions for cost and lead time are met. Transport cost is viewed as the most important choice criteria at the strategic level, while transport service is more favoured by managers at the operational level.

Road transport is the dominating mode for shipments within Europe. Shipper C would be interested in being offered transport solutions that are more sustainable and cheaper but have longer lead times. They could then negotiate with their customers about using these options. Global shipments are mainly transported by road and waterborne transport and sometimes by air. Shipper C compares freight rates regularly each month. However, if the customers place rush orders they also pay for air freight which is why Shipper C does not spend much time comparing the cost for air transport. The shipments that go by barge or truck are usually paid by Shipper C and the costs of these modes require more attention.

The company does not have a strategy on environmental sustainability. According to the respondent, more sustainable transport solutions are possible if they also reduce transport cost. Hence, cost is the most important incentive for Shipper C to use multimodal transports. If public policy would make such solutions cheaper and more cost effective compared to trucks, shipper C would go for these options. According to the respondent however, the local authorities have not engaged actively in the region where the company is located to stimulate sustainable transports.

Shipper D

Shipper D is a world-leading manufacturer of consumer products. It distributes 5000 shipments annually from its factory in the Netherlands to the markets in the UK, Germany and Benelux countries. The respondent is a supply chain manager at the company.

The modal choice is ultimately made by the LSPs that the company contracts. The services are procured each year in a process where Shipper D specifies its yearly freight forecast and requirements and then selects five LSPs based on their offers. Each LSP is guaranteed a yearly volume but otherwise compete for the company’s shipments through a bidding scheme. A transport planner at shipper D place daily orders in a software system that the five LSPs have access to and the LSPs in turn offer their freight rate and service level for the order. Shipper D selects the bid with the lowest rate, given that it meets a sufficiently high service level. Shipper D is not concerned about the modes being used as long as the specified pick-up time at the factory and the loading time at the receivers are met. If an intermodal solution would entail the same service quality to a lower cost, shipper D would select it.

Road transport is used in 90 % of the cases. One reason is that high daily volumes and limited storage capacity the service frequency of trucks makes them competitive. Another factor is the occurrences of rush orders to meet the customers' requests. Intermodal solutions are used for shipments between the Netherlands and the UK. Trucks are used from the factory to an inland terminal, thereafter barge to the port of Rotterdam, short sea shipping to the UK, and then road transport for the last leg. Shipments to Italy are transported by road because the company lacks adequate access to rail.

Although the company lacks a sustainability strategy it still wants to reach environmental targets and have agreed on a 20 % energy reduction with one of their LSPs. They aim to reach this goal by using a newly built warehouse which is much more energy efficient than the old one. No sustainability key performance indicators (KPIs) are measured, except for KPIs on waste and utilization rates. The respondent holds a strong positive attitude towards sustainability and found that more sustainable alternatives must come with cost savings in order for the mangers at the strategic level to consider them.

The respondent thinks that public authorities could increase the scope for multimodal solutions by providing rail terminal infrastructure closer to their factory. He also thinks that the company would react to taxes on road transport or other measures that make trucks less appealing. The local authorities want the area to be a logistical hotspot, but just offering a piece of land to build a warehouse on will not be sufficient according to our respondent. He calls for the authorities to provide multimodal terminals and secured areas for international truck drivers.

Logistics service provider A

LSP A is a small-to-medium-sized company with two facilities in the Netherlands. It is mainly operating in the road transportation segment with its core business as a courier (express). LSP A has its own trucks and contract third parties for air, sea and rail services. Its customers are mainly located within Europe. The respondent is the founder of the company and makes decisions at the strategical level.

The company makes the mode choice based on the customers' requests. Many are last-minute orders and trucks are therefore chosen because they are the fastest alternative and time pressure favours habitual choices. The location of LSP A does not give much room for other modal choices for domestic shipments. The scope for alternative solutions is wider for international shipment and LSP A use intermodal road/rail combinations for shipments between the Netherlands and the UK. LSP A also favours road transport because they have their own vehicles. When their customers want the shipments to be sent by barge or rail, LSP A contracts third-party logistics companies to meet these requests. But the company prefers to carry out the transports themselves using trucks so they can control the level of service.

LSP A tries to optimize and consolidate their courier transports but they still have runs of empty vehicles, partly due to uncertainty in transport forecast planning. The company may start with ten trips scheduled for a day but end up with 35 as the customers call them the last minute. LSP A also tries to downsize their vehicles. If the customer requests a truck for a shipment of one pallet, the LSP makes sure to ask about the weight and volume and advices the customers on alternative, smaller vehicles. The customers are also offered transport solutions that include non-road modes, which have longer transit time (e.g., three days instead of one) but lower rates.

The company does not have a strategy or KPIs on environmental sustainability. It is still open to alternative transport solutions, like electrical vehicles, which they would favour as long as they could drive 500-800km without having to be charged. The company also wants to open new facilities and thereby increase the possibility to consolidate goods and avoid empty vehicles on roads. It tries to increase the use of multimodal solutions, given that they meet the time frames that their customers request.

According to the respondent, public authorities could make multimodal solutions more cost-efficient and more easy to use by increasing the availability of rail infrastructure and promote the multimodal concept by information and practice sessions.

Logistics service provider B

LSP B operates in the global forwarding, supply chain and distribution segments and offers various transportation services, including import and export for customers in Europe. They operate their own vehicle fleet and contract third parties for shipments by air, sea and rail. The respondent is a managing director.

LSP B makes its mode choice based on the customers' requests and in 90 % of the cases the customers opt for road transport. Rail or barge would typically entail two extra days of transport time and in many instances they are not even the options with the lowest freight rate. In addition, rail transport suffers from capacity problems and IWW from problems associated with too low or high water levels. LSP B prefers rail transport because of the cost savings. The rail operator will pick up a container the first or second day after arrival and bring it to the inland depot which results in no extra charges from the port. Going by truck directly from the port, the client has two hours to load/unload the container and is charged extra if that time is exceeded. The company has a policy of advising its customers to use rail or barge if the shipment is located near an inland terminal and includes cost and transit time information in the advice. In most cases, the customers still opt for road transport. The respondent thinks that better planning from the customers' side would increase the scope for using other modes than road.

The respondent called for a reduction of the costs related to the transportation from new sea terminals. The additional cost is €100 (€50 each way) and in a small country as the Netherlands where you have to pay (roughly) around €1 per km, trucking gets a cost advantage.

Logistics service provider C

LSP C has its core business in road transportation of small consumer products (up to seven parcels and up to three pallets) and also provides last-mile distribution, cross-docking[10] and transports of temperature-controlled health care products. The first respondent is a manager at the strategic level and the other is a transport analysist at the operational level.

Because of the short duration between the cut-off-time and delivery planning, and the fact that they are distributing in cities, road is the only feasible transport mode. The need for short transport time prevents the company from using rail or waterborne solutions even for long-distance transport. Air transport would meet most of the requirements for the long-distance transport but is too expensive to compete with direct road transport.

The company has two city hubs with electric vehicles and are expecting to expand this to other cities. Although the hubs do not generate any profits, they are important for showing that LSP C is a green company that can provide "smart logistics" for its customers. According to the respondents, profitable

[10] Cross-docking is the practice of unloading materials from an incoming truck or railroad car and loading these materials directly into outbound trucks or rail cars with little or no handling or storage in between.

city hubs are difficult to realize because of challenges to collaborate with other LSPs and lack of subsidies.

Case studies conclusions

Table 3-4 summaries the results from the case studies. One important lesson is the many differences between companies in how they reason in their selection of transport solution. Some are influenced by their customers' requirements, last-minute requests and limited storage capacity, while others mention availability of rail infrastructure or ownership of a vehicle fleet as weighing in on the mode choice. The choice of transport solution is also tied to differences in production and distribution chains. Rail and waterborne services often requires large volumes, which can be obtained by bundling flows within a firm or between firms. Selection of other modes than road may have to be coordinated with other changes in the supply chains, like having the receivers accepting longer lead times.

How is choice of transport solution made?	In most cases logistics service provides (LSPs) are contracted by shippers who specify the details of their shipment (such as destination, load locations, transit time). The LSPs in turn offer a freight rate and transit time associated with a transport solution. The shippers assess the offers from the LSPs and selects one option. Cost is often the most important choice criteria, given that the transport service requirements are met. The shippers generally put little weight on which modes are being used as long as the specified conditions are fulfilled. Road is the most commonly used mode, both when the transport is organized by the LSP and by the shippers. Trucks are chosen because they have the lowest freight rate, due to last-minute request so that the speed and flexibility of trucks can be utilized, because of limited storage capacity so that the service frequency of trucks makes them attractive, because of time pressure/habitual choices, poor rail infrastructure availability and because the LSP operates its own vehicle and wants to have control over the service level of the transport chain. Rail and waterborne services are more likely to be chosen when freight volumes are large and/or regular or when customers accept longer lead times.
Are there organizational strategies or KPIs for sustainable mode choice?	Some companies have a sustainability strategy but in neither of the cases are there key performance indicators relating to sustainable mode choice. The sustainability measure that companies do take are mainly aimed at higher efficiency (by combining flows, improving energy efficiency in warehouses or increasing utilization rates). Some companies also participate in logistics platforms with similar targets.
How do the respondents think public authorities can influence mode choice?	Internalize the environmental impact in the pricing of the modes, increase the availability of (rail) infrastructure, reduce terminal fees, pro-actively inform about public measures, include firms in the development of new plans and spread information about multimodal solutions.

Table 3-3. Summary of case studies

The respondents also discuss a range of choice criteria that influence their choice of mode, including transport cost, transit time, flexibility, frequency. Cost is generally cited as the most important one, although requirements on service quality (like speed and reliability) must typically also be met. But the sensitivity to cost can differ depending on transport solution. For some shipments, the shippers themselves pay the freight rate and therefore look more actively at cheaper options. In other instances, the receiver pays the rate and the shipper has less incentives to look for lower rates.

There are also signs that habits and disruptions interfere with the choice of mode. Receivers are often accustomed to specific requirements and typically unwilling to accept the longer lead time of intermodal solutions. Time is often a constraint among shippers and last minute requests from customers are common. This makes it challenging to use intermodal transport. Rush orders to meet customers' request lead to time constraints which favour trucks.

Because case studies only investigate the conditions for a limited sample of firms there is some uncertainty in the generalizability of the results. Despite this, many of the conclusions from these cases are supported by similar studies from other countries. Cost is consistently referenced as a top choice criteria (e.g., Grønland et al. 2014) and several studies link supply chain characteristics to the mode choice: stable and large volumes provide good conditions for firms to select solutions that includes rail or waterborne services (Flodén et al. 2010; Transport Analysis 2012; Morales-Fusco et al. 2013). Habits, individual attitudes and perceptions of the modes' advantages and disadvantages is discussed as influencing factors by Department of Transport (2010).

3.4. Importance of attributes of different modes

The previous section highlighted a set of choice criteria that shippers and LSPs cite as important for their mode choice. These criteria essentially describe the transport cost and service quality offered by the various modes. A large body of research confirms that these attributes are important considerations for the choice of transport solution (Grønland et al. 2014; Grue and Ludvigsen 2006; Witlox and Vandaele 2005; Dionori et al. 2015). This section summarizes the importance of cost, time, reliability, service frequency and damage risk. These factors are consistently referenced in the literature and often considered as the most relevant factors (see surveys in Reis, 2014; Feo-Valero et al 2011a; Cullinane and Toy 2000). Section 3.5 briefly describes other modal attributes cited in the literature.

While the previous section provided an in-depth analysis of individual decision-making within organizations, the studies reviewed in this section estimate how aggregate demand for a transport mode respond to changes in a modal characteristic. The influence of modal attributes is summarized by elasticities, which measure the percentage change in demand for a transport mode following a one percentage change in one of the attributes explaining the demand (e.g. cost).[11] The elasticities are interpreted as the influence of each individual factor holding all the other attributes constant.

An own elasticity gives the impact of an attribute of one mode on the demand for that same mode, and a cross elasticity gives the impact on other modes. This makes elasticities valuable for analysing and predicting demand changes for different modes. For instance, an own-price elasticity of -0.5 and a cost increase of 20 % is expected to lead to a decrease of transports by (-0.5*0.2= -0.1) 10 % relative to the current volumes. Box 3.2 provides further details on the interpretation of elasticities.

[11] It should be noted that the cost of transport not necessarily is the same as the price of transport, i.e. the actual freight rate. Since rates are typically unobserved to the researcher, most studies effectively estimate elasticities with respect to transport cost.

The results from the literature are based on discrete choice models, simulations in freight transport models and surveys of stake holders. Information about these methods is provided in box 3.3 (see also Tavasszy and de Jong (2014) for an overview of freight transport models and Train (2003) for a description of discrete choice models). Since variation in methodology and data can lead to different results in the studies under review, we put more weight on findings that are robust to the choice of method and data.

Box 3.2. Elasticity of demand

Elasticities are used to summarize the responsiveness of one variable to a change in another. For instance, an own-price elasticity is defined as the percentage change in the demand for transport mode 1 when the price of mode 1 increases by 1%. Formally, the elasticity is given by:

$$\varepsilon_{11} = \frac{\partial\, Q_1(p_1, p_2, \dots, p_n)}{\partial p_1}\frac{p_1}{Q_1},$$

where p_1 denotes the price of transport mode 1 and Q_1 the quantity demanded of transport mode 1 (at prices p_1, p_2, …, p_n). Own-price elasticities thus answer the question "How much does the demand for transport mode 1 change in response to a 1 % change in its price?" A 1% increase in price leads to a ε_{11}% change in the quantity demanded.

A cross-price elasticity conversely gives the percentage change in demand for transport mode 1 when the price of mode 2 increases by 1 %, and is defined as:

$$\varepsilon_{12} = \frac{\partial\, Q_1(p_1, p_2, \dots, p_n)}{\partial p_2}\frac{p_2}{Q_1},$$

where p_2 denotes the price of transport mode 2 and Q_1 the quantity demanded of transport mode 1 (at prices p_1, p_2, …, p_n). A 1% increase in the price of transport mode 2 leads to a ε_{12}% change in the quantity demanded for transport mode 1. Whereas a disaggregate elasticity measure the response of an individual decision-maker, an aggregate elasticity represents the reaction of a group of decision makers (possibly the entire market). The elasticities presented in this review are aggregate elasticities, since these are more relevant for policy making.

Box 3.3. Estimating elasticities

The elasticities obtained from the literature review are estimated by discrete choice models or derived from simulations in freight transport models.

In freight transport models, the researcher specifies the behaviour of agents in the model by some mathematical formulation and feeds it input data (on e.g., transport volumes, network, cost parameters etc.). The optimal transport solutions, including mode choice, are decided by agents in the model, generally by minimizing logistics cost or through some stochastic choice model. Estimates of the impact of various policy variables are derived by comparing the optimal outcomes under different scenarios. For instance, if the road transport demand is 6% higher in a scenario when road tonne-km cost is reduced by 10%, the implied tonne-km cost elasticity of road transport demand is -0.6.

Discrete choice models relate the modal choice to the attributes of the modes, decision makers, shipments and/or some other characteristics. The models usually rely on raw data consisting of individual decisions or on macro datasets typically constructed by national statistics bureaus. The data can be based on observed choices (revealed preferences) or choices under hypothetical circumstances (stated preferences). The information is used to estimate the probability that a particular mode is chosen and how that probability changes with the attributes (i.e. the elasticity).

The following sections report elasticities for transport cost, time reliability, service frequency and damage risk. Readers who are not interested in the details of the studies may jump directly to the summaries of elasticities in section 3.4.6.

3.4.1. Transport cost

Transport cost refers to the costs that occur as goods are moved from shipper to receiver. To ease the comparison between elasticities, the focus in this section is on transport cost per tonne-kilometre. We stick with the conventional terminology and refer to these measures as price elasticities (rather than cost elasticities)[12] .

The price elasticity of demand for a transport mode consists of two effects. The first is the shift in transport volumes between modes because of changing relative prices, holding total transport demand constant. We call this effect the elasticity of mode change. The second is the induced demand for the mode that follows from the fact that transports have become either cheaper or more expensive. We refer to this effect as the elasticity of demand. This survey will focus on the first effect, the elasticity of mode change, but include best-guess values for the elasticity of demand. The following sections present price elasticities for each transport mode.

Road Transport

Studies that use discrete choice models to estimate elasticities are based on revealed preferences (RP) and stated preference (SP) data from shippers in Sweden and Spain, and generally report values between 0 and -0.7 (Johnson and de Jong 2011; de Jong and Ben-Akiva 2007; Abate et al. 2014; Garcia-Menendez et al. 2004). Recently, larger estimates of -0.9 and between -1.5 and -1.8 are found in studies on Spanish shippers by Roman et al. (2016) and Arencibia et al. (2015) respectively.

Another set of studies derives road price elasticities from freight transport models. de Jong (2003) obtains estimates of -0.4 for Sweden, -1.0 for Norway, -1.0 for Belgium and an EU average of -0.6. Rich et al. (2009, 2011) base their analyses on origin-destination pairs in Scandinavia and find elasticities ranging from 0 to -0.3 across commodity groups. Haraldsson et al. (2008) obtain estimates between - 0.5 to -0.6 for Sweden, while Marzano and Papola (2004) report a value of -0.2 for Italy. Abate et al. (2016) use the Swedish Commodity Flow Survey and find elasticities between -0.1 and -0.3, although their results are sensitive to the choice of model.

Some studies analyse transport flows in Belgium using a cost definition that also accounts for the valuation of time. Beuthe et al. (2001) obtain elastic estimates of -1.2, while values between -0.1 and -0.3 are reported by Beuthte et al. (2014) and Jourquin et al. (2014). Davydenko (2015) estimates combined trade and transport elasticity of the national Dutch road transport segment to be around - 0.3. Studies using aggregated time series data from Denmark, France and the United Kingdom report similarly inelastic estimates between -0.2 and -0.3 (Bjørner and Jensen 1997; Lenormand 2002; Agnolucci and Bonilla 2009). Taken together, the own-price elasticities fall between 0 and -1.8. Most estimates are closer to zero, which holds true for nearly all European countries under study.

Ex-post analyses of changes in road transports due to policy-induced cost changes are scarce. One analysis of the road pricing scheme in Germany conclude that no effect on modal shift has been reported (de Jong et al. 2010). A similar analysis of Austria concluded that the introduction of the distance-based tax for heavy trucks coincided with higher growth rates for rail transport compared to

[12] It should be noted that the cost of transport not necessarily is the same as the price of transport, i.e. the actual freight rate. Since rates are typically unobserved to the researcher, most studies effectively estimate elasticities with respect to transport cost.

road transport. The authors note however that this could also be explained by changing economic conditions that affected road and rail transports differently (de Jong et al. 2010). There could also be an effect of short and long term market responses on the changing conditions, as it takes substantial time for the market to react to changing relations between the modes (e.g. investment in vehicles, long term contracts, etc.).

In Sweden, HCVs were introduced gradually during the 1990s and 2000s. The increase in loading capacity of these vehicles amounted to about 50 % of that of a regular (40 tonne) truck and meant a tonne-kilometres cost reduction of around 20 % (Nelldal, 2001; Adell et al., 2016). One study (Vierth et al., forthcoming) estimates that the long-run increase in road transport in Sweden following the introduction of HCVs was about 20 % and the reduction in rail transport was between 2-7 %. This corresponds to a long-run own-price elasticity for road transport of -1 and a cross-price elasticity of demand for rail transport between 0.1 and 0.35.

Rail Transport

Rail price elasticities mainly come from freight transport models. De Jong (2003) derives estimates for Belgium (-1.4), Norway (-3.9), Sweden (-2.0) and an EU-wide average in the range of -1.5 to -1.7. Ben-Akiva and de Jong (2007) also obtain elasticities larger than one in absolute value. Other studies report more moderate values. Estimates on Scandinavian data generally fall between - 0.1 and -0.4 depending on model specification (Johnson and de Jong, 2011; Rich et al., 2009; Rich et al., 2011). Estimates on Belgian data range from -0.3 to -0.7 in Beuthe et al. (2014) and between -1.1 and -1.3 in Beuthe et al. (2001). The figures for Italy are -0.4 for intermodal rail and between -0.8 and - 1.4 for the all-rail alternative (Marzano and Papola, 2004). Empirical estimates come from Bjørner and Jensen (1997) who report elasticities of -0.8 for Denmark, and Roman et al. (2016) who obtain elasticities between -1.8 and -2.0 using SP data from Spanish shippers. Overall, the own-price elasticities vary considerably between -0.1 and -3.9, with most estimates around -1.

Waterborne Transport

Elasticities for inland waterway transport come from the market in north-western Europe. These generally fall between -0.4 and -0.6, with some estimates as large as -1.3 for certain commodities (Beuthe et al., 2014; Jonkeren et al., 2007; 2011). The exception is the elastic estimate of -2.0 obtained in Beuthe et al. (2001).

Elasticities for short-sea shipping vary between regions in Europe: Estimates on Scandinavian data generally range between zero and -0.4 across commodity groups and specifications (Vierth et al., 2014; Rich et al. 2009; 2011), while Johnson and de Jong (2011) report estimates between -0.1 and -0.9. Notteboom (2011) surveys short-sea operators in North Europe and report an average elasticity of - 0.8 (based on values between -0.6 for intra-Baltic shipments and -1.3 for trade between the UK and continental Europe).

More elastic estimates are found in studies on other regions in Europe. Several studies use SP and RP data and estimate elasticities using discrete choice models. Bergantino et al. (2013) survey Italian freight operators and report an estimate of -2.0. Roman et al. (2016) and Arencibia et al. (2015) obtain estimates between -1.8 and -2.5. Garcia-Menendez et al. (2004) use a similar approach and find elasticities between -0.4 and -3.2 across specifications. Feo et al. (2011b) report elasticities of -0.9 based on data on freight forwarders in Spain, while Baindus and Vegas (2011) use a freight transport model to estimate the elasticity to be -1.5 for shipments between Italy and France.

Air Transport

There is mixed and limited evidence on the price elasticity for air freight demand. Elasticities based on Swedish shipments range between 0 and -0.3 (de Jong and Ben-Akiva, 2007; Johnson and de Jong, 2011), while Arencibia et al. (2015) obtain elasticities between -1.8 and -2.0 for Spain. The two sets of estimates are based on studies using different approaches, why it is hard to attributed the difference between them to a specific factor. Evidence from non-European markets is scarce but of the same magnitude; most estimates fall between -0.2 and -2.5 (Lo et al., 2015).

3.4.2. Transport time

The studies under review measure transport time as the duration of transport operations. Elasticities for road transports range from 0 to -0.9 (Garcia-Menendez et al. 2004; Arencibia et al. 2015; Bergantino et al. 2013; Román et al. 2016, de Jong, 2003). This holds true for different commodity groups, regions and model specifications (Rich et al. 2009; Johnson and de Jong, 2011).

Elasticities for rail transport range from -0.1 to -2.2. Estimates on Scandinavian trade flows vary between -0.1 and -0.5 (Johnson and de Jong 2011; Rich et al. 2009). Bühler and Jochem (2008) use survey data from Germany to obtain an estimate of -0.5 for intermodal transports, while Roman et al. (2016) report an elasticity of -0.8 based on Spanish shippers. Larger elasticities are found in de Jong (2003) who report estimates for the all-rail alternative of -1.3 in Belgium, -0.7 in Norway and -2.2 in Sweden.

Elasticities for waterborne transports are found to be between zero and -0.8 (Rich et al. 2009; Vierth et al. 2014; Feo et al. 2011; Roman et al. 2016). This result is based on studies covering both short sea shipping in northern and southern Europe. Less moderate values are found in Garcia-Menendez et al. (2004) who obtain estimates between -0.6 and -9.0, with the larger elasticities being driven by estimates for the ceramics sector and more moderate values are found for textiles, agricultural products and furniture products.

Johnson and de Jong (2011) find own-time elasticities for air freight between -0.9 and -1.5 across specifications, while Arencibia et al. (2015) report estimates between -0.6 and -0.7 for the intermodal alternative (consisting of combinations of road haulage and waterborne, rail or air transport).

3.4.3. Reliability (delay time)

The studies under review use shipper surveys where reliability is measured as delay time, i.e. the difference between expected and actual arrival. Arencibia et al. (2015) surveys producers/distributors of manufactured goods that handles shipments between Spain and Western Europe. They document an elasticity with respect to delay time of -0.3 for road transports and between -0.2 and -0.4 for the intermodal alternatives (road in combination with rail, air or waterborne transports). Roman et al. (2016) perform a similar study and find average elasticities for road transports of -0.3 that varies between -0.2 and -0.5 across decision makers. The equivalent elasticities for the intermodal alternatives was -0.3 on average and between -0.1 and -0.4 across decision makers.

3.4.4. Service frequency

Here, service frequency is defined as the number of departures per time unit and the studies base their estimates on surveys of stake holders in southern Europe. Arencibia et al. (2015) find that the elasticity of service frequency is around 0.2 both for road transport and the intermodal alternatives. Roman et al. (2016) obtain elasticities of 0.1 for road and 0.2 for the intermodal transports (rail and short sea shipping). Bühler and Jochem (2008) obtain an elasticity of 0.2 for intermodal transports, while both Feo et al. (2011) and Baindur and Vegas (2011) find elasticities of similar magnitude (0.1) for short sea shipping.

3.4.5. Damage risk

Garcia-Menendez et al. (2004) measure risk of damage as the percentage of cargo losses and damages of a specific product to a determined point of destination. They find elasticities for road transports around -0.2. The average elasticities for short sea shipping vary between -1.9 and -3.4. These values are mainly driven by a high sensitivity for transports of ceramic goods. More moderate values are obtained for furniture products (-1.6) and agricultural products (-0.9) while the elasticity for textile products is very low (-0.1).

3.4.6. Summary of elasticities

Table 3-4 includes the estimates of own-price elasticities (in the diagonal cells) and cross-price elasticities (remaining cells). All elasticities are for tonne-kilometre prices and tonne-kilometre demand and supported by at least 80 % of the studies under review. The elasticities give the percentage change in demand for a mode following a one percentage change in price, holding total transport demand constant. In other words, the elasticities do not reflect any induced demand that follows from the cost change.[13] The own-price elasticities are as expected of negative sign which means that an increase in the price of one mode reduced the demand for that mode. The other cells show cross-price elasticities. Their positive value means that an increase in the price of one mode increase the demand for the alternative modes.

	Road demand	**Rail demand**	**IWW demand**	**SSS demand**	**Air demand**
Road cost	0 to -1.2	0.4 to 1.7	0.3 to 0.9	0.2 to 1.1	*
Rail cost	0.1 to 0.5	0 to -1.6	0.2 to 0.8	0 to 0.3	*
IWW cost	0.1	0.2 to 0.9	-0.4 to -1.3	*	*
SSS cost	0.1 to 0.3	*	*	0 to -1.8	*
Air cost	*	*	*	*	0 to -2.0

Table 3-4. Values of price elasticity of demand

The own-price elasticities for almost all modes are bounded by zero, indicating that some decision makers do not respond at all to price changes. These are likely captive to one mode (as the only mode or a mode in the transport chain). Demand for road and inland waterway transports is insensitive to changes in cost; most estimates fall around -0.5. Demand for rail transport respond moderately to cost, with elasticities clustering around -1. Own-price elasticity for air demand and short sea shipping show a wide spread of values.

Cross-price elasticities are generally lower in magnitude than own-price elasticities. This means that the demand for a transport mode tend to respond more to a percentage change in its own cost than to the same percentage change in the cost of a competing mode. But there are notable differences in cross-price elasticities between the modes. Both rail and waterborne demand can be relatively responsive to changes in the price associated with road transports, although the estimates vary considerably. In contrast, road transport demand is insensitive to the cost of the alternative modes. One explanation for this is that trucks are considered to have a comparative advantage in service quality that is sufficiently high to off-set any price cuts of competing modes. As shown in Figure 5.1,

[13] It should be underlined that the elasticities are representative for changes in tonne-kilometre prices. Changes in other cost components (such as cost per tonne or vehicle kilometre) should be translated into the corresponding change in tonne-kilometre cost for the elasticity values to be applicable.

road transport has the highest modal share in all EU countries. It should be noted that the way elasticities are calculated make their values sensitive to the market share of each mode in the specific setting. This is a concern not least for cross-price elasticities.

Given the relatively large number of studies that find own-price elasticities for road transport in the same range, these results are fairly robust to the choice of method and data. Elasticity estimates for rail transport on the other hand exhibit a wide range of values which indicate that the result is sensitive to the methodological approach, the relatively limited amount of reliable rail goods flow data, the specific context of the setting under study or a combination of these factors. Estimates of IWW elasticities are fairly similar across studies, but the limited number of studies (four) is a concern for the robustness of the results. For short sea shipping, the estimates from Northern Europe seem robust and fall between 0 and -1. Estimates from other regions exhibit a much wider range of values. Own-price elasticities of air transport demand are collected from a limited number of studies showing very different results.

Other literature reviews present elasticities of transport demand, which includes mode change as well as any induced demand. These elasticities are constructed by adding together the impact of the separate responses. This measure is more suitable for predicting long-run effects since it better captures demand and supply changes that can take place on this time interval. De Jong et al. (2010) report such elasticities for road transport between -0.6 and -1.5, which is comparable to previous survey results (Graham and Glaister 2004). They estimate that mode substitution accounts for 40 % of the total effect and the rest is made up of induced demand.

Vierth et al. (2010) perform the same procedure to construct elasticities of transport demand for rail transports. They report an interval of -0.9 to -1.7 where the induced demand is deemed to account for 0.1 percentage points of this range. In other words, own-cost reductions are assumed to attract more additional demand for road transport than for rail transport. No elasticity of transport demand has been constructed for the other transport modes.

Table 3-5 summarizes the own elasticities with respect to time, service frequency, reliability (delay time) and damage risk. The intervals presented are not best-guess values as in Table 3-4, but represents the full range of estimates found in the literature. The limited number of studies means that the results should be extrapolated with great care. The elasticities are interpreted as the effect on mode substitution holding total transport demand constant. The results for waterborne transports are only applicable to short sea shipping.

Own elasticity	Road	Rail	Waterborne	Air
Transport time	0 to -0.9	-0.1 to -1.3	0 to -0.8	-0.6 to -1.5
Service frequency	0.1 to 0.2	0.1 to 0.2	0.1 to 0.2	0.1 to 0.2
Delay time	-0.2 to -0.5	-0.1 to -0.4	-0.1 to -0.4	-0.1 to -0.4
Damage risk	-0.2	*	-1.9 to -3.4	*

Note: See each section for variable definition. *no studies to base estimates on.

Table 3-5. Values of own transport service elasticities.

All elasticities reflect the demand for a transport mode following changes in its own attributes. The sign of the elasticities with respect to transport time, delay time and damage risk are negative, meaning that the modes are less likely to be chosen when their transport duration, delay time or risk of damage increases. In contrast, the sign of the impact of service frequency is positive. This means that each transport mode is more likely to be chosen when it offers more departures per time unit.

Demand for road transports seems to be less time sensitive compared to the other modes. Although the average values overlap, demand for road is consistently less elastic than demand for the other modes when estimates from the same study are compared (Roman et al. 2016; Garcia-Menendez et al., 2004; Arencibia et al., 2015; Rich et al., 2009; Johnson and de Jong, 2011). One explanation for this is that trucks are considered superior in other regards so that longer transport duration has little impact on the choice. The responsiveness to the other variables is similar across the transport modes, although demand for waterborne transport stands out as being sensitive to the damage risk.

Variation in elasticities

The variation in elasticities, both within and between modes, have several explanations. Some of the variation can be attributed to the competitive advantage of each mode, which was discussed in section 3.2. Road transport demand is more price sensitive on longer distances, whereas the opposite is true for rail and waterborne transports (de Jong, 2003; Beuthe et al., 2001; Beuthe et al., 2014; Notteboom, 2011; Rich et al. 2011). Road transport demand is also more price sensitive for heavy bulks, for which alternative modes compete more intensely. Symmetrically, demand for rail and IWW services is less price sensitive for heavy bulks and more price sensitive for time-sensitive goods (agricultural products and food) (Beuthe et al. 2014; Beuthe et al., 2011; Jonkeren et al. 2011).

The responsiveness to transport service factors is also likely to differ across decision makers. Although there is little evidence on how elasticities vary, there is a large body of research on how the valuation of service factors differ across groups. Because the value of time and reliability tend to be higher for high-value goods and the shorter the transport distance (Feo-Valero et al. 2011), the responsiveness to changes in time and reliability is likely to be larger for these shipments.

Other studies show that the responsiveness of shippers to transport cost vary between cost increases and decreases and depending on the magnitude of the change (Abate et al., 2016, de Jong et al., 2010). The elasticities are also influenced by data and methodological choices.[14] In addition, the way elasticities are calculated make them sensitive to the market share of each mode in the specific setting. This is a concern not least for cross-price elasticities. A given change in the absolute volume of demand for a transport mode will translate into a larger elasticity the smaller the market share of that mode is.

The variation in estimates means that the elasticities, especially the cross-price elasticities, should be generalized to other settings with care. Practitioners should be aware that the responsiveness of demand can differ greatly depending on several firm and shipment characteristics, including the commodity and distance class. We recommend practitioners to carry out a sensitivity check when applying these estimates, using different values from the intervals given in the tables, including the upper and lower bound.

[14] The input data and parameters in simulation models are likely to affect the scenario outcomes. For instance, Rich et al. (2011) show that larger zoning definitions can give the false impression that there is a wider choice of transport solutions than in practice. The choice of explanatory variables and functional forms of discrete choice models are similarly likely to bear on the results. For example, Johnson and de Jong (2011) show how different model specification produce different elasticities.

3.5. Importance of other choice criteria

The literature identifies an additional set of attributes that may influence the modal choice. The importance of these variables is not summarized by elasticities, but rather in terms of how shippers value one factor relative to others. The attributes are summarized in Figure 3-6.

Environmental impact is attributed less importance than transport cost and service quality indicators in many studies (Laitila & Westin 2000; Björklund 2002; Björklund 2005; Grue and Ludvigsen 2006; Berdica et al. 2005). A series of surveys of Swedish shippers carried out in 2012 and 2014 showed that a quarter of the respondents did not put any weight at all on environmental efficiency of transports and half of the sample agreed that more environmental efficient transports would increase logistics costs (Andersson et al. 2016). Wolf and Seuring (2010) conduct in-depth analyses of transport buyers and 3PL and find that buying decisions are still made on "traditional" performance objectives, such as cost and transport service quality.

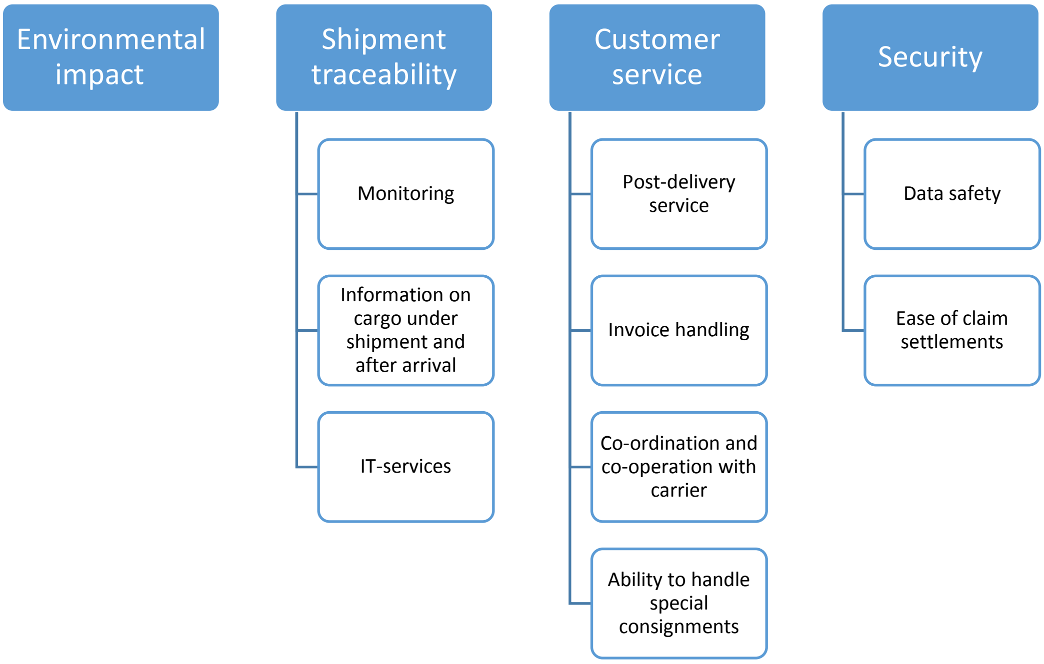


Figure 3-6. Other choice criteria

One explanation for this is shippers' low willingness to pay for more environmental friendly transports (Lammgård, 2007; Lundberg, 2006). But recent survey results suggest that the willingness to pay might be increasing: the share of Swedish firms paying extra for environmentally friendlier transport increased from 3 to 21 % between 2012 and 2016 (Styhre, forthcoming). This does not necessarily imply that firms will be switching between modes with different environmental impact. They may simply switch between transport solutions within the same mode. For instance, Styhre (forthcoming) shows that firms choose between road carriers that provide different environmental classes. (How environmental sustainability is incorporated in the selection of transport solution is also reviewed in section 3.3. See also section 2.3.)

Surveys also show that shippers also care about customer service, security and shipment traceability (particularly important for express freight services). These factors are more related to the service offered by the seller of transport (carrier or logistics provider) rather than the mode itself, and may induce firms to switch between carriers or logistics providers rather than change transport solution.

Nevertheless, policy-makers and administrators should be aware that these factors may weigh in on firms' choice.

3.6. Conclusions

This chapter has identified and discussed factors influencing firms' choice of transport solution. Section 3.2 showed the influence of shipment attributes and transport distance. This set of factors imposes "restrictions" on the firms' ability to choose between transport solutions in the first place. Because the transport modes have different qualities, shipments of certain value, weight, value density and/or volume are better suited for some modes than others.

The take-away from this section is that i) for some shipments, the distances class and shipment attributes are such that firms are captive to a single transport solution, ii) the degree of competition between modes is different depending on the distance class and shipment characteristics and iii) differences in the commodity mix and transport distances explain some of the country-differences in modal split and modal competition. NRAs should therefore understand the nature of modal competition in the market they analyse.

The case studies in section 3.3 offered several lessons regarding firms' decision-making. The way the transport solution is chosen differs between settings and both shippers and logistics service providers can be decision-makers. In most of the cases we analysed, logistics service provides (LSPs) are contracted by shippers who specify the details of their shipment (such as destination, load locations, transit time). The LSPs in turn offer a freight rate and transit time associated with their transport solution. The shippers assess the offers from the LSPs and selects transport solution based on some choice criteria. In cases where shippers perform their transport on own account or contract carriers directly, they naturally have more direct influence on the choice of mode.

The nature of decision-making can influence the effectiveness of policy measures and other external influences. For instance, the case studies show that when shippers themselves pay the freight rate they naturally search actively for cheap options. But when the receivers pay the rate the shippers are much less cost sensitive in their choice of transport solution. Policy impacts are therefore better understood by identifying decision-makers and assessing the contractual relationship between freight agents.

As for choice criteria, both the case studies and the literature review point to the same conclusions. Cost is often the most important one, given that some transport service requirements are met. Section 3.4 presented a set of elasticities that showed the average demand responses of these factors. The elasticities can be applied by NRAs in impact assessments and other analyses. One important finding is that decision-makers' sensitivity vary considerably across market segments. The relative competitive positions of the modes explain much of the variations of elasticities: road transport demand is as expected the least cost-sensitive in segments where trucks are the most competitive option, and likewise for rail and waterborne transport.

Another finding is that demand for road transport is generally less sensitive to transport cost and time compared to the demand for the other modes. One explanation is that trucks in many cases are considered superior in several regards so that higher cost or longer transport duration for road transport have little impact on the mode choice. Another explanation is that trucks are needed for most door-to-door transports anyway.

Both the case studies and freight transport statistics show the road is the most commonly used mode of transport. The case studies provide several possible explanations for this. Sometimes trucks are used because they have the lowest freight rates. In other instances, it is due to last minute requests from end-customers so that the speed and flexibility of trucks can be utilized. Other reasons include time pressure/habitual choices of transport managers, poor rail infrastructure availability and because an LSP operates its own vehicle and wants to have control over the service level of the transport chain.

The possibility to use other modes than road increases with larger volumes, receivers accepting longer lead times and consolidation of flows within and between firms. This illustrates how the choice of transport solution is tied to a range of other logistics decisions. Drivers of modal shift are not only external influences such as policy measures but can also include changes in supply chains, technology and other factors that originate solely from the side of firms. The results from the case studies suggest that such initiatives are most likely to come about if they entail cost savings for the firm.

The firms interviewed for this chapter list a number of measures that public authorities can take in order to influence the choice of mode. They call for public policies to internalize the environmental impact in the pricing of the modes, increase the availability of (rail) infrastructure, reduce terminal fees. They also want public authorities to pro-actively inform about their actions, bring together shippers when they develop new plans and spread information about multimodal solutions. Sometimes, low volumes may prevent firms from making use of other modes than trucks. In these cases, private and public programmes that bring together freight agents could foster consolidation and multimodal solutions.

To conclude, this chapter has identified a wide range of factors that influence the choice of transport solution. These serve as important inputs for the NRAs in their work to promote an efficient transport system that reaches the targets on energy efficiency and reductions of energy efficiency. It is important to have in mind that increased efficiency may not only come from modal shift but also from a higher utilization of firms' existing transport solutions. This means that NRAs also should be analysing firms' choices of vehicle types and care about measures that promotes higher efficiency. The results from the cases studies show that there is a potential for a win-win situation in this field; many firms are keen on increasing efficiency (e.g. by combining flows, improving energy efficiency in warehouses, increasing utilization rates) and are already active in formalized collaboration with other stake-holders. In other words, the institutional setting for such collaboration already exists in many cases.

The findings in this chapter provide NRAs with information about decision-making in the freight sector, but they still need to be supplemented with data and transport models in order to conduct richer analyses. The factors identified in this chapter will serve as a basis for the data requirements of NRAs that is discussed in chapter 5. In chapter 6 we will discuss how these data can be used in freight transport models to analyse the effects of policy measures and trends.

4. Terminals

4.1. Introduction

This chapter addresses a range of topics related to the role of terminals in transport chains. Section 4.2 includes a description of different terminals and load units. A survey of the terminal structure and the role of the terminals in transport chains follows in section 4.3. It covers the aspects of availability of terminals, their connectivity and service frequency, their accessibility and factors that influence the transhipment costs. Different policy measures to promote intermodal transports are discussed in section 4.4. The results are based on a literature review and information on various terminals in Europe.

4.2. Terminals and load units

4.2.1. Classification of terminals

A terminal is a place where goods are consolidated between sub-modes, e.g. from light to heavy trucks, or transhipped between two or more modes (road, rail, inland waterway (IWW), sea or air). This chapter focus on terminals that comprise two or more modes and that are open for all firms. Especially in sea ports, private-public partnerships have become more important in recent years (Bergqvist and Cullinane 2016). In contrast to the FLUXNET-project (Paul et al. 2017), we do not address warehouses, distribution centres and cross-docks.[15] These are typically operated by private firms that offer the storage of the goods and different value added services. Logically, only these firms' clients have access to the warehouses, distribution centers and cross-docks.

An intermodal terminal is a place for the transhipment of Intermodal Transport Units and involves different stake-holders:

- Pre- and post-haulage operators (drayage[16] operators) perform transports to/from terminals by road, rail or waterborne modes.
- Operators that perform the transports between the terminals by rail, IWW or sea and select the most appropriate route through the networks (Macharis et al 2008).
- Terminal operators that carry out the transhipment operations in the terminals.
- Infrastructure managers (like the NRA) are responsible for the connecting road, rail and waterborne infrastructure both for the main mode and the pre- and post-haulage in the transport chain.

Maritime intermodal transports can be divided into continental transports between two inland terminals and intercontinental transports. Continental transports are often time sensitive as they compete directly with road door-to-door transport and utilize standardized units like swap bodies or semitrailers, which have the same capacity/volume as an all-road semitrailer. Intercontinental transports are generally less time and cost sensitive than continental transports (Woxenius et Bergqvist, 2011).

[15] While traditional warehouses require that a distributor holds stocks of product to transport to the customers, cross-docks use the best technology and business systems to create just-in-time transport process.

[16] Drayage is the transportation of goods over a short distance, often it is part of a longer haul.

4.2.2. Examples of different terminal types

4.2.2.1. Rail-road terminals

Rail-road terminals or combi terminals consist of one or several yards. A yard forms a rectangle and has parallel lanes; two to four lanes for rail, one or two lanes for road and a buffer lane for the storage of intermodal transport units (ITUs). One or two gantry cranes evolve over this rectangle to tranship the ITUs between road and rail. The length of the yard is the same as the length of a train to avoid cutting the train between two tracks when it enters the terminal. In France, the maximum train length is 750[17] meters and a French yard is a rectangle of 750 x 50 meters[18]. This yard needs to be well connected to the road and rail network. For rail, there should ideally be a connection to the electric tracks at the two ends of the yard. If there is no catenary in the terminal, diesel trains must move wagons between the terminal and the rail network. Lastly, locomotives and wagons are often stored before entering the yard and need therefore another set of rail tracks outside the terminal. Reach stackers used in some yards. They are cheaper than gantry cranes and can move from one yard to another but need a great deal of space for maneuvering in front of the rail track to handle ITUs.

Figure 4-1. A gantry crane (left) and a reach stacker (right). Source: P. Niérat

4.2.2.2. IWW terminals

Transhipment in IWW terminals is organized along the quay, which has the length of a barge (100 meters). On the quay side, maritime containers can be stacked on many levels. ITU stacking reduces land requirement (but increases handling for the ITUs that are not on the top of the stack).

Duisburg is an interesting example. The IWW DeCeTe terminal and the rail-road DUSS terminal are adjacent (Figure 4-2). The rail and IWW quays have about the same length, but the storage capacity under the crane is along two lines at the rail terminal (about 160 TEUs or 320 TEUs if there are two levels of ITUs) and at least eleven lines on several levels for the IWW terminal (about 2 640 TEUs if there are three levels of containers). But IWW cranes are more expensive because they are bigger, higher and more expensive because they are equipped to go and fetch containers up to ten meters off the quay.

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[17] Since 2012 some trains are 850 m long in France.

[18] As seen in chapter 2, there are trends towards standardization and industrial concentration in European politics, which will lead to a more homogeneous system.

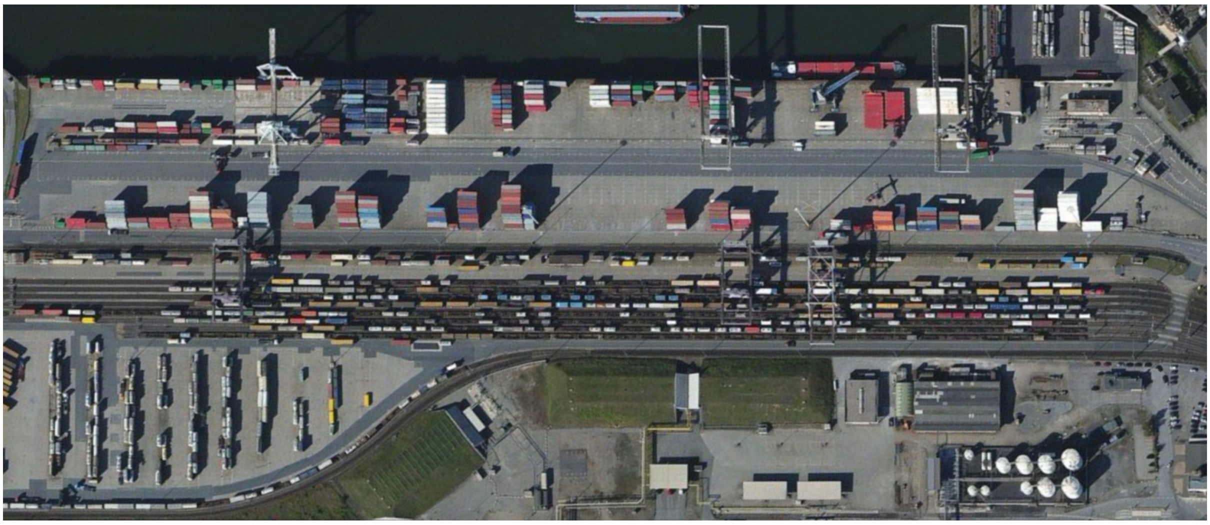


Figure 4-2. IWW (top) and rail-road (bottom) terminals in Duisburg. Source: Google Earth (2017a)

4.2.2.3. Terminals in seaports

Several terminals are often located in the same port. This is especially true for large sea ports. For instance, the port of Rotterdam has six container terminals in the Maasvlakte I and II and further terminals in the older part of the port near the city.

The terminals consist of dedicated areas for deep-sea ships, storage, barges, wagons or trucks. The components of a seaport include gantry cranes (deep-sea ships, rail, river-ship), straddle carriers, reach stackers and large storage areas. Maritime quays need to have a minimum depth. Verhoeven (2010) analyzed capital investments in seaports and found that port authorities mainly have financial responsibilities for capital assets related to maritime access, terminal-related infrastructure and transport infrastructure inside the port area. In seaports with the largest throughput authorities do not have any financial responsibility for cargo-handling equipment (cranes) and warehouses. These assets are likely to be operated by other companies.

4.2.2.4. Terminals in airports

Airports have designated areas for freight terminals in which two main types of air freight services can be distinguished: express services (as Fedex) and general cargo services (as Air France Cargo or KLM Cargo). Both require space in the direct vicinity of the tarmac. Freight arrives by road or rail[19] to large platforms and goes through customs to enter the quay. Air pallets or containers are loaded and stocked until the arrival of the plane.[20] Automatic guided vehicles or automatic sorting machines are common in airports[21]. Figure 4-3 shows platforms in Roissy Charles de Gaulle.

[19] Carex (Cargo Rail Express) is a freight project that aims to link the major European airports with a TGV offer.

[20] In airports, shipments are consolidated before the arrival of the airplane to be able to perform the (un)loading as quickly as possible. The process is more labor-intense and sometimes requires expensive equipment (e.g. automated guided vehicles, automatic sorting chains, automatic air container storage). For instance, G1XL, the AF/KLM terminal in Paris Charles-de-Gaulle, is twelve hectares and is equipped with thirty-two automated guided vehicles to move air pallets (AF/KLM cargo website).

[21] They are also used in some port terminals (i.e. Hamburg Altenwerder).

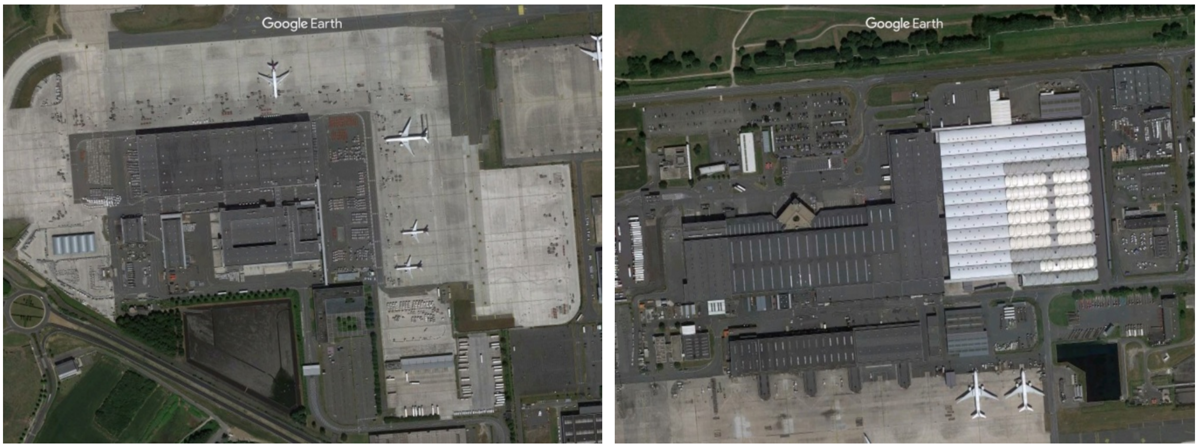


Figure 4-3. Freight terminals at Charles de Gaulle. Source: Google Earth (2017b)

4.2.3. Load units for intermodal transports

Figure 4-5 shows different types of intermodal transport units (ITU). The most popular is the ISO container, built for maritime intercontinental transports and are stackable at seven levels. The dimensions of the containers are standardized with a width of 8', a length of 20', 30' or 40' and a height of 8'6" or 9'6". 40' ISO containers fit well for manufactured goods while 20' containers are used for dense goods such as semi-manufactured or bulk[22]. Some containers are also high cube (HC - 45' and 8' wide) or pallet wide (PW - 2.438 m interior wide vs 2.348 for an ISO container).

Semitrailers have been used for a long time for continental intermodal transports but are gradually being replaced by the lighter swap bodies. Today, swap bodies represent 81% of the consignments of the European UIRR (Intermodal Union for road-rail combined transport) members (EC 2016).

Figure 4-4. An ISO 40' container (left), intermodal semitrailer (centre), swap body (right). Sources: Jpparts (2017), Intermodal-cosmos (2017), Sicom (2017)

4.3. Terminal structure and role of terminals in transport chains

As developed in chapter 3, terminals are necessary for multimodal or intermodal transports. Below the conditions in different parts of Europe are described. Section 5.3.6 contains details about terminal data.

[22]The maximum gross weight is the same for all containers (20', 30', 40' or 45'), 30,480 kg. But the volume is not the same.

4.3.1. Availability of terminals

4.3.1.1. Europe

An overview of the availability of intermodal terminals in Europe is provided in Figure 4-5. The information comes from the Intermodal Map[23], initiated by the German Promotion Centre for Intermodal Transport (Studiengesellschaft für den Kombinierten Verkehr, SGKV), and comprises over a thousand terminals currently. The availability of intermodal terminals (and therefore the access to intermodal services) varies geographically. Terminal density is higher in the Benelux countries and Germany than in France, Italy, Spain, Poland and Sweden. Waterborne terminals are obviously located along the sea coast, particularly in the North Range (Le Havre to Hamburg) and the main European river as Rhine, Rhone, Seine and Danube.

Figure 4-5. Intermodal terminals in Europe. Source: Intermodal Map (2017)

[23] http://www.intermodal-map.com/en/ Operators of missing terminals are invited to complete an online questionnaire to be integrated in the map in order to improve the coverage.

4.3.1.2. Sweden

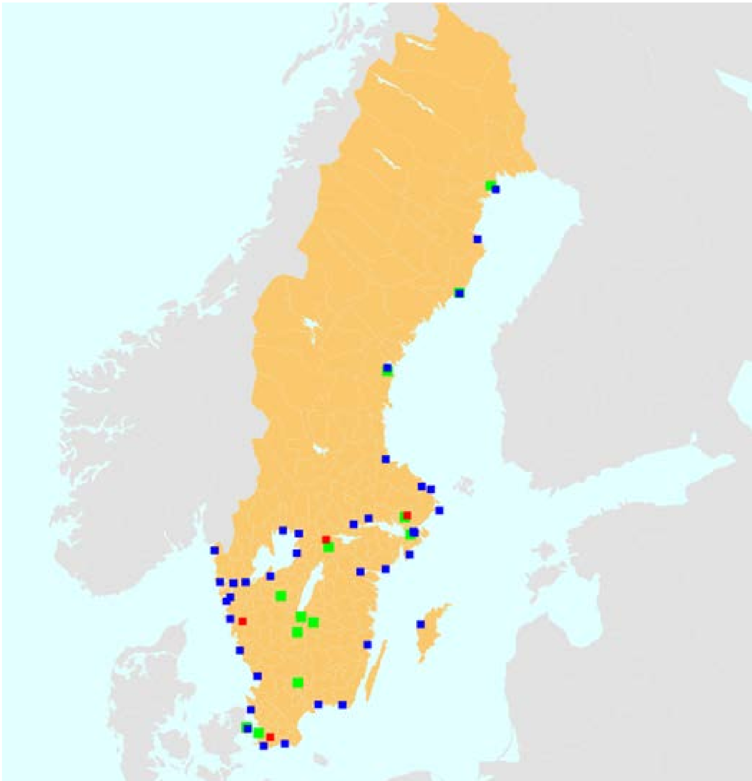
Figure 4-6 shows the intermodal terminals in Sweden in the Intermodal Map from SGKV.

Figure 4-6. Intermodal terminals in Sweden. Source: Intermodal Map (2017)

The Swedish Transport Administration (STA) is also compiling information about the 35 largest sea ports[24], eleven rail-road terminals[25], one dry port[26], and four airports[27] in Sweden (Wallinder 2016, 2017). This database is not restricted to intermodal transports and contains information about the

[24] Luleå, Skellefteå, Umeå, Gävle, Sundsvalls, Hargshamn, Norrköping, Oxelösund, Mälarhamnar Västerås and Köping, Stockholm, Grisslehamn, Kapellskär, Visby, Nynäshamn, Oskarhamn, Karlskrona, Karlshamn, Ystad, Trelleborg, Helsingborg, Copenhagen/Malmö, Halmstad, Stenungssund, Strömstad, Uddevalla port, Wallhamn, Varberg, Brofjorden, Göteborg, Vännerhamnar Karlstad, Kristinehamn, Gullspång and Lidköping.
[25] Luleå, Umeå, Sundsvall, Hallsberg, Stockholm/Årsta, Rosersberg, Copenhagen/Malmö, Malmö, Jönköping/Nässjö, Jönköping/Torsvik, Älmhult.
[26] Falköping
[27] Stockholm/Arlanda, Örebro, Göteborg/Landvetter, Malmö.

location, owner and organization, revenues, number of employees, terminal performance, type of terminal operations, relevance for the Transeuropean Network for transport (TEN-T), the rail network, the condition of the infrastructure (road, rail and waterborne transports), whether the terminal is of national interest, the throughput in tonnes, major customers, major production arrangements, contacts at the management level in the terminal, current major issues, weaknesses in the connections (and maybe future needs) as well as weaknesses related to the terminal. The STA is mainly interested in the connections to all ports, dry ports, air ports and combi-terminals, i.e. if there are bottlenecks or other problems. This information will be used in the preparation of the next national infrastructure plan.



Note : Blue = ports, green = rail-road terminals and dry ports, red = airports.

Figure 4-7. Main ports, combi terminals, dry ports and airports in Sweden. Source: STA (2017)

The Swedish agency Transport Analysis has commissioned a pilot study relating to the accessibility to terminals in the West of Sweden (Västra Götaland) (Transport Analysis 2016). One result is that the freight transports (origin, destination and traffic flows) and terminals are concentrated to the four main freight corridors (European routes E6, E20, E45 and national highway 40) and the major agglomerations. This structure is assumed to be enhanced during the coming five to ten years as seen in chapter 2 (trends).

4.3.1.3. The Netherlands

Figure 4-8 shows the intermodal terminals in the Netherlands from the SGKV's Intermodal Map. The importance of IWW-terminals is obvious.

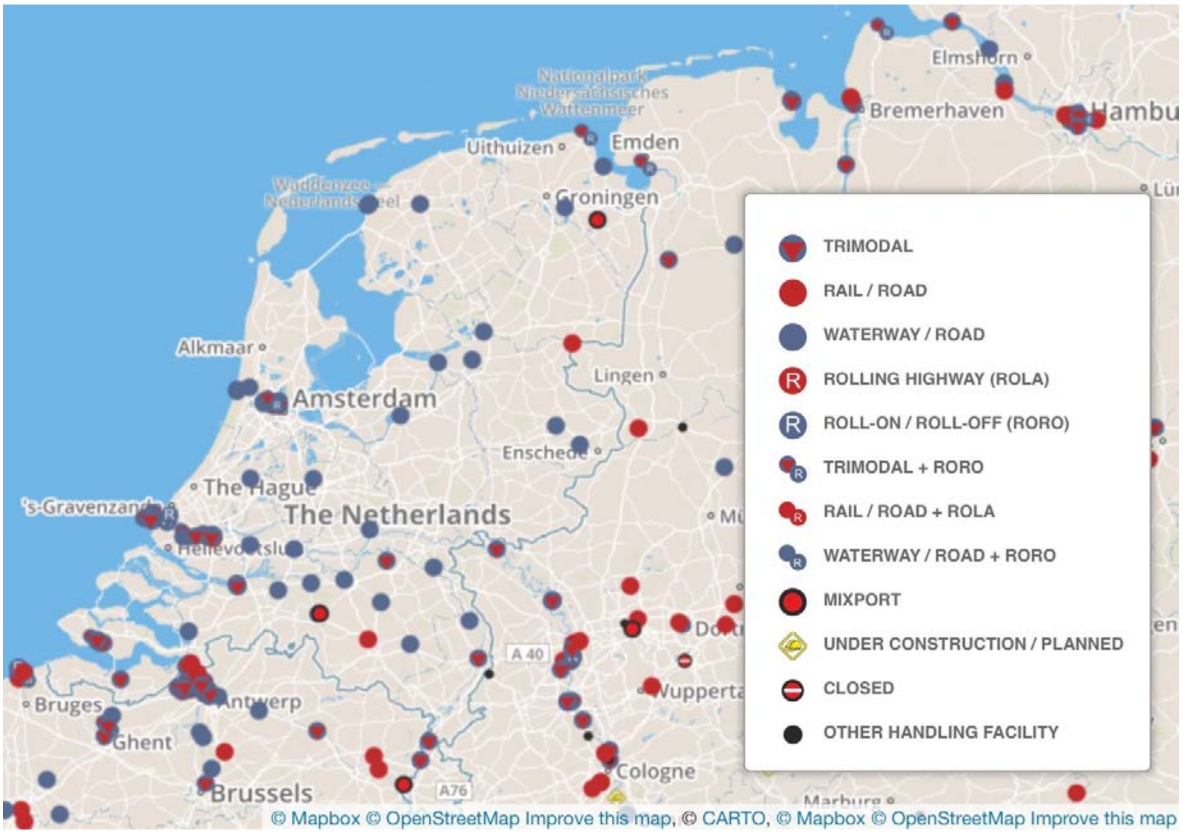


Figure 4-8.Intermodal terminals in the Netherlands. Source: Intermodal Map (2017)

In the Netherlands, there is also information about the 60 IWW and 28 rail terminals in the 40 NUTS3[28] regions in the Netherlands and the throughput in tonnes (loaded and unloaded) in each NUTS3- region. The results are presented in Figure 4-9. The top right part of the figure shows in which of the four NUTS1-regions (Northern, Eastern, Southern and Western Netherlands) the terminals are located. [29] The number of terminals per NUTS3-region is based on information in the European project ETISplus[30], inland terminals 2010 and the Dutch MIRT OOST project. The bottom right part of the figure shows the throughput per NUTS1-region in tonnes. The information for rail is derived from an origin and destination matrix (Rijkswaterstaat HB matrix spoor, 2015) and two IWW-data-bases from Rijkswaterstaat (2014a, 2014b). The throughput of the 60 IWW-terminals is about three times as high as the throughput in the 28 rail terminals. On average the throughput of an IWW terminal is about 38% higher than the throughput of a rail terminal.

[28] NUTS = Nomenclature of Territorial Units for Statistics,

[29] With no distinction between bimodal and trimodal terminals

[30] European Transport Policy Information System Development and implementation of data collection methodology for EU transport modelling.

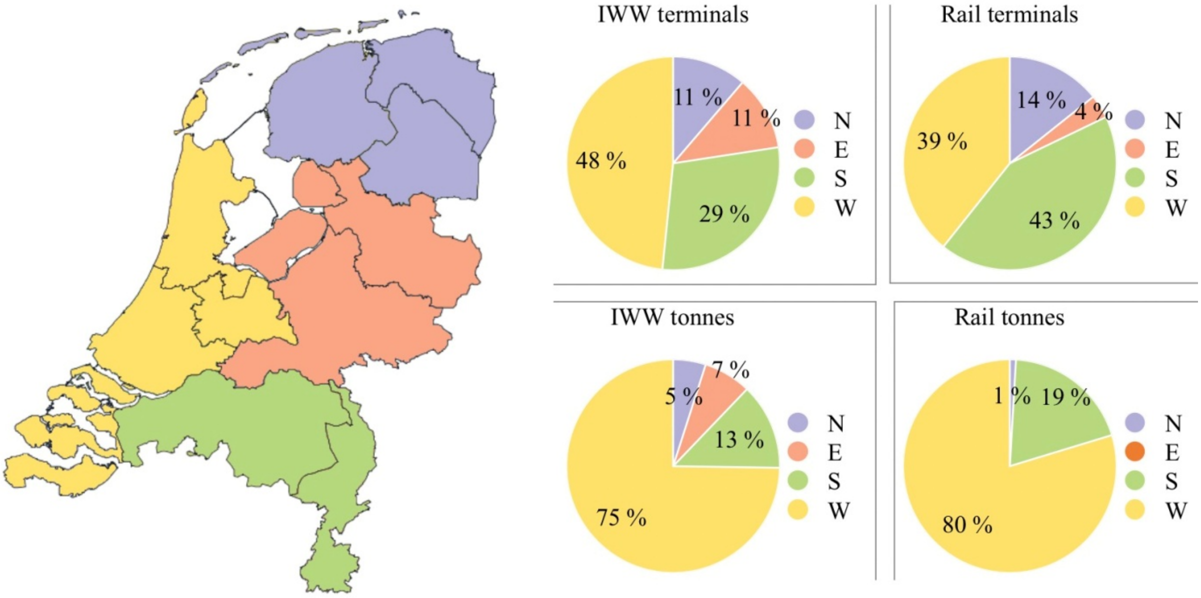


Figure 4-9. Dutch rail and IWW-terminals by NUTS1 region (left) and throughput in tonnes by NUTS1 region (right). Source: Niérat

Thirty of the 40 Dutch NUTS3-regions have one or more IWW-terminal**.** About half of IWW-terminals are located in the Western region in which the port of Rotterdam is located. More than 25% of the IWW-terminals are in the Southern region, mainly along the river Maas. The Eastern and the Northern region have a share of 11% each. Within 75% the Western region has an even higher share when we look at the throughput. The NUST3-region Rotterdam has 58% of the total turnover. The Southern region has a throughput share of 13%.

Fourteen of the 40 NUTS3 regions have at least one rail terminal. They are distributed over the Southern NUTS-1 region (43%), the Western NUTS-1 region (39%), the Northern NUTS-1 region (14%) and the Eastern NUTS1-region (4%). This means that the Western region has a relatively high share of both IWW-terminals and rail terminals. Measured in throughput the dominance of the Western region is even larger: 75% of the throughput in the IWW-terminals and 80% of the throughput in the rail-terminals are in the Southern region (manly in the NUTS3-region of Rotterdam). Nearly all the remaining 20% of the throughput in rail-terminals is in the Southern region. In addition to the information above, average transhipment costs per tonne for rail (€3.125 per tonne) and IWW (€2.1 per tonne). [31]

4.3.1.4. Germany

Figure 4-10 shows the intermodal terminals in Germany in SGKV's Intermodal Map. According SKKV (2017) there were about 160 terminals including rail-road, inland waterway-road and trimodal terminals in Germany in 2016.

[31]These are provided by TNO in the framework of the 'Impuls Dynamisch Verkeersmanagement Vaarwegen (IDVV)' (Dynamic Traffic Management for Waterways) program ran by Rijkswaterstaat.

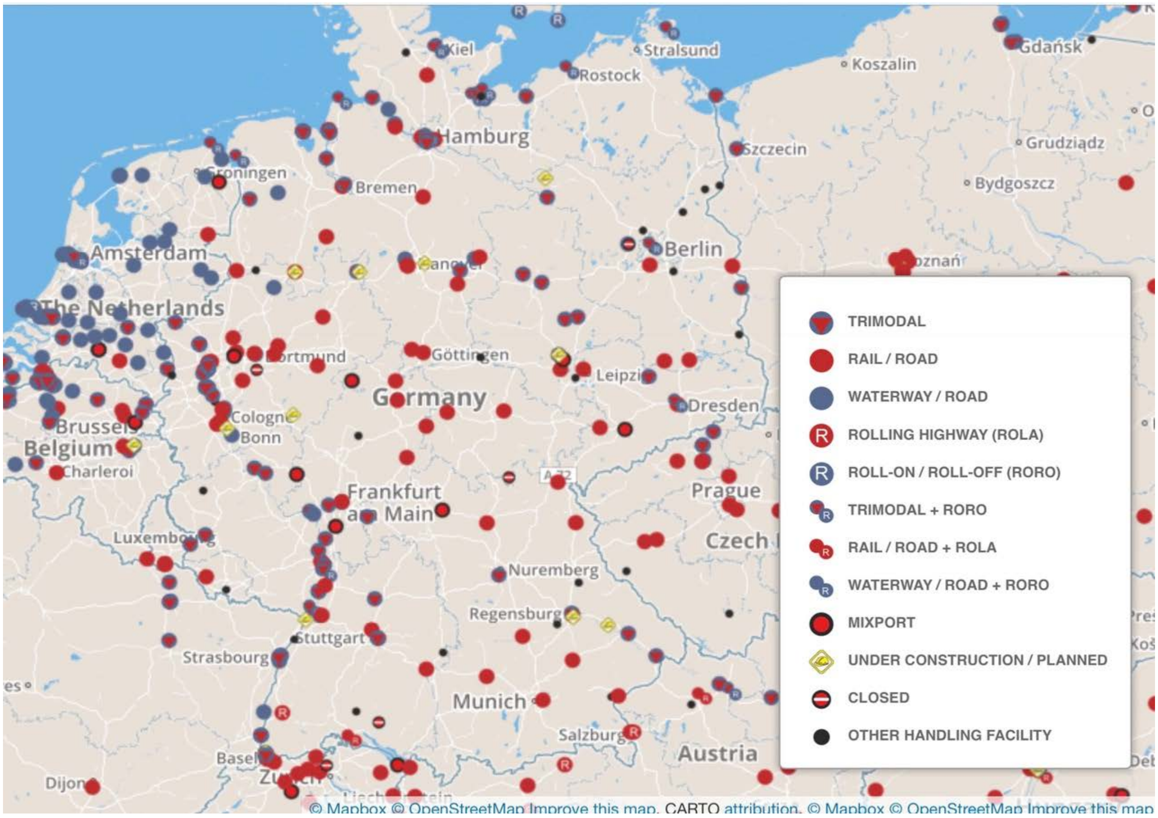


Figure 4-10. Intermodal terminals in Germany. Source: Intermodal Map (2017)

4.3.1.5. France

Figure 4-11 shows the intermodal terminals in France in SGKV's Intermodal Map. The map gives the impression that the terminals are somewhat equally distributed over the country. This is false for several reasons:

1) Each small and medium size terminal is typically only connected to a few other terminals (see section 4.3.2).
2) Service frequency differ from one terminal to another. More than half of all terminals have an annual combined rail transport equivalent to less than 30,000 TEU, i.e. one train per day[32]. For continental combined rail transport, most of the domestic links have an average of five return trips per week; for combined transport of maritime containers there are between two and five return trips per week (see section 4.3.2).
3) Differences in the accessibility and costs to go to/from the terminals (see section 4.3.3)
4) Terminals have different transshipment cost due to differences in capacity (area and yards) and utilization.[33]

[32] The capacity of one train is around 80 TEUs. One train per day in each way for 200 days per year is 32,000 TEUs.

[33] Large terminals include Valenton in Paris Region (Fifteen tracks, six yards, 7,400 m total tracks length) and Dourges near Lille (Seven tracks of 750 m, 5,200 m total track length). An example of a small terminal is Gerzat in Clermont-Ferrand (Two tracks, one yard, 600 m total tracks length).

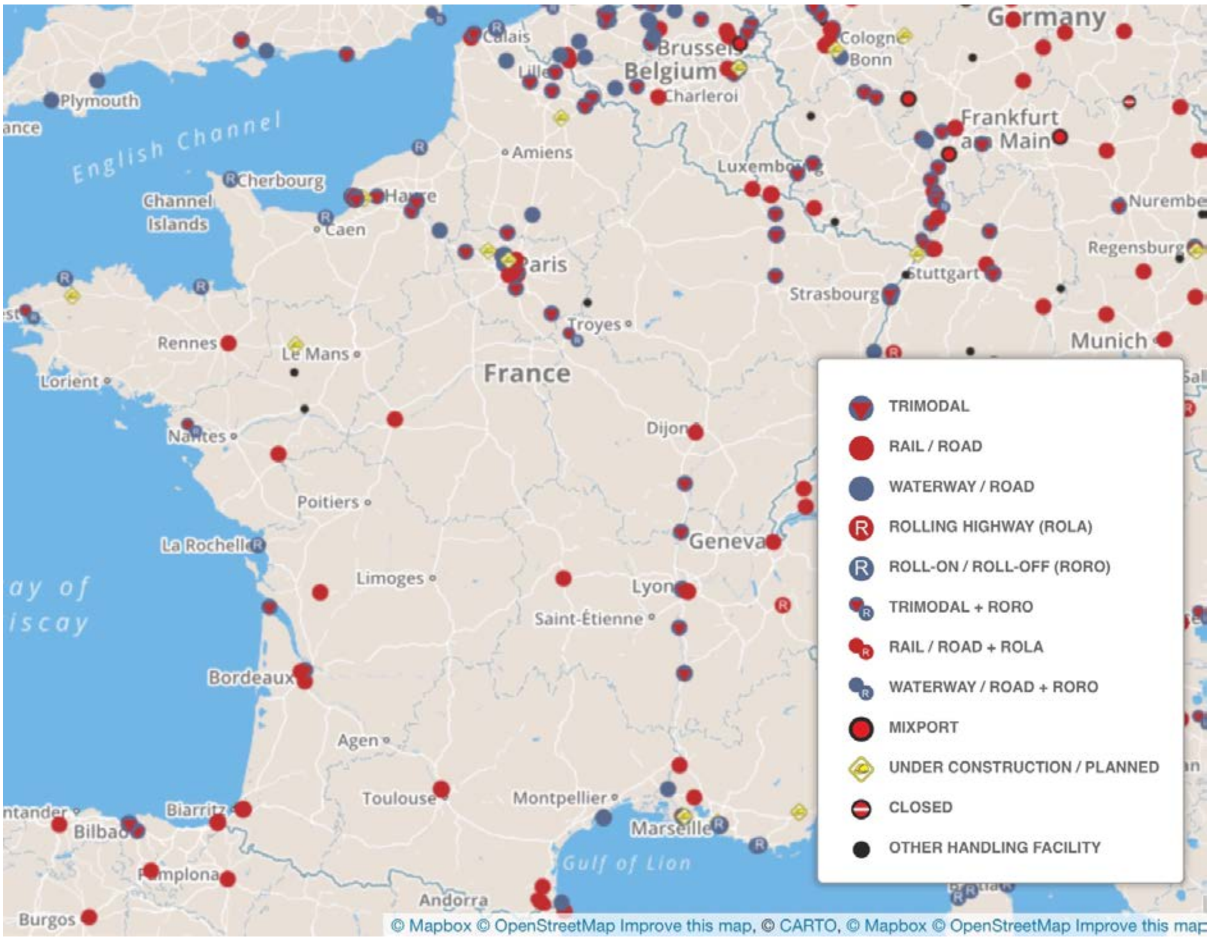


Figure 4-11. Intermodal terminals in France. Source: Intermodal Map (2017)

In France, most of the continental intermodal rail transport is oriented towards the biggest rail terminal in Valenton, near Paris. This terminal is well connected to most of the terminals in Southern France. Small terminals, as the one in Toulouse, are typically only connected to Paris (and sometimes to Lille). Intermodal rail is also used for transports from Le Havre to minor cities like Clermont-Ferrand. Regarding intermodal IWW, the Seine is used to connect the port of Le Havre and Paris and the Rhone to connect Marseilles and Lyon. The terminals are included in larger systems. For example, dry ports are inland terminals used as gateways to a seaport (Roso 2007). See also section 4.4.2.3)

The French Groupement National des Transports Combinés (GNTC) publishes once a year a transport plan (GNTC 2016) which gathers the transport plans of the different public and private stakeholders.

To our knowledge, there is no official information about the yearly throughput of these terminals or the total of handling operations in France. The statistical department of the Ministry of Ecology, Sustainable Development and Energy only provides aggregated data on combined rail freight transport. However, transport plans and schedules are sometimes available on the operators' websites.

4.3.2. Connectivity and service frequency

Five features can be used to build a typology of terminals (Wiegmans et al, 1999):

- the pairs of modes which the terminal directly or indirectly connects;
- the number of modes the terminal connects (bimodal terminal connects two modes, trimodal connects three modes);
- the types of cargo or commodities handled in the terminal
- the types of intermodal transfers for which the terminal is designed (direct, short-term storage, or long-term storage);
- whether the terminal is privately or publicly owned;
- whether use of the terminal is open or restricted relative to either shippers or carriers.

The service frequency in the terminals is naturally linked to the goods volumes between two terminals. Large volumes allow i.e. for one or several train departures between two intermodal road/rail terminals per day which in turn attracts additional volumes. Lower service frequencies between two terminals, i.e. one or two train departures per week, make it often difficult to compete with door-to-door road transports.

4.3.3. Accessibility of terminals

4.3.3.1. Accessibility indicators

The European project TRansport ACCessibility at regional/local scale and patterns in Europe (TRACC 2015) defined a set of generic accessibility indicators for passenger and freight transports in global, European and regional spatial contexts. In the frame of this project, accessibility is defined as the possibility to reach potential locations in order to carry out commercial or private actions or “as some measure of spatial separation of human activities”. Time and costs to reach a terminal alone are obviously not very adequate to determine the importance of a certain terminal. For example, a terminal that has low accessibility costs and can be reached in relative short time can also offer very limited transport services to a given region (i.e. related to gateway functions). Table 4-1 presents the indicators for freight transports.

Spatial context	Travel costs	Cumulated opportunities	Potential
Global	Travel time/cost (inter-modal) to major intercontinental terminals (New York, Shanghai).	Intercontinental container throughput of European sea ports reachable within maximum travel time.	By road and rail to container throughput of European sea ports.
European	Generalized cost to nearest port.	GDP accessible within allowed truck driving time.	Accessibility potential to GDP by different modes.
Regional	Weighted access time to freight terminals.	Freight terminals within 2 h by truck.	National potential accessibility freight to national GDP by truck.

Table 4-1. Accessibility indicators. Source: TRACC (2015)

The indicator for the global accessibility is a construct of two functions: (a) attractiveness of the intercontinental ports measured by their intercontinental container throughput, (b) generalized cost[34] needed to reach intercontinental ports from the regions. Regions can then be ranked according to proximity to the main gates for global trade. Accessibility to all intercontinental ports matters so being

[34] Generalized cost is the sum of the monetary and non-monetary costs of a passenger or freight transport.

close to just one big port is not enough to get a high rank according to this indicator. An example for the global accessibility indicator is shown in Figure 4-12. The indicator for the European accessibility is related to the nearest ports and the indicator for the regional accessibility to freight terminals.

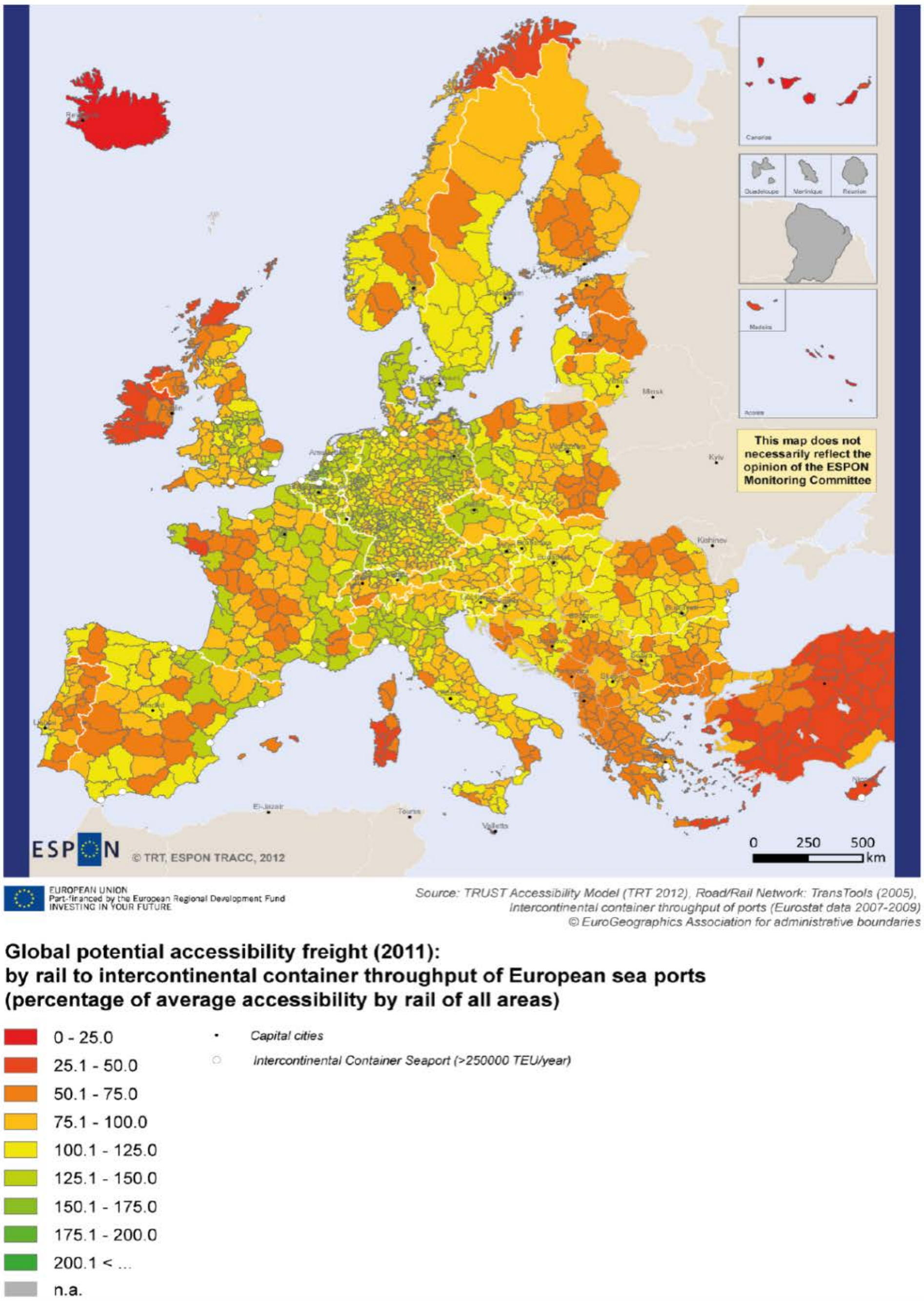


Figure 4-12. Global potential accessibility for containers. Source: TRACC (2015)

Transport Analysis (2016) defined regional accessibility indicators for municipalities in Sweden which are in line with the accessibility indicators developed in the TRACC-project:

- Closeness to terminal, measured as the driving time from the center of the municipality to the closest terminal, weighted by the financial turnover of the terminal.
- Terminal potential, measured as the sum of the value (of the terminals net turnover) that can be reached within sixty minutes driving time from the center of the municipality.

- Potential for combined transports, measured as the sum of the throughput of the terminals that can be reached within sixty minutes driving time from the center of the municipality.

4.3.3.2. Pre- and post-haulage costs

Wichser et al. (2007) estimate that cost of rail-road transhipment (between Eastern and Western Europe) represents between 23-31 % of total transport costs. Although it covers only a small portion of the total distance travelled, pre- and post-haulage represents up to 37% of the overall cost per TEU. Waiting times for drivers as well as trucks, barges and sometimes also trains in and in connection to the terminals are also cost drivers. See also section 4.3.7.

4.3.3.3. Market areas

Niérat (1997) makes a comparison of the cost for a carrier who chooses between two ways to carry a full truck or a full ITU between two given locations. The first option is direct road transport and the second option is an intermodal solution using rail or IWW. He calculates the market area of the terminal, i.e. all the destinations where intermodal services are cheaper than the direct road transport. This shows that modal choice of the carrier depends on the location of his clients and leads to several other conclusions about the location of the terminal in relation to the clients:

- Sometimes there is no market area for intermodal transport. This is the case when road transport is lower than intermodal transport cost (sum of transhipment costs (price charged by the intermodal operator) and the pre- and post-haulage costs).
- The size and shape of the market area depend on pre- and post-haulage performances, measured by the number of containers dealt in a day by a truck and the percentage of empty kilometres. The size of the market area also depends on long distance empty hauls, weight (when intermodal prices are weight related) and the distance of the long haul.
- The terminal is not located at the centre of its market area. The market area is “shorter” when the truck goes back in the direction of the origin and larger in the opposite direction. Assuming that half of all pre- and post-haulage kilometres are empty, the market area is three times “longer” when the truck gets away from the origin compared to when it gets closer. Therefore, it is important to locate the terminal in relation to potential customers, otherwise the terminal will not be able to capture enough traffic.
- The carrier’s choice of transport solution depends on the location of its clients in relation to the terminal location and the pre- and post-haulage performance. As pre- and post-haulage performance vary between carriers, so does the market area. Carriers may therefore choose different transport solution even though their shipment, origin and destination are identical.
- When the comparison between transport solutions account for time or quality it reduces the size of the market area. This is due to higher service frequency and flexibility of trucks.

4.3.4. Transhipment cost

This section examines the transhipment cost including the costs for waiting times in and in connection to the terminals.

4.3.4.1. Capacity utilization in the terminal

4.3.4.1.1. Terminal capacity

It is useful to distinguish between different capacity concepts. Theoretical capacity is the maximum capacity assuming ideal conditions and non-stop operations (i.e. operating round-the-clock) without interruptions of any kind (Damij and Damij 2014; Jonsson 2008; Slack et al., 2013).[35] Meanwhile,

[35] In operations management, the capacity of a system from a strategic perspective is defined as “the potential output of a system that may be produced in a specific time, determined by the size, scale and configuration of

nominal capacity refers to the maximum capacity assuming ideal conditions, but considering actual operating times (Brown et al., 2013; Jonsson, 2008; Slack et al. 2013). Calculating terminal capacity (maximum throughput in ITUs or tonnes) is complex. A lack of information about given terminals might mislead the efforts made to improve efficiency and instead waste resources (Woodburn, 2008).

Because terminal operations exhibit economies of scale, the long-term planning of terminal capacity is crucial for the transhipment costs. Oversized terminals generally imply high capital cost wile undersized terminals incur high costs due to congestions. Uncertainty about the level of throughput should be considered in the long-term planning.

Hueltz-Prince (2015) identified factors influencing capacity utilisation of rail-road intermodal terminals (see Table 4-2). Transport demand is typically exogenous and cannot be influenced, while infrastructure (number of tracks, yard size etc.) and superstructure (gantry cranes and other equipment) are under the discretion of terminal operators and/or owners.

Factor type		**Factors**
	Mix of load units Train timetables Wagons with dangerous goods	Maximum allowed train length in network Share of shuttle trains and trains with wagon cuts.
Infrastructure factors	Number of transhipment tracks Number of side tracks Length of transhipment tracks	Length of side tracks Electrical access to terminal Connectivity of side yard to terminal Yard size
Superstructure factors	Mix of cranes (type of load service offered) Number of gantry cranes Number of mobile cranes	Performance (speed) of cranes Lifting (weight) capacity of cranes
Policies	Prioritization of incoming trains In-store empty wagon keeping	Allowance for late units Physical organization of units within yard
Communication technologies	Internal coordination	External coordination with transport chain actors (rail operator, intermodal operator, hauler)

Table 4-2. Capacity factors. Source: Hueltz-Prince (2015)

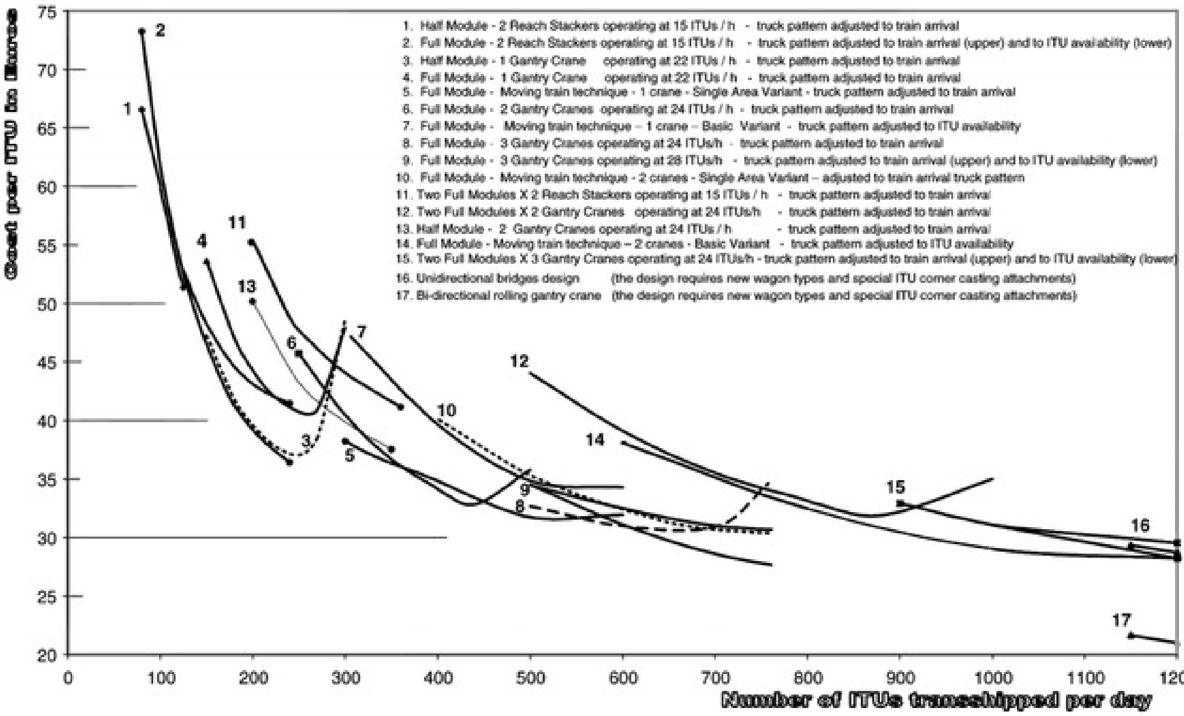
Cost structures differ between intercontinental terminals, in which up to seven ITUs can be stored on top of each other (see section 4.2.3), and continental terminals, in which ITUs are usually not stackable. This implies that intercontinental terminals have a higher storage capacity but also higher superstructure investments. The terminals' policies regarding the allowance of late load units influence also the use of the capacity. Communication technologies, that are used in the terminal and the whole intermodal chain, can be applied to improve the capacity utilization.[36]

the system´s transportation inputs" (Brown et al. 2013). From an operational perspective, it is defined as "the maximum level of value-added activity over a period that a process can achieve under normal operating conditions" (Slack et al. 2013).

[36] Poor capacity management leads to bottlenecks in the system, rising average total costs and outweighing the benefits brought by economies of scale (Prentice 2003).

4.3.4.1.2. Exploitation of economies of scale

Ballis and Golias (2002) evaluate the cost of a rail-road terminal based on size, design and equipment. They build cost versus volume curves (Figure 4-13) that show how costs per ITU decrease as volumes increase but stabilizes at €30 per ITU.



Note: Number or ITUs transhipped per day (x-axis) against cost per ITU in euros (y-axis).

Figure 4-13. Transhipment costs in rail-road terminals, by technology and volume. Source: Ballis et al (2002)

Smid et al. (2016) calculate the annual cost of European IWW terminals of different capacity categories. The terminals have capacity between 20,000-500,000 TEU/year and various characteristics in terms of equipment, length of quay, terminal area, number of cranes and reach stackers. The authors distinguish between fixed costs (depreciation of equipment and area), semi variable costs (labor) and variable costs (fuel, electricity, repair and maintenance). Table 4-3 gives an overview. The results illustrate the variation in annual costs between terminals (between €1.4-12.1 million) and the fact that fixed and semi-variable costs constitute most of the total amount. The results also show that economies of scale greatly improve the cost per container, particularly at higher capacity utilization rates. The authors also compare the cost and the price by container (€35 to 40) to conclude that small and medium intermodal terminals are not viable without subsidies[37]. (For subsidies see section 4.4.2.1.)

	XXL	XL	L	M	S

[37] A container of two TEU is charged €35 to 40 but the handling cost is two times the figures in Table 4-4 which are in €/TEU. As a consequence, it is not sure that large and very large terminal can be viable. In France and in some countries, the throughput of an IWW terminal is defined as the sum of all entries and exits. A container going through a terminal is handled two times and the number of containers actually dealt with by the terminal is half the yearly score. In this paper, a container is equal to one TEU and is assumed to be handled two times. Then all terminals would have the double volume (an IWW terminal deals 20,000 TEU/year, which is 40,000 TEU in France).

TEU/year	500,000	200,000	125,000	50,000	20,000
Terminal area (ha)	20	7	3	3	1,5
Quay length (m)	400	300	240	200	200
Cranes	3	2	2	1	1
Reach stackers	2	3	2	1	1
Annual cost (million €)	12.105	5.838	3.638	2.185	1.399
Fixed costs (%)	44%	47%	51%	58%	67%
Semi variable costs (%)	28%	29%	25%	25%	22%
Variable costs (%)	28%	24%	24%	17%	11%
Cost per TEU (€)					
100% capacity	24.21	29.19	29.11	43.70	69.95
80% capacity	30.26	36.49	36.38	54.62	87.44

Table 4-3. TEU per year in intermodal IWW terminals. Source: Smid et al. (2016)

4.3.4.2. Waiting time

Delays and waiting times in or in connection to the terminal influence the transhipment costs. This is true for the main mode in intermodal transport chains. The delay of vessels leads to waiting time of equipment and employees and thus additional costs (Wiegmans and Konings, 2013). This same is true for delayed trains. In ports for instance, barges are often loaded on the same quay and with the same crane as deep sea ships. Priority is often given to deep sea ships so barges must wait to the end of the shift to be loaded. Barges with multiple stops at ports can lose several days because of loading time. Improvements are expected from information systems that track barges and make appointments at terminals. Terminals can then be offered a detailed list of containers before the arrival of barge to move the expected containers near the transhipment place (Konings 2007).

The waiting time related to pre- and post-haulage, often performed by trucks, can be crucial for the transhipment costs in terminals. A French truck company using intermodal services estimated (Niérat in 2017) that each ITU unloading/loading takes 25 minutes on average. If each driver carries out two operations per day, this means that 50 minutes per day (or one tenth of the actual working time) is spent waiting.

Up to five hours of waiting times for trucks loading or unloading containers in the port of Gothenburg were reported in Sweden in 2016 (Öster 2016). The delays were caused by a change of computer system in the container terminal and the shutdown of the previous queuing system with patches. Jacobson et al. (2016) followed six trucks during one week in road haulage from a port and from an inland terminal in Sweden. They showed that waiting time for entering the port, at the administrative gate and the transhipment area account for one fifth of the truckers' working time. They observe longer waiting time at the port (up to four hours) than at the intermodal terminal (maximum 30 minutes).

(Long) waiting times in terminals can also arise because cranes or reach stackers handle trucks one after the other according their arrival time. Each truck needs to take one specific container and the crane has to move along the train to go and fetch the right container. Congestion in terminal handling (e.g. the arrival of large inland vessels that must be unloaded or loaded quickly) will also lead to increased costs per handling.

4.3.4.3. Other factors

The transhipment costs are influenced by factors such as the different development phases of a given terminal, or the possibility to rent the land to establish a terminal instead of buying it. Noise and/or emission restrictions imposed by local governments can limit the terminal operating hours and this may result in a higher cost per handling as the equipment cannot be used as intensively as without regulation (Wiegmans and Konings, 2013). Severe weather conditions can also influence efficient terminal operations due to temporary closures of the terminal.

Public information on transhipment costs in terminals is generally sparse. An overview of handling costs (that we assume are the same as the transshipment costs) in intermodal rail terminals in scientific papers is provided by Wiegmans and Behdani (2017).

Source	Handling costs
Newman and Yano (2001)	$1–2 per container
Van Duin and Van Ham (2001)	Range: €14–68/TEU; average €40/TEU (Twenty-foot Equivalent Unit)
Arnold et al. (2004)	The relative cost of rail (compared with road) is assumed €0.65 per km and the transhipment cost is equivalent to 100 km.
Bontekoning (2006)	€35 per ILU (average market price)
Jourquin and Limbourg (2007) Limbourg and Jourquin (2009, 2010)	(Un)loading cost is €1.297/tonne (an average TEU weighs about 15-16 tonnes)
Bhattacharya et al. (2014)	$70–100 per container
Zhang and Facanha (2014)	$40 per FEU (Forty-foot equivalent unit)
Black et al. (2002)	€36–60 per handling
Vold (2007)	€45 per handling
Bozuwa et al. (2011)	€40 per TEU
Victorian Department of Infrastructure	$15 per lift

Table 4-4. Transhipment costs in scientific papers. Source: Wiegmans and Behdani (2017)

4.4. Barriers

The need to promote intermodal transports to cope with increasing freight volumes and reduce the external costs caused by freight transports has been discussed for a long time. The European project ”High efficient and reliable arrangements for crossmodal transport” (HERMES 2011) identified several types of barriers to the production of co-modal services, both from the perspective of public decision makers terminal operators, transport operators and user associations.

	Public decision makers	Terminal managers
Legal/ Regulatory	• Complex legal framework • Hard to monitor a deregulated market • Absence of implementation of existing intermodality policy by national governments • Environmental rules curb intermodality (e.g. standards on noise)	• Intermodality has not been part of planning process of existing infrastructure • Different regulation in different countries or cities • There are no homogenous standards for information services and safety aspects
Institutional	• Lack of co-ordination authority, co-operation between operators and co-operation between the institutions on the central and the local level • Several actors with different responsibility	• Lack of co-operation among transport modes • Irregular market; many stake-holders, different agreements • Different authorities lead to diffuse responsibilities
Contractual	• Absence of common standards in contracts and incentives for intermodality (transport operators)	• Lack of temporal co-ordination between transport operators • Conflicting economic aims of transport operators and terminal managers
Informational	• Lack of co-ordinating authority to define information standards	
Physical	• Absence of co-operation • No right to change or extend the interchange	
Economic	• Complex economic framework	
	Transport operator	**User association**
Legal/ Regulatory	• Long-winded planning and licencing process before investments in infrastructure can be made • Lack of simple technical standards	• Intermodality no part of the planning process • Not enough intermodal offers or they are unnoticed by customers
Institutional	• Absence of authorities that co-ordinates the provision of operators	• Lack of local authorities' participation in terminal activities

Table 4-5. Barriers to the production of co-modal services, Source: HERMES (2011)

4.5. Policy measures

4.5.1. Reduction of transhipment costs

Some EU countries provide subsidies to freight intermodal terminals. However, there is not a common financing scheme in the European Union.

Subsidy programs for the establishment of terminals (up to 25% of the total investment costs in the Netherlands, and 80% of investment costs of the quay in Belgium) have contributed to a rapid development of a dense terminal landscape in these countries (Decisio 2002; Van Ham and Macharis 2005; Wiegmans and Konings 2013).

In France, the subsidy level for inland terminals was €12 per transhipment and per ITU in 2014. Some ask whether to subsidize all terminals or to concentrate on the most promising projects in terms of traffic concentration (De Tréglodé, 2015). Research from Germany suggest that subsidies in combination with internalization of external costs is particularly suitable in less developed markets (100 TEU/day), compared to regions with higher demand (Liedtke and Carillo Murillo, 2012).

In Germany, public authorities promote the construction of terminals for combined transport (rail-road) and fund up to 80% of costs for land acquisition, infrastructure and transhipment equipment (EBA, 2017). One example is the PPP scheme, where financial aids are given to the Deutsche Bundesbahn (DB) or private companies. The financial aid involves grants of 80 % and 20 % of subsidized loans. DB must keep the terminal open for public use for 20 years. The private operator must keep the terminal open for 5, 10 or 20 years depending on their own financial engagement. The more the company finances itself, the shorter the obligation to keep the terminal open for public use.

4.5.2. Reduction of pre- and post-haulage costs

Bergqvist and Behrends (2011) study how the cost efficiency of intermodal transport chains can be improved by implementing an innovative and flexible legal framework regarding the PPH transports by road. They find that the efficiency could be greatly improved using 2 × 40 foot or even two semi-trailers using only one vehicle in the context of the Swedish regulatory framework. Their results indicate that a typical shipper can experience cost reductions of about 5–10% of the total costs of the intermodal transport chain. Furthermore, the authors stress that an innovative and flexible legal framework regarding the road vehicle length in the PPH can contribute to a greater modal shift, improved cost efficiency and more environmentally friendly transportation systems. Also, Sanchez-Rodrigues et al. (2015) who evaluate the HCV-trials in Germany, mention that HCVs might support intermodal transports by improving the efficiency of the pre- and post-haulage transports.

The port of Gothenburg has for example developed a rail shuttle system for containers (Bergqvist and Woxenius 2011). Bergqvist & Cullinane (2016) show the impact of privatization in the port of Gothenburg. One of the most challenging aspects was the coordination and development of rail services in relation to the different terminals and freight services. “The issue of promoting the use of rail as the preferred mode of connecting to the port for load-units other than containers would appear to be a much more intractable problem, given the rigidity of post-privatisation structures.” Also, the port of Basel in Switzerland uses to a certain extent rail for the pre- and post-haulage (Brackman et al. 2016).

Electrified tracks at the rail gate of a rail-road terminal allows a better service and can reduce the main haul time of more than an hour. It allows to have an electrified locomotive at the head of the train and to directly go to the main tracks when the train is loaded. Otherwise, a diesel machine is needed to leave the yard and to go to a track where an electric locomotive is set at the head of the train.

4.5.2.1. Reduction of waiting times in terminals

Different measures are applied to reduce the waiting time of truck drivers and trucks. In the port of Rotterdam**,** innovative technologies enable trucks’ arrival times and waiting times to be accurately predicted, thus greatly enhancing the efficiency of the container terminal’s logistics process. A promising approach to optimize traffic flows is to control approaching road traffic at an early stage (TNO Time 2016). Such it is planned to inform truck drivers about the traffic jams in the port of Hamburg and recommend the use of pre-gate car park (Transver 2011).

4.5.2.2. Reduction of transport chains

Another strategy is to develop dry ports a few kilometres away from the port and connect it by rail or IWW shuttles. This reduces usually congestion as it is easier for trucks to fetch containers in **a** terminal in a dry port than in a terminal in a seaport. Roso (2007) evaluates and simulates the time spent by a truck in the port of Gothenburg and in a dry port connected by rail to the port of Gothenburg. The time spent in terminals is the sum of three phases: waiting time at the gate, loading time and administrative service time. The average waiting time at the terminal gate during peak hours was simulated to be 85 minutes in the port of Gothenburg and 13 minutes in the dry port**.** Dry ports can also be active nodes in shaping transport chains, offering opportunities of space for logistics location.

Regarding the role of terminals in re-shaping the supply chains, as Monios and Wilmsmeier (2012) suggested, ports should develop landside logistics strategies proactively through site development strategies, aiming at restructuring transport chains of large shippers through new corridors and "challenging the inertia of supply chains". Monios and Wilmsmeier (2012) develop two concepts: port-based versus inland-based logistics. Port centric logistics is defined as "the provision of distribution and other value-adding logistics services at a port", not only providing warehousing services at ports but inducing customer to locate within warehousing/logistics areas adjacent to the terminal; if the port has plenty of room for storage and other activities, the port authority would prefer customers to perform these tasks onsite. These activities on their land generate additional revenue, even if it reduces the value of intermodal transport and inland container availability for exporters. In case of congestion on ports, the inland strategy is suitable; by moving non-essential activities inland ports can retain customers and earn possible revenues if they have invested in the inland node.

4.5.2.3. Other measures

The national strategy France Logistique 2025 (République Française, 2016) was adopted in 2016 and aims at promoting optimization of logistic flows and transport infrastructures. To do so, a call was launched in 2016 for projects on logistics and intermodality to develop technological solutions that would improve transhipment, tracking of goods, or development of new and standardized containers for all modes.

4.6. Conclusions

This chapter has addressed a range of topics related to the role of terminals in transport chains. Section 4.2 provided a typology of terminals and load units and described a set of different terminals. Section 4.3 started with a description of the terminal structure in Europe. This exercise showed that the density of terminals is not the same everywhere. Terminals are numerous in some regions, scarce and scattered in other. Not all terminals are directly connected to each other which can make it difficult or costly to get from one terminal to another. Some terminals serve as a key node for firms' transport chain and attracts large volumes. Other may be of less importance because of competing terminals in the neighbouring regions. Terminals also vary in the modes they connect, the types of cargo they handle and the size.

Section 4.3 addressed a range of topics related to the role of terminals in transport chains. It examined the terminals' accessibility, which typically refers to the time and cost required to reach a terminal or the market areas of the terminals. Higher availability and accessibility tend to reduce the cost of multimodal transport solutions. Although most pre- and post-haulage (PPH) is performed by road, rail or waterborne transports are also possible. Road PPH can account for a significant part of the cost in a multimodal transport chain.

Transport modes are in some instances complements rather than competing alternatives. Improving the conditions for one mode will increase its attractiveness but it can also benefit transport chains that include this mode. A case in point is the introduction of high capacity vehicles, which is estimated to bring about a reduction in road transport cost – and thereby also a reduction in pre- and post-haulage costs to/from terminals.

In section 4.3.4 the factors that influence the transhipment costs in terminals were analysed. Main drivers are terminal capacity (infrastructure and the superstructure) and how this capacity is utilized.

Capacity use is determined by some factors external to the terminal (like the development of transport demand and the mix of the load units) and measures that the terminal owner and/or operator can influence (infrastructure and superstructure). Waiting time for drivers and vehicles also have an impact on transhipment costs. Waiting time is estimated to constitute 10-20 % of truck drivers' working time, a non-trivial cost component. Estimates of transhipment cost are quite dispersed but point to €40 per twenty-foot equivalent unit (TEU) on average.

Collaboration between actors in the transport chains, namely the operators that perform the transports between and to/from the terminals as well as the infrastructure authorities responsible for the connecting modes, should be intensified. For instance, the Swedish Transport Administration collaborates with terminal operators to obtain information on the quality of the connections in the preparation of the national infrastructure plan.

Terminal capacity and the capacity of vehicles and vessels are to some degree complements. The effectiveness of increasing capacity in one part of the logistics chain (e.g. larger vessels or trains) is limited by the capacity in other parts of the chain (e.g. terminals or canals). Communication technologies can be applied to improve capacity utilization and reduce cost for whole transport chains.

Section 4.4 comprises policy measures that have been implemented or discussed by different stake holders. Some terminals adopt sophisticated appointment procedures to reduce the idle time. Others predict arrivals and inform the drivers about traffic conditions in real-time. The development of dry ports in connection to seaports can also be a way to reduce congestion in ports. Different countries apply different types of subsidies to reduce the transhipment costs in the intermodal terminals or the pre- and post-haulage costs.

To conclude, this chapter has shown how various aspects of freight terminals can influence the choice of transport solution. The results are closely linked to chapter 3 which discussed modal choice more broadly. The topics review in this chapter - transhipment cost, availability, connectivity, accessibility – can be translated into the mode choice variables identified in the chapter 3. Well-functioning and efficient terminals are therefore likely to improve the attractiveness of multimodal transport and increase firms' selection of transport chains. Together, chapter 3 and 4 describe how firms make their decision on mode choice and the environment surrounding these decisions. The subsequent chapters, chapter 5 and 6, show which data and assessment tools are needed for NRAs to incorporate these findings in their analysis of the transport sector.

5. Data

5.1. Introduction

Different type of quantitative information is needed to analyse the factors influencing freight transport and modal choice. This chapter provides an overview of the most important topics regarding NRAs use and collection of freight transport data. Section 5.2 identifies what types of freight data is required for informed public policy making. Section 5.3 describes the various ways in which freight transport data are collected and provides an overview of the available data at national and European level. Section 5.4 discuss confidentiality issues, the NRAs access to data and various initiatives for data sharing. Finally, section 5.5 concludes and assess the gap between the need for data and the availability of data.

5.2. Data needs

McKinnon (2010) provides a general overview of the need for freight transport statistics in Europe based on a literature review and discussions with stake holders. He identifies four main questions that transport policy-makers typically ask: 1) how much freight is being moved, 2) which modes are used, 3) how efficiently is the freight being transported and 4) how much road traffic is generated by the movement of freight.

The amount of freight being moved is important to policy-makers and NRAs when they provide infrastructure capacity for freight transports, assess the freight sector's demand for other resources (such as energy, vehicles and labour) and asses the externalities the sector is producing. Since transport modes differ in their resource cost per unit transported and because modes have different infrastructure, policy-makers and NRAs also require freight statistics disaggregated by mode. The efficiency of freight transports, meaning how inputs such as infrastructure capacity, energy, vehicle space and labour are used to produce transports, matters both for the resource costs and environmental impacts of the transport system as well as for its international competitiveness. Information on indicators of efficiency is therefore required to help formulate a variety of transport policies and analyse their effects.

McKinnon and Leonardi (2009) specify data requirements for long-distance road freight, which include information about transport activity (by loaded and empty vehicles), commodity mix, vehicle types, load factors, resource consumption, externalities, scheduling, supply-chain structure, intermodal links, market structure and infringements. McKinnon (2010) and McKinnon and Leonardi (2009) both highlight the lack of data on the cubic volume of freight moved, which can be used to study the impact of high capacity transport.

National freight transport models also have data requirements. The models typically require aggregated data on freight flows and transport movements between regions as well as network information and transport cost (see chapter 6). Some models also require disaggregated data on shipment characteristics and the transport modes. These kinds of variables are also important for the firms' choice of transport solution (see chapter 3).

Table 5-1 shows requests regarding freight transport statistics put forward by a Swedish government commission that included Transport Analysis (responsible for transport statistics), the National Transport Administration (responsible for national long term infrastructure for all modes), the National Maritime Administration and the Swedish Transport Agency (regulator) (Transport Analysis 2016). The commission identified a handful of variables that were deemed particularly critical to collect information on (shown in bold letters in the table): regional rail transport activity by commodity class, intermodal transport activity, urban freight flows and terminal structure. Surveys of shippers in the UK also indicate that there is lack of data on location and information on international freight terminals (ORR 2012). The Swedish government commission emphasized that the increased response burden of the organizations that deliver data is an important limitation for the measures that Transport Analysis can undertake (Transport Analysis 2016).

Aspect	Variable
Mode-specific variables	**Regional transport activity by commodity (rail)** Volume and value of the goods (all modes) Cargo type (all modes) Vehicle/vessel type (all modes) Use of light trucks (road) Transport activity by imports and exports (rail)
Transport quality and efficiency	Load factors (all modes) Transport chains (all modes) Delivery reliability (rail)
Transport chains	**Intermodal activity (tonnes, km, tonne-km)** **Terminal structure and nodes (all modes)** Combinations and transhipments (all modes) Terminal costs (all modes)
Geography and corridors	**Urban freight flows (all modes)** National/European corridors and maps per mode (all modes) Local/regional, national, international freight flows (all modes) Loading on specific corridors (all modes)

Note: Requests in bold letters are deemed to be particularly critical.

Table 5-1. Requests regarding freight transport data. Source: Transport Analysis (2016)

5.3. Available data

EU legislation set minimum requirements that harmonize the data collection methods and make the statistics comparable between countries. The data collected by Eurostat consist of mode-specific transport activity measures (tonnes-lifted, tonne-kilometres, vehicle-kilometres and journeys).[38] In most countries, the national data have more detail than the data that is delivered to Eurostat.

There are two fundamental differences between the data collection for road transports on the one side and rail, IWW, sea and air transports on the other. For road transports, surveys among national carriers are carried out while data from all transport firms are collected for the other modes. The nationality principle is applied for road transports and the territoriality principle for the other modes (see section 5.3.1). The EU legislation specifies which data are mandatory to report, either for a sample (road) or all companies (other modes).

The way the road transport data is collected means that there are potential quality problems due to incomplete or incorrect answers by the hauliers that answer the questionnaire. International and cabotage transports have to be assigned to the territory where the trip took place. Transport activity by non-EU hauliers is not included in Eurostat's statistics (except those from Norway, Liechtenstein (until 2012) and Switzerland). Section 5.3.1-5.3.6 contain details of the data collection methods, including the application of new technologies for data collection.

[38] The main variables available at Eurostat are compiled in Appendix B.

5.3.1. Transport performance data

Road

Road freight transport statistics in the EU are collected under the framework provided by Regulation 1172/98 (EU 1998) and Regulation 70/2012 (EU 2012). The data are based on sample surveys carried out in the reporting countries and record the transport of goods by road, as undertaken by vehicles registered in each of the EU Member States. Most Member States exclude light trucks[39] from the survey (Eurostat 2014).

The Swedish agency Transport Analysis validated the national freight statistics and concluded that the road survey underestimated the freight activity (Transport Analysis 2015). Trucks were incorrectly being reported as unused during the period of study, which lead to lower levels of road transport than the actual values. To correct the problem, the agency conducted an additional survey on the extent of trucks being unused and adjusted the statistics from the original road freight survey accordingly. The vehicle kilometres, tonnes, tonne-kilometres and the number of trips increased by 25-40 % compared to the original values. The Department of Transport (2016) in the UK reported a consistent discrepancy between survey-based measures of vehicle-kilometres and estimates based on traffic counts. In Germany for the last entire year for which a report is available (2013) no such systematic bias is reported but there are problems with low response numbers.

International road transports need to be 'territorialised' as it is reported by the countries based on the nationality of the haulier, not based on where the transport was carried out. For example, a haulier from the Netherlands might undertake a journey to Portugal. Though only a part of this journey is in the Netherlands, the entire transport performance is accounted for by the Netherlands, as the vehicle carrying out the transport is registered there. To calculate the modal split based on the 'territoriality principle', the international road freight transport data have been redistributed according to the national territories where the transport took place. This redistribution involved modelling the likely journey itinerary and projecting it on the European road network. Box 5.1 provides additional details on this method.

National road transports also need to be "territorialised", as EU-trucks perform domestic transports (cabotage transports) in other than their home country. There are likely to be quality problems with these data too. In Scandinavia, the so-called "cabotage study" was carried out 2013 (Sternberg et al. 2013), in which users of a specific app could enter the licence plate number of an observed vehicle and submit its position using the phone's GPS coordinates. The authors concluded that the data collected in their study can be used to complement the Eurostat cabotage statistics, especially since several of the most frequently occurring truck nationalities are not represented in Eurostat.

The Dutch Ministry of Infrastructure and Environment and Rijkswaterstaat requested data on transport carried out in the Netherlands by foreign trucks, the number of foreign trucks active in the country and their transport performance. The data were going to be used for policy making and to investigate whether the EU legislation on cabotage (Regulation (EC) No 1072/2009) was adhered to. Because there were no direct data on cabotage available in the Netherlands (the data that was available was came from the "Weigh in Motion" system) this information was derived using models.

[39] Vehicles with a carrying capacity below 3.5 tonnes (or less) or a gross vehicle weight below 6 tonnes (or less) (EU 1998).

Box 5.1. The ILSE tool

In order to redistribute the tonne-kilometre data proportionally to the countries concerned by the journey, the ILSE tool (Index of Locations for Statistics in Europe) is used. The tool allows the calculation of the total distance between the NUTS level 3 region of origin and the NUTS level 3 region of destination and breaks down the total distance into sections according to the countries in which this transport took place. The distances driven on the territories of the individual countries were calculated and the declared tonne-kilometres were proportionally attributed to the countries concerned. However, the likely routes used and their corresponding distances defined by the tool were revised in 2013 and were applied to the previous years. Revisions were such that comparing statistics processed with the previous version of the tool would have resulted in a break in series. Therefore, data of the previous years have been re-processed to ensure comparability and continuity. The consequence of this re-processing using the revised routes/distances is that the Modal Split figures published in an earlier Eurostat publication Statistics in Focus 13/2012 have become obsolete.

Furthermore, transport performance of road freight journeys to non-EU countries (apart from EFTA countries) has not been taken into account. Therefore the cumulated values of the territorialised transport performance will always be lower than those declared in compliance with relevant EU legal acts. Some journeys have their origin or destination in regions that are not covered by the ILSE tool (which is notably the case for islands such as the Canary Islands, Madeira, etc). In such cases, the region of origin/destination have been given the NUTS 3 region code where the main freight ferry terminals are located in order to avoid further underestimation of the data.

Given the quality problems of existing data and the need for specific statistics, there are various new methods for data collection being developed:

- In the Netherlands, the national statistical office CBS has been making a technological shift in its primary data collection process for road, from paper forms filled in by the businesses to information collection via web-forms and web-based survey. The current technological shift in the information collection process is to automate it fully and let the businesses report in software generated form, using the XML technology[40]. As of 2017, some 80 transport companies deliver their statistics reporting in XML.
- In Sweden, Transport Analysis is testing new methods for the truck survey and the commodity flow survey. These new methods are expected to reduce the data collection costs and to increase the quality of the statistics (Transport Analysis 2015).
- In Germany, the regular survey questionnaire for heavy vehicles can only be completed online or sent in via an online mask.
- In France, electronic data collection has been implemented since 2016. A week before the survey respondents receive a mail which indicates the connexion codes made of the questionnaire number and the license plate. It is also possible for respondents to forward an XML flow that automatically fills in the questionnaire.
  In addition, the French Ministry of Transport used weighting equipment and automatic number plate recognition (ANPR) to construct a detection system connected to a national database. The system provides real-time information on the heavy traffic and is used for collection of statistics. As of 2017, around 29 detection systems are installed on the structural road network.

[40] The Extensible Markup Language (XML) is a way to encode documents in a format that can be read both by humans and machines.

Rail

Rail freight statistics are collected under the framework provided by Regulation 91/2003 (EC 2003). The data are collected quarterly (usually limited to larger enterprises), annually (covering enterprises of all sizes) and every five years in relation to a regional analysis (NUTS level 2). Statistics for rail freight are not available for Malta and Cyprus (or Iceland) as they do not have a railway infrastructure. Aside from the mandatory collection of data based on legal acts, Eurostat also collects rail transport statistics through a voluntary data collection exercise. The questionnaire used for this exercise provides information in relation to railway transport infrastructures, equipment, enterprises, traffic and train movements. Different organizations are responsible for the rail data collection in the different countries.

- CBS, the national statistics office in the Netherlands, has an integral observation using data from rail companies and data from the rail infrastructure manager ProRail (a state-owned company responsible for maintenance and extensions of the national railway network infrastructure (excluding the metro and tram), of allocating rail capacity and of traffic control).
- The Swedish Transport Administration collects rail data on behalf of Transport Analysis.
- In France, SoeS (statistics department of the transport ministry) is responsible for the rail data provision. As of 2016, ARAFER (regulatory body for rail and road) collects quarterly and annually data from the railway operators on train paths reservation, delays, quality of services as well as tonnes, tonne-kilometres and train-kilometres by product type and origin-destination. Economic and financial data are also collected.
- In Germany, there are statistics on transport (collected from the Train Operating Company (TOC)), infrastructure and on flows on certain tracks (collected at the infrastructure owners). All information is collected by the federal statistics office (Statistisches Bundesamt). In addition to the mandatory data supplemented to Eurostat, the data includes detailed information on intermodal rail transports as well as the length of and traffic on specific tracks.

Inland waterways

The legal framework for the collection of statistics on inland waterway freight transport is Regulation 1365/2006 (EU 2006). Data on inland waterways are only required for those Member States with an annual transport volumes above one million tonnes, namely: Belgium, Bulgaria, the Czech Republic, Germany, France, Croatia, Luxembourg, Hungary, the Netherlands, Austria, Poland, Romania, Slovakia and the United Kingdom. The data collection for national and international transports is based on an exhaustive survey of all inland waterway undertakings for all goods that are loaded or unloaded. In the case of transit, some countries make use of sampling methods to estimate the quantity of goods.

For inland waterways, CBS in the Netherlands receive electronic information from the Regional Public Works Directorates (Rijkswaterstaat RWS), based on the records of the Information Processing System (IVS) of RWS on the Dutch waterways. Bargemen are required at different points of the waterway to provide information about the ship, the trip and any cargo carried. This often happens at locks and bridges. The skippers also have the option to use the electronic system BICS (Barge Information and Communication System) from RWS. These reports are passed to the IVS.

Sea

Maritime transport data are collected according to Regulation 1090/2010 (EU 2010). Maritime transport data are available for most Member States from 2001 onwards, although some countries have provided data back to 1997. Statistics on maritime freight are not transmitted to Eurostat by the Czech Republic, Luxembourg, Hungary, Austria and Slovakia as they have no maritime ports.

Eurostat collects maritime data of tonnes transported between port of loading and port of unloading. These data only cover ports handling more than 1 million tonnes of goods annually. To calculate transport performance in tonne-kilometres for maritime transport, Eurostat has developed a distance matrix based on the most likely sea routes taken by vessels. Multiplying tonnes transported between a pair of ports by the relevant distance allows the calculation of the maritime transport tonne-kilometres at the EU level.

All records where goods are reported as an incoming by one EU port and outgoing by another are identified and adjusted to avoid double counting. However, some uncertainty in the recording of the partner ports of loading or unloading may influence the results. Due to data uncertainty for outwards transports, all outgoing goods with an 'unknown' partner port declared by some countries, have been excluded from the tonne-kilometres calculations on the assumption that this transport has been correctly reported as incoming goods by the partner country.

In Sweden, a research project by Transport Analysis and Statistics Sweden investigated the possibility to use AIS-data to construct maritime freight statistics. The project showed that utilizing the exact position of the vessels increased the level of detail of the statistics and made it possible to construct maritime freight traffic data by area, port-pairs, transport relations and economic zones (Justesen et al. 2017).

Air

The legal framework for air transport statistics is provided by Regulation 437/2003 (EU 2003). Statistics on air freight are collected for freight and mail loaded and unloaded in relation to commercial air flights. The information is broken down to cover national and international freight transport. Air transport statistics are collected at the airport level by the EU Member States, Norway, Iceland, Switzerland and candidate countries. Annual data are available for most of the Member States for the period from 2003 onwards, while some countries have provided data back to 1993. Air freight statistics are also collected for a monthly and a quarterly frequency and with a regional analysis (NUTS level 2). The national aggregates and total intra-EU-28 aggregates exclude any double counting. They include all reported departures and reported arrivals for which the corresponding departure of the partner airport is missing.

Similarly, to maritime transport, Eurostat collects air transport data of cargo (expressed in tonnes) forwarded between airport pairs. The legal act defines categories of airports according to the annual passenger units; 100 kilograms of freight and mail is equivalent to one passenger unit. Three datasets are defined according to different concepts ('Flight Stage' dataset, 'On Flight Origin Destination' dataset, 'Airport' dataset). Air transport data used for the calculation of tonne-kilometres are based on the 'Flight Stage' concept. Air transport covers transport to and from any airports in the reporting countries with more than 150 000 passenger units annually. In order to calculate transport performance in tonne-kilometres for air transport, Eurostat is using a distance matrix that contains great circle distances (minimum distance on a spherical line) between airport pairs.

5.3.2. Modal split

As an illustration of the freight statistics collected, Figure 5-1 shows the modal split in tonne-kilometres for the inland modes (road, rail and IWW) for Europe (EU28) and per country in 2014 based on the 'territoriality principle'.

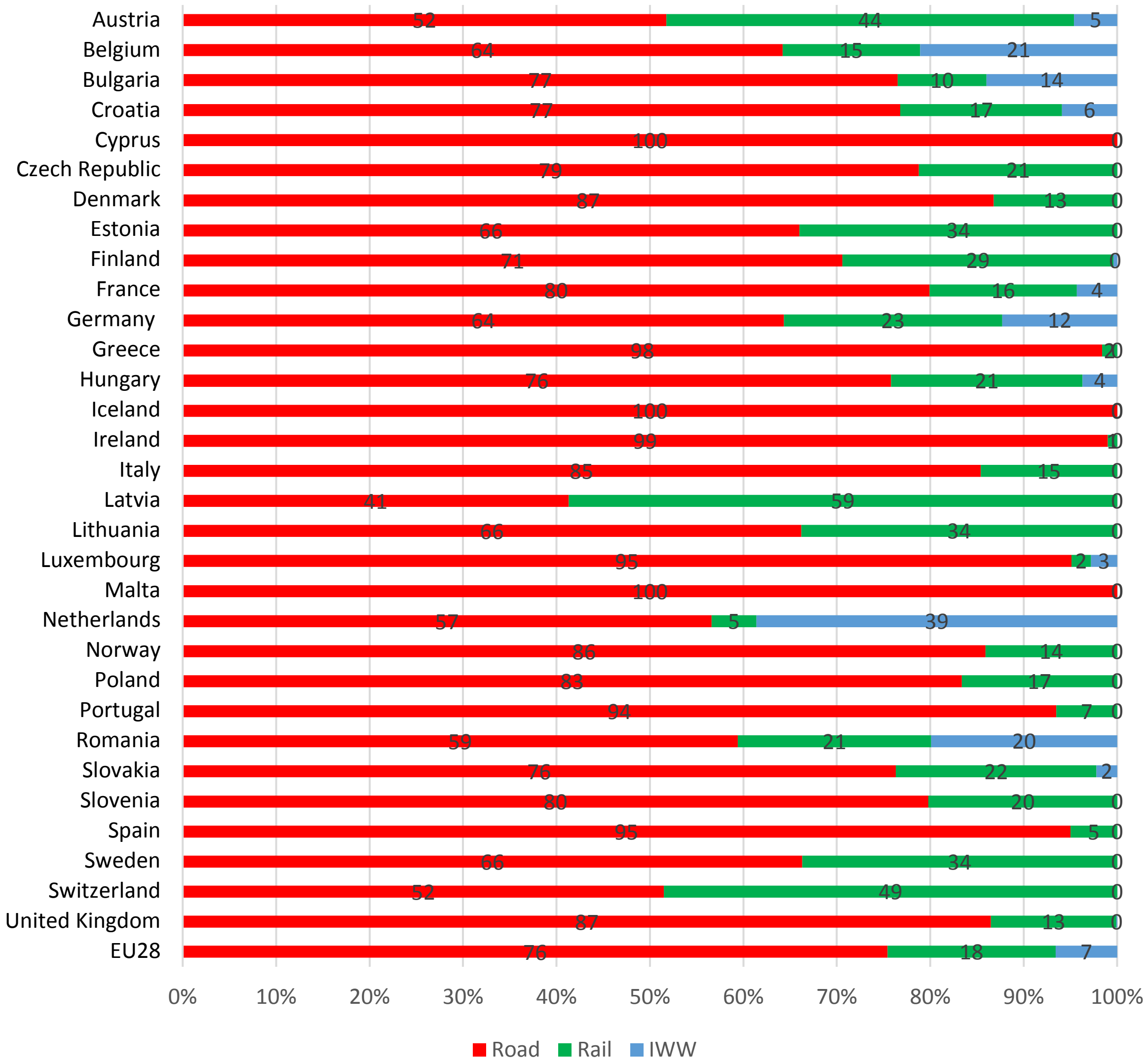


Figure 5-1. Modal split (tonne-km) of inland freight transport, 2014 Source: Eurostat (2017b)

In most countries, road transport is the dominant mode, although the share varies considerably between countries. The modal split for the EU28 is: road 75%, rail 18% and IWW 7%. The modal split in France and Germany is similar to the modal split of the EU28. For the Netherlands, the share of IWW is almost as large as the share for road. Sweden has no IWW and a relatively high rail share compared to the EU28. In Cyprus and Malta there is only road transport, IWW is available in 17 countries. In Estonia, Latvia and Lithuania, the rail share is larger than the road share

5.3.3. Commodity flow data

In Sweden, Norway and France commodity flow surveys (CFS) have been and still are conducted. In the Netherlands, a CFS was held in 1998-1999 as part of the European project Mystic. This survey was developed in cooperation with INRETS, and was continued as the ECHO survey in France. There was no continuation in the Netherlands and therefore the Dutch survey is only briefly discussed in this report. While national transport statistics contain information on the transport activity of each mode separately, one benefit of the CFSs is that they provide information about the respondents' use of transport chains.

Swedish Commodity Flow Survey

The Swedish CFS consists of data on individual shipments to and from local units in Sweden. The aim of the survey is production of official statistics and production of data on transport chains to the national freight model. The surveys have been carried out in 2001, 2004/05, 2009 and 2016, after trials in 1996 and 1998 The producers of the surveys has been Statistics Sweden and the private compay Statisticon on behalf of Transport Analysis.

The Swedish CFS is similar to the American CFS (USCB 2017) in terms of content and methodology. It is partly a sample survey and partly a register based survey. In the survey part, shippers and receivers (of goods from outside Sweden) answer. Several of these firms had/have problems to answer all questions in detail. This problem was solved in the French CFS by including forwarders. The Swedish CFS provides information on the attributes of outgoing and incoming shipments. This allows for a compilation of data differentiated by commodity group, value, weight, transport chain and cargo type per shipment. The included variables are shown in Table 5-2.[41]

Shipment variable	CFS 2001	CFS 2004/05	CFS 2009	CFS 2016
Date			X	X
Value	X	X	X	X
Weight	X	X	X	X
Address	X	X	X	X
Commodity classification	X	X	X	X
Cargo type	X	X	X	X
Dangerous goods	X			
Modes used for transports within Sweden	X	X	X	
Modes used for transports outside Sweden	X	X	X	
Modes used in transport chain				X
Sector classification of receiver		X	X	X
Sector classification of sender	X	X	X	X
Postal address of receiver (delivery in Sweden)	X	X	X	X
Final destination in Sweden	X	X	X	
Final destination abroad	X	X	X	X
Country of origin	X	X	X	X
Place of origin	X	X	X	X
Country of destination	X	X	X	X
Access and use of rail track	X	X		
Access and use of quay	X	X		

Table 5-2. Included variables in the Swedish CFS

Norwegian Commodity Flow Survey

The Norwegian Commodity Flow Survey (carried out by Statistics Norway) was published in 2015 (for the reference year 2014) and in 2008/09 (for the reference year 2008). The surveys are produced partly as a sample survey and partly as a register based survey. The sample survey includes local units from manufacturing, mining and quarrying, wholesale and retail trade, waste collection and management. These firms provide information on their outgoing shipments to destinations within

[41] More details about the variables in the CFS are found in Appendix D.

Norway. Additional data on transports of forestry, petroleum, agricultural, forest and fishing products as well as foreign trade are collected from the registers of various government and sector bodies.

Variable	Description	CFS 2009	CFS 2014
Shipment size	Sum of the weight or volume of all goods that were sent from the local unit to a client in 2008	X	
Shipment quantity	Number of shipments sent from a local unit in 2008	X	
Payment	Whether the receiver pays for the transport or not	X	X
Address of sender	Postal address of the location from which the shipment was sent	X	X
Address of receiver	Postal address of the location to which the shipment was sent	X	X
Date of shipment	Time of and/or date of departure		X
Cargo type	Bulk goods (solid or liquid), container goods (large or other), palletized goods, pre-slung goods, mobile self-propelled units, other mobile units, other cargo types or unknown		X
Transport mode(s)/chain	Truck, vessel, train, air or other		X
Shipment value	Shipment value excl. VAT		X

Table 5-3. Included variables in the Norwegian CFS. Source: Statistics Norway (2017)

French Commodity Flow Survey

The French CFS was renamed ECHO in 2004 (Envois CHargeurs Opérateurs – Consignments Shippers Operators) and collects information on three levels; shipper establishment, shipment and transport operator/journey link.

Shipper establishment

After a few questions about the volume and structure of the company's ingoing and outgoing transport flows and its own fleet of vehicles, a face-to-face interview is administered to the logistics manager of the company. The questions concern the economic characteristics of the firm: production, distribution, storage practices, relationships with its customers and suppliers, and the management and communications systems it uses. A "transport" section is added to this description of the firm's industrial and logistical organization. It deals with the firm's relationships with carriers, terms of access to the various types of infrastructure, and how responsibility for transport is shared between the firm and its partners.

- Economic activity: shippers are described by their economic activity group, and turnover.
- Relationship with the economic environment: shippers are described by the type of contract they most often have with carriers (three levels: long period contracts, occasional contracts, or both); the number of clients which constitute 80 % of their activity; and the number of carriers or freight forwarders with which they worked during the year.
- Organization of the production: the number of distinct product ranges, the number of references or SKU, and the share of transport cost in the product value.
- Employment: shippers are described by the number of employees and by their main qualification level (four levels: unskilled, without certification, skilled, highly skilled).

Shipment level

At the end of the establishment questionnaire, three of the last 20 shipments are randomly selected and traced to their final consignee. The consignment questionnaires are filled in either by the manager mentioned above or the manager in charge of dispatching; they deal with the economic relationship between the shipper and the consignee and the terms of business between the two. This relationship between the shipper and his clients is described by the physical and economic characteristics of the shipment, the yearly tonnage and number of shipments to the client, the split of responsibilities with regard to transport organization and the contractual allocation of transport costs and associated services. The first information required to reconstruct transport chains is also collected at this level, with the identification of the consignee.

Transport operator and journey link

For this part of the survey, questionnaires are administered by telephone. Questions deal with the economic characteristics of the operator, including the operator to whom it handed the shipment and with the characteristics of the transport leg: mode and vehicle type, load, etc. The next operator is in turn questioned up to the final consignee and the description of the whole transport chain. The transport chain is split into as many legs as there are changes to another vehicle. The transport chain is therefore reconstructed throughout Western Europe and includes an interview with the consignee. For a shipment, which travels beyond the limit of Western Europe, the transport chain is surveyed only until the first transfer point after the frontier of Western Europe.

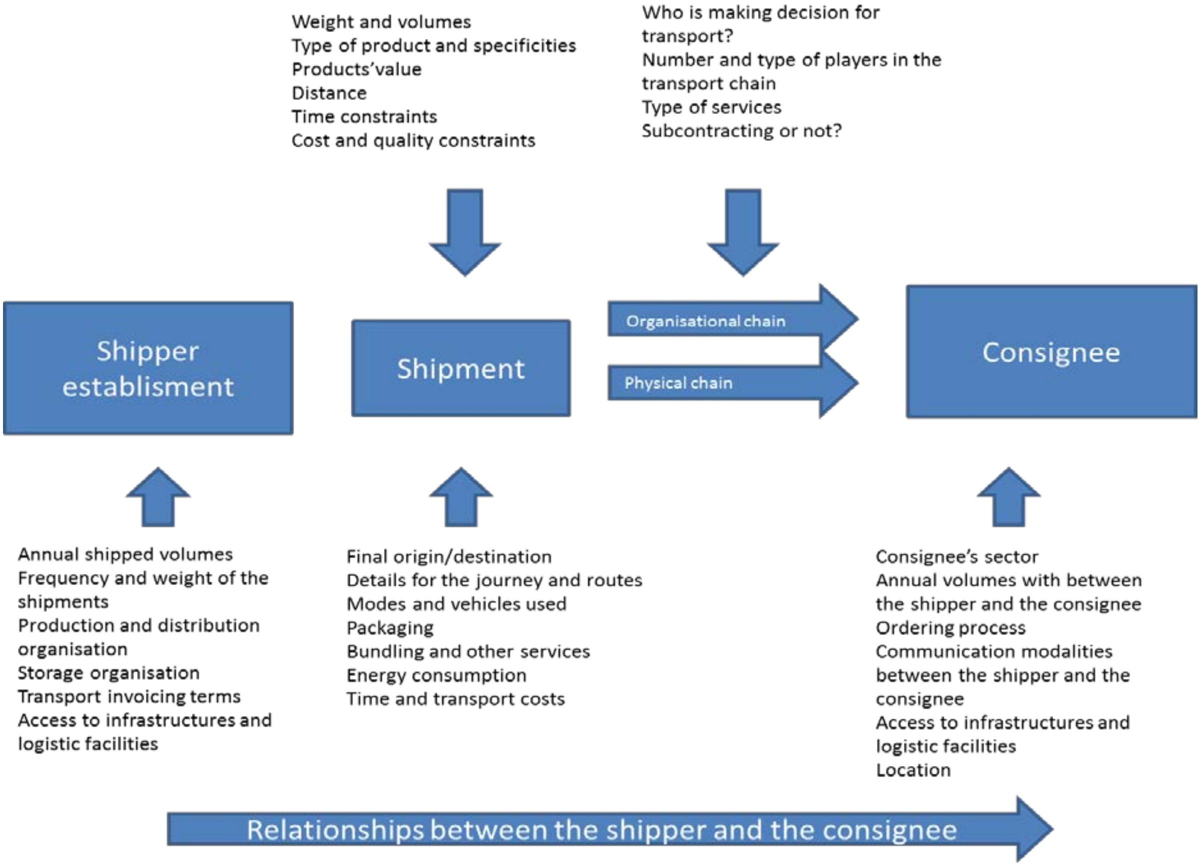


Figure 5-2. Included variables in the French CFS. Source: Cerema (2017)

The data base from the ECHO survey is made of 4 different tables: one related to the shipper establishment, one to the shipment, one to the journey (describing the transport between the loading/unloading operations for one shipment) and the last one to the players in the transport chain. Figure 5-2 summarizes the information being collected.

Dutch Commodity Flow Survey

The survey in 1998-1999 that was conducted in the Netherlands was also conducted in France at the same time. These surveys were part of the European Research project MYSTIC (Methodological Framework for Modelling European Passenger and Freight Transport). The sampling was done in two steps: among the firms and among the shipments of this firm. In the figure below an overview is given of the collected information.

It appeared that the response rates in the Netherlands and France were very different. In the Netherlands, only 12% of the shipment were fully surveyed, while in France this percentage was 86%. The main reason for this rather low response rate in the Netherlands was the refusal for cooperation because of the confidentiality of the information. The high rate of response in the French survey is related to the fact that the shipper had already accepted the survey.

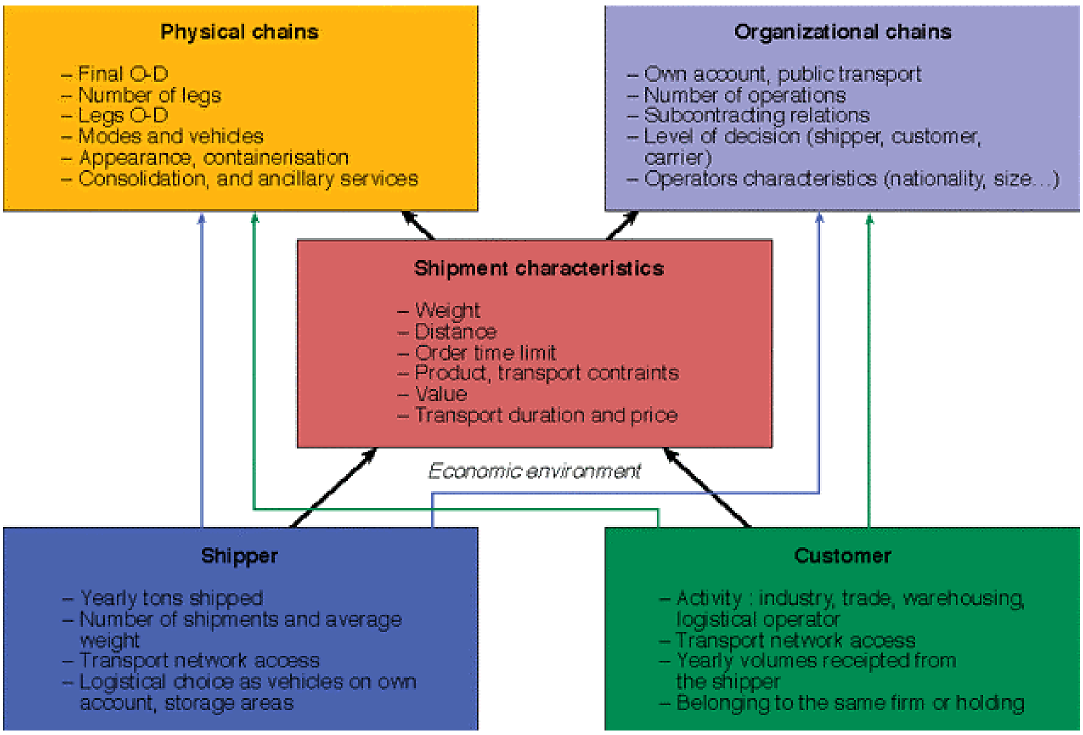


Figure 5-3. Overview of shipper survey in France and the Netherlands. Source: Rizet et al (2001)

5.3.4. Transport cost data

Micro-level data on transport cost are generally scarce due to secrecy concern of firms. In the Netherlands, Sweden, France and Norway, the National Statistics Offices publish freight transport price indices for the different modes. Freight rates for individual shipments are also available at various online freight exchanges. In the UK, road haulage cost trends are monitored by trade associations and market research companies (e.g., RHA 2016).[42]

In France, the Comité National Routier (CNR) publishes a yearly survey on truck costs. About 220 truck companies are followed and cost structure is analysed to get a cost in relation of the truck activity. It gives kilometric cost, driver cost, vehicle cost and structural costs. For 2015, the yearly cost was €137,326 for a truck operated 229.7 days with 1.07 driver and 114,920 km. Kilometric costs were 36% of the total, vehicle costs 13%, driver cost 37% and structural costs 14%. Other parameters are given as 87.2% of kilometres were loaded; when they run loaded, a truck carries 88.6% of its capacity (measured in relevant unit, tonne or volume or linear meters). Similar cost information is collected in Germany by the BGL (Bundesverband Güterkraftverkehr Logistik und Entsorgung).

In the Netherlands, Panteia publishes every six months calculations of kilometre- and hourly cost for sub-sectors per vehicle-type (in total 47 cases). These calculations give an indication of the costs per sub-sector and are based on actualized cost calculations from commercial transport companies. The costs are divided into fixed cost (including depreciation, interest, motor vehicle tax, insurance), variable costs (tire, fuel, repair and maintenance), specific transport costs (cargo insurance, permits and Inspections), cost of driving staff (wages, social security costs, accommodation costs) and general expenses (including salary administrative staff, housing).

5.3.5. Road traffic data

Table 5-4 provides an overview of road traffic and network data in selected countries. Country specific information is presented below.

	NL	SE	FR	GE
National road database	NWB	NVDB	SIREDO	BISSTra
Weigh in motion	x	x	x	
Road traffic counts	x	x		x
Cameras	x	x		
Automatic number plate recognition	x	x		
Laser detectors		x		
SiTraM			x	
Toll statistics			x	x

Table 5-4. Road and road traffic data collection.

Netherlands

The Nationaal Wegen Bestand (NWB) is a digital and geographic database of all public, for traffic opened roads in the Netherlands, which have a street name or a street number and are in the administration by the national government, by provinces, by municipalities or by regional water authorities. The database makes it possible to determine the location of events, model traffic flows and give a spatial representation of the data. Within the Ministry of Infrastructure and the Environment the NWB is the standard network. There is a NWB available for road, waterways and railway.

[42] See chapter 4 for information on transshipment cost in terminals.

The NWB can be used on different administrative levels, from the national and provincial level to municipal and regional water authorities level. When coupled with other data, it is very suitable for analysis and policy support. The NWB-database can be linked to other road data, data on accidents, data on congestion and noise reduction measures. In addition, the NWB is the basis for various operational information systems, both inside and outside the Ministry of Infrastructure and the Environment. For instance, emergency services control their access routes based on NWB data and traffic control measures during work are scheduled through the System Planning and Information Netherlands (SPIN) using NWB data.

On road traffic, data is collected by the Dutch NRA using among others the “Weigh in Motion” system. With this system for each truck with or without a trailer, or a combination of truck and trailer, the following data is collected: the weight data and pictures of license plates. This is done as vehicles drive over a measurement site. Although the main purpose of the system is to detect overloaded vehicles, through the pictures of the license plate in most cases the nationality of the vehicle can be derived. Because the measurement sites do not cover all the Netherlands, these observations do not give a complete overview of the structure of the traffic on the Dutch motorways.

Rijkswaterstaat uses cameras to collect data for traffic management, incident management and traffic research. The cameras for traffic and incident management are used by personnel in traffic centres to monitor the traffic on roads (and waterways) and to signal incidents. The cameras are only used for showing the actual situation on the road, the recordings are not saved. For traffic research, temporarily placed cameras are being used hat are equipped with ANPR (Automatic Number Plate Recognition). The use of the data is regulated by a law that protects the privacy of people. The data that is collected in this way is not shared with third parties. The only exception is when there is a formal request from the Public Prosecution Service.

Sweden

The national road data base in Sweden is maintained by the National Transport Administration. The database comprises the road network in Sweden and a range of data connected to it. The road network is described geometrically (i.e. where the roads are located) and topologically (i.e. how the road network is connected). The database covers all roads where motor vehicles are allowed and includes some of the bike lines (NTA 2016). The data base contains a range of variables that describe the road network along a certain interval or at a specific point. The variables represent physical objects (such as road blocks) or other characteristics (such as speed limit). Included in the data base are also road traffic data (e.g. average annual daily traffic, speed, travel time and the weight of vehicles) on selected parts of the road network (NTA 2016).

Another source of traffic information is the system of Automated Number Plate Recognition (ANPR)-cameras on the Swedish road network, which register the registration plates of passing vehicles. These cameras are placed at different locations in the road network and register information on several routes which is used to calculate travel time information. Floating Vehicle Data describing the positioning on taxis and other commercial transports is also used to estimate travel times (Karlsson et al. 2013).

The National Transport Administration has also installed two different types of weigh-in-motion (WIM) system in Sweden. The High Speed-WIM consist of a road sensor and an infra-red camera that weighs and identifies the vehicles. It provides rich information on the weight, number of axles and speed of the vehicles. The Bridge-WIM is mounted into bridges and provides information on the gross weight and axle loading of the passing vehicles. A WIM system was being developed and implemented in Norway as of 2013 (Karlsson et al. 2013).

Finally, the congestion charge systems in Stockholm and Gothenburg consist of laser detectors that register vehicles passing in and out of the congestion charging zones. The detectors generate data describing the traffic flows (Karlsson et al 2013).

France

The IT data collection system SIREDO was developed at the request of the French Ministry of Transport, and provides standardized road traffic information in real time. The system is essentially based on data collection stations, intercommunication modules and data processing software. Implemented progressively since the early 1990s, the SIREDO system today offers its users (traffic managers, road traffic information centres) an automatic, reliable, standardised and accessible comprehensive traffic data collection, transmission and exchange network. In addition to 80 weight stations and 170 stations classifying trucks according to their shapes, WIM equipment is also used in the public statistics.

Germany

The Federal Highway Research Institute (BASt) maintains the federal information system for roads (BISSTra) which combines information on the technical state of roads and other elements (such as bridges and tunnels) as well as traffic flow and accident information for the federal highway network. The Bundesamt für Güterverkehr (BAG) publishes aggregate monthly figures of traffic on roads that are subject to a toll (all federal highways and some federal roads with four lanes). Data are collected from the GPS-based toll charging system for heavy trucks. Leerkamp and Klemmer (2017) used floating car/phone data to analyse the use of the truck parking spaces on German highways over time (per day, week and year). Traffic management centres of the federal states also collect data for traffic management.

5.3.6. Terminal data[43]

Sources for information on terminals include terminal owners and operators, ports and logistics centers in which the terminals are located and the regions or countries in which they are located. An overview of European intermodal terminals is given by the Intermodal Map (2017) initiated by the German Promotion Centre for Intermodal Transport (SGKV). The Intermodal Map has currently a list of more than 1.000 terminals for intermodal transport.

The database of the International Union for Road-Rail Combined transport (UIRR 2017) contains over 350 European terminals used by UIRR's operators in 20 countries. It comprises general information of the services offered at each terminal, technical descriptions, contact details, main destinations that can be reached as well as the transport services that are offered to/from the terminal.

In France, the Groupement National des Transports Combinés (GNTC 2016) annually publishes a transport plan which gathers the transport plans of its members (public and private). In Germany, Rolko and Friedrich (2017) constructed the Logistics Location Database, which contain attributes of a large sample of logistics service providers (such as location, logistics purpose, transport equipment and infrastructure connection). Their application of the data set includes analysis of the spatial distribution patterns of LSPs which can be used to represent network routing of shipments more accurately. Rijkswaterstaat in the Netherlands and the Swedish Transport Administration possess data on details about national terminals and their throughput (see chapter 4).

[43] The terminal structure and data in Europe are described more thoroughly in section 4.3.

5.4. Data access

5.4.1. Privacy and confidentially issues

While the aggregated transport statistics of Eurostat are publicly available, the more extensive data of the member states are not always available for public use because of privacy and confidentiality issues. Common principles governing the development, production and dissemination of European statistic are established in Regulation 223/2009 (EU 2009). Some transport data are so detailed that the individual company can be identified if one has knowledge of the sectors. Because of competition reasons this information cannot be made public.

In the Netherlands, the policy by the National Statistics Office is to protect the identity of its data suppliers (persons, companies, government services and other respondents) and the confidentiality of the information they supply, and to use the information for statistical purposes only. The Act on Statistics Netherlands lays down that Statistics Netherlands may only use the information it receives for statistical purposes. Information may only be made public in a way that no individual person, household, company or institution can be identified. In Sweden, similar rules are stipulated in the Public Access to Information and Secrecy Act (Ministry of Justice 2009).

In France, public statistics are regulated by the law 51-711 of 1951. Within this framework, a firm cannot be identified from aggregated data, which means that statistics are undisclosed if they are associated with less than three firms or if one single firm makes more than 85% of the result.

In Germany, the policy on confidentiality depends on the statistics and the purpose. In general, the statistics office offers special queries from the microdata, but how far they are allowed to go has to be figured out in the concrete case. If projects are in public interest (i.e. ordered by some authority) there are sometimes detailed data released. One such case is the federal infrastructure investment plan where railway flows on the level of NUTS3 zones were released to the consortium (Schubert et. al. 2014). Expanded sample data of the road transport survey was also released on the level of NUTS3 zones. These are not directly microdata but on a higher zonal level of detail, as what is normally available for third parties.

5.4.2. NRA's access to data

In the Netherlands, the Rijkswaterstaat has access to the most detailed data that is available by the Dutch national statistical office CBS. CBS delivers detailed road transport data, while inland waterways data are collected by the Dutch NRA and for rail by ProRail.

In Sweden, the STA has access to detailed transport data, partly collected by themselves (rail) and by other public authorities (road, air, maritime). A web-based portal of official transport statistics and API (Application Programming Interface) tools is currently under development (Transport Analysis, 2016). The contents of the portal will be publicly available and users will be able to extract tailor-made data in various format.

In France, the Observation and Statistics Directorate (SOeS) is responsible for collecting, producing and disseminating statistical information in the areas of the environment, energy, construction, housing and transport. In the area of transport, the SOeS produces freight transport price indices and monitors the activity of companies, the working conditions of bus and trucks drivers, the flow of goods and passengers by mode of travel and the different types of vehicle. The reference data are collected in databases (Sitram, FCA) and publications, while all the results are posted on the SOeS website.[44] Databases are accessible online, allowing users to download customized tables. On demand data processing services, can be ordered. Statistical data dissemination is also relayed via a network of regional centres in the decentralised offices of the Ministry of Ecology, Sustainable Development and Energy.

In Germany, authorities that qualify as top-level federal agencies have access to the microdata of statistics that fall under the “Verkehrsstatistikgesetz”. For the case of transport, the corresponding agency is the Federal Ministry for Transport and Digital Infrastructure (BMVI). The authorities that make up the German NRA are subordinate to the BMVI and thus not directly applicable for obtaining microdata. For scientific purposes, also microdata can be released on a case by case basis.

5.4.3. Sharing data

With the emergence of new technologies and increasing digitalization of public and private practices, there are growing opportunities for data sharing that the NRAs can make use of.

In the Netherlands, various data sources are combined to construct an index of the national daily transport activity. For road, a selection of 216 million records of real-time data provided by the National Data Warehouse for Traffic Information are audited and used. For maritime/IWW transports, real-time positions of ships (AIS) entering and leaving ports are used and for rail transports, train and wagon movement from-, to- and within the Netherlands. Data for each mode are normalised with separate norm for each day of the week, and modes of transport are weighted and added to produce a raw activity score. A seven-day rolling average is taken to produce the final index. The process is fully automated with results being presented for auditing daily before final publication.

Research has been undertaken to investigate the possibility to combine road sensors in motorways, GPS data and camera footage with information from questionnaires to estimate how goods are transport over the Dutch road network. The results indicate better accuracy in the estimates of road haulage movement (Ma, 2016). In addition, in the European project Transforming Transport, 47 transport, logistics and information technology stakeholders are working on finding a more efficient and sustainable transport paradigm. Its objective is to demonstrate the transformations that big data will bring to the mobility and logistics sector.

The use of big data sources to improve freight transport planning, operations, mobility and visualization is also discussed in the US (Transportation Research Board 2017). A study released by the International Transport Forum (ITF) examines ways to improve compliance with road freight regulations through the use of new data sources and technical solutions (OECD/ITF 2017).

[44] The Sitram database (information system on freight transport) puts together data from the Customs database about the transport mode at the border, as well as data from different sources on national and international land transport. The customs databases consider tonnes and value, and the other sources consider tonnes and tonne-km. The SoeS (department for statistics of the transport ministry) is responsible of this database. Sitram is made of four different sources: customs data for freight transport associated to the French external trade, the national road transport survey, rail transport with data provided by the rail operators through a compulsory survey since 2007 (and since 2016 provided to the regulatory body ARAFER), IWW transport with data provided by Voies Navigables de France, responsible for the management of the majority of France’s inland waterways network and the associated facilities.

In Sweden, a research project by Transport Analysis and Statistics Sweden investigated the possibility to use AIS-data to construct maritime freight statistics. The project showed that utilizing the exact position of the vessels increased the level of detail of the statistics and made it possible to construct maritime freight traffic data by area, port-pairs, transport relations and economic zones (Justesen et al. 2017). Furthermore, a pre-study commissioned by the Swedish Transport Administration analyses the possibilities to increase the use of "reality-based" traffic and transport data (Trafikverket 2017).

In April 2017, The Finnish Transport Agency (2017) opened over 1.8 Terabytes of data (2.5 million separate csv-files) collected in the automatic traffic counting system TMS. The Finnish Transport Agency now offers open access to measurement data collected in the TMS system since 1995. In the Finnish road network, there are about 500 monitoring stations that automatically collect road transport data. Loops embedded into the road pavement monitor the passing vehicle's driving direction, lane used, driving speed and vehicle length. Based on these results, vehicles are categorised into seven groups. The data collected at these monitoring stations is now openly available.

One interesting parallel is the EU's chemical legislation REACH (2017) which requires companies to provide very large amounts of information to their customers on a regular basis. If similar rules applied for companies involved in freight transport, it would entail a large amount of useful information on firms' logistics operations.

Some NRAs' attempts to acquire data from firms in the freight market are hindered by the firms' lack of willingness to share commercially sensitive information. Data on freight traffic flows and routes or other similar variables may contain information that reveals firms' strategies and comparative advantages. One way to circumvent this problem is to aggregate the data handled or take other actions to de-identify the data material. This poses a trade-off between having as detailed data as possible for the sake of the analysis and protecting the identities of the respondents. A different way to tackle this problem is to find areas where there are mutual benefits of data sharing. For example, firms may be more willing to share data if it helps identify bottlenecks in the infrastructure network, which can subsequently be used to target investments or pursue other policies to ease congestion. Another example is the pooling of route and transport cost data from firms to a third party, who in turn analyses cost saving measures among the firms, such as freight-consolidation strategies. One such project was the FISS (Food industry sustainability strategy) study in the U.K., in which the food consumption industry agreed to share commercially sensitive data. The project identified opportunities that could bring down external costs of domestic transportation by up to 20%, including improving local supply and distribution networks, transport methods and infrastructure (Defra 2007).

5.5. Conclusions

This chapter has provided an overview of the most important topics regarding NRAs use and collection of freight transport data. Section 5.2 identified the type of data needed to analyse and monitor the freight transport sector. This was based on the key factors influencing firms' modal choice (as identified in chapter 3, input requirements from freight transport models (see chapter 6) and requests from national transport authorities. We conclude that an analysis of firms' choice of transport solution typically requires disaggregated (micro) data that describe the attributes of individual shipments (e.g. commodity, weight, value and transport distance) and the characteristics of the different modes (e.g. cost, time, delays, service frequency). A comprehensive overview of the freight transport sector requires aggregated (macro) data on transport demand between regions, by mode and commodity class. This kind of data is also typically required for freight transport models. In addition, NRAs need data on the cubic volume of freight moved, which can be used to study the impact of high capacity transport and the efficiency of freight transports (e.g., load factors). NRAs may also be interested in data that are comparable over time and across modes, regions and data sources.

Section 5.3 provided an overview of existing data sources and data collection methods. There are publicly available statistics on national and international freight transport activity (in terms of tonnes lifted, vehicle-kilometres and tonne-km) differentiated by mode, commodity group, geographic region and other key variables. These data provide a solid base for cross-country comparisons and comparisons over time. In several countries there are additional valuable data sources. The commodity flow surveys in Sweden and Norway provide information on the characteristics of a large amount of shipments. The French survey covers fewer shipment but contains information on an additional set of aspects (including the distribution chain and modal attributes). The national transport authorities use national road data bases and weigh-in-motion systems to collect information on traffic flows in the road network. This type of data can be used in a variety of applications, including traffic monitoring and management as well as detailed analyses of freight (and passenger) traffic flows.

We conclude that there is a gap between what kind of data NRAs need and what kind of data they have access to. All NRAs have adequate access to aggregated data that describe the level of freight activity and traffic. But there is a shortage of disaggregated data describing variables that affect firms' mode choice, including shipment characteristics (e.g., weight, value, commodity class), modal attributes (e.g., transit times, delivery reliability) and terminal structure. This makes it harder to evaluate how trends and transport policies affect the freight transport sector and modal choice. There is also a lack of data describing load factors and the cubic volume of freight moved. Table 5-5 provides an overview of the main variables that NRAs need to analyse the freight transport sector together with the data source and the aspect they relate to (mode choice, transport efficiency and level of freight activity and traffic).

Aspect covered	Data variable needed	Data source	Availability
	Freight activity		
	Road, rail, water, air	Eurostat	Good
Level of freight activity	freight*	Eurostat	Good
and traffic	Intermodal freight		
	Vehicle/vessel	National road data base	Moderate
	movements	-	Poor
	Road traffic	Marine traffic	Moderate
	Rail traffic	Int. Air Transport	Moderate
	Waterborne traffic	Association	
	Air traffic		
Transport efficiency	Vehicle/vessel utilization		
	Load factor	-	Poor
	Empty hauls	Eurostat	Good
	Shipments		
	Transport chain	CFS (FR, NO, SWE)	Moderate
	Shipment weight	CFS (SWE, NO, FR)	Moderate
	Shipment value	CFS (SWE, NO, FR)	Moderate
	Shipment volume	CFS (NO, FR)	Moderate
	Cargo type	CFS (SWE, NO, FR)	Moderate
	Commodity	CFS (SWE, FR)	Moderate
	Distance	CFS (SWE, NO, FR)	Moderate
	Modes		
Mode choice	Transport cost	Nat. Statistics Offices /	
		Surveys/CFS(FR)	Moderate
	Average transit times	-	Poor
	Delivery reliability	-	Poor
	Time utilization of	-	Poor
	vehicle equipment		
	Shippers		
	Production and	CFS (FR)	
	distribution chain		Moderate
	Terminal information		
	Terminal structure	Intermodal map	
	Terminal capacity	-	Good
	Terminal cost	-	Poor
			Poor

* includes freight activity (t, km, tonne-km, journeys) by commodity class, trip distance, cargo type, loading and unloading region.

Table 5-5. Summary of data needs and availability. Source: Transport Analysis (2016), McKinnon (2010), McKinnon and Leonardi (2009) and own estimations.

One way to narrow the gap is to increase the scope of data collection. But as highlighted in section 5.4 there are various issues in this area to be aware of. A large response burden of firms generally leads to low response rates and quality problems of the statistics. There is also a discrepancy between freight statistics from road freight surveys and traffic counts. The challenge is to apply data collection methods that are cheaper, have less quality problems and reduce the response burden of companies. The technological development of communication systems and increasing spread of online and mobile data communication are promising in this regard. WIM, ANPR, cameras, detectors, AIS data and intelligent transport systems (ITS) are sources that can be used separately or together to construct more detailed and reliable statistics. This calls for increased cooperation between NRAs and the private sector on several issues, including designing a system for transferring data.

There is also potential in narrowing the gap by sharing data and experiences between countries. The nature of the data collected nationally sometimes differ between countries so that sharing data sets may provide value added for the parties involved. Because transports often take place across-borders, a combination of data from several countries may provide a more detailed, precise and accurate foundation for decisions.

To conclude, for NRAs to be able to incorporate the findings regarding the influences of modal choice in chapter 3 and 4, they must have access to adequate data. Here, we propose several ways in which NRAs can fill the gap between the data they need and the data they can easily access. It is important to note that data give a good description of the current situation but may have to be supplemented with transport models in order to carry out policy analysis and forecasting. This is the topic in the following section.

6. National transport models

6.1. Introduction

The previous chapters identified factors influencing modal choice (chapter 3), the role of terminals in transport chains (chapter 4) and the need and availability of quantitative information to analyse these factors (chapter 5). In many cases quantitative studies using transport models are needed in NRAs analyses. These models are used to estimate the potential impacts of different trends (e.g. long term economic development), infrastructure projects, policy measures as well as packages of measures. The results of impact analyses can be used directly as basis for political decisions or as inputs in social cost-benefit-analyses (CBA).

Below we address national aggregated transport models that comprise all modes (or nearly all modes). The foundation for the national transport models is formed by models that forecast transport demand and traffic flows for forecast horizons up to 30 years. This type of models is required for passenger and freight transports and the results from the respective models need to be integrated as passenger and freight transport usually share the same infrastructure.

Box 6.1 General description of freight transport models

Many of the current national freight transport models evolve around a four-step structure:

1. **Generation**: Production (P) and consumption (C) for each pair of geographical zones in the model (P/C flows). Usually expressed in tonnes and tonne-kilometres per commodity class.

2. **Distribution**: Production and consumption are distributed between pairs of origin (O) and destination (D) zones (O/D flows). Usually expressed in tonnes and tonne-kilometres per commodity class.

3. **Mode choice**: Distributes tonnages of commodities to modes (and possibly sub-modes).

4. **Assignment**: Assigning vehicles and vessels to the appropriate network to produce vehicle flows.

Note that step 1 deals with the amount of freight generated while step 2 deals with the number of transport movements required to transport the freight generated. A single PC flow (describing the trade between a producer in one zone and a consumer in another) can consist of several OD flows, since every handling activity (inventory or transhipment) leads to a new OD flow.

Step 3 consists of a mode choice or modal split model that explain the allocation of the given OD flows over the available transport modes. A key distinction is between disaggregate models (unit of observation is an individual firm) and aggregate models (unit of observation is an aggregate of decision-makers, typically geographical regions). Step 4 deals with the assignment of the (sub)modes to the transport network. An ongoing trend is the development of more sophisticated models for logistics decisions, such as the simultaneous optimization of shipment size and transport chain.

Sources: de Jong et al. (2013), de Jong and Tavasszy (2014)

The national freight transport models calculate the commodity specific transport demand between zones (based on commodity flow data and other sources). Information from different transport authorities is used to describe the characteristics of the mode-specific infrastructure and terminals. Information about transport costs and times is collected from private firms. The models calculate transport flows (measured in tonne-kilometres) traffic flows (measured in vehicle-kilometres) as well as the throughput in the terminals (measured in tonnes) in a base situation and a situation where a policy measure is implemented. Typically, geographic information systems (GIS) are used to visualize the impacts on the traffic flows in the network.

One advantage of the models is that they present the whole transport system and all modes. National road databases like the Swedish NRDB contain data on the average annual daily truck traffic on different links in the road network. However, the database does not have information about the sender and the receiver of the goods, the transport chains that comprise the road transports on the specific links, whether the trucks are loaded or not and the type of commodity transported. Ideally, the national freight models should be used to identify measures that lead to a transport system that optimises the efficiency of the modes one by one and in combination, e.g. identify in which cases it would be efficient to encourage the use of larger trucks to/from rail terminals. This requires a validation of the transport model that should be done in cooperation with the private sector.

Typically freight transports are more complex than passenger transports because several decision makers are involved (see chapter 3). A logistic service provider (LSP) fulfils the requirements of a shipper to transport single shipments with different origins and/or destinations. The LSP tries to exploit economies of scale that result from all shipments that the LSP and possibly other firms transport. Such a procedure is called *logistics optimization* and comprises, among other things, the consolidation (bundling) of shipments and the routing of these bundles through the network of the considered firms as well as the infrastructure network itself. Logistics optimization takes part on the (micro) level of single firms. Yet the collective logistics behaviour of the firms can influence the shape of the transport and traffic flows on an aggregate national level.

Logistics optimization has only been considered quite recently in aggregated national freight transport models (de Jong et al 2013). As new models slowly catch on (the Swedish, Norwegian, Danish and Flemish modes are representatives), the possibilities for incorporating the effects of logistics trends into the freight transport models increase. In the new tools (door-to-door) transport chains between the producers (P) and the consumers (C) of the goods are modelled. One PC-relation can consist of several origin-destination (OD) relations, e.g. between the shipper and the first transhipment terminal. The new models address the choice between different transport chains (that can consist of several modes) for PC-relations while the conventional models address the choice between different modes for OD-relations. The new models incorporate logistics aspects such as the choice of shipment size by considering the trade-off between warehouse costs and transport costs (Davydenko and Tavasszy, 2013), extending the classical 4-step freight transport modelling framework with an extra fifth step for explicit modelling of logistics decisions at the macro regional level. Logistics chain modelling can be applied on the national scale, as well as for larger international markets, such as the EU. Such models can be considered as policy tools for decisions on attraction of distribution and logistics facilities (Davydenko, 2015). The exploitation of economies of scale and empty transports are modelled as well. One advantage with the new type of tools is that it is possible to model how the introduction/revision of infrastructure charges can lead to higher load factors – which means a more efficient use of a mode.

The inclusion of logistics aspects does not mean that the models can address all emergent or possible developments in freight transport demand. The main reason is that the models that cover whole countries (or Europe) and their surroundings are quite coarse grained with respect to spatial zoning, influencing factors that are addressed and the level of detail in which the decisions of the different stakeholders are modelled.

Another aspect is that the impacts on the transport system are typically short or medium-term, as in the case of e.g. the introduction/revision of charges or regulations, or long-term, as in the case of infrastructure investments. Compared to these time horizons, firms' decisions can emerge quickly and do not have to be long lasting. This can in principle be remedied by addressing various scenarios in the forecasts and choosing the measures that fit best to all of them given their probability of occurrence and their consequences. However, such a procedure can turn out to be impossible due to the variety of ways even a single trend can manifest itself. Given only the identified trends and forecast horizons in chapter 2 and their reciprocal effects the number of possible combinations will grow very fast.

It is important to have in mind that assessment tools are not detailed descriptions of the reality. There is a trade-off between using a simple transport model that can give answers to simple questions fast and a complex transport model that requires more detailed modelling and input data and can give more detailed answers.

The outline of this chapter is as follows. In section 6.2 we give an overview over the national transport models that are used in Sweden, the Netherlands, Germany and France. We also include the HIGH TOOL model that has been developed on behalf of the European Commission. Section 6.3 describes the possibilities and limitations of the models. Readers who are not interested in these topics can jump directly to section 6.4 where examples of impact analyses in national transport models are presented. General guidelines for impact assessments are provided in section 6.5.

6.2. Selected national transport models

The selected transport models below, the Swedish SAMGODS model, the Dutch BASGOED model, the German BVWP model and the French MODEV model, are models with underlying infrastructure networks for the respective countries and their surroundings. The European HIGH-TOOL model was developed as a tool for pre-assessing policy measures. Besides freight transport, it includes modules for Demography, Economy & Resources, Passenger Demand, Vehicle Stock, Environment and Safety. HIGH-TOOL is quite coarse grained on the spatial level and the network elements are represented by hyperpaths between the regions (simplified proxies for the distance and time to be covered) instead of an underlying infrastructure network. The HIGH-TOOL model is a complement to the TRANSTOOLS-model that has an underlying network for Europe and surroundings.

The Swedish transport model is owned and controlled by the National Transport Administration (NTA). The NTA performs impact analysis in house and with help of consultants. The national models in the Netherlands, Germany and France are owned by the respectively ministry and typically controlled by consultants or consortia. The HIGH-TOOL model is owned by the European Commission and controlled by a consortium.

For consultants that have not been involved in earlier projects the effort to perform new model runs with altered input values can be very high. This is especially true when a consortium has set up a model several years earlier for a special purpose and has to be contracted. Especially at the European level there have been actions to alleviate this problem. The European Commission has planned to release the HIGHTOOL model for download and to launch a website, where queries and calculations can be made online. However, this has not happened as of now (August 2017).

The four national transport models are somewhat different in their in- and output, the level of detail of their structure and the extent to which logistics decisions are a part of the transport models. One main difference is that the Swedish Samgods model takes into the decisions of different types of firms and minimises the annual logistics costs of these firms. The logistics costs comprise transport costs, ware house costs and order costs. The four other models consider interregional flows between zones without addressing the firms that ship or receive them and take the generalized cost of transport as the main decision criterion. These figures are derived from the operating costs of representative standard vehicles, trains or vessels and comprise components as driver, fuel, depreciation, interest, maintenance insurance and toll costs. Handling costs at transhipment points are also considered. The models do not consider costs that accrue to consigners and consignees, such as storage and capital cost.

6.2.1. Dutch BASGOED model

In 2009, the Dutch transport ministry decided to invest in a relatively straightforward freight transport model that also would be easier to maintain (de Jong et. al. 2012). A basic freight transport model was developed, called BASGOED (where BAS comes from basic and GOED from good). This model was developed in about a year and was aimed to answer the most pressing policy questions of the transport ministry (Significance et al. 2010). BASGOED is a conventional four-step transport model, which distinguishes between only a limited number of spatial zones and commodity types. The model's distribution and modal choice model parameters were estimated on aggregate data, leading to reasonable elasticity values. Input data on regional production and consumption volumes are based on the economy module of the SMILE model (de Jong et. al. 2012). The model's functionality has recently been extended with a module for road vehicle type choice (ViaGoed), which predicts at the strategic level what type of truck will be used for specific commodities. In 2016 Significance, TNO and Demis extended the model with construction of intermodal PC tables, thus extending model functionality with intermodal chain choice model for container transport.

Name	**BASGOED (Netherlands)**
Owner	• Client: Dutch Transport Ministry • Developed by Significance, NEA, DEMIS, TNO, PBL
Considered Modes/Vehicles	• Road, including the choice of road vehicle type (ViaGoed module) • Rail • Inland Waterway
Spatial Scope and Level of Detail	• 40 domestic zones (NUTS 3) • 30 foreign zones • 10 types of goods (NST\R level 1)
Time Scale/ Forecast Horizon	• Time slices of one year
Input	• Cost and level of service figures from various existing models
Output	• O/D Matrices for the considered spatial zones • Results of assignment on infrastructure networks • Values of time for commodity types from the modal split model
Modelled Decisions/Aspects	• Generation/Attraction taken from the existing model SMILE+ • Distribution • Modal Split, road vehicle type choice • Assignment • Decisions based on transport costs
Examples of studies that used the model	The BASGOED model is used by the Dutch transport ministry for basis prognoses of freight transport and for the National Market and Capacity Analysis (NMCA) (TNO and Rijkswaterstaat WVL, 2017). The primary purpose of the NMCA is to determine the national goals at the level of national mobility networks. Secondary goals include facilitating the conversation between the state and regions, and provision of model estimations of trends and developments.

Table 6-1: BASGOED. Source: Significance, NEA and DEMIS (2010).

6.2.2. Swedish SAMGODS model

The model is an application of the Aggregate-Disaggregate-Aggregate approach. Generation of trade flows from which transport flows emerge (P/C-flows) is treated in aggregate way. These flows are disaggregated to annual flows between single firms in the corresponding regions. Not every firm is considered but a corresponding number of representatives described by industrial sector and size class. Every pair of representative firms chooses shipment size and transport chain simultaneously. Transport chains are fed into the model exogenously. The aggregate flows resulting from the chain decisions of all firm-pairs form the O/D flows that are observable on the corresponding networks. The O/D flows deviate from the P/C flows as the single shipments take the way that minimizes the total logistics costs of the involved firms. This way is not necessarily the direct or shortest one.

Name	**Samgods (Sweden)**
Owner	National Transport Administration
Considered Modes/Vehicles	• Modes: Road, Rail, Sea, Air • Vehicle/vessel types: Road (6), Rail (11), Sea (21), IWW (1), Air (1)
Spatial Scope and Level of Detail	• Application to Sweden incl. international and transit movements • Area divided into Zones (290 domestic, 174 abroad) • Firm types: For each sector, large, medium and small firms • 35 different commodity types • Transport Chains on the level of single zones
Time Scale/ Forecast Horizon	• Produces output for base year (currently 2012) and forecast year 2040

Input	• Economic data suitable to be disaggregated to single firms
	  • Employment
	• Production and consumption figures
	• National Commodity Flow Survey (see section 5.3.2)
	  • Information on single shipments and their way
	  • Information on shippers and recipients
	• Weight/Value conversion data
	• Detailed cost figures for the considered transport chains

Output	• Origin/Destination (O/D) Tables • Aggregate transport chain information • Tonnes, Tonne-kilometres, Vehicle-kilometres

Modelled Decisions/Aspects	• Aggregate Generation and distribution of trade flows (Production/Consumption [P/C]-flows) between pairs of zones
	• Disaggregation to flows between representatives of firm types (described by economic sector and size class)
	• Iterative simultaneous choice of shipment size and transport chain
	  • Shipment size modelling for the firm to firm flows
	  • Choice of transport chain for single shipments
	• Aggregation of single shipments and flows to transport flows between pairs of zones (Origin/Destination [O/D]-flows)
	• Assignment of O/D-flows on networks of the considered modes
	• Decisions based on logistics costs

Examples of studies that used the model	Effects of More Stringent Sulphur Requirements for Sea Transports. (Vierth et al. 2015). See also section 6.4

Table 6-2: Samgods. Source: Edwards (2008), Sundberg & Berglund (2015), De Jong & Baak (2016)

6.2.3. German BVWP model

The model was compiled mainly for the investment plan for federal transport infrastructure. Special logistics or production aspects enter the model insofar as certain locations with known large attractors and generators of certain kinds of freight transport are addressed in more detail than others. For example, the locations of large power plants or of steel works are entered manually as they constitute a remarkable part of the demand for coal. Likewise, car manufacturing plants are considered for their role in generating high volumes of cars transported to the ports by train.

Name	**BVWP (Germany)**
Owner	• Client: Federal Ministry of Transport and Digital Infrastructure • Developed in several batches by several consortia of scientific institutes and consulting companies. • New scenarios cannot be calculated without further effort.
Considered Modes/Vehicles	• Modes: Road, Rail, Inland Waterway • Vehicle/Vessel types: Road (3), Rail (4), IWW (15). There is no vehicle type choice, types only serve as proxies for obtaining cost figures.
Spatial Scope and Level of Detail	• Domestic: 412 zones (NUTS 3 level) • Foreign: 155 zones (various levels from NUTS 3 to NUTS 0) • Ports and airports are considered own transport cells • 25 commodity types
Time Scale/ Forecast Horizon	• Base year 2010, forecast horizon: 2030 • O/D Matrices are compiled for annual flows • Assignment

Input	• Observed transport flows for the base year for the several modes from expanded samples.
	  • Structural data for the prediction of future transport flows
	  • Contribution to Gross Domestic Product of the respective economic sector
	  • Fuel Prices
	  • Foreign Trade Prognoses
	  • Expected Policy Measures
	  • Demographic data

Output	• O/D Matrices for the considered spatial zones • Assignment on infrastructure networks for years and typical days • Greenhouse gas emissions • Values of time and reliability for aggregate commodity type groups from the modal split model
• **Modelled Decisions/Aspects**	• Generation/Attraction • Distribution • Mode Choice • Assignment • Decisions based on transport costs
Examples of studies that used the model	• Consequences of long trucks on modal split (Sonntag and Liedtke 2015) • Feasibility of overhead line trucks (Siemens et.al. 2016) • Financing of infrastructure for sustainable freight transport (Sutter et. al. 2016)

Table 6-3: BVWP. Source: Schubert et. al. (2014)

6.2.4. French MODEV model

The MODEV model is currently used by the French Department of Transport to analyse the impact of transport policies on modal split, network congestion and the optimal use of infrastructure. It is structured to estimate transport demand in the medium (2030) and long (2050) term.

Name	**MODEV (France)**
Owner	• Client: Department of Transport • Developed by MVA and Kessel und Partner
Considered Modes/Vehicles	• Road • Rail (intermodal, block train, wagonload) • Inland Waterway
Spatial Scope and Level of Detail	• 342 domestic zones • 230 foreign zones • 10 types of goods (NST\R level 1)
Time Scale/ Forecast Horizon	• Base year 2012, forecast horizons 2030 and 2050
Input	• Macroeconomic and demographic forecasts on the level of the considered zones • Transport costs • SitraM database (see even section 5.4.2)
Output	• O/D Matrices for the considered spatial zones • Assignment on infrastructure networks • Greenhouse gas emissions
Modelled Decisions/Aspects	• Generation/Attraction • Distribution • Mode Choice • Assignment • Decisions based on transport costs
Examples of studies that used the model	Transport demand forecast for 2030 and 2050 (Pochez et. al. 2016)

Table 6-4: MODEV. Source: Pochez et. al. (2016)

6.2.5. European HIGH-TOOL model

Freight demand is generated from the output of the Economy & Resources module, where trade relationships between pairs of regions are derived. Deviations from P/C to O/D relationships due to logistics are covered by relation-specific logistics factors in the conversion from trade values (EUR) to transported volume (tonnes). Assignment does not take part to a network but rather to a set of hyper-paths between the considered regions, that are a simplified representation of the real networks. Mode choice for road, rail, inland waterway and sea is done for single legs within these paths. Demand for air transport is separated from the rest from the trade flows and treaded differently.[45]

[45] The code of the model will be available for download in the course of the year 2017. Thus, users can make own calculations with the model by altering defined input values.

Name	Strategic high-level transport model (HIGH-TOOL) – (Europe)
Owner	European Commission (DG MOVE)
Considered Modes/Vehicles	• Road, Rail, Inland Waterway, Short/Deep Sea
Spatial Scope and Level of Detail	• NUTS2 level for the 28 countries of the EU plus Norway and Switzerland • Neighbouring European countries: NUTS0, Rest of the world: 19 intercontinental bundles
Time Scale/ Forecast Horizon	• Base year 2010, forecast horizon until 2050, time slice, one year
Input	• Historical data up to 2010 (Mainly databases) • CARE database: Road accidents, • ETISplus database: Freight Demand and Passenger Demand • EU COMEXT database: International Trade Historic Statistical Figures • Eurostat database: used in the Demography, Economy & Resources and Safety modules • EXIOBASE database 2.0: Multi region input output data • OECD database: Economic indicators for non-EU countries • TRACCS Database: Mainly transport cost data • Assumptions up to 2050 (Output of models that make forecasts) • TREMOVE: effects of different transport and environment policies on the emissions of the transport sector • EUROPOP2010 Scenario database estimates EU27 population growth up to 2060 • VACLAV: European transport network model • EU Reference Scenario 2013 projections on transport activity, energy and emissions up to 2050 for the EU28 • MOVEET: Projections on maritime freight transport and fuel prices • TRANS-TOOLS model: Modal split in freight transport
Output	• Tonnes, tonne and vehicle kilometres by origin/destination at NUTS-2 level per mode, commodity and distance band • Total transport cost in EUR per tonne by origin/destination at NUTS-2 level per mode, commodity and distance band • Average toll cost in EUR per vehicle-km by country and mode • Vehicle kilometres by origin/destination at NUTS-2 level per mode, commodity and distance band • Average load rate for transport in EUR per vehicle-km (no differentiation by country) • Average load capacity for transport in EUR per vehicle-km (no differentiation by country)
Modelled Decisions/Aspects	Predefined parameters from the policy areas i) efficiency standards and flanking measures, ii) pricing, iii) research and innovation, iv) internal market. Parameters can be adjusted in predefined value bands. • Various policy measures can be implemented at the same time. Interdependencies between measures are accounted for. • Possibility for expert mode: Edit single values in the freight demand matrix and single hyperlinks in the distance deterrence module • Decisions based on generalized transport costs
Examples of studies that used the model	• Case studies in the course of the model development (Kiel et.al. 2016): • Introduction of CO_2 standards for cars and vans • Introduction of speed limits for light commercial vehicles • Potential of maritime ports related to liberalization policies • Increase of public and private transport infrastructure investments

Table 6-5: HIGH-TOOL. Source: Szimba et. al. (2016)

6.3. Possibilities and limitations of transport models

The decision to implement transport policy measures for the improvement of the transport system considers a wide range of aspects, e.g. investments and effects on tonne-kilometres, transport volume and modal shift. The decision-making process can be supported by ex-ante assessment of the effect of planned measures and the national transport models provide tools with which such assessments can be made.

An essential condition for the modelling of specific measures is that they have a concrete influence on the model parameters transport costs and transport time (see section 3.4). For example, the introduction of road user charges on a specified network from a specified date increases the distance-based transport costs for trucks. All mentioned transport models generally estimate the effect of measures from a national or international perspective due to an assumed change of transport costs and transport time. Furthermore, they all consider the transport volume for specific commodities aggregated over one year (with an average daily transport volume). Still, there are some differences between them, which influence the kind of questions that can be answered with the models. The models can be categorized into two groups:

- The first group contains models which focus on transport flows in tonnes and considers changes in transport volumes and aggregated transport flows per mode. This group comprises the BVWP, HIGH-TOOL, BASGOED and MODEV model. Typical questions to be answered by these transport models are how does the introduction of new vehicles influence the modal split? How does a raising importance of terminals or ports change transport flows and tonne-kilometres per mode?
- The second group of models focus on the transport of shipments. The Samgods model belongs to this group. The model calculates the choice of the shipments sizes, the transport chains, the size of the vehicle types used and the degree of consolidation. A typical question to be answered is how do more/fewer terminals influence the transport chains (and thus spatial flow patterns of goods) as well the choice of the vehicle sizes and loading factors?

These models estimate the effects of measures regarding a specific national or international area and for a timeline of at least one year. Questions regarding the behaviour of single actors (e.g. transport service providers) and in changes in distribution over the day cannot be modelled.[46] The customization of the models to address specific questions can be time-consuming. Furthermore, measures must be translated into the model parameters.

An exception to this is the European transport model HIGH-TOOL. Here, changes in input variables can be entered through a user interface and results of model runs with these new figures can be obtained without changing the internal structure of the model. However, HIGH-TOOL is a comprehensive transport model that makes use of several interacting modules, so that knowledge about the model structure is needed in order to arrive at sensible results and to interpret them. The advantage of the model is that it is intended to make it downloadable for the public. Thus, interested applicants can perform own model runs without having to contract the consortium that originally set up the model. This contrasts with the other national models mentioned above.

It should be noted that the models we review in this chapter have a comprehensive scope. Answers to questions that arise from day-to-day politics can only be obtained with reasonable effort. Thus, methods that provide roughly estimated results are advisable to apply. There, single effects of

[46] Microscopic models for urban areas or models regarding very specific questions like lot size models represent alternative options for these kinds of questions.

developments or trends in freight transport demand are considered in isolation in order to get a first impression of their magnitude. If the rough analysis reveals significant impacts on the freight transport system, more thorough analyses can be made with more comprehensive approaches.

6.4. Examples for impact assessments

Below we show for five examples how impacts of the trends described in section 2.3 can be assessed with help of transport models: 1) Road infrastructure charges, 2) Port choice in Europe, 3) Automation of trucks, 4) Permission of longer/heavier trucks and 5) Innovations in the rail freight sector.

6.4.1. Reduction of road infrastructure charges

The impacts of lower road infrastructure charges were estimated in the French model Modev (Pochez et al. 2016). The model considers all national and international traffic of road, rail and IWW that takes place in France. A baseline scenario for the year 2050 was estimated under the assumptions of annual GDP growth of 1,8% and a petrol price of €117 (in 2012 price level).

In the scenario under consideration, the expiring of concession contracts and termination of back-to-back financing reduces the motorway tolls in France to cover only maintenance and operating cost. This corresponds to a reduction of the tolls by 42% on average. The effects on the transport performance (in tonne-kilometre) of each mode in 2050 is shown in Table 6-6. Road transport increase by 1% relative to the baseline scenario, IWW tonne-kilometres decreased by 1,2% while rail transport decreased by 5,9%, possibly reflecting the closer competition between road and rail.

Impact on	Results	Source
Modal split	Reduction in motorway tolls in France: -42% Change in road transport (tonne-km) by 2050: +1% Change in IWW transport (tonne-km) by 2050: -1,2% Change in total rail transport (tonne-km) by 2050: -5,9% • Change in combined rail transport (tonne-km) by 2050: -6,6% • Change in conventional rail transport (tonne-km) by 2050: -5,7%	Pochez et al. 2016

Table 6-6. Estimation result for road infrastructure charges

6.4.2. Port choice in Europe

The effects of a shift of container volumes from ports in Northern European ports (in the Netherlands, Belgium and Germany e.g. Amsterdam, Antwerp, Bremerhaven, Hamburg, Rotterdam, Wilhelmshaven) to Southern European ports (in France, Italy, Slovenia, Croatia and Greece e.g. Genova, Marseille, Piraeus, Trieste) are estimated in a study performed by DLR. It is assumed that a higher share of the shippers in Bavaria, Czech Republic, Austria, Switzerland, Italy, Slovakia, Slovenia, Hungary and the Balkan States choose a port in Southern Europe. Based on European statistics (Eurostat, 2017a) it is assumed that about 15% of the container volume in the Northern ports is transported to/from these regions to ports in Southern Europe. To determine the impact on the German infrastructure (except Bavaria) the above described German BVWP model is used.

In order to estimate the impact in Bavaria and the neighboring countries and with a detailed focus on the road infrastructure, the characteristics of port- hinterland container flows are analyzed for Germany. These characteristics are then transferred to the affected regions in Europe. It is assumed that transports in the Trans-European Network-Transport (TEN-T) behave similarly as the transports in the German network which means that road transport has a share of 43 % of the hinterland shipments. The calculated impacts in Germany (except Bavaria) on the one hand and Bavaria and the remaining countries on the other hand are presented in Table 6-7.

Impact on	Results	Source
Road network	Reduction of road transported goods: -5.8 million tonnes per year, corresponding to about 250 trucks per day (in Germany, excluding Bavaria). Increase of road transported tonnes: 11.6 million tonnes per year corresponding about 500 trucks per day (in Bavaria, Czech Republic, Austria, Switzerland, Italy, Slovakia, Slovenia and Hungary, Balkan States).	Own estimation of DLR based on traffic integration forecast commissioned by the German Federal Ministry of Transport (BMVI, 2014)

Table 6-7: Estimation results of port choice in Europe

A shift of 15% from the ports in Northern Europe to the ports in Southern Europe ports results in a reduction of about 5.8 million tonnes per year on the German roads. This can be broken down into 15,970 tonnes per day and 250 trucks per day (assuming a load of 27 tonnes per truck). This is estimated to reduce the daily tonne-kilometres in Germany by 10 million. The projection of Europe results in an increase of 11.6 million tonnes and 500 trucks per day on the motorways in Czech Republic, Austria, Switzerland, Italy, Slovakia, Slovenia and Hungary.

The change measured in number of trucks is rather small. If we set the reduced container transports measured in number of trucks on the roads in relation to the average truck flows on German motorways (6,000 and 8,500 trucks per day [MVIBW, 2012]) we calculate a reduction of about 3 to 4% of the heavy traffic in Germany. In turn, however, the volume of transported tonnes and the number of trucks from and to the Southern European ports is about 6 to 8%. Even if the role of the Mediterranean ports becomes more important for traffic flows to Southern and Eastern Europe, the overall impact on transit traffic flows through Central Europe is expected to be low, because national and international transport flows through whole Europe dominate.

6.4.3. Automation of trucks

In the short term, the retrenchment of drivers because of autonomous trucks leads, everything else equal, to a reduction of the road transport costs and favours road transport. In the medium term, changes of logistics processes due to the usage of autonomous trucks are expected. A study carried out by DLR (2017) examined how road transport cost reductions caused by truck automation influence the demand for rail transport in the short and medium run.

The effects were estimated for relations related to Germany by an aggregated model (described in Sonntag and Liedtke 2015) using the elasticities as given in the final report of the BVWP-model. In Scenario 1 it is assumed, that the automation leads to a 30 % drop of the road transport costs (since no driver is needed). The rail freight tonne-kilometres are calculated to be reduced by about 17 %. This implies a cross price elasticity of 0,57 which is in the interval that is found in the literature. All types of rail transports, maritime/continental combined transports, wagon load transports and block train transports, are calculated to be reduced. In Scenario 2 the 30% cost reduction and changes of logistic processes for road freight transport are assumed. This is calculated to lead to a 43% reduction of the rail tonne-km. See Table 6-8.

Impacts on	Results	Sources
Modal split in Germany	Scenario 1: 30 % reduction in road transport costs Rail (tonne-km): - 17 % Scenario 2: 30 % reduction in road transport costs and change of logistic processes of road transport Rail (tonne-km): - 43 %	DLR (2017)

Table 6-8: Results of the estimation of automation of trucks.

Janssen et al (2015) analysed the effects of truck platooning. They note that platooning reduces fuel use by the leading and following vehicles by 10%, with corresponding costs reductions. The authors estimate that 15%-25% of labour time can be reduced, although there are some extra costs associated with the technology. All scenarios considered, the annual savings per vehicle will be in the range between €2,000 and 33,000. The costs savings at the vehicle level will eventually translate into lower tonne-kilometre costs and a shift in competitive situation within the road sector, as well as between the modes (no specific effect on modal split estimated). Transport demand price (cross) elasticities may provide a first estimation of the potential effects on the rail and inland water navigation that will be realized by market adoption of the truck platooning.

6.4.4. Permission of high capacity vehicles

High capacity vehicles (HCV) reduce the road transport costs because of a higher utilization and the exploitation of economies of scale which lead e. g. to reduced energy consumption and lower driver costs per transported unit. The impacts of using larger trucks has been estimated by e.g. (1) by Sonntag and Liedtke (2015) for longer trucks in Germany, using the elasticities from the BVWP-model, (2) by Vierth et al (2008) for longer and heavier trucks in Sweden and, using the precursor of the SAMGODS model, (3) by Vierth and Karlsson (2014) for longer trucks (and freight trains) in a corridor between Sweden and Germany, using the SAMGODS model and (4) by Ceuster et al. (2008) using the European TRANSTOOLS model. The results are summarized in Table 6-9.

Impact on	Results	Sources
Modal split in Germany	Increase of trips per truck per day: 7000 Decrease of rail tonne-km: -7.6%	Sonntag and Liedtke (2015)
Modal split in Sweden and CBA for Sweden (see Table 6.9)	Scenario 1: 24% increase of road vehicle-km: when no modal shift is assumed Scenario 2: 14% decrease of road vehicle-km (12% decrease of road tonne-km) and 25% increase of rail tonne-km when modal shift is assumed	Vierth et al. (2008)
Modal split in corridor Sweden -Germany	Increase of modal split (ton-km) of road: + 0.5% Vehicle-km on road constant (in Sweden)	Vierth and Karlsson (2014)
Modal split in Europe	Increase of modal split (ton-km) of road: +0.42-0.99%. Increase of vehicle kilometres of road: 4.3-12.9% Decrease of modal split (ton-km) of rail: -3.8% Decrease of modal split (ton-km) of IWW: -2.9%	De Ceuster et al. (2008)

Table 6-9: Effects of HCV in Germany, Sweden and corridor between Germany and Sweden

Sonntag and Liedtke (2015) assume that longer vehicle with 44 tonnes gross vehicle weight and an effective volume of 150 m^3 are available – which is assumed to be a higher capacity of about 50%

compared to conventional trucks. Further they assumed lower energy consumption but higher investment costs of about 20 % compared to conventional trucks. They show, that the permission of long trucks increase the daily truck trips on road of about 7,000 trips. Contemporary, the amount of rail tonne-kilometres decreases by about 7.6%.

Vierth et al. (2008) analyse the introduction of a “European standard” for road vehicles instead of the “Swedish road vehicles standard”. The European vehicle dimensions (in 2007) are assumed with a maximum of 40 tonnes and a length of 18,75 m and the Swedish vehicle dimensions are assumed with maximum 60 tonnes and a length of 25,25 m. The total freight transport demand is assumed to be constant. Because of the smaller dimensions of the European standard a 24 % increase of the costs per vehicle-kilometre are assumed. This lead to a 24 % increase of road-vehicle-km, in Scenario 1 where no modal shift is assumed. In Scenario 2 where modal shift is assumed a 12 % decrease of the road -tonne-km (corresponding a 14 % decrease of road-vehicle-km) and a 25% increase of rail-tonne-km is calculated.

The result of the cost-benefit analysis that has been carried out is that it is not cost-effective to use shorter and lighter trucks (the European vehicle dimension) in Sweden. The loss for society is estimated to be greater in Scenario 1 (around SEK -8.9 billion) than in Scenario 2 (around SEK -3.9 billion). The dominant effect is increased transport costs. (1 SEK is about €0,1.) See Table 6.10. A minus sign indicates a deterioration and a plus sign an improvement for society.

	Scenario 1 (excl. modal shift) Million SEK/year	**Scenario 2 (incl. modal shift) Million SEK/year**
Transport costs	-7 525	-3 147
Road wear	+140	+201
Railway wear	0	-83
Road safety	-491	-291
Time delay	-50	-34
CO_2 emissions	-363	-220
Pollution	159	69
Noise road	-690	-390
Noise rail	0	-30
Tax effects	63	-91
Total	-8 925	- 3 941

Table 6-10. Economic costs and benefits to society (at 2001 prices). Source: Vierth et al 2008

Vierth and Karlsson (2014) analyse the use of trucks with a maximum length up to 25.25 m and a weight of 60 tonnes in a corridor between Sweden and Rhein-Ruhr-area in Germany. They calculate a 0,5% increase of the road tonne-km and a 0,7% decrease of the rail tonne-km. This means that the shift from rail to road is larger in the study regarding changed dimensions in an international long-distance corridor (Vierth and Karlsson 2014) than in the study on all transports on the Swedish territory (Vierth et al. 2008). This is expected as the competitiveness of the rail mode increases when transport distance increases. See also section 6.4.4.

De Ceuster et al. (2008) used the TRANSTOOLS model, to study the effects of the use of longer and heavier vehicles. Three scenarios were developed for the year 2020: i) the full option: unlimited use of trucks up to 25.25m and 60t on the entire European primary road network, ii) the corridor option: unlimited use of trucks up to 25.25m and 60t on the primary road network of a coalition of six countries (Finland, Sweden, Denmark, Germany, the Netherlands and Belgium) and iii) the compromise: unlimited use of trucks up to 20.75m and 44t on the entire European primary road network.

The results showed that the extra capacity of HCVs leads to lower transport costs. In accordance with basic economic rationale, this leads to an increase in demand. The calculations showed a 0.99% increase in road tonne-km and a decrease in vehicle kilometres of 12.9% in the full option-scenario compared to the reference scenario. In the compromise-scenario, road transport tonne-km increased by 0.42% and vehicle kilometres increased by 4.3%. Rail and IWW transports were estimated to decrease by 3.8% and 2.9% respectively. As the total transport volume in the reference scenario was forecasted to grow by between 30-60% to 2020, this meant that the absolute volumes still grew.

6.4.5. Innovations in the rail sector

For the assessment of innovations in rail sector the following two studies are described and the results are shown in Table 6-11.

Impact on	Results	Sources
Modal split in corridor between Sweden Germany	Increase of rail tonne-km inside and outside Sweden: (1) + 1 %, (2) +3,4%, (3) +5.4% Decrease of road tonne-km inside and outside Sweden: (1) - 0,5%, (2) - 1,3%, (3) – 2,1% Decrease of sea tonne-km inside and outside Sweden: (1) -0,3%, (2) –1,1%, (3) -1,.3 %	Vierth and Karlsson (2014)
Modal split in Germany	Increase of tonnes transported by rail (72 billion tonne-km) and increase of rail share by 9 % in comparison to Business-as-usual Scenario in 2030 + 72 billion rail tonne-km	Lobig, Liedtke, and Knörr (2017)

Table 6-11: Impact of innovations in the railway sector

Vierth and Karlsson (2014) study the use of longer freight trains in a corridor between Sweden and Germany in the same way as for trucks. They assume train length of 750 m (Scenario Rail 1), 1000 m Scenario Rail 2) and 1500 m Scenario Rail 3) instead of a maximum train length of 650 m.

As expected, the permission for maximum 25.25 m-long trucks in the road corridor in *Scenario Road 1 (25.25 m)* leads, all else being equal, to shifts from rail to road. The competition between the rail route via Jutland and the road route via Travemünde becomes clear in the difference map in Figure 6.1 (first map). The competition between the rail route and the road route is also illustrated in *Scenario Rail 1 (750 m)* See Figure 6.1 (second map.) The lower costs in the rail corridor are expected to 'attract' goods along the entire route Sweden-Ruhr area as well as the south and west of the Ruhr area. The competitiveness of the rail mode increases with the transport distance.

Note: 1 Calculated effects in terms of tonnes on links compared to base for Scenario Road 1 (25.25 m) (left), Scenario Rail 1 (750 m) (centre) and Scenario Road 1 + Rail 1 (right). The different maps show the tonnage of goods transported: red colours road transports, green colours rail transports and blue colours sea transports. The dark nuances demonstrate increases and the light nuances decreases. The same scale is used in all the maps.

Figure 6-1. Calculated effects in terms of tonnes on links. Source: Vierth and Karlsson (2014)

The results of a rough cost benefit analysis indicate that the permission for up to 25.25 m-long trucks in the corridor would lead to annual cost savings for the industry of about € 8 million. The benefits of *Scenario Rail 1 (750 m)* are calculated to be about € 18 million due to reduced logistics costs and about €11 764 due to reduced CO_2 emissions. This means that the short-term investments in the rail infrastructure are expected to be repaid after about one year and the long-term investments after about five years. A further indication is that the profitability of rail investments does not decrease if up to 25.25 m long trucks and up to 750 m long trains are simultaneously used in the corridor.

Lobig, Liedtke and Knörr (2017) estimated a range of different measures fostering the rail freight transport:

- Longer trains (up to 740 m)
- Heavier trains with a gross train weight over 2,000 t
- Higher energy efficiency
- Avoiding of operational stops
- Faster transhipment in combined transport
- Accelerated train composition and
- Reduction of delays in terminals.

It is assumed, that investment costs in rail technology are funded by the federal state and the rail infrastructure is expanded. The measures show a theoretical potential of achieving a higher rail share by applying today existing technologies. This former described potential of modal shift from road to rail can be further increased, if additional measures fostering rail freight are considered. Here, a theoretical potential of additional 72 billion rail tonne-km can be achieved in Germany. The study shows, that longer trains alone do not have a high impact on the rail share. The authors conclude that additional innovations in rail freight transport and further development of the rail infrastructure would increase the rail share.

6.5. Guidelines for impact assessment

As a first step for an estimation of the effects of some measure it can be sufficient to estimate the general magnitude of the effect before modelling the measure with extensive adjustments of the transport model. An approach for such a rough estimation of the general magnitude is to use the elasticities of the transport model and to calculate a rough change of transport volume – as was done for the trend automation and longer trucks in section 6.4.

Approaches for quick assessment of questions related to freight transport are proposed in the Quick Response Freight Manuals in the United States (Cambridge Systematics 2007) and in de Jong and Tavasszy (2013, ch. 11). These make use of existing comprehensive models, as the ones described in this chapter, and their results: 1) Information about the flows of goods and/or vehicles between any pair of zones in the considered area and on the links of the considered transport network. These figures are provided for a base year and a forecast year (usually up to 20 years). 2) The values of input data and behavioural parameters used to derive the transport demand figures for the base year as well as the forecasts. and 3) A description of what was done to derive the results in point 1) from the input data and parameters in 1).

Simple models can be compiled from these three sources of information. This does not mean that the original model has to be recreated from its publications but rather that single components of the model can be considered in a simplified way. Such considerations strongly depend on the model at hand, its input values and degrees of freedom and the additional data that are available for the considered regions.

Box 6.2 provides starting points for simplified transport models based on the four-step-approach (generation, distribution, mode choice and assignment). As can be seen from Box 6.2., only the generation and the mode choice stage are comparatively easy to access by simplified modelling approaches. These stages can be used to clarify whether a trend has impacts that are high enough to justify a deeper examination and to sort other trends out that are expected to entail negligible consequences.

One consideration is that the measure to be analysed must be described in terms of the input data of the original model. While these data typically describe demographic, economic, geographic and transport aspects on a zonal level, logistics trends usually work on the firm level. Moreover, the behavior parameters have to be provided from somewhere, as own field research and parameter estimations in freight demand require efforts that are often prohibitive. In most cases, these behavior parameters result from the existing national models where they are usually published in deliverables or final reports. Thus, these parameters can only describe the aspects that were already addressed in the original model and the latter often do not address logistics aspects on the level of detail that is necessary to deal with logistics trends.

Box 6.2 Starting points for simplified transport models

1. **Generation**: Production (P) and consumption (C) depend on structural data in the considered zones. These refer to the economic and consumptive activities that are producing or using the respective type of goods. Examples include employment in the considered economic sector, inhabitants by income groups and GDP by industry sector.

Often, the amount of production and consumption in the zones is obtained by linear regression of observed base year figures against the structural data. Regression parameters are sometimes given in reports or deliverables of the national or comprehensive models so that the impacts of trends can possibly be obtained by entering altered values in the regression equations. Two aspects have to be considered here. First, a measure must be converted into a change in one or several of the variables in the regression equation. The structural data are often generic (e.g share of GDP or number of employees) so that it is unclear how the variables are influenced by the measure. Second, a measure's impact at the firm level must be aggregated into the effect at the level of the regression (typically single zones and commodity types).

2. **Distribution**: Production and consumption are distributed between pairs of origin (O) and destination (D) zones (O/D flows). This distribution depends on the attractiveness of a destination zone given a particular zone of origin and the costs that have to be covered for the interzonal transport. Attractiveness often results from the generation step in a way that zones with higher consumption are more attractive. Generalized costs can be influenced by logistics trends, so that altering them could be an option for estimating the effects of trends on interzonal flows. However, this is encouraged due to a high complexity that comes along with setting up an own distribution model for several reasons. First, the generalized transport costs partly depend on the distance covered and time spent on the networks. These figures are calculated in the assignment stage (4) and there are usually feedback loops between these stages in a more comprehensive model. As the complexity for setting up and calibrating an assignment model is very high, own simplified models can usually not be set up in a short period of time. Second, the distribution model is often calibrated to observed values (census or sample survey) for a past reference year. Such calibration is normally too time consuming to set up for a quick analysis.

3. **Mode choice**: Given the topic of this handbook, mode choice will be the main focus of interest of model applicants. Here, simplified estimations can be undertaken in an aggregate way. Reports and deliverables on the comprehensive national models often contain mode choice parameters and elasticity values on an aggregate national level for several commodity types. Moreover, variable values for typical transport cases are given, e.g. in BVU et. al. [2014] for the case of Germany. Effects of changes in variables on the modal split can be assessed by means of a spreadsheet software together with a description of the choice model.

4. **Assignment**: As this modelling step is the most complex one, it should be omitted in simplified models. However, if analysis on the first three steps shows that remarkable effects are expected, the impacts on the flows on the respective networks may have to be addressed in a more comprehensive analysis over the available transport modes.

6.6. Conclusions

This chapter has addressed national aggregated transport models and how they can be used in NRAs' operations. There is a wide scope of applicability of national transport models for the national transport authorities. As shown in chapter 2, there are several trends within the transport sector that NRAs should be monitoring in order to keep up with potential changes in traffic volumes. There are also a range of transport policy measures whose impact is of interest to NRAs. The NRA are at least responsible for some of these measures, especially to those that related to the infrastructure. In addition, changes in mode choice variables identified in chapter 3 should also be of interest to NRAs to analyse.

National transport models are a potentially powerful tool for assessing the impacts of these trends, policies and mode choice variables. The models typically allow for studying impacts of these factors one by one or in combination. One advantage is that the national models generally cover all modes, both national and international transports and are sometimes integrated with passenger transports. The wide scope of the models make them attractive to study aggregate, wide-spanning effects of national and international policies.

In section 6.2, we provided a description of transport models used in various countries and at the European level. This highlighted some noticeable similarities and differences. The models have various level of complexity; some model in detailed firm-to-firm-flows, logistics decision and have a fine-grained categorization of sub-modes and commodity groups. Other settle for a higher level of abstraction.

There is sometimes a trade-off between using a simple model that can answer simple questions fast and a complex model that requires much effort and can give more detailed answers. However, it is crucial to understand and model firms' logistic decisions like the often-simultaneous choice of shipment size and transport chain and the exploitation of economies of scale. These aspects have been considered recently in the national freight transport models in Sweden, Norway, Denmark and Flanders. A higher level of complexity in the transport model usually goes with requirements on more detailed input data. On the other hand, more complex models can calculate more detailed output variables which allow for richer analyses.

Public authorities are most often owner of the model and/or clients to private or academic organization who in turn develop the models. NRAs' access to the models can therefore be limited. Recently, the European Commission has started activities to share their transport models online. This is a positive development that should be developed further. Increased sharing of the transport models makes it easier to achieve consistency between national models from neighbouring countries and between national and European models. This is important because of the increasing importance of international transports and the development of international freight corridors.

Section 6.4 provided several examples of how national transport models can be used to analyse the impact of policies and trends. It showed that many of the trends and policies described in chapter 2 need to be translated in model variables like transport cost and transport time to be used in the models. The impacts are measured by a range of outcome variables, including volumes per modes measured in tonnes, tonne kilometres, vehicle-kilometres and number of trips as well as graphical visualization of flows. The model output can also be supplemented with cost-benefit analyses. The impact assessments are country- and context-specific and it may not be meaningful to compare results of these assessments directly.

Finally, we note the existence of EU-level guidelines for conducting cost-benefit analyses but nothing equivalent for running transport models, except for the Quick Response Freight Manuals in the United States and national guidelines for transport forecasts (e.g. STA 2012). In section 6.5 we therefore provided general guidelines on how to conduct a first impact assessment using freight transport model based on generation, distribution, mode choice and assignment. We conclude that only the generation and the mode choice stage are comparatively easy to access by simplified modelling approaches. Here, mode choice will be of particular interest to NRAs. For this component, reports and deliverables on the comprehensive national models serve as valuable sources for mode choice parameters and aggregate elasticity values for several commodity groups. A first impact assessment can be conducted by means of a spreadsheet software. The scope for running the freight transport models (simple and more comprehensive) is partly dependent on the availability of data, which was reviewed in chapter 5.

7. Lessons learned and recommendations

The purpose of this Handbook has been to provide a detailed review of the factors influencing modal choice, describe developments in the transport sector and the data and tools needed to analyse the impacts of trends and policy measures. We summarize these points below, highlight differences and similarities between countries.

We also offer recommendations for the transport infrastructure authorities in Europe, with focus on national road administrations (NRAs). In Section 7.1 we briefly describe a collection of guidelines that can be applied within the respective authorities and with help of existing technologies. These guidelines are further described in Appendix C. Section 7.2 addresses the whole transport system and derives recommendations for the long-term perspective until 2030 respectively 2050.

7.1. Lessons learned

There are ongoing trends towards higher freight transport demand and higher logistical requirements from various types of customers, which are expected to continue to the year 2030 and beyond. This leads to increased requirements on the efficiency of the transport system and all its' components; namely the firms that provide logistics and transport services, their employees, different vehicles and energy sources as well as the physical and digital infrastructure. Increased logistical requirements pose a challenge for reaching the European Union's targets on energy efficiency and a 30% reduction of the greenhouse gases by 2030. The requirements may need to be relaxed to cut energy use and emissions and to reduce the vulnerability of the transport system. Alliance for Logistics Innovation through Collaboration in Europe ALICE and other European organizations have set up European Technology Platforms and the goal to increase efficiency in end-to-end-logistics by 30% until 2030.

There is a common understanding that the requirements, and therefore also the technological developments, are likely to be different between urban and non-urban transportation. Electrification of vehicles and suitable multistage distribution concepts may be required to tackle noise and greenhouse gas emissions from urban transportation, while automation has more potential for long haul transports between cities.

Typically, freight transport corridors are used to connect terminals and warehouses close to or in cities. The FLUXNET-project studies how to integrate land use and infrastructure planning and how to improve the cooperation between the different stake holders at the local and regional level. The FALCON-project focuses on the long haul, where mode choice matters, and the overall transport system.

As described in chapter 2, various technological developments and policy strategies are likely to improve the efficiency of the transport system. Some technologies are already in use in some countries (high capacity vehicles), some are ready to be used on a larger scale (alternative fuels) and some are under development (synchromodality, automation of vehicles, Internet of things and Physical Internet).

Our review of the trends shows that several policy and infrastructure-related requirements need to be fulfilled before new technologies can be implemented at a larger scale. The use of autonomous trucks requires e.g. sensors. Typically, longer or heavier vehicles put higher requirements on the infrastructure See section 7.2.

As shown in chapter 3, increasing freight volumes and logistical requirements necessitate an increased utilization of the transport modes one by one and in combination and in some cases a modal shift. A key input for an efficient transport system is a solid understanding of firms' logistics decisions in general and the choice of transport solution and mode in particular. Chapter 3 provides several key lessons regarding firms' modal choice.

- Mode choice is normally not a standalone decision but part of broader decisions on transport solutions (and logistics).
- Shipment attributes (e.g. commodity, value, weight, value-density) and transport distance impose restrictions on the firms' ability to choose between transport solutions. This means that i) for certain trip distances and shipment attributes, shippers are captive to a single transport solution or mode, ii) the degree of competition between modes is different depending on the distance class and shipment characteristics. Differences in the commodity mix and distances explain some of the country-differences in modal split and modal competition. NRAs should therefore understand the nature of modal competition in the market they analyse.
- The way that transport solutions are chosen differs. Both shippers and logistics service provides (LSPs) can be decision-makers. Typically though, the shipper specifies the details and requirements for the shipment, the LSPs offer a freight rate and transit time associated with their transport solution and the shipper selects the most attractive one.
- Transport cost is the most important choice criterion for shippers, provided that sufficiently high requirements on time and reliability are met.
- The cost sensitivity varies considerably across market segments. The relative competitive positions of the modes explain much of the variations of price elasticities: road transport demand is the least cost-sensitive in segments where trucks are the most competitive option, and likewise for rail and waterborne transport.
- Cost sensitivity also depends on whether the decision-maker bears the transport cost. When shippers themselves pay the freight rate they naturally search actively for cheap options. But when the receivers pay the rate and the shippers are responsible for the choice of transport solution shippers are less cost sensitive. Policy impacts are therefore better understood by identifying decision-makers and assessing the contractual relationship between freight agents.
- Road transport is the most common choice due to its cost advantage as well as the end-customers' last-minute requests and demand for short lead-time. The possibility to use other modes than road increases with larger volumes, receivers accepting longer lead times and consolidation of flows within and between firms. This illustrates the connection between the mode choice and other logistics decisions.
- Shippers and LSPs list several measures that public authorities can take to influence the choice of mode. These include policies to internalize the environmental impact in the pricing of the modes, increase the availability of (rail) infrastructure and reduce terminal fees. They also want public authorities to pro-actively inform about their actions, bring together shippers when they develop new plans and spread information about multimodal solutions. Private and public programmes that bring together freight agents could foster consolidation and multimodal solutions.

Various aspects of terminals can also influence the choice of transport solution. As described in chapter 4, the choice of transport chain and mode(s) is closely linked to the availability and attractivity of terminals. We draw several lessons from this chapter:

- Transhipment costs, including the time needed for transhipment and any waiting time for drivers and vehicles, influence the competitiveness of multimodal (or intermodal) transport chains compared to door-to-door transports by road.
- In many cases the transport modes are complements rather than competing alternatives. The costs for road transports to/from the terminals can account for a significant part of the cost in

intermodal transport chains. Improving the conditions for the road mode will most certainly increase its attractiveness for door-to-door road transports, but it could also benefit transport chains where pre- and post-haulage by road is included.
- The importance of terminals is different in different countries and regions. Some terminals attract large volumes while others are of less importance because of competing terminals in the neighbouring regions. Terminals also vary in the modes they connect, the commodities/load units they handle and how well they are connected to the surrounding infrastructure. See section 7.2.
- There is a shortage of data describing terminals and how they are connected to the transport network. See section 7.2.
- Measures to reduce transhipment cost include subsidizing transhipments directly and funding land acquisition, infrastructure and transhipment equipment.
  Measures to reduce waiting time in terminals include controlling approaching road traffic at an early stage and using technologies to predict trucks' time of arrival and waiting more accurately. In addition, dry ports connected to ports by rail or IWW shuttles can reduce congestion and waiting time.

Chapter 5 shows that the authorities need different types of reliable data in their monitoring and analyses of the transport and traffic flows related to freight transports. We conclude that there in many cases is a gap between what data the authorities need and the data they have access to. It is important to differentiate between aggregated (macro) data and disaggregated (micro) data.

- We find that the authorities in the four countries that were studied in more detail (France, Germany, The Netherlands and Sweden) use national road data bases to follow up and study the aggregated traffic flows in the road network. There is a lack of vehicle utilisation data (in volumetric and weight terms). Furthermore, there is a discrepancy between the national road databases and the official road transport statistics in the respective countries. The tonne-km statistics at the national and European level comprise single mode specific links within the transport chains, but no information about the composition of the transport chains.
- The understanding of single firms' choice of transport solution and mode(s) for door-to-door transports requires disaggregated data that describe the attributes of individual shippers, shipments and the characteristics of the available modes. This type of information is only available in countries that have carried out commodity flow surveys (France, Sweden and Norway).

As shown in chapter 6, data alone are often not enough to form a solid understanding of the potential impacts of trends, policy measures etc. on firms' solution of freight transport solutions that comprise the choice of mode(s), vehicle (types), degree of consolidation, load factor share of empty transports etc.

National freight transport models that ideally include all modes are used to estimate the potential impacts of different trends (e.g. long term economic development), infrastructure projects, policy measures as well as packages of measures. The results of the impact analyses can be used directly as basis for political decisions or as input in social cost-benefit-analyses (CBA). It should be noted that the models we review have a comprehensive scope. Answers to questions that arise from day-to-day politics can only be obtained with reasonable effort. Thus, methods that provide roughly estimated results are advisable to apply. There, single effects of developments or trends in freight transport demand are considered in isolation in order to get a first impression of their magnitude. If the rough analysis reveals significant impacts on the freight transport system, more thorough analyses can be made with more comprehensive approaches. We state that there are no guidelines on how to apply the models. See section 7.2.

One important overall lesson is that the various technological developments and policy strategies described in chapter 2 have a large potential to solve the problems related to terminals, data and transport models described in chapter 4, 5 and 6. We see a need to develop a “road map” that shows how the goals to reduce the greenhouse gases by 30% and to increase the logistics efficiency could be reached until 2030. In section 7.2 we provide measures in the transport sector.

7.2. Recommendations

In order to offer recommendations for the NRAs it is important to first consider the role of the national transport authorities. This role is not the same across countries as the responsibilities in the transport sector is differently organized in different European countries. In some countries, like the Netherlands and Sweden, a single public agency is responsible for the national infrastructure. In other countries, like Germany, France and Norway, the responsibilities are spread out over several executive agencies.

There are many measures within the scope of the transport authorities in Europe, including financial support to terminals and provision and maintenance of the connecting infrastructure. In some cases, the transport authorities are responsible for data collection or the development of new data collection methods. Some authorities promote collaboration between private firms, others are active in the development of systems for new transport solutions like synchromodality. Despite these differences, we have identified a set of recommendations to should apply to most, if not all transport authorities. We list them below with a motivation and a list of stake-holders relevant for implementation.

7.2.1. Within authorities and with help of existing technologies

Appendix C contains guidelines for activities that relate to the findings in chapter 2-6 and can be readily applied by NRAs in their operation. The purpose of Guideline 1 is to monitor the development of trends relevant for the NRAs. Guideline 2 is used to identify segments in which transport modes compete as well as the modal shift potential. Guideline 3 shows NRA how to apply price elasticities to give a rough assessment of policy measures and trends. Guideline 4 provides NRAs with an example of how to assess the availability and concentration of freight terminals. The purpose of Guideline 5 is to give an example of how NRAs can utilize data to identify road transport network inefficiencies. Finally, Guideline 6 links the main components of transport models to the data source, which can be used as a template by NRAs.

7.2.2. Within the transport system and with help of new technologies

Below we provide recommendations of measures that should be taken by different stake holders in the transport sector. These measures are related to collaboration, digitalisation and data as well as new technologies and infrastructure.

Collaboration

We recommend to increase the collaboration between stake holders at the European, national, regional and local level and between public and private stakeholders. For instance, the infrastructure aspect is currently not covered in the European technology platforms. The presence of the authorities representing road, rail, waterborne and air infrastructure in such collaborations is needed. As far as we know CEDR are currently not part of European technology platforms. Below we list examples of measures.

Examples of measures	Motivation	Implementing stakeholders
Increase collaboration between transport authorities responsible for different transport modes.	National infrastructure authorities that are not responsible for all modes should co-operate with authorities representing other transport modes than road. The modes are in many instances complements and combined together. Collaboration with other authorities could provide NRAs with valuable insights about the interaction between the modes, e.g. in the development of intermodal services within the TEN-T network.	NRAs and infrastructure authorities responsible for other modes.
Increase collaboration between transport authorities and private sector, including stake-holders' meetings and other information and communication channels.	National infrastructure authorities should make use and deepen existing collaboration with the private sector in e.g. infrastructure planning and adapting to climate change. NRAs will benefit from understanding the driving forces behind firms' decision in the freight transport sector. Firms could also provide a valuable data. The private sector call for better communication with and from NRAs in order to plan ahead. Collaboration therefore has potential to bring mutual gains.	Infrastructure authorities, national and European trade bodies representing the logistics sector, freight forwarders organisations, etc.
An international strategy for the continental combined transport should level a more efficient use and development of the infrastructure.	A strategy for combined transport should strengthen rail freight and relieve the bottlenecks on the road infrastructure.	National and international policy-makers, infrastructure authorities, combined transport associations, railway companies.
Push the collaboration between the market partners	Horizontal co-operation agreements can lead to substantial economic benefits. See European Commission (2011/C 11/01), Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements	

Table 7-1. Recommended measures for collaboration

Digitalization and data

We recommend NRAs and infrastructure authorities responsible for other modes to make use of the digitalization of the transport sector.

Examples of measures	Motivation	Implementing stakeholders
Push the development towards the equipment of load units and vehicle/vessel with tracking and tracing devices. These devices provide data on tonnes and volume transported and movement of the load unit in time and space. Such data would make it possible to calculate load factors (tonnes and m^3), the extent of empty transports and kilometres travelled in different regions. **Push that relevant stake holders solve privacy and confidentiality issues**	There are wide-spread quality problems in freight statistics, discrepancies between data sources and a chronic lack of volumetric data. There is also a need to reduce firms' response burden and data collection costs and improve the input data in freight transport models. Increased use of tracking and tracing devices would help tackle this challenges.	Policy-makers, NRAs and infrastructure authorities responsible for other modes, national statistics offices, private firms, Eurostat.
Increase the scope of data collection in the freight sector. Commodity flow surveys could be used in a larger extent, possibly including shippers' logistics structure, volumetric measures, scheduling variables and/or vehicle/vessel utilization.	Increased scope of data collection would increase the understanding of freight flows and firms' decision in the freight transport sector.	Infrastructure authorities, national statistics offices, Eurostat.
Improve existing transport models and the possibility of sharing transport models.	Access to adequate tools for analysing the freight transport sector is important for policy analyses and forecasts.	Infrastructure authorities, private firms.
Organize a round-robin where suppliers/users of national transport models are requested to analyse a specific transport problem.	Transport models (and the required data), as used in different countries, are different which limits the comparison of transport issues at EU-level. Applying different models for the same (well-defined) problem leads to understanding on these differences, and will result in further steps to make the models more comparable	Policy makers, NRAs, infrastructure owners, private firms.

Table 7-2. Recommended measures for digitalization and data

New technologies and infrastructure

We recommend NRAs to make use of new technologies and infrastructure.

Examples of measures	Motivation	Implementing stakeholder
Assess infrastructure requirements that come with an increased use of autonomous vehicles, electrification of vehicles and high capacity vehicles.	Automation of long distance transports (especially on road) are expected to become established in the coming years. This means that requirements on infrastructure beside the vehicle-to-vehicle communication have to be checked.	Infrastructure authorities, policy-makers.
Increase the use of Smart Infrastructure Access Policies (SIAP) and performance-based standards (PBS).	For safe and efficient use of the infrastructure and to promote the development of efficient vehicle-related technologies.	Infrastructure authorities, policy-makers.
Initiation of cross-company logistics clusters at the urban periphery for freight centres to enable multistage distribution systems (link between urban and non-urban transportation) with eco-friendly vehicles. These freight centres should be connected with national and international road, rail and inland waterway infrastructure and open for all companies.	Electrification of the last- mile logistics until 2030 is urgently necessary in order to reduce noise and emissions. Therefore, multistage distribution systems suitable for alternative vehicle concepts are required in order to transfer loads from HCV to e.g. light commercial electric vehicles or carrier bicycles.	Local and regional policy-makers, infrastructure operators, logistics associations.

Table 7-3. Recommended measures for new technologies and infrastructure

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Appendix A Synchromodality

This section introduces the concept of synchromodality. The concept aims to enhance the flexibility in the transport chain, resulting in a more robust network, lower transport costs and a better environmental performance.

This section will first introduce the concept of synchromodality and its main benefits. The section will then present a step by step growth model on introducing synchromodality in practise and will provide some innovations for each of the steps. Finally, the section will present some conclusions.

Synchromodality concept

Synchromodality is the optimally flexible and sustainable deployment of different modes of transport in a network under the direction of a logistics service provider, so that the customer (shipper or forwarder) is offered an integrated solution for his (inland) transport. The concept aims to combine several modalities (road, rail, inland waterway, short sea) when planning a container shipment to a given destination. In the case of a synchromodal transport consignment, modalities, routes and schedules may be switched at any given moment according to local conditions (especially transport availability and time restriction on the consignment). This makes synchromodal transport more complex than regular intermodal operations, but the flexibility it creates leads to higher utilization of barges and trains. This helps to deliver higher efficiencies and more environmental benefits at lower transport costs.

The logistics service provider operating in a synchromodal network offers an integrated transport solution that can be offered to the customer, in which different modes of transport are combined efficiently. An essential aspect of a synchromodal solution is that the customer (shipper/ receiver or freight forwarder) provides freedom to the logistics service provider in the booking of the transport. This relates both to the mode of transport that is to be used, the route that needs to be taken or the time schedule in which the transport needs to be performed (see figure below). This freedom allows the logistics service provider to plan the transports more flexibly, and therefore enables a more optimized utilization of the transport network, for instance by bundling of transport orders.

Table A-0-1. Flexibility options for multimodal transport

A second aspect of the synchromodal concept is that the logistics service provider is able to switch seamless between transport modes, by having access to real-time information on the status of the transport network and the requests of customers. This enables the logistics service provider to utilize their assets effectively and to have the flexibility to switch to alternatives if necessary (for instance in case of an incident on the fairway or an operational delay.

Main benefits of synchromodality

Applying synchromodality can lead to benefits both to supply chain partners and to the transport system as a whole.

Benefits on the level of the supply chain

A main benefit for supply chain partners is that transport costs can be decreased significantly and Logistics Service Providers (LSPs) can choose the modality given the circumstances of the network and are able to choose the lowest cost option that still meets the requirements of the client according to the service level agreement (TNO 2016). Example cases in Dutch corridors show that LSPs are able to increase the share of inland waterway transport and rail significantly. On a whole, this leads to lower transport costs for clients.

Furthermore, the companies are able to utilize their transport equipment better. In case of (unexpected) excess capacity on ships or trains, additional capacity can be switched from road transport. By being able to better utilise their capacity, companies to better guarantee that there is enough cargo to maintain a transport line at a profitable rate.

By being able to switch swiftly between transport modes, delays can be avoided, thus increasing the reliability but also the predictability of the supply chain. In the long run, this enables clients to keep lower stocks, and thus save inventory costs. Furthermore, hindrances in the production process as a result of supply chain delays can be avoided.

Benefits for the transport system as a whole

When aggregating the benefits of an individual supply chain to the transport network as a whole, an important benefit of synchromodality that comes forward is a better utilization of the capacity of the network. This is caused by a better utilization of the capacity of transport equipment (through a higher occupancy rate), which leads to less transport movements, and thus less usage of infrastructure capacity. Furthermore, the ability to switch seamlessly between modalities enables companies to shift cargo in case of expected and unexpected capacity constraints. For example, in case of increased road traffic, cargo can be swiftly switched to rail or waterborne transport. Another example is that in case of low water in the river Rhine, and thus the capacity of inland waterway transport is much lower, cargo will be switched to rail and road effectively. Infrastructure capacity can be used more effectively and the transport system becomes more reliable.

By shifting cargo to the most efficient transport modality, truck kilometres are saved. This also leads to a significant decrease of CO_2 emissions.

A staged approach for implementing a synchromodal network

Practical experience with synchromodality shows that the market is not able to fully integrate concept instantly (TNO 2016). Instead, supply chain partners implement elements gradually to come to a synchromodal transport system. The following figure presents a growth model for synchromodality. The figure shows several stages in the development of a synchromodal concept, from the initial stage on bottom left of the figure to the final stage right at the top of the figure. The different stages of the growth model are elaborated in the remainder of this section.

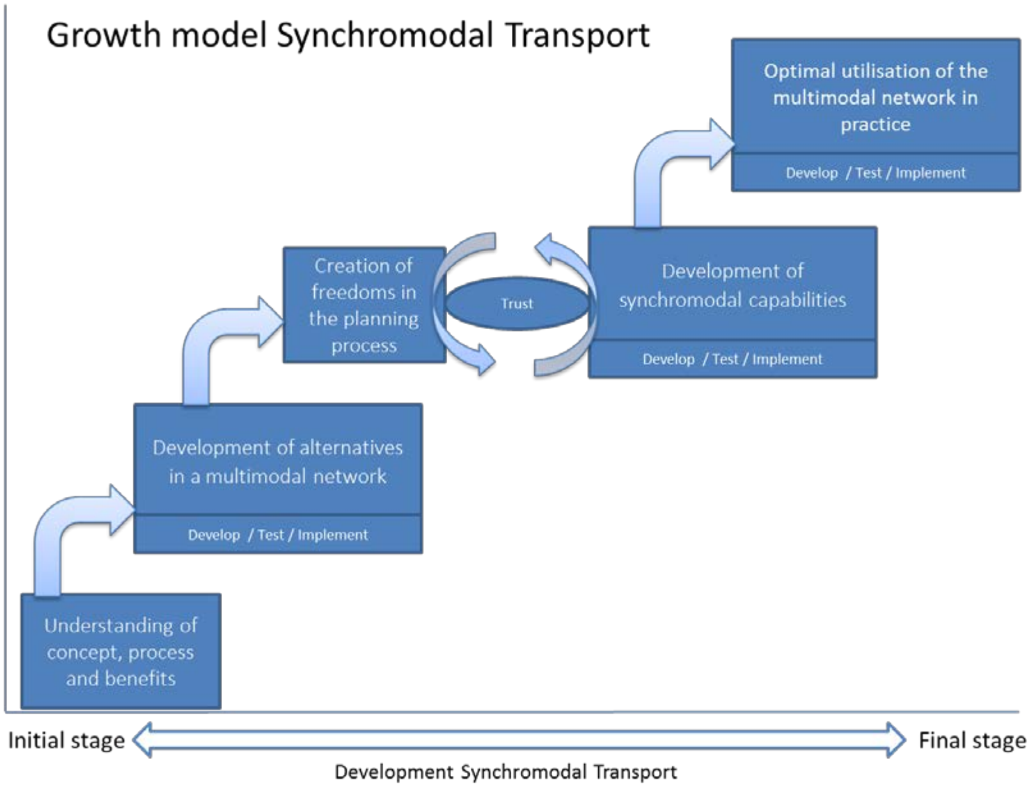

Table A-0-2. Growth model for synchromodal transport

Understanding of concept, process and benefits

Although there are already many supply chain parties working on synchromodal transportation, there are (even in the Netherlands) many market parties that are unfamiliar with this concept. To increase awareness on the concept, companies should be given more insight in synchromodal transport: what is it, why is it important, how does it work, what are the benefits and what is needed to be done implement it. Different tools can be used to create this awareness. Application of serious gaming, which is discussed in the next section, is considered to be an important innovative measure, to raise stakeholder awareness.

Development of alternatives in a multimodal network

To apply synchromodal transport, multiple transport options are needed. Therefore alternatives need to be developed, either in terms of transport routes, alternative modalities or transport schedules. An example is the development of a new rail service as an alternative to road transport. Applying such a service for multimodal transport alone is not yet creating the necessary freedom needed for a synchromodal network. However, it is an important precondition that these alternatives are developed to implement synchromodality at a later stage.

Creation of freedoms in the planning process

When different alternatives are available, flexibility needs to be created in the planning process to use the multimodal network optimally. This flexibility can only be applied, if shipper or freight forwarders provide freedom in terms of modality choice (A-modal booking), transport route and release time. The client will only consider this if there are clear benefits to be expected. These benefits must be clear before the shipper will offer this freedom in the planning process.

Development of synchromodal capabilities

In order to utilise a synchromodal network, a logistics service provider needs to develop capabilities to make an optimized transport decision. This requires that the logistics service provider has good (preferably real time) information on the availability of alternatives (among others travel time, transport capacity of different modes, constrains in the network), and has the knowledge and resources to take these into account properly. In order to do so, ICT support systems are required.

Interaction between freedoms in the planning process and development of synchromodal capabilities: Trust

The growth model shows the steps of creating freedoms in the planning process by the shipper and the development of synchromodal capabilities by the logistics service provider at the same level. Both steps are highly dependent on each other. If the shipper creates freedoms in the planning process but the logistics service provider is not able to exploit the alternatives (because i.e. information is missing or synchromodal planning capabilities are lacking) the concept will not work. On the other hand, if the logistics service provider is able to facilitate alternatives but the shipper does not (or only temporary) provide the necessary freedom in the planning process (for instance the shipper still wants to only use a fixed modality) the concept also will not work. Trust between the shipper and logistics service is needed so that both parties are working together to make synchromodal transportation as effectively as possible is of great importance. The shipper needs to be able to trust that the logistics service provider can realize the potential benefits and can ensure a reliable service. The logistics service provider needs to be able to trust that the shipper is willing to make a longer term commitment to provide flexibility in the planning process. In many pilot projects on synchromodality (such as the case of Mepavex described in section 6.2.6) this step is considered to be crucially important. It requires a strong partnership and pain and gain sharing.

Optimal utilisation of the multimodal network in practice

The final stage includes the utilisation of a synchromodal network in the practical day-to-day operation. Parties can further improve and implement parts of synchromodal transport, for instance by applying synchromodal planning algorithms, development of new partnerships and by developing new business and pricing models for new alternatives.

Synchrogaming: Innovation for creating understanding of the concept

Delivering a Synchromodal transport solution demands much more from the various stakeholders in the network than is customary in intermodal transport in terms of education, understanding and cooperation. As discussed in the previous section, a first step is to create understanding of the concept and convince stakeholders of the benefits. This requires a mind-shift by various stakeholders at the same time.

Serious games are considered to be effective tools to create a mind shift because they get people's attention, are motivating, enable people to feel competent about performing a task, allow people to actively participate instead of passively watch, show all the steps necessary to perform a behaviour or a series of behaviours and allow repetitive practicing (Buckley & Anderson, 2006). Therefore, development of a serious game is considered to be a good medium to explain and teach the complex concept of synchromodality and seems to be a good medium to create awareness for this matter.

Synchromania

In order to create a wider understanding of synchromodal transport in the Netherlands, ECT, a deep-sea container terminal in the port of Rotterdam, EGS, an operator of a multimodal hinterland network, Danser, an intermodal transport operator, and TNO, a Dutch research organization, developed a serious game to provide insight to stakeholders involved on the benefits of synchromodal transport planning. The serious game, SynchroMania, makes it possible for all those involved in logistics planning (transport planners, sales representatives, etc.) to experience how synchromodal planning works and the decisions it requires. The game also outlines the benefits that can be obtained from reducing the number of constraints and enhancing collaboration; not only between planners, responsible for various corridors, but also between different stakeholder categories, such as: salespersons and customers. In this way the game helps to establish the necessary mind-shift.

In the game, players step into the shoes of a transport planner tasked with finding the optimal route to ship the orders placed by three demanding clients to various locations within a container hinterland network. In planning each order, the planner must strive to comply with the specific requirements imposed by each client while also optimising the overall costs and emissions level.

Table A-0-3. Screenshot of the Synchromania game

The game consists of three rounds. Each round takes 10 minutes to complete and represents one workweek of the planner. At the start of each day, the player receives a number of transport orders. He needs to assign each order to one of the available transport services. The planner has a limited amount of time to allocate the orders to one or more transport units. At the end of each round, the planner's performance is evaluated in three metrics: total cost, emissions level and customer satisfaction. This score is then discussed in a group setting to support more adequate choices in upcoming rounds.

In between rounds the player can make investments by playing action cards. The action cards represent the strategic choices to be made when organising synchromodal planning. Each card offers the planner some extra planning freedom. The figure below shows an example screenshot of different action cards. Action cards can effectuate route free transports, mode free transport, earlier deliveries at terminal, additional transport capacity, and more. The entire set of action cards consists of 18 cards. In the beginning of rounds two and three, the player chooses two action cards.

Table A-4. Screenshot of the Synchromania action cards

SynchroMania was developed as public private partnership. 50% of the project was funded by the participating companies and the remaining 50% was paid by public authorities, as part of the Topsector Logistics (TKI).

To develop SynchroMania, a paper-based version of the game was developed first. In this paper based version, all the operational procedures and customer requirements were thoroughly discussed and reviewed by operators. Based on the outcomes of these preliminary workshops, a digital version of the serious game was developed.

This digital game was played with several members of staff of the different involved companies, including management, sales representatives and operators. This approach ensured that the game was a realistic representation of the involved processes. The digital game is available in English.

Results

SynchroMania is intended to challenge the participants' current assumptions and attitudes towards planning and collaboration. By playing the game, participants personally experience the added value of working with a synchromodal system.

The game is currently used for different audiences:

- ECT, EGS and Danser use the SynchroMania game in sessions with their operational planners and sales force. By better understanding the working of the concept, the companies are able to get all staff up to speed on synchromodal transport.

- The serious game is used as part of workshops on synchromodal transport with different stakeholders who are not yet familiar with the concept. The workshop consists of playing the game and having an interactive discussion on how to implement the concept in practice. The workshop is held with supply chain partners, such as shippers, logistics service providers and transport operators, but also with other important facilitating stakeholders such as port authorities, infrastructure managers and regional and national governments.

- Logistics courses at applied universities in the Netherlands use the game as part of the education program. The game helps students familiarize with transport planning in general and synchromodal planning in particular.

Pilot Bergen op Zoom: Creating freedoms and developing synchromodal capabilities

Bergen op Zoom is a small city in the province of North-Brabant, and is situated along the Scheldt-Rhine Canal (the fairway connecting Port of Antwerp to the Rhine and the port of Rotterdam). Since opening a barge terminal in 2008, there has been intensive cooperation between regional stakeholders such as shippers, logistics service providers and the inland terminal operator. This cooperation led to development of a synchromodal transport service connecting Bergen op Zoom to Rotterdam. This section will highlight two important aspects of the development towards a synchromodal service:

- Roundtable discussions between stakeholder in order to gain trust and to look for opportunities for cooperation

- Development of an IT support system for the logistics service provider

Round table discussions between stakeholders

After deciding to set up a new barge terminal in 2008, the involved logistics service provider decided that individual negotiations with a large number of international customers would not bring the desired transparency between the customers and might lead to mistrust towards the service provider. Lack of trust and transparency were identified as critical risks for failure for the new terminal.

In order to tackle this, the logistics service provider organised roundtable sessions with the most important clients. Goal of these meetings was to identify under what preconditions the clients were willing to give away control over the container transport flows towards the service provider. The overall goal was that all participants had to benefit from the cooperation. For shippers this meant a significant decrease of costs.

Discussions at the roundtables concluded that the region had a balance of import and export flows. However, all clients used different container carriers, leading to many empty transport movements. By matching import and export flows and booking containers at the same carrier, leading to significant lower transport costs and lower CO_2 emissions. Benefits gained were distributed towards the different partners via a uniform system.

Integration of IT systems

In order to extend the cooperation and for the logistics service provider to be better able to organise transport flows directly for the customer, a better integration was needed between the Enterprise resource planning (ERP) systems of the clients and the transport planning systems of the logistics service provider. This would lead to less administrative burden, a more fluid operational process and a better information position on real time status of the network.

A new multi-actor order management platform was developed in which information can be added directly from existing IT systems of different partners. The platform gives real-time order information on individual containers and gives the transport operator the opportunity to match the container with another booking (import-export matching) and to make a synchromodal transport decision.

The development of the IT-system was a public-private partnership in which 50% of the budget was funded by the participating companies and the remaining 50% was paid by public authorities, as part of the Topsector Logistics (TKI).

Through this system, the logistics service provider is able to increase the use of inland shipping (up to 85% of all bookings). This enabled the company to significantly lower costs and to lower the CO_2 emissions.

Complexity Methods for Predictive Synchromodality (Comet-PS)

Comet-PS is a project co-financed by the Netherlands Organization of Scientific Research and lead by the Dutch National Research Institute for Mathematics and Computer Science. Comet-PS is a four-year project (started in 2017), which bring together universities, research organizations, port authority (Rotterdam) and heavy users of transport (Tata Steel, Air Cargo Netherlands), service providers (Combi Terminal Twente B.V., Amsterdam Airport Schiphol) .

The main problem addressed by the project is that under the current state of the art, the exploitation of synchromodality is strongly challenged by the inherent complexity of logistic supply chains due to the omnipresence of uncertainty (weather, delays, transport demand, disruptions, traffic dynamics, driver behavior), influencing many decisions of many stakeholders. Motivated by this, Comet-PS proposes the concept of predictive synchromodality, incorporating models, methods and tools based on predictive data analysis and stochastic decision making in distributed control environments, for exploiting the great potential of synchromodality, addressing the question what to transport, how and when. Thus, the project proposes a way in which the gap from the intransparent and inefficient current transport state can be bridged to a streamlined logistic system with improved transport efficiency, higher loading rate of vehicles, less emissions and costs.

The concept of **Predictive Synchromodality (PS)** from the start explicitly takes into account the presence of uncertainty in planning and operational control of logistical transport services. With PS the performance of transport services is enhanced by taking into account (at an early stage) not only the *current state*, but also (*predictions of) uncertain future states of the entire transport system,* and the fact that multiple decision makers can be present. Comet-PS pays direct attention to the following:

● **Certainty** -- Not all information regarding various variables, degrees of uncertainty, objectives and dynamics are known in practice. Having certainty in information is a preferred feature of synchromodality as it forms the basis for decision making.

● **Optimality** -- Having all information regarding dynamics, variables, degrees of uncertainty, objectives now and in the near future available at once in one central place, enables new decision making strategies. Optimality is a preferred feature of synchromodality as it represents making the theoretically best system-wide decision given all available information.

● **Cooperativeness** -- Information is not always available in one central place. Via different levels of cooperation transport operators can in a distributed way align their actions. Cooperativeness is a preferred feature of synchromodality as it expresses the explicit taking into account of various stakeholders and their different degrees of information sharing and cooperation willingness.

The project will run the following three (application & valorization) cases:

Combi Terminal Twente, CTT: CTT provides container terminal services in three locations: Rotterdam, Hengelo and Bad Bentheim (Germany). These locations are connected via different modalities (inland, road and railway), which provides huge opportunities for exploring the possibilities of synchromodal transport planning. The issues that CTT would like to address involve the three aspects that play a central role in the project: certainty, optimality and cooperativeness. CTT wants to efficiently plan transportation vehicles (barges, trains and trucks) by using a combination of data driven and centralized approaches. To this end, the following steps need to be taken: 1) Develop tools to gather relevant travel data about the barges and trucks; 2) Use this data to predict both the arrival and turnaround times of their transport vehicles and see the different metrics on a dashboard; 3) Use and optimize synchromodal planning

Dry Bulk Logistics (Tata Steel and Port of Amsterdam): Tata Steel is seeking opportunities to come up with a robust shipping model for the Danube Region: Germany (from Regensburg into Central and Eastern Europe), Austria, Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Bulgaria, Romania. Tata Steel believes it is possible to supply its products in a competitive manner via a barge shuttle model into the region whereas nowadays the current mix of modalities and routings does not make it possible to distinguish itself from a logistic perspective.

Air Cargo Logistics (Air Cargo Netherlands (CAN)): The supply chain of air cargo is a complex interplay between airlines, ground handlers, forwarders and shipping agents. A by TNO has shown that large cost savings, CO_2 emission and reduction of waiting times can be obtained by a better coordination between ground handlers, forwarders and shipping agents. The celebrated Milkrun-project (http://www.acn.nl/milkrun/) has shown the huge potential cost reduction by coordinated planning for air side to land side cargo. The key challenges in the air cargo domain, for which the concept of Predictive Synchromodality could be beneficial are route optimization, efficiencies through combining import and export, direct deliveries to the final destination bypassing intermediaries, other. The case will realize an efficient use of trucks, and also a smoother inflow and delivery of freight. Large cost savings are expected to be realized through (1) reduction of the number of truck movements, (2) higher throughput in the warehouse (possibly leading to a higher handling capacity), and (3) less bursty delivery of freight, which makes personnel planning much easier and less costly.

The project results and knowledge built up by the research partners will be made available to industry parties not directly involved in the project, e.g. through publications and by exploiting the obtained knowledge and results in consultancy projects.

Conclusions on Synchromodality

Synchromodality aims to create a flexible and efficient deployment of different modes of transport under the direction of a logistics service provider. The concept can help logistics service providers to optimally use their assets and switch more cargo from road to inland shipping and rail, while still being able to maintain a flexible network. This leads to lower transport costs, a better environmental performance and a more robust network.

Introducing a synchromodal network requires a step by step approach. Firstly, stakeholders should become aware of the working of the concept and the benefits. Innovations such as serious gaming can greatly increase this awareness. In a second stage, clients need to provide freedoms in the planning of the transport consignments and logistics service providers need to develop synchromodal capabilities. As shown by the case in Bergen op Zoom, the development of trust between partners is an essential aspect in this step. Finally, the optimization of the network needs to be utilized in the day-to-day operations. Here innovations such as those developed in the Comet-PS project can make a difference.

Appendix B Main data variables in Eurostat

Multimodal transport			
Variable	**Description**	**Unit of measure**	**Data coverage**
Modal split	Percentage of each inland mode (road, rail IWW) in total freight transports	TONNE-KM (road, rail IWW)	Selected EEA countries Annual data, 1990-2014
Modal shift potential of long-distance road freight in containers	Road transport (in tonnes) below 300 kilometres relative to total road transports	TONNE-KM (all modes) Tonnes (all modes)	Selected EU countries Annual data, 2011-2014
Railway transport			
Main variable	**Segmentation variables**	**Unit of measure**	**Data coverage**
Goods transported	Transport operation (national, international)	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 2004-2015
	NST/R classification	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 2000-2015
	NST 2007 classification	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 2008-2015
	Loading and unloading country	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 2000-2015
	Type of consignment	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 2000-2015
	Type of intermodal transport unit	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 2000-2015
	Dangerous goods	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 2000-2015
	Cargo type	Tonnes, journeys	EU countries Annual data, 1982-2002
	Distance class	TONNE-KM, tonnes	EU countries Annual data, 1982-2002
	Loading and unloading region (NUTS 2)	Tonnes	EU, EEA and candidate countries 2005, 2010, 2015
Road transport			
Main variable	**Segmentation variables**	**Unit of measure**	**Data coverage**
Goods transported	Transport operation (loaded, empty, national, international)	TONNE-KM, VEHICLE-KM, tonnes	EU, EEA and candidate countries Annual data, 1999-2015
	Transport operation (own account, hire/reward, not specified)	TONNE-KM, VEHICLE-KM, tonnes	EU, EEA and candidate countries Quarterly data, 1990-2016
	Loading and unloading region	TONNE-KM, tonnes, journeys	EU, EEA and candidate countries Annual data, 1999-2014
	Distance class	TONNE-KM, VEHICLE-KM, tonnes, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	Axle configuration	TONNE-KM, VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	Age of vehicle	TONNE-KM, VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	Max permissible weight of vehicle	TONNE-KM, VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	Load capacity	TONNE-KM, VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	NACE	TONNE-KM, VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data 2008-2015
	Type of container	TONNE-KM	EU countries Annual data, 2007-2014

	Dangerous goods	TONNE-KM, VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	Cargo type	TONNE-KM, VEHICLE-KM, tonnes, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	NST/R classification	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data, 1982-2007
	NST 2007 classification	TONNE-KM, tonnes	EU, EEA and candidate countries Annual data 2008-2015
	Region of loading and unloading (NUTS 3)	Tonnes	EU, EEA and candidate countries Annual data 1999-2015
	Country of loading and unloading	TONNE-KM, Tonnes	Worldwide. Annual and quarterly data 1999-2015
Vehicle movements	Reporting country	VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data, 1999-2015
	Transport operation (loaded, empty, own-account, hire/reward)	VEHICLE-KM, journeys	EU, EEA and candidate countries Annual data, 1999-2015
Vehicle transit movements	Transit country	Tonnes, journeys	EU 28, EU 27, EU 25, EU 15, EEA Annual and quarterly data, 1999-2015
	Transport operation (loaded, empty)	Tonnes, journeys	EU 28, EU 27, EU 25, EU 15, EEA Annual and quarterly data, 1999-2015
	Max permissible weight	Tonnes, journeys	EU 28, EU 27, EU 25, EU 15, EEA Annual and quarterly data, 1999-2015
Cabotage transport	Reporting country	TONNE-KM, tonnes	Selected EU-countries Annual data, 1999-2015
	Country in which cabotage takes place	TONNE-KM, tonnes	Europe, Asia Annual data, 1999-2015
Inland waterways transport			
Main variable	**Segmentation variables**	**Unit of measure**	**Data coverage**
Goods transported	NST/R classification	TONNE-KM, tonnes	EU countries Annual data, 1982-2007
	NST 2007 classification	TONNE-KM, tonnes	EU countries Annual data, 2007-2015
	Transport operation (loaded, unloaded, national, international, transit)	TONNE-KM, tonnes	EU countries Annual data, 1982-2015
	Packaging (containers, non-containers, empty containers and unknown)	TONNE-KM, tonnes	EU countries Annual data, 1982-2015
	Region of loading and unloading (NUTS 2)	TONNE-KM, tonnes	EU countries Annual data, 2007-2015
	Type of vessel	TONNE-KM, tonnes	EU countries Annual data, 1982-2015
	Nationality of vessel	TONNE-KM, tonnes	EU countries Annual and quarterly data, 1982-2015
	Dangerous goods	TONNE-KM, tonnes	EU countries Annual data, 2007-2015
Goods transported by container	NST/R classification	TONNE-KM, tonnes, TEU, TEU-kilometres	EU countries Year 2007
	NST 2007 classification	TONNE-KM, tonnes, TEU, TEU-kilometres	EU countries Annual data, 2007-2015
	Transport operation (loaded, unloaded, national, international, transit)	TONNE-KM, tonnes, TEU, TEU-kilometres	EU countries Annual data, 2007-2015
	Container size	TONNE-KM, tonnes, TEU, TEU-kilometres	EU countries Annual data, 2007-2015
	Cargo size	TONNE-KM, tonnes, TEU, TEU-kilometres	EU countries Annual data, 2007-2015

	Region of loading/embarking and unloading/disembarking (NUTS 2)	TONNE-KM, tonnes, TEU, TEU-kilometres	EU countries Annual data, 2007-2015
	Nationality of vessel	TONNE-KM, tonnes, TEU, TEU-kilometres	EU countries Quarterly data, 2007-2015
Vessel traffic	Transport operation (loaded, unloaded, national, international, transit)	VEHICLE-KM, journeys	EU countries Annual data, 2007-2015
	Maritime transport		
Main variable	Segmentation variables	Unit of measure	Data coverage
Goods handled in all ports	Direction of flow (inwards, outwards)	Tonnes	EU, EEA and candidate countries Annual and quarterly data, 1997-2015
Goods handled in main ports	Type of cargo	Tonnes	EU, EEA and candidate countries Annual data, 1997-2015
Goods transported to/from main ports	Type of traffic (national, international)	Tonnes	EU, EEA and candidate countries Annual data, 1997-2015
	Direction of flow (inwards, outwards)	Tonnes	EU, EEA and candidate countries Annual and quarterly data, 1997-2015
	Type of cargo	Tonnes	EU, EEA and candidate countries Annual and quarterly data, 1997-2015
	Nationality of vessel	Tonnes	EU, EEA and candidate countries Annual data, 1997-2015
	Region (NUTS 2)	Tonnes	EU, EEA and candidate countries Annual data, 1997-2015
Containers handled in main ports	Loading status (loaded or empty)	TEU	EU, EEA and candidate countries Annual data, 1997-2015
Goods transported by short sea shipping to/from main ports	Direction of flow (inwards, outwards)	Tonnes	EU, EEA and candidate countries Annual data, 1997-2015
	Sea region	Tonnes	EU, EEA and candidate countries Annual data, 1997-2015
	Cargo type	Tonnes	EU, EEA and candidate countries Annual data, 1997-2015
Goods transported in containers by short sea shipping to/from main ports	Loading status (loaded or empty)	TEU	EU, EEA and candidate countries Annual data, 1997-2015
	Air transport		
Main variable	Segmentation variables	Unit of measure	Data coverage
Freight and mail air transport	Country of origin and destination	Tonnes, flights	EU, EEA and candidate countries Quarterly data 1997-2016 Annual data 1993-2017
	Main airports	Tonnes, flights	
	Scheduled and non-scheduled	Tonnes, flights	
	Transport operation (national, international, intra-EU, extra-EU)	Tonnes, flights	
	By region (NUTS 2)	Tonnes	EU, EEA and candidate countries Annual data 1993-2015

Source: Eurostat (2017): Eurostat database. Available at [http://ec.europa.eu/eurostat/web/transport/data/database]

Appendix C Guidelines for activities within NRAs

Activity 1: Trends monitoring

Purpose: Monitor the development of trends relevant for the NRA.
Method:

- Select the trends that are relevant for the responsibilities for the NRA. As a suggestion, these could be all or some of the trends in Table 2-2 in chapter 2.
- Identify indicators for the selected trends. The indicators should be updated regularly (e.g. annually, quarterly, monthly). Examples of indicators and the corresponding trend are given in the table below. NRAs may also develop new indicators using the data at their disposal.
- Update the indicators regularly and perform in-depth analysis of the areas that call for attention. NRAs should be advised of the limitation of indicators to fully capture the development of ongoing trends.

Trend	Indicator	Type of indicator
E-commerce	Enterprises having purchased/received orders online Share of enterprises' turnovers on e-commerce (Eurostat, 2016)	Quantitative
Customer demand	Consumer surveys, postal service information	Qualitative
Reverse logistics	Waste generation and treatment (Eurostat)	Quantitative
(De)concentration in production	Outsourcing surveys (e.g. Deloitte, 2014; EY, 2013)	Qualitative
Outsourcing of transport services	Commercial road freight as a share of total road freight (Eurostat)	Quantitative
Port choice in Europe	Gross weight of goods handled in main ports (Eurostat)	Quantitative
High-capacity vehicles	World Port Index (Nat. Geospatial-intelligence agency) Average gross tonnage per vessel (Eurostat)	Quantitative Quantitative
Innovation	Progress reports (MARATHON, Shift2Rail, Mercedes Future Truck, Transforming Transport)	Qualitative
Alternative energies	Share of renewable energy in fuel consumption of transport (Eurostat) Share of electrified lines in rail network (Eurostat)	Quantitative Quantitative
Digitalization	ICT usage in enterprises (Eurostat)	Quantitative
Policies for high capacity transport	Progress report TEN-T network (COM(2017) 327 final)	Qualitative

Activity 2: Analyse modal competition

Purpose: Identify segments where modes compete and modal shift potential
Method:

- Collect data describing the movements of goods for the relevant geographic area. Data should provide information on mode(s) used, trip distance and/or commodity class at the minimum. See chapter 5 for data sources.
- Identify segments (e.g. by distance and/or commodity class) without modal competition based on some threshold value (e.g. mode has more than X % of market within segment).
- Identify segments with modal competition by calculating market shares of each mode in different segments.
- The scope for shift between modes can be estimated by calculating how many tonnes are being lifted/moved within all segments in which modal competition exists.
- The scope for shift between specific modes can be estimated by calculating how many tonnes are being lifted/moved within the segments where these modes compete.

Activity 3: Applying price-elasticities

Purpose: A simple application freight transport elasticities to roughly assess the effects of external events (e.g. policies and trends) on modal split.
Method:

1. Calculate the tonne-kilometre cost before (C_o) and after (C_1) the event.
2. Calculate the percentage change in tonne-kilometre cost $\%\Delta C = (C_1\text{-}C_0)/C_0$. Uncertainty about C_o and/or C_1 can be dealt with by using a range of possible values for C_o and/or C_1, thus obtaining a range of values for $\%\Delta C$.
3. Translate $\%\Delta C$ into the percentage change in tonne-kilometre demand ($\%\Delta D$) using the price elasticity (ε) given in chapter 3 and $\%\Delta D = \varepsilon * \%\Delta C$. Use the own-price elasticity to assess the change in demand for the transport mode who was subject to the cost change. Use cross-price elasticities to assess changes in demand for the other modes. Use a range of likely values for the elasticities, preferably the lowest and highest bound and the median value.
4. Translate the percentage change in demand $\%\Delta D$ into the tonne-kilometre demand change (ΔD) using $\Delta D = D_o * \%\Delta D$, where D_o is the tonne-kilometre demand before the policy change. D_o is the tonne-kilometre demand for the same mode as the price-elasticity of demand corresponds to.
5. Repeat 4) and 5) to obtain a set of likely changes in demand.
6. Possible extensions include using elasticities for different commodity groups, trip distances, regions, etc. to obtain more detailed impact projections.

Activity 4: Assess concentration and availability of terminals

Purpose: Assess the concentration and availability of terminals and volume in the relevant region.
Method:

- Collect data on the location of terminals in the relevant region. A potential data source is national business registers, in which location is identified by postal address of the facility and NACE codes can be used to identify the business activity. The data sources in section 5.3 could also be used.
- Add information on terminal type (see chapter 4) and/or size (area, TEU capacity, turnover) if the data material permits.
- Examine visually the geographical concentration of terminals and their location in relation to the transport network and cities. This could be performed in a geographical information system (GIS) program or any map visualization program.
- To construct indicators for terminal availability for different areas, calculate i) geographical distance to closest terminals, ii) driving time to closest terminal or iii) number of terminals that could be reached within a given time limit (e.g. 60 minutes). Terminal type and/or size can be used to construct more detailed availability indicators.

Source: Transport Analysis (2016)

Activity 5: Utilize big data for road freight traffic

Purpose: Use high-frequency data to identify road transport network inefficiencies.
Method:

- Collect data from road sensors over an interval of time (e.g. week, month, year).
- Distinguish between movements of passenger traffic and freight traffic.
- Analyse road freight vehicle movements over space and time. Do the occurrences of freight and passenger vehicle movements, free-flow speed and congestion exhibit any pattern depending on the season, month, day-of-the-week or time-of-day? How does the pattern differ between road segments?
- Based on these results, identify road segments and times where network inefficiencies occur.
- As a potential extension, perform the procedure repeatedly to investigate whether the patterns persist.

Activity 6: Overview of data requirements of transport models

Purpose: Linking the main components of transport models to the data sources.

Transport model component	Input data
PC matrices for base year	Trade statistics National accounts Commodity flow data
OD matrices for base year	Transport performance Commodity flow data Traffic count data
Aggregate mode choice models	Transport statistics Network data with cost functions
Disaggregate mode choice models	Commodity flow data Stated preference surveys Network data with cost functions

Source: Tavasszy and de Jong (2014)

Appendix D Shipment characteristics

Commodity (NST 2007)	Road	Rail	Air	Waterborne
Weight (kg)				
01: Agriculture, forestry, fish, etc.	11,900-37,900	*	*	23,300-50,400
02: Coal, crude petroleum, nat. gas	*	*	*	*
03: Metal ores, mining/quarrying etc.	5,100-23,000	*	*	21,600-4,131,400
04: Food, beverages, tobacco	50-1,000	300-1,800	*	1,000-20,100
05: Textiles, leather	1-3	*	1-2	1-3
06: Wood, pulp, paper, media, etc.	4-1,800	20,000-60,000	5-70	100-25,000
07: Coke, refined petroleum	2,500-51,500	19,200-20,100	*	37,000-10,000,000
08: Chemicals, rubber, plastic, etc	1-40	10-100	1-100	700-20,000
09: Glass, cement, construction mat.	30-11,600	1,600-27,000	1-60	200-22,500
10: Basic/fabricated metal(s)	10-700	4,800-12,400	1-120	50-5,800
11: Machinery, equipment, etc.	1-10	3-2,900	1-20	20-1,300
12: Transport equipment	20-1,500	1,300-1,500	20-1,600	900-1,600
13: Furniture, manufactured goods	1-20	2-30	5-180	1-2
14: Wastes, secondary raw materials	23,900-31,000	*	*	*
Value (€)				
01: Agriculture, forestry, fish, etc.	400-1,300	*	*	1,000-9,900
02: Coal, crude petroleum, nat. gas	*	*	*	*
03: Metal ores, mining/quarrying etc.	170-200	*	*	5,300-180,000
04: Food, beverages, tobacco	140-2,000	170-1,000	*	2,800-32,300
05: Textiles, leather	30-110	*	50-100	40-130
06: Wood, pulp, paper, media, etc.	20-2,200	9,300-30,100	80-800	400-12,700
07: Coke, refined petroleum	1,500-53,400	2,000-2,100	*	3,000-3,400,000
08: Chemicals, rubber, plastic, etc.	80-1,700	100-700	400-11,100	1,900-22,900
09: Glass, cement, construction mat.	150-3,000	2,000-16,600	200-3,500	600-12,100
10: Basic/fabricated metal(s)	80-2,000	3,000-9,100	200-5,500	600-16,800
11: Machinery, equipment, etc.	60-500	400-40,000	100-2,500	500-13,300
12: Transport equipment	130-11,900	9,100-14,500	700-8,500	6,900-15,500
13: Furniture, manufactured goods	20-150	90-400	600-4,500	4-30
14: Wastes, secondary raw materials	1,700-5,400	*	*	*
Value density (€/kg)				
01: Agriculture, forestry, fish, etc.	0.03-0.3	*	*	0.3-2.9
02: Coal, crude petroleum, nat. gas	*	*	*	*
03: Metal ores, mining/quarrying etc.	0.01-0.2	*	*	0.05-0.6
04: Food, beverages, tobacco	0.8-4.2	0.3-0.9	*	1.3-4.8
05: Textiles, leather	22-99	*	50-160	27-100
06: Wood, pulp, paper, media, etc.	0.8-13.6	0.4-0.7	4.7-37	0.4-1.8
07: Coke, refined petroleum	0.4-0.5	0.10-0.11	*	0.4-1.4
08: Chemicals, rubber, plastics, etc.	6.4-250	4-21	40-610	1.1-5.9
09: Glass, cement, construction mat.	0.3-7	0.5-1.5	60-330	0.5-5.2
10: Basic/fabricated metal(s)	2-14.4	0.5-0.9	15-200	2-17
11: Machinery, equipment, etc.	22-200	15-116	30-370	6-47
12: Transport equipment	7-17	7.2-8.9	3.6-42	7.0-9.6
13: Furniture, manufactured goods	4.4-29	12-43	17-244	3-30
14: Wastes, secondary raw materials	0.1-0.2	*	*	*

Note: the figures show the range between the 25th and 75th percentile of each cell. Value is defined excluding VAT and transport cost, weight is defined net of packaging. SEK converted to EUR through rate 1 SEK = 0,1 EUR. A transport mode is considered as being selected if it is part of a transport chain or the only mode used for the transport. * too few observations. Source: CFS 2009.

Ref: CEDR Contractor Report 2017-07 (November 2017)

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