4
Freight transport: indicators, determinants and drivers of change

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4.1 INTRODUCTION

Freight transport flows are a result of the interplay between economic activities such as production and consumption on the one side, and the supply of logistics and transport services on the other. This chapter discusses how freight transport flows result from this interplay. We examine freight transport from three angles:

1. **Indicators** for the description of freight transport flows: measures related to the weight of the goods moved and to the resulting transport and traffic performance as well as the impact on the environment from these activities.
2. **Determinants** of freight transport: the primary decisions of the actors within the logistics system that create the need for freight movements.
3. **Drivers of change** in freight transport, i.e. external forces that influence demand: economic growth, globalization, technology, consumer preferences and pressures to keep the system sustainable.

The chapter is organized as follows (see Figure 4.1). The indicators for freight transport and their interrelations are treated in Section 4.2, while Section 4.3 describes the determinants of freight transport. Section 4.4 takes an exploratory perspective, discussing future trends or trend breaks and their influence on freight transport, including the (un)sustainability of freight transport. We summarize and conclude the chapter in Section 4.5.

We use mostly data material from Europe to illustrate the characteristics of the freight transport system, also pointing out differences between Europe and other continents in the world, where the available data allows to.

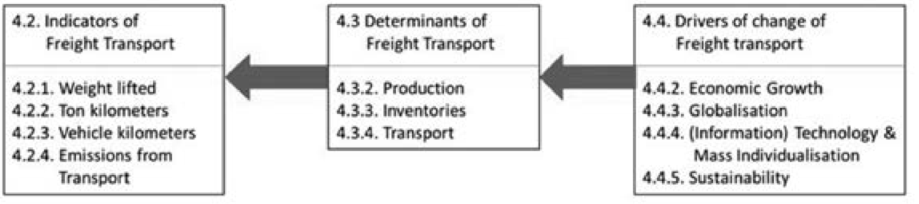


Figure 4.1 Structure of this chapter, arrows indicating how change occurs in the freight system

4.2 INDICATORS OF FREIGHT TRANSPORT

There are various ways to describe the volumes and patterns of freight transport and the developments in the different modes of transport. We elaborate on four key indicators:

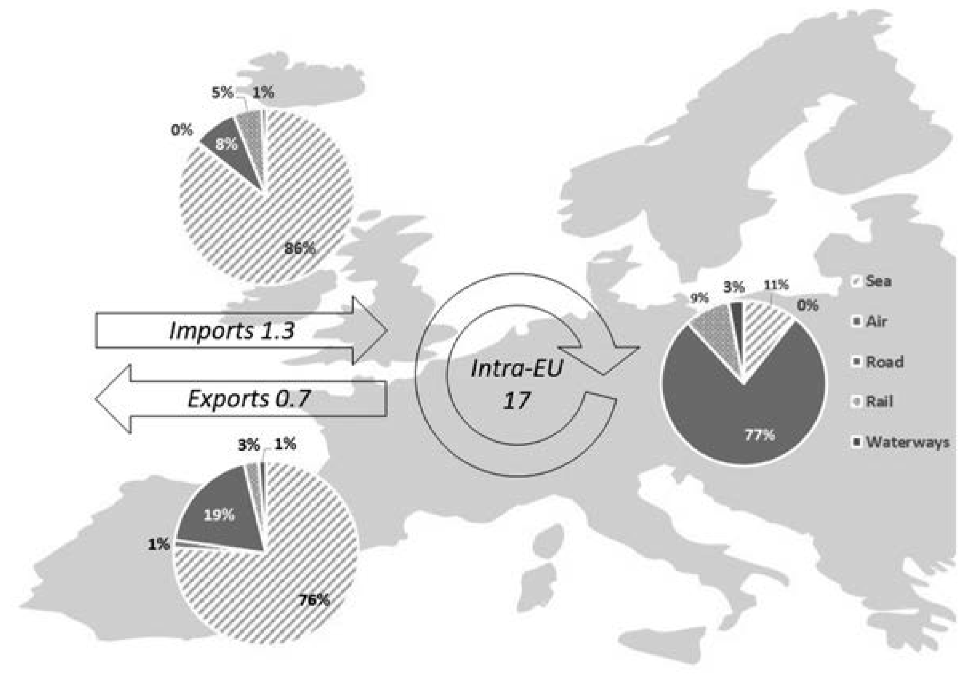
- Volume of transport, measured by the **weight lifted** of the goods. This is measured by the mass of the goods expressed in metric tonnes.
- **Transport performance**, which includes the distance the freight moved (ton kilometres). This integrative indicator is a measure of the need for movement and is used most often to characterize freight transport.
- **Traffic performance**, measured in distance moved by the transport means in question (e.g. vehicle kilometres).
- The **environmental emissions** of harmful gases and particulates that this creates.

We also discuss the interrelationships between the four and conclude the section with a discussion of the economic importance of freight transport.

4.2.1 Weight Lifted

Volumes of freight transport are generally expressed in transport statistics by means of the weight of the shipments moved. Note that this requires a translation from statistics of international trade, which are part of the standard registration system of the economic households of countries and noted in monetary terms (for example, US dollars). Figure 4.2 shows the main volumes of trade within and to or from the European Union in 2020, including their modal split, measured by the weight of the shipments moved (tonnes).

The balance of transport modes used depends strongly on whether one looks at intra- or intercontinental flows. Within the EU, road transport dominates, and alternative modes such as rail and inland waterways carry far less freight, with volumes sometimes around a tenth in size of those of road freight. Due to the relatively short transport distances and the fragmented national systems for rail transport, this mode has a considerably lower share than in other regions of the world, where the rail shares lie in the range between 10% for the USA (FHWA,

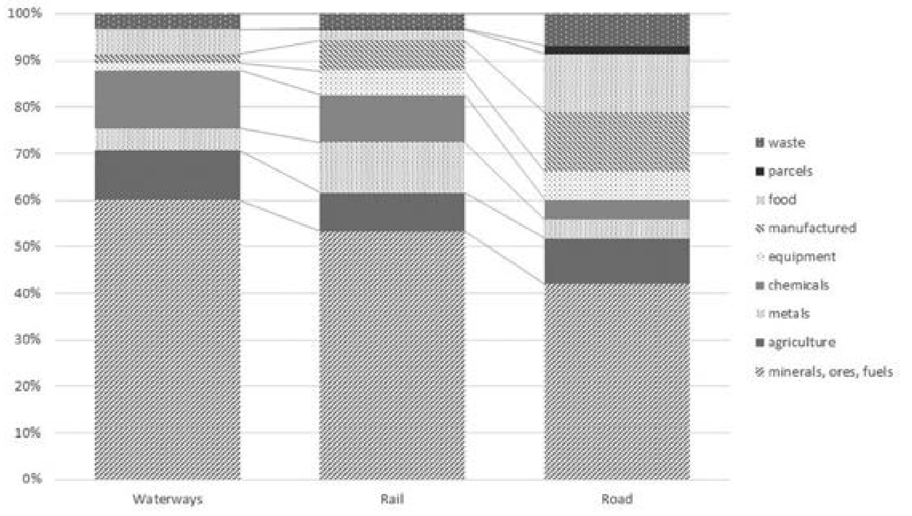


Note: Flows totals in arrows in billion tonnes
Source: Eurostat (2022).

Figure 4.2 Freight transport flows by mode within and to/from Europe (2020)

2010) and 40% in Russia (Rosstat, 2010). Sea transport dominates intercontinental flows, but it also has an important role for intra-European international traffic: deep sea and short sea together carry as many tonnes of freight between countries as the railways. This important role for sea for continental transport is also found in Asia, but much less so in other continents. Geographical differences such as availability of infrastructure and their consequences for cost per mode of transport explain these variations.

A second important characteristic of freight transport demand is its heterogeneity. There are many types of commodities associated with various sectors, with each sector organizing its movements differently. This heterogeneity is nicely illustrated by the use of modes of transport by the different commodity groups. Figure 4.3 shows the distribution of goods types across the different inland modes of transport; this tends to change little over time. We see that almost half of the weight of road transport is occupied by building materials. This is due to the short distances that these materials move; here, road transport offers the most flexibility in building projects. As we will see later, this does not translate into a high transport performance (in ton kilometres) because of the short distances. The weight share of the other two modes is dominated by bulk products such as solid and liquid fuels, ores and building materials (e.g. sand).



Source: Eurostat (2022).

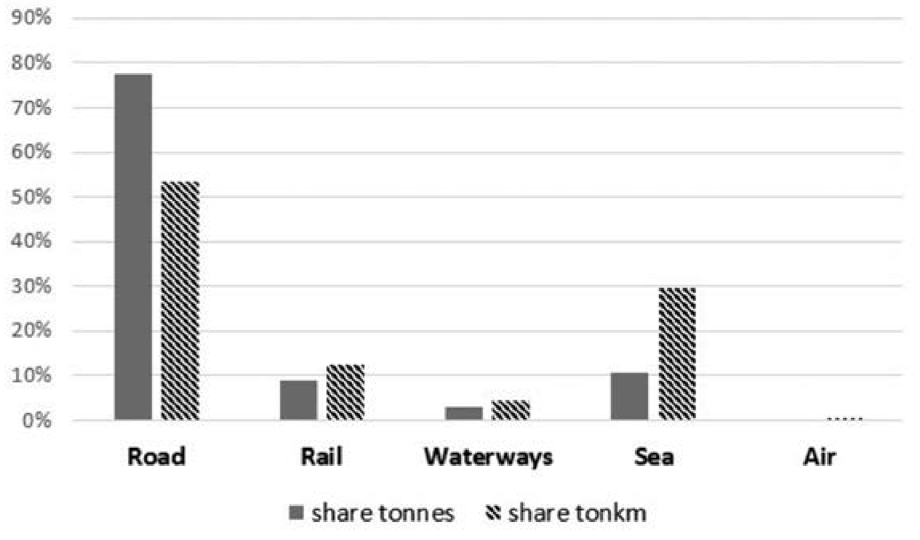
Figure 4.3 Share of commodities for three modes of transport in the EU (2020)

4.2.2 Transport Performance

When measuring freight transport in terms of weight lifted (tonnes) we need to interpret statistics with care, as tonnes lifted is not necessarily the same as tonnes produced or consumed. As individual transport movements are often part of a larger transport chain, the same unit of freight may appear more than once in the statistics, if the chain has several transport modes. Every time goods are unloaded and loaded onto a next mode of transport, they will be counted again as registration occurs on a transport mode basis. One tonne of goods produced may thus appear as two tonnes or more in transport statistics. This implies that the number of tonnes will depend on the structure of the transport chain and the transport technology used (intermodal or door-to-door unimodal transport). When we measure freight demand in tonne kilometres, this risk is absent, as tonnes will only be counted for the distance moved.

Another drawback of tonnes lifted as a measure of freight demand is that it does not reveal much about the economic importance or societal impacts of transport. Concerning the economic impacts, the value density of goods (this is the value per m^2) may vary with several orders of magnitude, from 10 USD/tonne for raw minerals such as sand and gravel, to over 10,000 USD/tonne for manufactured products. Secondly, indicators such as costs, energy use and emissions of transport are all distance related. Hence, an indicator that includes distance will be a more accurate basis for examining the social costs and benefits of transport, its energy use and the environmental effects. We measure transport performance in tonne kilometres, the weight moved multiplied by the distance that it is moved.

It is useful to address the differences between the tonnes lifted and transport performance, especially when we speak of the modal split in freight transport. Figure 4.4 shows the differences in the share of modes measured in tonnes lifted and ton kilometres. Road transport is carried out more frequently on shorter distances than rail or inland navigation, therefore transport performance of these modes is comparatively higher than for road transport.



Source: Eurostat (2022).

Figure 4.4 Freight modal split in the EU27: measured by tonnes lifted and tonne kilometres, tonnes based modal split estimated based on time series (2006–19)

Although this measure for transport performance is easier to interpret from a policy perspective than the weight measure, we note also that the concept of tonne kilometres is not homogeneous and should be treated with care, as the shipment sizes vary widely between and within modes. Taking one ton of freight over 1000 kilometres will involve a different usage of resources than 1000 tonnes over 1 kilometre, because of economies of scale and density, or the technology available for that size of shipment and distance. Taking into account the number of vehicles needed to move freight eliminates part of the problem.

4.2.3 Traffic Performance

Once we can convert tonnes moved into the number of vehicles, and we can express freight demand in terms of traffic, this provides us with additional information for transport network design and the measurement of transport costs, energy use, etc. Many policy measures are related to the individual vehicles and, directly or indirectly, to the exact network distances driven (e.g. taxes, tolls, permits). Knowledge of vehicle kilometres driven makes assessment of these measures easier. Conversion from tonnes to vehicles is not straightforward, however. Average load factors vary by country and typically lie between 40% and 60%, when measured in weight. Empty running typically varies between 20% and 40%. Note that a load factor of 50% may seem low, until we consider that a full truck leaving for a return trip and arriving empty will be half full on average. The only option is to pick up freight on the way and to organize a round trip, which is not always possible. As these measures relate to the truck capacity in weight and not vehicle size, the real efficiency of the system is probably higher. This is the case, for example, if the maximum amount of goods that can be transported is not restricted by weight limitations but by volume, e.g. the transport of empty plastic bottles.

A distinction between types of vehicles used is also useful. Freight transport is carried out by many types of vehicles, from vans up to trucks and (sometimes double or even triple) trailers. Also for sea transport and inland navigation, a huge variation in transport means exists, each with its own characteristics.

4.2.4 Emissions from Freight Transport

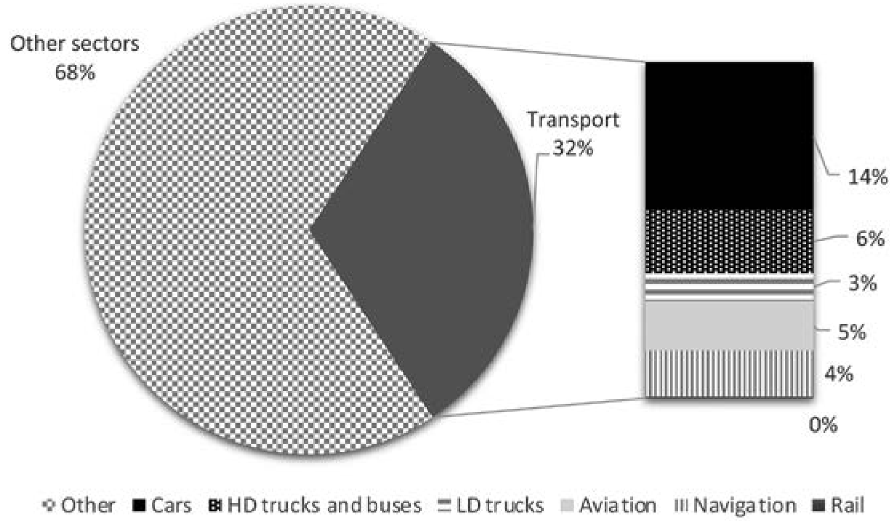
As one can see in Chapter 8 of this book, all the activities that are performed in the Transport sector create emissions, not only by the transport activities themselves but also by the production of vehicles and infrastructure. These emissions involve noise and toxic gases such as NO_x, Particulate Matter and SO_2, but the most attention nowadays goes to Greenhouse gases (GHG), because of their effect on climate change. The freight transport sector is responsible for a large share of emissions, dependent on the size of the vehicles it uses and the type of fuel it consumes.

As shown in Figure 4.5 below, light-duty vehicles (passenger cars and vans) are the greatest contributor to EU transport GHG emissions, followed by heavy-duty vehicles (trucks and buses), marine navigation and aviation.

Figure 4.5 highlights the direct transport emissions: emissions from fuel production refining, and distribution are included in the other sectors' total. Carbon dioxide (CO_2) accounts for roughly 99% of these direct transport carbon dioxide equivalent (CO_{2e}) emissions, based on a 100-year global warming potential. For a more detailed description of this issue, we refer to Chapters 8 and 10 of this book. Approaches to improve the sustainability of freight transport are also briefly discussed in section 4.4.5.

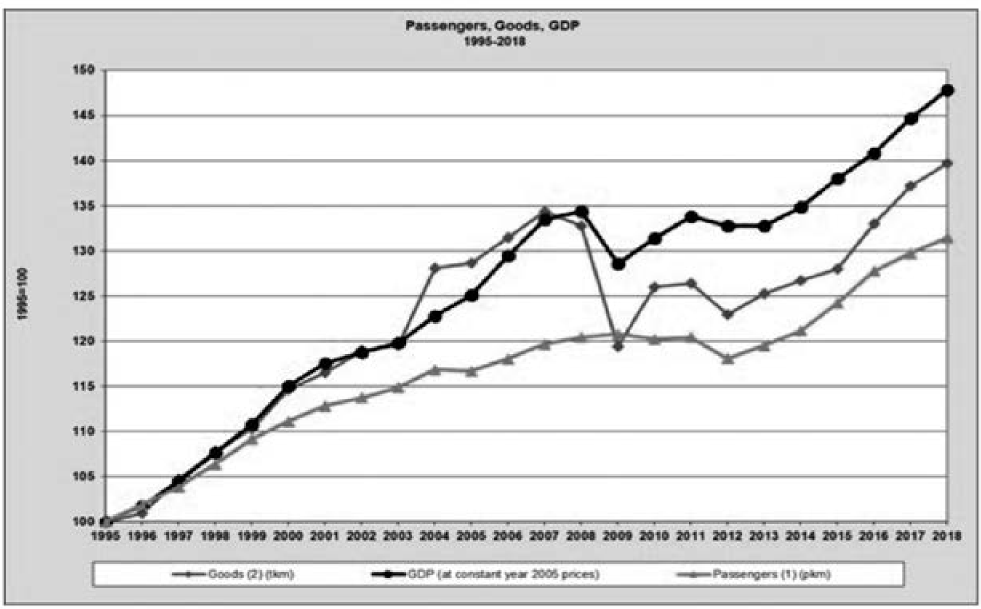
4.2.5 Evolution of Different Indicators Through Time

With certain regularity, global supply chains have seen major economic and social disruptions throughout the decades, like the economic crisis of 2008 and the recent COVID-19 pandemic. In the past, the resilience of the total economic system has been such that old patterns have re-emerged quickly, as illustrated by Figure 4.6 (and later in this Chapter, Figure 4.11, which shows the initial COVID effects). Overall, the evolution of these indicators has shown to be quite robust over decades. Nevertheless, every new disruption brings new uncertainty about the spatial scale of its impacts and the time needed for the global economy to rebound to (or close to) earlier patterns of growth.



Source: EEA (2021).

Figure 4.5 Shares of EU wide GHG emissions in 2018 by subsector (total 3.9 Gt CO_2e)



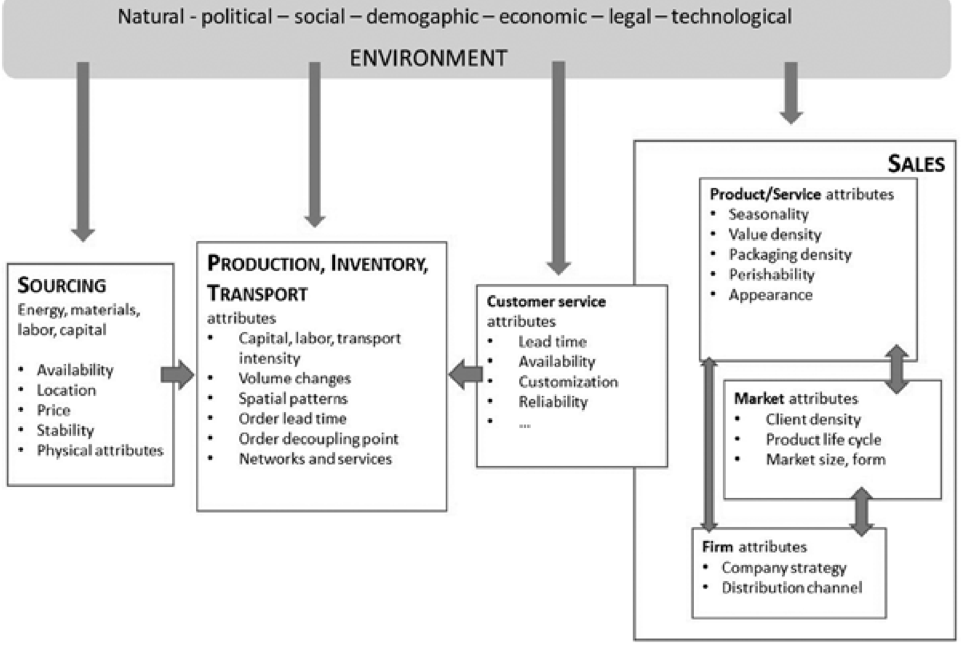
Source: EC (2020).

Figure 4.6 Comparison of trends in passenger and goods transport in comparison with GDP development

Demand for freight transport is generated through decisions made by shippers and transport companies that operate on the freight transport market as representatives of the demand side and of the supply side respectively. In the next section we focus on the decision and the decision makers from the demand side.

4.3 DETERMINANTS OF FREIGHT TRANSPORT

Transport is said to be a derived demand, as it depends on the demands for goods and services originating from manufacturing sectors, consumers and governments. In this section, we characterize the supply chain system that determines the demand for transport as one consisting of five elements: Sources, Production, Inventories, Transport and Sales (SPITS). Figure 4.7 illustrates these elements and their relations.



Source: Kuipers et al. (1995).

Figure 4.7 SPITS Model

The way the elements interact was described in the SPITS model in the Netherlands in the early 1990s (Kuipers et al., 1995). The elements of the system follow the supply chain from raw material (source) to the final demand by the customer (sales). The components P, I and T are central in this system and interact with each other to connect source and sales, by optimization of the supply chain, given the service requirements of the customers (Christopher, 2016). We summarize this objective into the following optimization function:

Min GLC | Service
GLC = T + I + H,

where GLC is the Generalized Logistics Cost (which is the sum of Transport (T), Inventory (I) and Handling (H)), to be minimized, given the service requirements (Service).

To the extent that service requirements do not act as a constraint to the design of logistics services, there is scope for further optimization. In most cases, however, there will be service requirements (e.g. pick-up and delivery times) that bound the solution space. The possibilities for minimizing the Generalized Logistics Costs rely on the opportunities to use economies of scale and scope as well as smart trade-offs between the three cost components of GLC. Supply chain management aims at exploiting these optimization possibilities. In many logistics processes, scale economies are essential to achieve a lower cost per item. Scale economies can be achieved by e.g.:

1. bundling of individual products into larger shipments;
2. using larger-scale modes of transport;
3. combining inventories upstream into central warehouses.

In this section, we describe in further detail these three main determinants of the logistic system: P(roduction), I(nventories) and T(ransport). We do this by highlighting the main trends of the last few decades in the development of these activities and the strategic decision factors that have governed the changes in their spatial and functional design.

4.3.1 Production

The number of production steps in a supply chain is increasing as companies continue to focus on their core business, trying to improve their competitive power by specializing and gaining scale advantages. This vertical disintegration of the supply chain applies to services as well as production steps and is also a response to a customer base that is increasing geographically. During the twentieth century, the world economy has emerged from a period with a high degree of economic protection and isolation into the present state that is characterized mainly by free trade and a high degree of specialization. One of the main drivers behind this growth of trade has been the differences in cost of producing the same type of product in different places around the world, which are due to differences in factor costs (especially labour costs but sometimes also cost of capital) and the availability of natural resources. As a result of reduced trade barriers, production moved from the West towards Eastern Europe, Eurasia and the Far East. Together with the cost of overcoming the distance, one can determine whether it is more attractive to import the products from elsewhere and to carry the burden of transporting goods over large distances or to avoid the costs involved in transporting these goods and producing them locally. Despite the general improvement of wage levels in Asia and Africa, there is no clear sign yet of massive re-shoring of business closer to consumer areas in Europe, the US or China (Delis et al., 2017). Possibly this may change after the strong perturbation of global supply chains during the COVID-19 pandemic era, or while trade barriers are increasing again due to a shifting global power balance from West to East.

Both the organization of production and transport economies of scale play an important role in the choice of production and physical distribution. An often-cited case is the production of automobiles. In general, the assembly of automobiles takes place not too far from the final customer but some of the parts are produced by factories that distribute their products to customers spread worldwide. The location of production plants is normally a long-term investment decision, and thus the geographic spread of production patterns used to be rather stable over time. Nowadays, the location of factories is re-evaluated more frequently and those that are not ideally located or have a lack of governmental support are under the threat of being closed down. Assembly plants, however, are more footloose and their location can change, influenced by regulatory measures (subsidies, regulation on the share of local content), the relative importance of transport costs in the cost of final products, congestion and other capacity restrictions (Dicken, 2003).

4.3.2 Inventories

Stocks or inventories of goods are inevitable where the processes of demand and supply do not handle the same amount of goods per unit of time, or if the batch sizes of these processes differ. Also, they have the benefit that they help to hedge against possible stock-outs if the demand or supply of products is uncertain. Inventories can build up in warehouses at the site of producers, at consumer households or at intermediate storage points in distribution centres. These centres can help to consolidate stocks at strategic and central locations, reducing the amount of inventory needed and allowing the storage of goods closer to consumers, thereby also reducing the distance for expensive movements and saving transport costs. Distribution centres are also used to sort goods from different manufacturers towards general retail outlets, a process called cross-docking. The spatial configuration of inventories, depots, cross-docking places for the distribution of goods is also called a distribution structure. Distribution structure designs are highly product and service specific (Fisher, 1997) and depend on many contextual factors (Onstein, 2021).

The advent of supply chain management, made possible by the mass introduction of personal computing and data processing facilities, was marked by a professionalization of firms' service quality improvement and cost control practices. Over the past decades, companies have become increasingly aware of the possibilities to optimize their inventories (Vermunt and Binnekade, 2000). Nowadays, supply chain management goes far beyond just-in-time deliveries. Supply chain management techniques developed in the last decade go under various names which we will not treat in detail here, such as quick response, lead-time management, lean logistics, agile logistics, efficient consumer response and process and pipeline mapping (see e.g. Christopher, 2016). These techniques have helped firms to drastically reduce their inventories while increasing service levels. Low volume but high-value segments have greatly expanded, benefiting from these new techniques and the opening up of new markets for customized and highly responsive services.

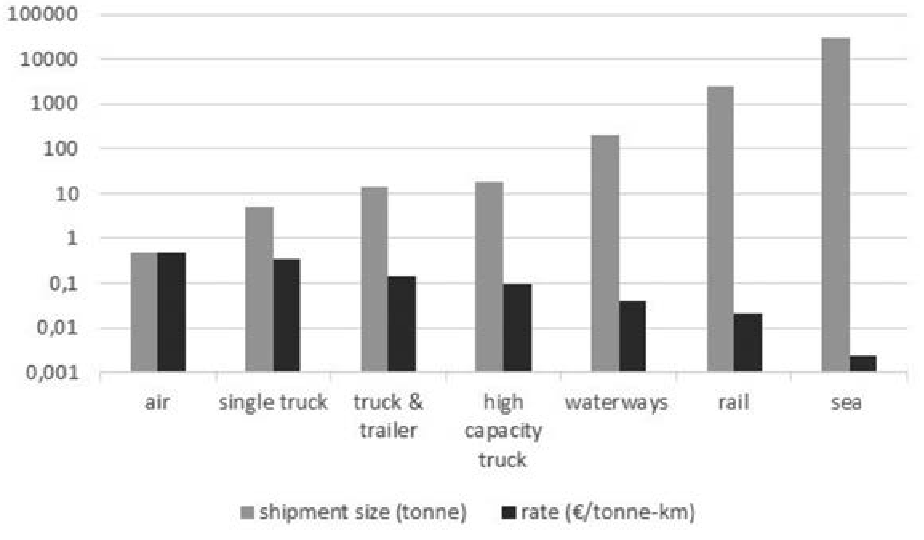
Distribution structures have been evolving throughout decades in waves (Tavasszy et al., 2012). The first wave of change took place in the '90s and involved the reduction of shipment sizes, an increase in frequencies and just-in-time transport as a first sign of mass individualization. This caused a fragmentation of goods flows into smaller streams. Driven by the need to keep costs under control, this was followed by a second wave of development (which reached a summit around 2000), which involved the internal rationalization of logistics processes within the company's own supply chain. In a recent third wave of change (2010's and onwards), firms are looking for economies of scale by means of external collaboration, across the company boundaries and their own supply chains. This so-called horizontal cooperation (as opposed to vertical cooperation, between vendor and supplier firms within the same supply chain) is seen as one of the major innovations which has transformed the logistics business landscape. We refer to Mason et al., 2007 for an early signalling of the phenomenon and Montreuil, 2011 for its framing in the Physical Internet system which is still a leading vision today for logistics professionals (ALICE, 2020). We return to this further in the chapter.

The increased transparency of the logistics process in supply chains and the technological means to plan and control logistics much better using advanced planning tools and IT systems have all increased. But it is also apparent that the practical application of these technologies is often hampered by a lack of cooperation and standardization. Real supply chain cooperation is then difficult to achieve because of transaction costs and countervailing powers between the supply chain partners. On the other hand, in order to achieve substantial cost efficiencies, this type of cooperation is essential to synchronize the activities in the supply chain and to take full benefit of potential scale economies.

4.3.3 Transport Logistics

Transport logistics concern the decision of the mode of transport to be used on a strategic level, i.e. which type of network to be built and given the available networks, at the tactical and operational level, the planning of movements and the routing of the freight, embodied by the design of the logistical organization and the planning of daily operations. We limit our discussion here to the strategic level decision of mode choice, i.e. the choice between different networks used by the modes of transport. As we have seen above, companies increasingly favour road, air and sea transport. Part of the explanation for this lies in external, socio-economic factors, like globalization and the individualization of society (see Section 4.4). In order to understand how such developments can translate into changes in mode usage we need to look into the mechanisms that govern these choices. Below, we discuss the influence of product and service characteristics on mode choice.

Jordans et al. (2006) found that 95% of the mode choices can be related to transport distances and basic product characteristics such as value density and packaging density. For many transport flows, transport distances and basic product characteristics are given and cannot be influenced. At the same time, mode choice is also governed by preferences of firms that are more difficult to observe and relate to the performance characteristics of transport modes such as transport time reliability, lead time and prices per shipment (see e.g. Vieira, 1992). We illustrate this relationship between supply chain characteristics and mode choice by means of the element of shipment size. The size of shipment, as one of the product characteristics, is an important decision variable in the minimization of GLC given required service levels. Figure 4.8 shows the average shipment sizes and related transport prices of some modes of transport. From this picture, it becomes clear that huge differences exist between the respective modes. Mode choice will be determined in part by the size of the shipment, as economies of scale in terms of shipment sizes can easily materialize by choosing a mode that allows lower unit costs. The figure clearly shows the pattern of costs across modes of transport.



Source: Dutch cost survey after Panteia (2021).

Figure 4.8 Differences in shipment size and transport charges for different modes of transport

Generalizing this further, one can specify continuous cost functions with different influences. Figure 4.9 shows two examples of such cost functions, for long distance shipments and two modes of transport, also called a-modal or mode-abstract cost function: (a) the joint effect of average transport times and shipment sizes on unit costs (here: per kg) and (b) the influence of uncertainty and value density on costs per unit. Higher value densities will lead to higher capital costs of inventory-in-transport, as we will illustrate further on in some more detail.

Figure 4.9 (a) shows an example of how two long-distance overseas modes (air and sea transport, as well as combinations of sea and air) can both be optimal solutions, depending on the circumstances. By specifying the weight of the shipment and the required speed, the mode choice and the generalized transport cost per kg can be derived easily, if all modes are available. 100,000 tonnes of crude oil will be transported by ship, a box of diamonds by air. There will be no discussion on the mode choice decision in these circumstances, at least in densely populated developed economies, where all the above-mentioned modes of transport are present, and the speed requirements of the shipments do not restrict the choice options. Figure 4.9(b)

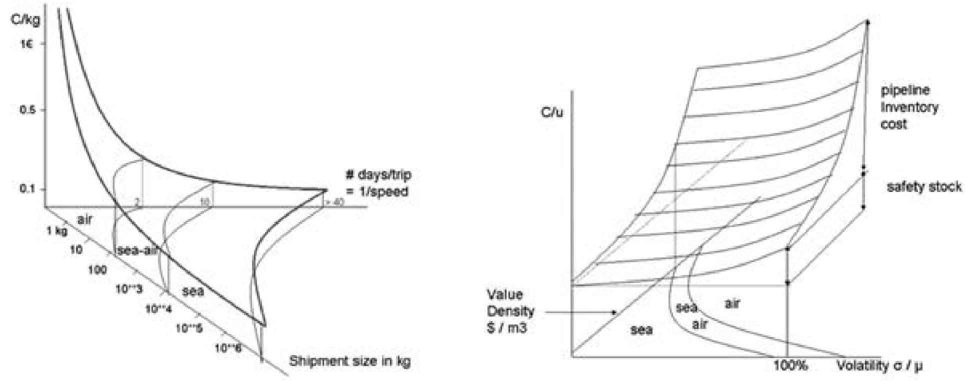


Figure 4.9 Unit generalized logistical costs as function of (a) speed and shipment size and (b) of value density and volatility

shows how lead time uncertainty (which is influenced both by demand uncertainty – here labelled 'volatility' – and the amount of safety stocks) affects transport costs, besides value density. When taking into account the value of the product and the volatility of demand (in the figure: demand variance σ divided by mean demand μ) we can also visualize the effect of inventory costs via increased safety stocks and the effect of pipeline inventory costs, adding to generalized transport costs/unit (C/u in the figure). When the value density is low, pipeline costs (the inventory costs during transport) will be negligible. When the value density becomes larger, the pipeline cost becomes significant. We provide an example of this trade-off below for the concrete case of laptop computers.

Example: laptops

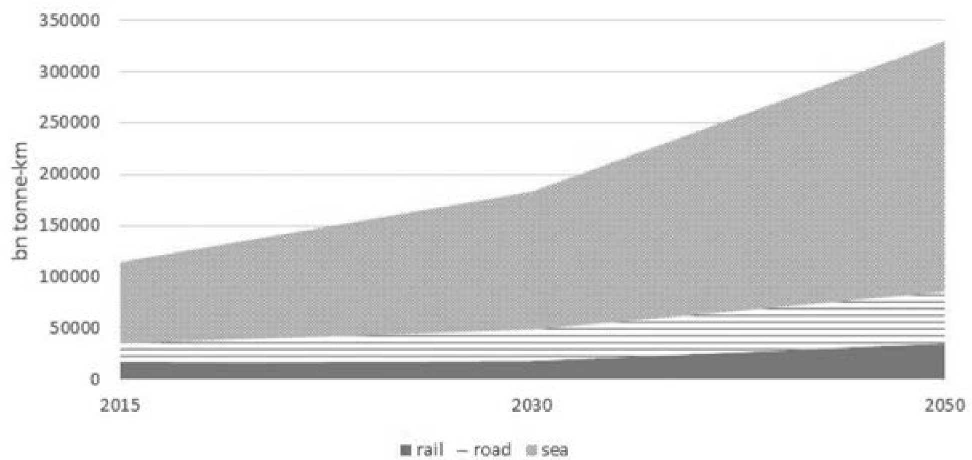
In the case of a shipment of one container with 1000 laptops (20 pallets of 50 laptops) with a production value of $500 per laptop, each container will have a pipeline inventory cost of $5000 (500*1000*0.1*36/365) if the trip takes 36 days and the yearly interest rate is 10%. The average shipping rate of this container from Asia to Europe is $1500, so the pipeline cost for this shipment will exceed the sea transport cost by more than a factor of 3. The generalized logistics costs of $6500 would be roughly the same when these products would have used the air mode. At 3kg per laptop at $2 per kg, the transport charge would be $6000, whereas, with an assumed total travel time of half a week, the pipeline costs would not be more than $500.

The example shows that, although transport costs differ substantially by mode of transport, generalized costs show less variation, taking into account other logistic cost factors. When the volatility is high, retailers and distributors do need safety stocks in order to avoid empty shelves if the demand for a product is higher than the stock and the demand during the reorder period. Safety stocks can be avoided for a great deal if fast and reliable transport options exist that can guarantee the delivery of products within the customer service requirements. So, trade-offs exist between inventory costs and transport costs and the generalized cost concept should take these trade-offs into account.

4.4 DRIVERS OF CHANGE IN FREIGHT TRANSPORT

4.4.1 Introduction

Over the longer term, the continued growth of global freight flows is expected, given, of course, that there will be no big economic crises or disruptions such as the COVID pandemic. Although this growth will be most conspicuous in the emerging Asian economies (especially China and India), flows are expected to continue to grow. Some sources predict more than a doubling of present flows between 2015 and 2050 (OECD-ITF, 2021).



Source: OECD-ITF (2021).

Figure 4.10 Projection for international freight per mode of transport

Apart from a large increase in welfare levels of developing countries due to economic growth and technological development, the expectation of further growth in freight transport was fuelled by continued globalization, via a decrease of barriers to international trade and transport. These projections were made before COVID-19 and it has become more difficult than before to indicate which scenarios are likely and which are not. However, there are clear reasons to expect that trade growth will be less excessive in the future than we have seen before:

1. equalization of income of developing countries with those in developed countries, leading to equalization of production costs and prices;
2. transport costs increasing due to supply chain congestion and internalization of external costs;
3. geopolitical instabilities, leading to the wish to become less dependent on the availability of products from elsewhere.

Towards the future, then, one needs to look at the megatrends and stable relations shaping these developments. In the next sections, we discuss three drivers of change in freight transport that have influenced production and consumption, trade, logistics and transport decisions: (1) economic growth, (2) globalization and (3) (information) technology in combination with mass individualization.

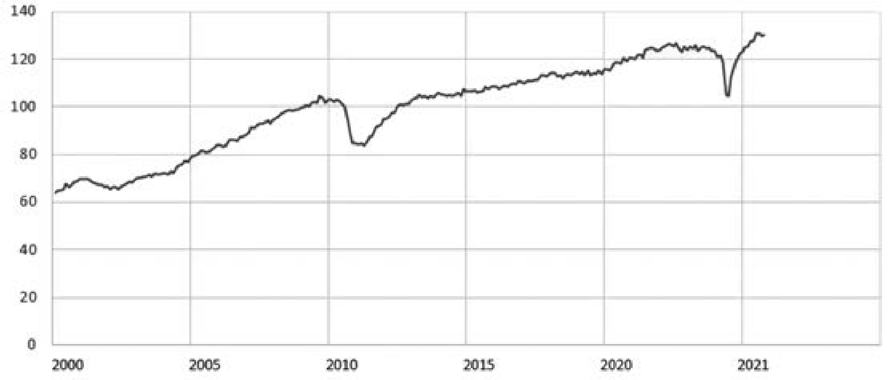
We discuss these main drivers in three separate subsections and conclude the Section in 4.4.5.

4.4.2 Economic Growth and Globalization

GDP appears to have a strong overall explanatory power for freight transport growth: earlier World Bank research suggests that it explains over 89% of the variation in observed freight volumes (Bennathan et al., 1992). In this study of about 17 countries, a fairly reliable indication of this relationship was that every million US dollar in GDP would add 170,000 road ton kilometres in transport performance. In other words, economic performance seems to be a strong driver of transport performance and we can expect economic growth to explain changes in freight transport flows as well. Roughly, freight transport has grown one-on-one with the economy. Some studies indicate, however, that growth of GDP and transport has been decoupling, with the possible implication that GDP would be a less important driver in the future than it is now. Industrialization and servitization of economies appears to create significant decoupling (see McKinnon, 2007; Tapio, 2005; Verny, 2005; Kveiborg and Fosgerau, 2007; Alises et al., 2014; Zhu et al., 2020). Within the US, decoupling between GDP and freight activity had already taken place (Gilbert and Nadeau, 2002). Indeed, it seems that domestic transport growth is decoupling from national GDP, due to dematerialization of flows and changes in logistics. At the same time, the economic integration between countries results in a growth of international trade, with growth above that suggested by GDP. These can balance each other out in open economies.

As mentioned, trade is an intermediate variable that has a significant effect on transport flows. The growth of world trade is directly linked to the demand for international freight transport, maritime transport and air freight. Complex global trading networks have evolved to exploit labour cost differences, regional production specialization, global product differentiation opportunities and availability of raw materials in particular countries. Their development has been facilitated by major regulatory changes. Trade liberalization, particularly within trading blocs such as the EU and North American Free Trade Agreement (NAFTA), has removed constraints on cross-border movement and has reduced the related barrier costs. Along with the reduction in transport costs, the relaxation of trade barriers since World War II has given a great stimulus to the development of global trade (Hesse and Rodrigue 2004, Rodrigue, 2006a and b). Up to recent times, one can look beyond the short-term volatility of world trade to see a stable, though not constant, growth trend (Figure 4.11).

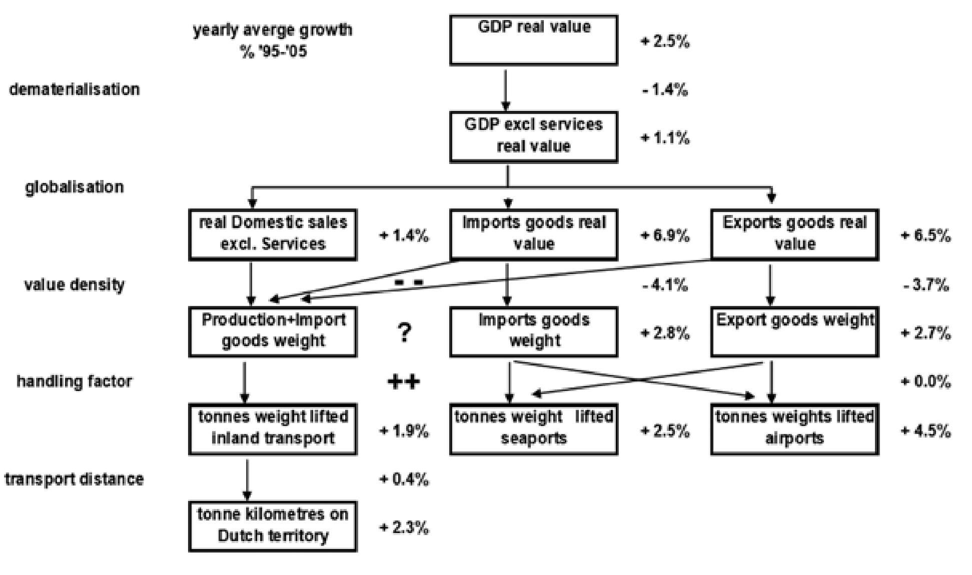
The net sum of the influences of GDP and trade growth on transportation depends on the relative share of domestic and international transport and the rates of growth in each segment. An illustrative example is the analysis of the relationship between GDP and transport for the Netherlands (KiM, 2006). Figure 4.12 nicely illustrates the counteracting forces typical for an



Source: CPB (2021).

Figure 4.11 World trade trend and volatility 2000–21 (index 2010=100)

international economy such as the Netherlands. The net increase in transport performance that occurred in these years can largely be explained by relatively strong growth in international flows on top of modest growth in the domestic economy. Although the numbers have changed since then, this pattern has remained largely the same for the Netherlands (KiM, 2019).



Source: KiM (2006).

Figure 4.12 Causal analysis of changes in yearly transport performance

In a more recent study by Knoope and Francke (2020) the development of freight transport in the Netherlands is explained by a time series analysis which assesses the relative importance of various explanatory variables mentioned in the literature, such as economic growth, globalization development of service industry, growth of population, dematerialization, transport costs and domestic consumption. They show that the development of domestic Dutch freight transport is largely explained by the development of the GDP of the Netherlands, the growth of the building sector, the service industry and the decline of the agricultural sector. The development of international freight transport to and from the Netherlands is largely explained by the growth of world trade.

A next dimension of change comes from the organization of supply chains, and in particular the increasing complexity of production and distribution processes, leading to more transportation steps and handling movements for products over longer distances. What is the implication of long-term changes in logistical structures upon transport flows at various spatial levels (local, regional, continental and global)?

4.4.3 Changes in Supply Chain Architectures

Since the middle of the previous century, there has been an increase in product variety, up to the level of single product or service units being individualized and unique. This is the result of the trend towards adjusting the supply of products to consumer preferences and using the principles of mass individualization, supported by the reduction of logistics costs and globalization. The developments in the field of information technology and the availability of internet connections have led to a worldwide visibility of supply chains that facilitated improved consumer services and the organization of efficient and effective supply chains. Here we distinguish between two types of change. Firstly, supply chains are being reorganized vertically to serve more diverse consumer needs, by increasing the degree of specialization of firms and the number of segments in the supply chain. Secondly, there is also a drive towards rationalization of logistics processes through horizontal collaboration between firms, by means of coordinated procurement, shared use of transport assets and bundled logistics operations. This helps to reduce the pressure on product costs caused by vertical disintegration. We discuss these two trends below.

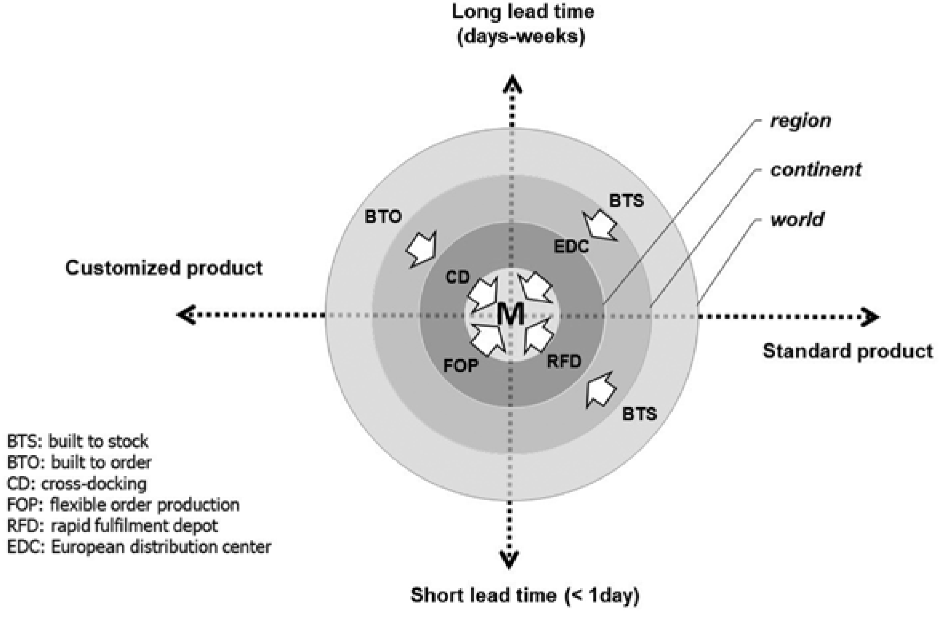
Vertical reorganization

The vertical organization of supply chains is visible in the number of steps that it takes to produce and distribute products to final markets. As a symptom of the mass-individualization of products and services, intermediate production steps have been added and logistics services have become more specialized. Overall, this has led to an increase in the demand for freight transport. Mass-individualization can be observed in two main dimensions: product customization and increased responsiveness of services (see Vermunt and Binnekade, 2000). These are supported by different chain configurations to satisfy product and service demand (see the seminal papers by Fisher, 1997 and Lee, 2001), including different production systems (building to order, flexible production, smaller batches, 3D printing), distribution structures (widespread inventories, just-in-time replenishment) and different locations of production and stocks, both centrally and close to consumer regions.

Figure 4.13 shows examples of different supply chain configurations that result from the change from standard to customized products and conventional to responsive services. The figure shows four segments:

1. Top right: standard products with a long order lead time (e.g. smartphones, chips)
2. Top left: customized products with long order lead time (e.g. cars, machines)
3. Bottom right: standard products with a short lead time (e.g. spare parts, medicines)
4. Bottom left: customized products with a short lead time (e.g. fresh pizzas, flowers)

The figure also shows the geographical dimensions from the global scale (outer ring) towards the local market (noted as **M** in the centre of the figure), indicating how far production and inventories are located from markets.



Source: adapted from Vermunt and Binnekade (2000).

Figure 4.13 Chain configurations in four demand segments

Typical changes in chain configuration concern the move from continental distribution centres, based on production to stock, towards production to order at a global scale, where delivery takes place directly or with an intermediate step of value-added logistics (e.g. packaging to prepare for the local market). Also, new concepts like *rapid fulfilment depots* (for low demand but urgent products like spare parts) and *flexible order production* (allowing fast switching in batch size and end-product specifications, close to the consumer market) are being introduced to allow for better responsiveness. The more individualized products are, the more these activities will be located closely to consumer markets. *Centralized international distribution*, introduced to reduce inventory and building on the decrease of trade barriers, is being supplemented by *regional distribution centres*. These systems will not operate exclusively, but simultaneously, to offer more choice in service levels. This development is also termed as *the omni-channel revolution* (see e.g. Galipoglu et al., 2018).

Horizontal rationalization

The move towards more customer-oriented logistics structures will inevitably increase logistics costs as shares of product costs. As also pictured in Figure 4.8, firms will only be able to control their logistics costs through a further rationalization of logistics processes. After some time, firms will have depleted the potential of improvements within the company and will try to make gains by cooperation with others. Horizontal collaboration, or consolidation and cooperation between firms at the same level of a chain, is a logical way to generate lower cost per unit of freight (Cruijssen, 2020). Through consolidation of flows, larger vehicles can be used so that the loading efficiency is optimized. Note that the high level of responsiveness that is required could possibly conflict with the above-mentioned need for smoother flows of goods. Avoiding this possible conflict is one of the biggest challenges in the design of logistic networks. The set-up of a hybrid supply chain, which allows different possibilities for flows to reach their destination, creates the flexibility required (Groothedde et al., 2005). This is supported by intermodal transport networks which combine slow and cheap modes with fast and flexible modes.

The volatile part of the demand is supplied by a fast (and more expensive) mode like road or air transport, while the stable part of demand is being delivered through the slow, large-scale modes via networks of consolidation hubs, which allows the exploitation of potential economies of scale. This intermodal logistics system has more recently been developed to allow flexible transport options in a network to be fully exploited, under the name of synchromodality (Tavasszy et al., 2018; Dong et al., 2018).

4.4.4 Innovations in Logistics Services: The Physical Internet

In the previous sections, we have elaborated on some important megatrends concerning trade and the design of supply chains. These create new and advanced demands for logistics service providers, of global reach and ultimate flexibility, at the lowest costs possible. There are many technological and organizational innovations in logistics services that can help to realize this new demand; these build on e.g.:

1. digitalization of information exchange;
2. automation of all processes, from transport and transhipment to decision making; and
3. new organizational approaches for the coordination of supply and service networks.

The Physical Internet (PI) is a strategic vision of logistics that binds these innovations together. Since the turn of the century, the logistics industry has been creating globally coordinated efforts to collaborate around this vision (Pan et al., 2011). The system is described in various publications (such as Mervis, 2014; Montreuil, 2017; and Pan, 2017). The vision includes a roadmap for the development of logistics innovations, which attempts to position several innovations in one consistent framework (ALICE, 2020):

1. A new standardized hierarchy of container sizes and shapes
2. Protocols for vertical and horizontal collaboration of multi-modal carriers
3. Routing algorithms and service protocols to connect shippers and carriers
4. Global network designs that allow system-optimal allocation of capacity
5. Information systems that allow nodes to help decide the routing of shipments
6. Specialized equipment to allow managing shipments below container level.

Besides aiming to create one coherent vision for innovations in freight transportation and logistics, the PI vision is also important as it addresses the soft side of innovation in terms of (1) human and business management factors influencing adoption and (2) the public/private governance aspects, including regulatory issues and corporate social responsibility. The ALICE roadmap shows that major steps are needed before the comprehensive PI vision becomes reality.

The expected added societal value of these logistics innovations is high. It is said to amount to 3.5 trillion USD (WEF, 2016), due to new business value created (1.3 tn. USD), a reduction of logistics costs (2 tn. USD) and increased sustainability (0.2 tn. USD). This is more than one-third of the 2020 business value of the global logistics industry.

4.4.5 Environmental Effects of Freight Transport, Decarbonization and Sustainability

In this section, we focus on the effects on nature via the emissions that freight transport activities create, CO_2 emissions in particular because of their importance for climate policies trying to reduce GHG emissions. Of course, the environmental problems are larger and also relate to other external effects such as health, safety and noise nuisance, but presently the dangers of all the potential negative effects of climate change gets the most attention because of its potential impact on extreme weather conditions, and the health impacts of direct and indirect effects, (IPCC, 2021). For further treatment of the environmental aspects of transport, we refer to Chapter 10 of this book.

McKinnon (2018) developed a useful framework for decarbonization in freight transport. The framework connects key indicators of the road freight transport system to opportunities for change in logistics organization, transport operations and technology. A comparable framework, adapted for a multimodal context, has been used by the ALICE alliance to formulate a roadmap for zero-emissions logistics in 2050, which includes in a list of potential GHG-reducing policies, including:

- managing freight demand volumes through e.g. restructuring of supply chains;
- shifting freight to low-emission modes;
- increasing freight asset utilization by e.g. consolidation of freight shipments and inventory;
- reducing energy use in transport by fuel-efficient driving and increased engine efficiency;
- change of drivetrains to more carbon-efficient sources of energy.

This provides a structure for a roadmap with policy options, each of which has to be justified by a careful calculation of return-on-investment not only to reduce GHG, but also to achieve efficiency and effectiveness. A qualitative assessment of the expected impact and feasibility of these options is given in ALICE (2019). Of course, the success of these policies relies on the willingness of companies, forwarders as well as transport companies, to invest in (planning) systems and technology and they will do that, in general, only if they are convinced of the benefits they create. The EU has set itself a long-term goal of limiting global warming to 1.5–2 degrees Celsius. The 2.0-degree target translates into reducing GHG emissions by 80–95% in 2050 compared with 1990 levels. To achieve this goal, emissions from transport must be reduced to over 60% below 1990 levels by 2050, all assuming a linear decline in emissions over time (CE Delft et al., 2020). Continuous economic growth is expected to increase the CO_2 reduction gap.

In 2021 the EU set an intermediate target of 55% emission reduction for transport between 1990 and 2030 in the 'Fit for 55' policy proposal (EC, 2021). To achieve this strong increase in carbon productivity requires an integrated approach that makes full use of the opportunities available to cost effectively increase energy efficiency, decarbonizing energy sources, and accelerating the development and deployment of new low-carbon technologies. For further reading on this subject we refer to Chapter 8 of this book. Furthermore, it should grasp opportunities for optimizing supply chains and logistics operations and changing business and consumer behaviour. CO_2 abatement options are needed at all system levels, i.e. energy carriers, powertrains, vehicles, fleets, logistics operations, behaviours and so on, and in all transport areas and for all transport modes (CE Delft et al., 2020).

As we have seen in subsection 4.4.2 the economy has quickly jumped back to old-growth levels after the COVID-19 pandemic. However, this crisis now also shows the risks of globalization and 'dragging around' people and goods. Combined with a shift in economic and political power, growth scenarios for production and trade may have to be redrawn completely. For instance, a return of production from the Far East to Europe is one of the potential developments that can apply to various segments. If so, supply chains will be redesigned accordingly. The main challenge for the logistics sector will remain the decarbonization task as required by the Paris Climate Agreement. As both size and character of international flows are uncertain, it is also hard to predict whether the freight transport sector will be capable of meeting the challenge of achieving zero-emission by 2050. Whereas the freight volume of perishables, non-perishables and industrial goods are expected to grow much faster than that of bulk and especially liquid bulk, the CO_2 reduction per volume needs to decline much more in these segments. The non-bulk segment relies more on the more carbon-intensive road transport, but at the time of writing this chapter (2022) the decarbonization strategies for road seem closer to implementation than those for inland waterway transport. The logistics chains will probably change due to the above-mentioned developments, but the need for transport, distribution and value-added services will remain – as will the negative impacts of road transport in terms of congestion, noise, safety and land use. The development of highly responsive logistics has led to the increased speed of delivery of individual consignments, which also asks for well-coordinated delivery networks, including automation of sorting and transhipment. It has also resulted in a big increase in activities from delivery vans and bicycle delivery services involved in City Logistics. Some of these services have increased the environmental burden of transport-related services; questions on the sustainable nature of these services could be raised.

These trends in logistics make the reduction target an ambitious one. The number of trucks and vans active in European freight transport has increased considerably over the last decades. Presently (2021) there are more than two million vans in Europe, and because of the COVID pandemic and the increased number of home deliveries, this number is expected to grow further. The number of trucks in Europe has stabilized at around 400,000, after a decline because of the economic crisis of 2008–10. It is not the volumes they transport that are declining, nor is it the decline of the fleet itself, it is the use of cleaner engines that has to achieve the target for GHG reductions (ICCT, 2020).

Efficiency improvements within the road transport sector can also lead towards a reverse modal shift, for instance when Super EcoCombis are competing with rail and barge transport. The reduction of transport emissions of bulk segments will rely particularly on zero-emission energy carriers, such as electricity and hydrogen, whereas the non-bulk segments will also be able to introduce more energy-efficient logistics concepts, mainly due to network optimization (see also Chapter 8 of this book). The supply chains of these segments are generally more complex, with larger numbers of links, logistics activities and actors. The contribution of sustainable, energy-efficient transhipment and storage is low in all segments except for perishables. The expected contribution of vehicle and vessel technologies, autonomous driving and Intelligent Transportation Systems (ITS) is applicable for all segments, while the impact of logistics measures, including modal shift, is far more important for the non-bulk segments. Consumer and investor pressure will push leading companies in markets close to consumers (B2C) towards the implementation of zero-emission technologies and more efficient logistics. Together with governments, these companies will act as front-runners and lead the followers in the market. This requires new and optimized business models using vertical integration, better utilization of equipment and investing in advanced-low/zero-emission technologies.

In the Netherlands, the logistics sector has stated that reaching a six-fold improvement in carbon productivity and, thus, the Paris goals seem possible *without* impacting the competitiveness of the logistics sector and the prices of products shipped (CE Delft et al., 2018, 2020). The transition will, however, require changes to the current structure of how logistics is organized, affecting individual interests and parties. The speed of the transition and its impact on CO_2 emissions will depend partly on how governments will implement policies such as standards and financial incentives to create the required level playing field for zero-emission technologies, while helping to accelerate large-scale implementation. Concluding, one can say that the freight transport sector has to explore all the options mentioned before, in order to be able to reach its CO_2 reduction targets.

4.5 SUMMARY AND CONCLUSIONS

In this chapter we have described a number of different dimensions of freight transport. We have discussed three basic indicators of freight transport activity: the total weight lifted (tonnes), transport performance (tonne kilometres) and traffic performance (vehicle kilometres). The relationships between these three depends on the structure of the supply chains, in terms of production, trade relations, inventories and transport modes used. These indicators should be used with caution, as an inappropriate choice of indicator can unnecessarily inflate or hide policy-relevant numbers.

We have looked at the most relevant causes for changes through time. In brief, transport is growing by all measures, and is increasing in efficiency. Freight transport growth is uneven across modes, however, with the environment-unfriendly modes taking the major share of increase in demand. Explaining these changes and their interrelations is not straightforward as demand for freight transport depends on many factors and many different users with dispersed needs. User needs depend on the type of products that are being transported and the logistics context of these products. An important constant is the fact that growth is still dominantly determined by GDP growth. This appears to be only weakly disturbed by dematerialization of economies and – over longer time periods – largely robust against world crises.

We have introduced generalized logistics costs as an important determinant in the process of logistics optimization, given demand requirements. We have seen that through combinations of smart planning and network design it is possible to minimize logistics cost and maximize customer service at the same time. The process of logistics cost minimization has run in parallel with deregulation, liberalization of trade and improvements in transport and information technologies. Lately, mass individualization has led to a strong fragmentation of supply chains. This places higher demand on the responsiveness of transport systems and increases its costs, internally and externally. An important solution lies in restructuring of flows to become consolidated wherever possible. For this, a coordinated effort within the logistics sector, across firms and between competitors, may be needed. Recent roadmaps for the decarbonization of logistics and the Physical Internet are instrumental to this effort.

The outlook for the transport sector is one of continued growth and difficulty to reduce its negative sustainability impacts. World trade is expected to continue to grow for decades ahead, even after occasional global economic recessions and pandemics. As a result, the growth of transport will also continue, spurring new demand for transport services and infrastructure. These developments will clash with the increased urgency to adapt to climate change and to internalize the external costs of transport.

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