A Contextual outline

A first overview on the German freight transport context will help to globally size the field of study. It is encompassed through different perspectives to measure the central element – the transport volume – as well as to identify suitable system boundaries and relevant actors.

2. Freight transport in Germany by volume

The total annual freight transport volume for Germany in 2012 and its modal split is evaluated by the *Federal Bureau of Statistics* in Germany, as e.g. depicted in Fig. A-1. The dominant road freight quantity, however, is only based on an estimation of the international road freight transport volume in Germany – a hindrance for more focused interpretations, as will be discussed in the following[11]. Nevertheless, it allows for the constitution of an overview on the overall land-based freight transport volume.

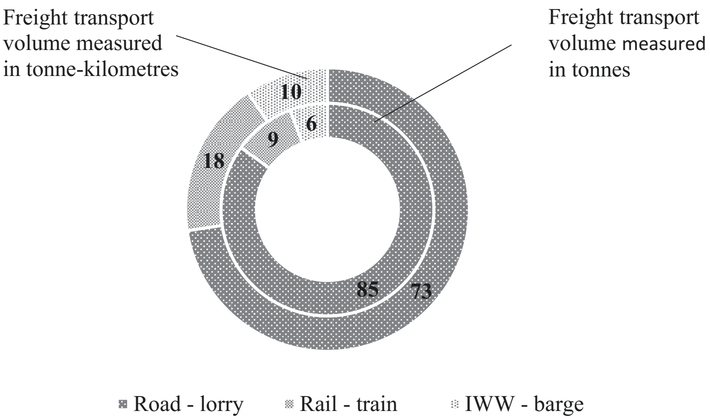

Fig. A-1 Shares of the modal split for a total 2012 land-based freight transport volume in Germany[12] [DESTATIS (2014m)]

[11] Cf. sections 4.4.3 for a discussion of the data base of corresponding statistical publications for Germany.
[12] See Table G-1 for absolute volumes.

S. Reiche, *A Disaggregate Freight Transport Model for Germany*, DOI 10.1007/978-3-658-19153-5_2

In addition to the modal split, the overall freight transport volume in Germany can be specified by national and international transports as well as transports performed by domestic and transports of international freight forwarders. This first overview on the scope of freight transport activities related to Germany will be useful for calibrations of the presented model.
One of these specifications leads to the overall freight transport volume measured in tonnes while the other one leads to a total measured in tonne-kilometres. Most of the relevant information in this context is retrievable from the *Statistical Office of the European Union* (Eurostat).

Freight transport volume per mode

According to EUROSTAT (2014g), the total national *road freight transport*[13] volume in 2012 is estimated at 2,761,152 thousand tonnes. Another 29,185 thousand tonnes are transported within Germany by foreign forwarders[14], whereof about 97% are enrolled by forwarders from a EU-27 country (EUROSTAT 2014k; EUROSTAT 2014j). For international transports by road[15] the share of domestic and foreign freight forwarders is depicted in a consolidated format in Table G-2, together with a tonne-kilometre specific evaluation in Table G-3.
The equivalent national *rail freight transport* volume in 2012 measures about 247,117 thousand tonnes in total (EUROSTAT, 2014i). Cabotage by mode rail is not reported[16]. The volume of transnational freight flows by rail is given in EUROSTAT (2014e). This transport volume is consolidated to 45,286 thousand tonnes going out and 58,226 thousand tonnes directed to Germany (cf. Table G-4). Rail freight transport volumes for Germany measured by tonne-kilometres are depicted in Table G-5.

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[13] See Table A-1 for references on volumes for road freight transports, rail freight transports and IWW freight transports.
[14] The share of road cabotage in terms of transported tonnes is about 1.1%. Measured in tonne-kilometre, the share of foreign freight forwarders for national transports by road is equivalent to 3.28% – the cabotage penetration rate for Germany in 2012.
[15] Freight transport statistics for Germany are set up on a different terminology – sending and receiving instead of import and export. The reason for this is that a receiving is not per se an import and vice versa, same as for outgoing loads and exports. For instance, a ship load arriving in the ARA area (ports of *Antwerp*, *Rotterdam* and *Amsterdam*) is usually not exclusively related to the Dutch, but also to imports by other European countries. Within the presented model, this effect will not be further differentiated apart from the context of country and port specific incoming and outgoing loads that are related to German imports and exports in section 13.4.
[16] Cf. section 14.3.

For inland waterways, the *IWW freight transports*, the total domestic transport volume in 2012 is about 54,569 thousand tonnes. For this volume a relevant cabotage rate is reported. 70% – that is 38,177 thousand tonnes – are transported by German flagged barges and 29% (16,392 thousand tonnes) are conveyed by freight vessels from other EU-27 countries (EUROSTAT, 2014n). International IWW transport volumes in terms of tonnes from or to Germany are presented in EUROSTAT (2014o) and EUROSTAT (2014m). Table G-6 and Table G-7 give a unified depiction this dataset.

Total freight transport volume

These mode specific transport volumes, measured in tonnes for Germany in 2012 – as reported in EUROSTAT (2014j, 2014k, 2014e, 2014n, 2014o, 2014m) – are displayed in the subsequent summary of Table A-1 by country of origin of related forwarders. A distribution of freight totals according to commodity classes is given in Table A-3[17]. As a result, a total freight transport volume of 3,815,014 thousand tonnes is identified to be related to Germany, whereof *3,706,181 thousand tonnes are directly related to either German origins and/or destinations*. This is an o1utline in terms of freight volumes for the subsequent freight model.

The goal of the subsequently presented model is to put in place a structure that allows one to understand the genesis as well as the related distribution of the identified overall German transport volume, accordingly.

[17] Note that statistical reports for Germany to EUROSTAT are basically submitted by DESTATIS. However, certain data discrepancies arise for variant data specifications when both reports are compared to each other for similar specifications – as e.g. given in DESTATIS (2014d, 2014c, 2014b). See also section 4.4.3 for more details on input data discrepancies as well as section 13.4 for a discussion of a commodity specific distribution of reported total freight volumes, respectively. For the presented determination of a *total freight transport volume* for Germany in 2012, results from EUROSTAT are decisive.

	National						International												Transit		
							sending						receiving								
	German forwarders			foreign forwarders			German forwarders			foreign forwarders			German forwarders			foreign forwarders					
	road	rail	IWW	road	rail	IWW	road	rail	IWW	road	rail	IWW	road	rail	IWW	road	rail	IWW	road	rail	IWW
BE				2%		9%	13%	4%	24%	8.3%		28%	15%	8%	14%	9%		12%	1%	16%	13%
BG				2%		0%		0%	0%			0%		0%	0%			0%		0%	0%
CZ				7%		2%	2%	8%	0%	7.3%		0%	3%	7%	0%	9%		0%	11%	3%	0%
DK				2%		0%	6%	1%		1.6%			7%	0%	0%	2%		0%	1%	4%	0%
EE				1%		0%													2%	0%	0%
IE				0%		0%									0%			0%	0%	0%	0%
EL						0%	0%	0%		0.5%			0%	0%		1%			0%	0%	0%
ES				1%		0%	1%	2%		3.2%			1%	1%		4%			0%	0%	0%
FR				1%		0%	19%	4%	6%	10.5%		3%	20%	3%	9%	9%		3%	2%	2%	27%
IT				2%		0%	6%	27%		5.1%			7%	15%		6%			0%	21%	0%
CY						0%			0%			0%			0%			0%	1%	0%	0%
LV				1%		0%									0%			0%	0%	0%	0%
LT				1%		0%		0%						0%					1%	0%	0%
LU				7%		2%	4%	2%	0%	2.6%		0%	3%	0%	0%	2%		0%	4%	2%	2%
HU				3%		0%	0%	2%	0%	2.0%		0%	0%	2%	2%	2%		0%	0%	0%	1%
MT						0%			0%			0%			0%			0%	4%	0%	0%
NL				23%		72%	19%	7%	61%	20.7%		63%	22%	31%	72%	21%		81%	12%	28%	31%
AT				7%		0%	11%	18%	3%	9.3%		0%	10%	12%	2%	8%		0%	8%	11%	5%
PL				33%		10%	2%	6%	0%	18.9%		0%	1%	9%	0%	18%		1%	39%	3%	0%
PT				0%		0%	0%	0%		0.4%				0%					0%	0%	0%
RO				2%		0%		0%	0%			0%		0%	0%			0%	2%	0%	0%
SI				2%		0%	0%	1%		0.9%				0%					3%	0%	0%
SK				2%		0%	0%	1%	0%	1.7%		0%	0%	4%	0%	2%		0%	4%	2%	0%
FI						0%		0%							0%			0%	0%	0%	0%
SE				0%		0%	1%	4%	0%	0.5%		0%	1%	4%		1%			1%	4%	0%
UK				0%		0%	2%	0%	1%	1.9%		0%	1%	0%	0%	2%		0%	0%	0%	0%
EU-27				98%		95%	87%	87%	96%	97.8%		95%	93%	97%	100%	99%		98%	98%	97%	78%
CH				2%		4%	13%	13%	4%	1.2%		2%	7%	3%	0%	1%		0%	2%	2%	21%
RU						0%		0%						0%	0%			0%		0%	0%
others				0%		1%	1%	0%	0%	0.5%		3%	0%	0%	0%	0%		0%			
Total	2,761,152	247,117	38,177	29,185	0	16,392	65,603	45,286	7,274	123,674	0	40,974	47,803	58,226	21,889	125,277	0	78,152	73,008	15,512	20,313
	3,706,181																				
	3,815,014																				

Table A-1 Identification of a total national, international and transit freight transport volume for Germany 2012 in thousands of tonnes[18]

[18] For a better readability entries with *no value* reported are indicated as blanks.

3. Freight transport in Germany as a general system

As the envisaged goal of freight transport planning policy measures is to be effective or, moreover, efficient, a profound understanding of the affected system is a prerequisite. This is especially true for complex systems, such as the outlined framework. For instance, at the socio-ecological level, impacts on global climate as well as on local air and noise emissions need to be considered for transport planning by public authorities. As a result, regional, national and international roadmaps and master plans are being released that call for a reorganisation of freight transport processes.

In response, models of the freight transport system are developed. In general terms, models serve as a tool to interpret a system's behaviour at a reasonable effort (BOSSEL, 2004, p. 15). In order to enable realistic representation of the transport system, it is crucial to identify its relevant components and respective interactions.

Therefore, a system analysis will be rolled out in the following. To analyse the freight transport system, general properties of systems and system states will be introduced first.

It is important to acknowledge that no specific modelling concept fits all facets of a complex system. However: '(…) *the key to effective advances is picking the appropriate categories within which to undertake analysis and subsequently build models*' (WIGAN AND SOUTHWORTH, 2006, 7 f.).

General properties of a system

In broad terms a system's essential is the integrity of a cause-and-effect structure that follows a certain purpose (BOSSEL, 2004, p. 35). Following Arnold et al. (2008, p. 76), systems may be:

- *defined as* a configuration of components or elements which are connected. These connections built upon specific attributes and related rules. In this sense, components represent a set of elements – the smallest and most basic unit of a system,
- *characterised by* a system state that contains the total of all state variables necessary to entirely describe the system at any time[19],

[19] Although static systems are purely hypothetic, they may be useful in a certain context. In such case they are described by constant state variables.

- *referred to* as a structure of components limited by distinct boundaries. Within these boundaries a system has interfaces to affect its environment and/or to be affected itself vice-versa. The system boundaries likewise define the range of values for the coupling of its components.

In the presented context, a freight transport system is regarded as a dynamic system, defined as the total of all interlinked components of the transport infrastructure, the transport demand as well as the transport supply. To understand the complex freight transport genesis – the inevitable starting point – a description of the interactions of a transport system's components in the context of an economic market contributes to this purpose.

4. Freight transport in Germany as an economic market

How does transport demand arise and how are transport services supplied? These questions may lead the way to a more specified analysis of the transport systems properties. In this sense, the general purpose of the transport system is stated as to bring together demanders and suppliers to trade freight transport services in a mutually beneficial way. This evolves from the perception that freight transport is formed by the effort that must be taken in order to bridge two spatially differentiated locations (BLAUWENS, BAERE AND VAN DE VOORDE, 2008, p. 21). This effort serves to convey products and goods between a number of suppliers and consumers – the transport demand[20]. The demand that meets a supply of transport services generates traffic on the corresponding transport infrastructure (NOTTEBOOM, 2013, p. 212).

Following this perception, the goal of the freight system analysis is to elaborate a system's cause-and-effect structure by identifying its components and their potential interactions. The focus is set on the general structure of the system as an economic market and more specifically on the interactions between different competences of logistics and relevant actors, respectively.

[20] See also BUTTON (2010) for further interpretations of a transport demand's evolution.

Components of the transport demand

Production facilities and retailers are considered to be the principles of a movement of goods, in accordance with e.g. BENDUL (2011, p. 48)[21]. As *shippers* they are located at the origin or source, as *receivers* at the destination or sink of a transport. Depending on the sourcing and distribution concept and the attributes of their manufactured goods, shippers demand a pick-up of certain products or goods, subject to logistics service requirements by transport service providers[22]. Similarly receivers attend a delivery specified by logistics quality attributes.
Shippers and receivers are distinct microeconomic market actors. They represent companies and their respective establishments – in the following referred to as firms – that can be grouped upon a varying resolution in accordance with:

- an economic activity and/or
- a spatial resolution of market elements.

Thus, the dominant economic activity of a firm can be helpful for a more aggregate classification of firms that, for instance, represent a common freight transport demand for *timber products* or the total transport demand of the *retail sector*. Thus, a distinction upon the economic activity either refers to an input or potential output of a firm.
Another typology of freight demand elements can result from a spatial differentiation into traffic cells. One example is the demand for freight transport in particular *urban areas*, another one is the *global* demand for freight transport.

Components of the transport supply

A transport market supply is organised by carriers and forwarders, such as road carriers, rail carriers and barge carriers. They make use of different

[21] See also section 6.2.2 for an interpretation of the role of households as a component of the freight transport market's demand.
[22] From an institutional point of view companies running production and/or retail facilities may be part of the market demand and supply at the same time in case they act as their own transport service provider. Their business activities and related business units may in most cases still be decomposed to fit the given context (PFOHL, 2010, p. 255 ff.). See also next section for continuation.

transport means, generally related to a mode of transport in a transport infrastructure[23]. Equivalent to shippers on the demand side, carriers and freight forwarders are regarded as microeconomic market actors/elementary institutions. According to NOTTEBOOM (2013, p. 214 f.), the market supply can be further divided into two categories:

- shippers/receivers operating their own fleet of transport means: the transport user deploys his own fleet of lorries, rail wagons and barges and
- third-party transports: specialised transport companies, such as trucking companies, railway or barge operators, offer a transport service to users[24].

However, as many production companies acknowledged that transport activities are not part of their core business, freight transport services are increasingly being outsourced (NOTTEBOOM, 2013, p. 214). In consequence, transport market demand and supply elements are evaluated independently in terms of potential interactions.

Market size

Neither transport service demand nor supply take place in a vacuum. Transport demand in a globalised business cannot be restricted by boundaries or walls of a particular nature. This also applies to transport services that, in order to meet the respective demand, perform operations on links as well as in nodal points within a complex transport system. Thus, the size of a transport system from a market perspective can hardly be limited. However, a segmentation of the transport system in time and space as well as for the nature of interactions allows for an exemplary qualitative market size limitation[25]:

[23] A transport infrastructure by region consists of roads, rail, sea, air, walkways etc. For further details see e.g. TAVASSZY AND BLIEMER (2013, p. 332). It can be represented by one or several networks (cf. next section).
[24] An overview on relevant companies for the transport market supply is e.g. given in KILLE AND SCHWEMMER (2013).
[25] Cf. section 6 for corresponding freight modelling analyses.

Scope of a freight transport market					
Allocation of shippers, receivers and terminals over time	Short-term	Long-term			
	Fixed location	Variable location			
Spatial extent and organisation of transports	Short-distance	Long-distance			
	Unimodal	Land-based		Non-land-based	
		Unimodal	Multimodal	Unimodal	Multimodal
Specification of sourcing and distribution interaction	Single-product	Multiple-product			
	Uniform vehicle	Uniform vehicle		Multiple-vehicles	

Table A-2 Exemplary morphologic transport market sizing

Market interactions

Starting from the perception that transport systems' interactions are performed as the result of logistics processes, the state of such a system is the result of logistics choices made by its subsystems and their decision making elements. In practice, these decisions are individually motivated. The system's state may – and in most cases will – differ from a theoretic system optimum then. From a market perspective this can be underlined.
For many markets the standard economic equilibrium framework for prices and quantities may provide only insufficient explanations because of vertical sub-markets and/or dynamic pricing phenomena (BEN-AKIVA ET AL., 2012, p. 446). These features are typical for transport markets. As a result of logistics processes they are segmented markets, e.g. in terms of the physical process design of transport services. Individual transport units, shipment sizes, delivery times etc. are only a few of various criteria that limit the number of elements concerning demand and supply of a homogeneous transport market segment. Furthermore, the effect of economies of scale, achieved through logistics' process coordination in the market, results in dynamic prices. The effect of economies of scale describes the phenomena that, for instance, a single forwarder or shipper achieves cost advantages by increasing the respective transport volume on a certain network link. This equally holds true

for the observation of interacting suppliers of transport service, e.g. in the case of transport bundling. In contrast, by reaching a certain level, this effect is opposed due to capacity limits. These effects constantly change their relevance over time and result in a dynamic that sets limits to a transport system analysis based on a general market equilibrium approach[26].
As a result, the approach to analyse the equilibration of demand and supply within the standard economic equilibrium framework is not appropriate for understanding a complex transport market's behaviour.

4.1. Freight transport demand and supply interactions

A freight transport system is of such complexity, that no single scientific discipline would be able to encompass its functions and operations (RODRIGUE, NOTTEBOOM AND SHAW, 2013, p. 3). Nonetheless, it may be stated that for an analysis of informational and – even more relevant – physical flows, which might be identified as core processes of a freight transport demand and supply interplay, the consideration of logistics organisation capabilities is indispensable. Hence, the interdisciplinary nature of logistics science may be regarded as a suitable approach for an analysis of the broad range of interactions behind the physical movement of goods. This gives reason to an implementation of logistics concepts within the presented framework in order to adequately model relevant freight market interactions.

A line may be drawn between an evaluation of 'classic' logistics interactions and a more refined analysis of supply chain interactions. From a managerial perspective, supply chains, in essence, are built among independent organisations to extend the concept of elementary logistics interactions (cf. BAUMGARTEN, DARKOW AND ZADEK (2004, p. 2 ff.) to a level that explicitly seeks to improve cooperative competitiveness, thereby enhancing customer satisfaction (cf. BOWERSOX (2013, p. 30 ff.), WERNER (2013, p. 5 ff.), STADTLER AND KILGER (2008, 9)). Two broad dimensions for improving competitiveness are identified by LEE AND NG (1997, p. 191):

[26] An additional effect is the limit of information flows in the sector of transport bundling potentials, hence the imperfection of market interactions.

- the first one comprises a closer *integration of firms*. This strategy targets the organisational boundaries by working more closely with its suppliers and customers and
- the second dimension encompasses the *coordination of flows* in a supply chain. These flows represent the threefold elementary structure of logistics process analysis: materials, information, and finance.

The assumption may be stated that by today basically no firm will neglect the supply chain management potential[27]. That is why an understanding of the way freight transport market demand and supply meet each other is crucial for an elaborated freight transport planning.

4.2. Structural framework

Besides market demand and supply, the transport network is a third significant component of the freight transport system. Physical interactions follow a network structure, which may be defined as a set of nodes and a set of connecting edges.

- Transport nodes serve as access points or as intermediary locations for the overall transport system or a particular subsystem. The latter function is mainly serviced by terminals. Terminals represent starting, ending and transhipment points for transport flows (RODRIGUE, NOTTEBOOM AND SHAW, 2013, p. 4).
- Transport edges connect transport nodes. Edges primarily represent transport infrastructure elements such as roads, rails and waterways.

A network link is defined in this context as a pair of nodes connected by an edge. In the centre of such a transport system is the shipment of goods and commodities. These shipments are realised by certain transport modes, either uni- or multimodal that, in turn, are accessible via transport terminals.

Transport network nodes

Transport is realised between origins and destinations, namely two transport nodes. A terminal – another major representative of an analytic transport

[27] See for instance STADTLER AND KILGER (2008, 1 f.) for an exemplary description of the supply chain management potential in practice.

node – may be defined as any facility where freight is being handled in a transport process (RODRIGUE, COMTOIS AND SLACK, 2009, p. 127). This may be a sea or an inland port as well as a freight yard. In a broader sense, each access or release point for trailer loads may be considered a terminal and likewise each origin or destination for transports. These nodes within a transport system are interlinked by edges to build up a transport network.

Transport network edges

Arcs within a transport network connect the network nodes. They are also referenced as arcs or links. Along them, a transport of goods and commodities takes place.
From a market perspective there is a demand for transports from an origin to a destination. These two representatives of network nodes are interlinked by transport paths that consist of one or the aggregate of multiple edges or links.

Shipments and commodity flows

In this context, the realisation of a transport demand is referenced as *a shipment*. A shipment, in turn, is defined as the amount of commodities shipped between two locations or transport nodes in a transport system – specified by shipment size, frequency etc. Shipments are mainly formed by market demand elements[28] based on individual lot size calculations. A further bundling with other shipments, induced e.g. by transport logistics service providers, and/or their realisation along similar freight transport network links, leads to *commodity flows*. In this context, a commodity flow refers to a realisation of a shipment within a transport network.

Shipment size determination as well as commodity flow configuration are individually motivated actions within a transport system. They are the outcome of calculations for at least the underlying logistics service costs. From this perspective, the overall result of transport market demand and supply interactions is a distinct commodity flow configuration.
A commodity flow configuration may – and often will – differ from production/consumption flows. Such a production-consumption trade flow (*PC*

[28] Less frequently also the market supply side within a transport system may be responsible for a lot sizing. Significantly more often a commodity flow bundling will take place on the supply side.

flow) describes a direct relation between two network nodes that are not necessarily equivalent to the origin/destination flow (*OD flow*) between certain network terminals. This phenomena is also considered as a micro-macro gap in freight transport systems[29].

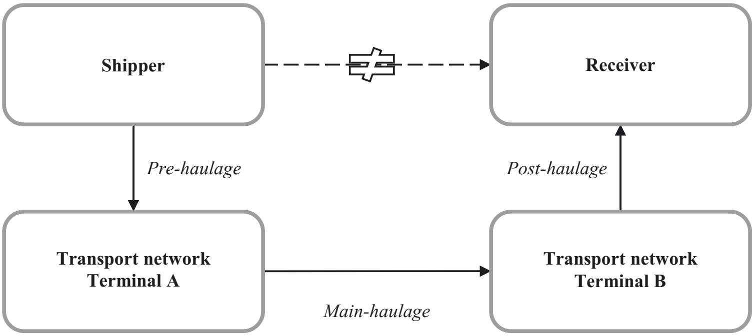

Fig. A-2 Micro-macro gap for intermodal transports [adapted from BLAUWENS, BAERE AND VAN DE VOORDE (2008, p. 32)]

Transport modes

Within a transport system usually multiple modes are relevant. Typical *land-based transport modes* are:

- Road
- Rail
- IWW (Inland Waterway Transports)

A transport via pipelines is only viable for selected commodities, e.g. crude oil and natural gas and furthermore merely part of transport systems that seek to analyse long-term market demand and supply interactions. Another alternative mode, the transport by sea, is almost exclusively bound to international transport relations and therefore restricted to certain locations and port access of international origins or destinations.

[29] For further discussions of this problem context see also section 15.1.

Multimodal or intermodal freight transport

A multimodal transport is performed with at least two different means of transport from the point where a good is originated, to a designated point of delivery. Multimodal transport may be further specified by the use of containers, swap bodies, road lorries and also their separated trailers as transport units to combine a transport between the road, rail, barge and sea infrastructure. For those transports where moved goods and commodities remain in one and the same loading unit or road vehicle for the entire transport operation, the wording *multimodal* is preferable to *intermodal* transports. The selected terminology is also in line with the definition of intermodal transports in UNECE (2012, p. 2). Intermodal and combined transports are applicable for the same context.

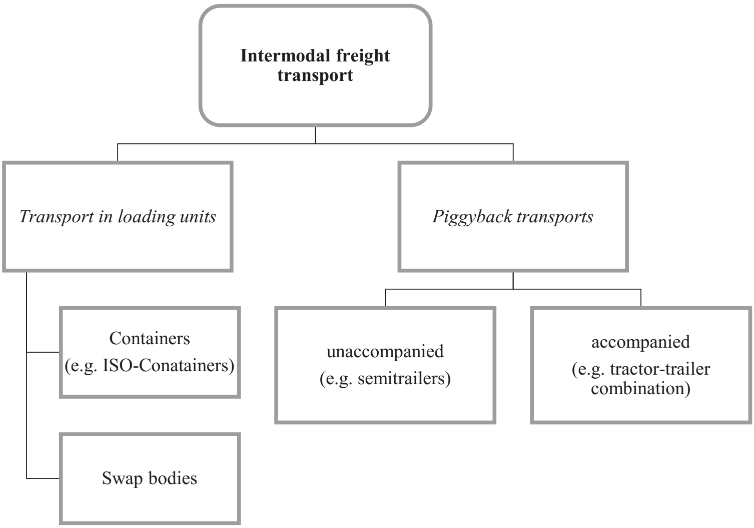

Fig. A-3 Types of intermodal transports in freight transport systems

Although transported by multiple modes, the non-land-based transport modes air and sea are not per se denoted as multimodal transport freight transport systems. Instead, the *land-based* transport sequence may be separately evaluated. Since for air freight hardly any of the transport units, as specified before, are deployed in practice along the entire transport chain, the role of intermodal transports including air-freight main hauls is often negligible. This differs from sea shipments to arrive in – or be sent from – national ports. Here, multimodal transports are realised with e.g. ISO-containers as a considerable alternative to unimodal transports.

Goods and commodities

Within a transport system's arrangement the general focus is usually set on the transported goods – a term mostly used in economic considerations that is also applied as a more general term for commodities. The notion commodity is used to mutually examine raw materials as well as semi-finished and finished products that have common characteristics.
Commodities can be classified by producers and/or consumers together with distinct characteristics, as exemplarily indicated for three basic economic sectors in Fig. A-4. Hence, they are related to a sector of an economic activity and further specified by individual characteristics such as weight, volume and value.

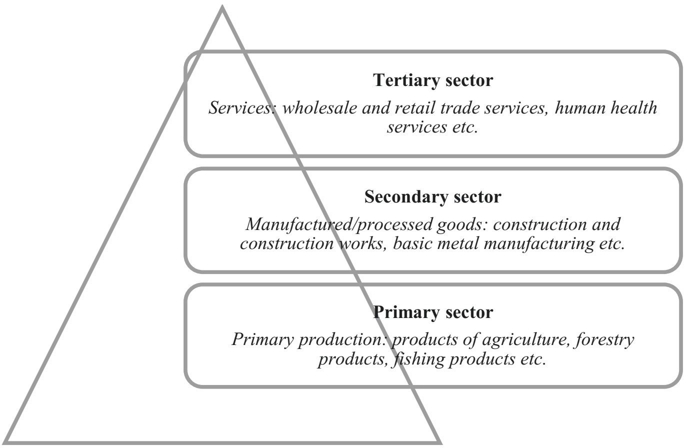

Fig. A-4 Exemplary classification of commodities according to their producers

The industry standard classification systems – such as the International Standard Industrial Classification (ISIC), sponsored by the United Nations

Statistics Division, the North American Industry Classification System (NAICS) of the Statistical bureaus of the U.S., Canada and Mexico as well as the Statistical Classification of Economic Activities (NACE) in the European Community – are also designated to classify economic activities and their respective outcomes within statistical reports for freight transport systems.

4.3. Synopsis

The result of the given interpretation of a transport system as a market with its components and their logistics interactions is a *commodity flow configuration*. One way to describe this specific setup is to depict a generic structure and its components as follows:

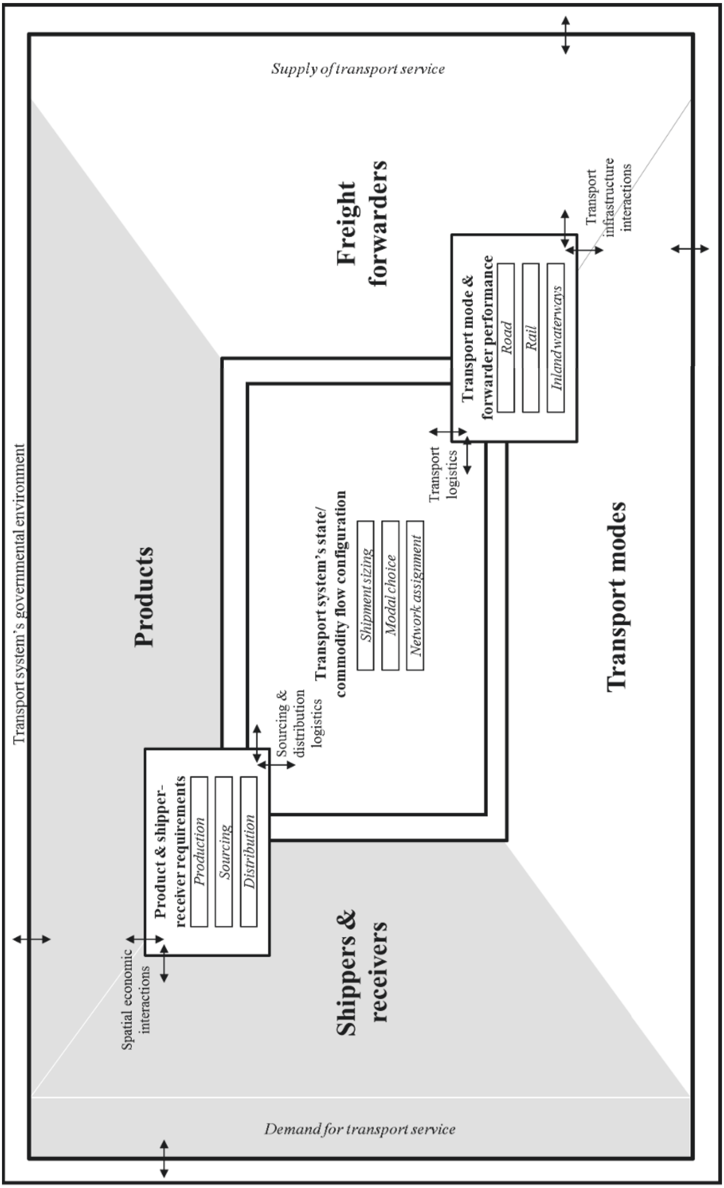

Fig. A-5 A generic setting of a freight transport market's setting and its driving forces

From this perspective, transport demand and supply can be observed between shippers or receivers and freight forwarders. In broad terms, they are connected to each other due to a demand or the supply of a product. The focus of a freight transport model is mostly set on the transport demand formed by economic interactions of spatially separate shippers and receivers. If the aim is to interpret a transport system's demand configuration in more detail, the supply of transport services on a given transport infrastructure cannot be neglected[30].

When this connection is interpreted in detail, as the result of a search to improve cooperative competitiveness – hence, a supply chain setup – the exchanged product is referenced as a specific commodity. This commodity is transported by freight forwarders along a transport system's infrastructure via multiple modes. The way these driving forces connect to each other is the transport systems' state, or from an economic perspective, a transport markets' setting.

Within this understanding, the governmental framework is a representative for exogenous influences to the market. It may be seen itself as a superordinate system that performs interactions to the transport system as externalities. In contrast, the economic, technical and logistics influences on the physical as well as informational organisation of the market are endogenous drivers for a change of the system. This is mainly described by a motivated use of certain routing configurations, transhipments and commodity bundling for each mode of transport.

As a result, it may be argued that:

- without a profound and likewise wide-ranging understanding of the cause and effect – here, a demand and the supply of transport in an economic context – a freight transport system's state cannot be effectively influenced and consequently,
- a representation of the freight transport system is required that explicitly links economics and freight transport activities, with the latter as a result of the former component.

[30] Cf. discussion on the role of alternative transport costs per path in the context of a modal selection in section 9.

4.4. Specific statistical data

Since an understanding of the way freight transport market demand and supply meet each other is crucial to elaborated freight transport planning, it has to be a feature of a model for the German freight transport system. However, the more detailed the model of a complex system is set up, the more informational content is required. A trade-off that can be dealt with when light is shed on individual firms' *supply chain interactions* and the related information at hand.

These interactions have be evaluated within a structural framework of *multiple modes*, namely road, rail and IWW. This selection is the result of a breakdown of the total annual transport volume in terms of tonnes for Germany in the base year of 2012, as depicted in Fig. A-1 and Table G-1. The total annual transport volume, including transits, is estimated to a total of about 4.3 billion tonnes[31]. Thereof, more than three quarters were transported by mode road, 9% by train followed by 7% for costal sea shipping and 5% for transports on inland waterways. A share of 2% of the aggregate transport volume in tonnes is reserved for crude oil transports in pipelines. The proportion of only a 0.1%, equivalent to 4 million tonnes, is transported by cargo flights.

Referring to the latter, the share of domestic air freight relations in 2012 is only 0.1 million tonnes, equivalent to an overall proportion of 0.002% (DESTATIS, 2013e, p. 12). Although of minor impact on the national modal split, cargo flights play a non-negligible role in international trade relations, especially with a view to oversea regions. In consequence, a freight model for Germany should consider air freight transports in addition to the land-based alternatives – at least by implementing synthetic network nodes of production and consumption.
Since statistical reports on national airports are limited in terms of their informational content, the share of domestic air freight transports is not appropriately separable from international transport volumes. With regard to a share of only 0.002% for the overall national transport volume, this impact is assumed to be negligible.

[31] Thereof 3.8 billion tonnes are related to mode road, rail and IWW as depicted in Fig. A-1.

For sea shipping the reported annual total transport volume of about 300 million tonnes is likewise spread to a large extent among international transport relations. According to DESTATIS (2013g), only 7.3 million tonnes are transported between domestic ports, that is about 0.2% of the overall national sea shipping transport volume. In contrast to air freight related statistical data, the national as well as the international sea freight transport volumes can be unambiguously distinguished[32].

Furthermore, for crude oil may be assumed that it is dominantly destined to refineries in Germany, each of which is connected to a pipeline system or an oil port (BMVI, 2014a, 16 f.). Thus, it is further assumed that no significant alternatives to pipeline transports are considered for German crude oil refineries[33]. Additionally, for natural gas similar assumptions might apply. As a result, neither the pipeline network will be part of further evaluations for a model of the German freight transport system, nor will be the product *extractions of crude petroleum and natural gas* of (CPA-06).

For the remainder of this study, only transports by mode road, rail and IWW will be evaluated for national transports as well as international transports. Additionally transports by sea and air are considered as options for international transports.

4.4.1. Regional specific information

These transport modes are accessible via *different types of transport nodes*. These are either locations of production and consumption or transhipment nodes. All together they are classified by a geographic referencing unit, the Nomenclature of Units for Territorial Statistics (NUTS) for European countries. The first level of this hierarchical system is referred to the current 28 EU member states (EFTA and EU-candidate countries are separated) with a two-letter country code. Further subdivisions into regional levels are represented by additional digits. For Germany according to the NUTS 2010 nomenclature, as given in EUROSTAT (2011, p. 29 ff.), these are:

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[32] Cf. section 13.3.

[33] Apart from that for coking plants, as a second part of the commodity group CPA 19, the remaining modes are genuine options for a modal choice within a freight transport system.

- NUTS-1: major socio-economic regions (19 German *Regierungsbezirke*)
- NUTS-2: basic regions (39 German *Regionalbezirke*)
- NUTS-3: small regions (402 German *Landkreise/ kreisfreie Städte*[34])

To identify a centroid of each of the modelled international NUTS-0 and national NUTS-3 administrative units, valuable indications are given in EUROSTAT (2015a), STÄDTESTATISTIK (2012) and IRPUD (2005).
Each transport considered node of the German transport system is assigned to either of these regions. Inland nodes are distributed within the centre of one of the NUTS-3 regions and international nodes are assigned to a NUTS-0 centroid. This setup likewise provides a distinct restriction criterion for system analysis – the spatial outreach of transport activities under consideration.

4.4.2. Commodity specific information

These nodes are connected via multiple transport links, enabling multimodal transport options of various commodities. For a German transport system a useful classification scheme for commodity classes is the European NACE industry standard classification system using a four-digit code for a classification of economic activities (EUROSTAT, 2014u). The economic origin of a commodity is referenced to this classification via the Statistical classification of products by activity (CPA), a universal classification of products at the level of the European Union (EUROSTAT, 2012). CPA product categories are related to activities as defined by NACE standards. The CPA classification has a hierarchical structure with six levels of detail. Up to the fourth level of detail the NACE and CPA coding are identical with very few exceptions and both may be used in the same manner in practice to express an economic activity by characteristic commodities (DESTATIS, 2008b, p. 49)[35].
The current NACE Rev. 2 standard is, according to EUROSTAT (2008, p. 61 ff.), classified as follows:

[34] The latest European statistics publication on regions in the EU does however not consider recent local administrative reorganisations, e.g. for small regions of Mecklenburg-Vorpommern by late 2011 in northern Germany, leading in consequence to declaration discrepencies of 429 NUTS 3 regions and the German equivalent of 402 Landkreise/ Kreisfreie Städte.
[35] Since only two-digit NACE and respective CPA codes are considered in the following, this proposed unification will be applied for a more convenient readability.

- 21 Sections – coded by an alphabetical letter
- 88 Divisions – identified by a two-digit numerical code
- 272 Groups – identified by a three-digit numerical code
- 615 Classes – identified by a four-digit numerical code

The CPA systematic is organised as (EUROSTAT, 2013):

- 21 sections (alphabetical letter)
- 88 divisions (two-digit numerical code)
- 261 groups (three-digit numerical code)
- 575 classes (four-digit numerical code)
- 1.342 categories (five-digit numerical code)
- 3.142 subcategories (six-digit numerical code).

Besides economic activities, the European NACE industry standard classification system also covers their outcomes. One classification scheme is Prodcom statistics by Product (EUROSTAT, 2010). Its name is derived from the French *PRODuction COMmunautaire* (Community Production). Prodcom statistics contain about 3900 different types of manufactured products for mining, quarrying and manufacturing. Therein, products are identified by an eight-digit code that, for the first four digits, corresponds to the NACE and, for the first six, to the CPA system (ibid.).

In addition, the *Standard goods classification for transport statistics* (NST) in its current version from year 2007 is a specific statistical nomenclature for transported commodities – by road, rail, inland waterways and sea. The latter classification scheme considers the economic activity from which the commodities originate, thereby connecting related commodities to the CPA standard and the NACE framework[36].

In principle, a transformation of statistical information from one standard to another is feasible according to the correspondence table given in EUROSTAT (2009). However, depending on the level of detail and the direction of a transformation, the correspondence is not unambiguous. On a two-digit level for the CPA classification and a three-digit level of detail for the NST systematic, a conversion from NST data to CPA leads to a direct comparison as depicted

[36] Cf. Table G-9 to Table G-11 for details on the European commodity classification scheme.

in Table G-12. Therein, double entries that require further adaptions are marked. They originate from subgroups of the NST scheme that, in turn, are related to multiple subgroups of the CPA scheme, for instance group NST-048 that relates to CPA-10 and CPA-12.

In more detail, the NST standard groups together *other food products n.e.c. and tobacco products* (NST-048) that are related to either *food products* (CPA-10) or *tobacco products* (CPA-12). It is assumed that the volume of food products from NST-048, which is not classified elsewhere within the group of CPA 10, is rather small, compared to the volume of *tobacco products* (CPA-12). The remaining double entries are treated accordingly to obtain a basis on which to work within further modelling stages[37]. For this system and its state or market configuration, an initial assumption is stated, whereupon:

- the setup of commodity flows is assumed to be constant and equally distributed over a certain period of time – here, one year.

Although this assumption limits the ability of the model to represent the reality, it is inevitable since the goal is to analyse the German transport market interactions at the most detailed level possible. Seasonal effects and other time-related changes are neglected in that context.

Furthermore, commodity specific information is related to firms that in fact may also represent multiple sites or establishments of a single firm in terms of its legal structure. That leads to the following simplification that:

- within the presented context, each organisational unit that has a distinct spatial location as well as a distinct object of business organisation is modelled separately, addressed as an individual firm.

In total, more than 2,000,000 firms as both an origin and destination of freight transport activities are modelled within the borders of Germany. Another 29

[37] Note that a transformation of CPA formatted data into the NST structure on a similar level of detail is less trivial. A significant number of divergent relations between subgroups of *Chemicals and chemical products* (CPA-20) and *Basic pharmaceutical products and pharmaceutical preparations* (CPA-21) hinder a direct transformation. Fortunately, this drawback is of minor importance for the presented model since mostly a correspondence from NST-3-digit data to CPA-two-digit information is required.

synthetic firms are modelled as aggregates for neighbouring countries. This set is completed by 44 extra origins and destinations with significant relevance for land-based transports in Germany. Along with this understanding another assumption is stated for the model's representation of a final consumption. Thereafter:

- the final consumption of a product is related to retailing firms within a region.

In other words, private transports for e.g. shopping of *electrical equipment* (CPA27) in a hardware store are not modelled, whereas the commercial transport from its origin of production to the hardware store is part of the freight transport model.

4.4.3. Mode specific statistical information on the German freight transport market

Apart from overall mode specific transport volumes as given in Table A-1, certain data sources are accessible to set up a distribution of transport volumes for Germany by commodity class[38].

For mode rail, national freight volumes are listed in EUROSTAT (2014h). For international rail freight transports commodity specific transport volumes are determined according to an unpublished data source of the German *Federal Bureau of Statistics* (DESTATIS, 2013b). A detailed distribution of the overall volume of goods transported by IWW can be determined accordingly, including data from DESTATIS (2013a).
Deviant to road freight volumes for Germany, each shipment by mode rail and IWW is statistically recorded. These annual commodity flow counts are published on demand by the *Federal Bureau of Statistics*. Reports on rail and IWW transports are accessible and contain for instance:

[38] Originally the NST two-digit classification scheme applies in this context. As presented before, this setting can be transformed to the CPA standard.

- a regional specification for origins (NUTS-2)[39] and
- a regional specification for destinations (NUTS-2) of a transport path,
- a related commodity classification according to the current *standard goods classification scheme for transport statistics* (three-digit NST) and therefore:
    - a total annual transport quantity in tonnes (including weight of transport unit) and
    - the share of quantities transported in vehicles, containers, swap bodies (without weight of transport unit)[40].

In contrast, statistically reported freight volumes for mode road are the result of a survey without a comparable spatial and commodity class specification. Hence, the results are only useful to a limited level of detail.

Data discrepancies for German road freight transports

The German *Federal Motor Transport Authority* collects a dataset on road freight activities as a monthly survey. However, this survey only represents about 5 out of 1000 vehicles of a preselected tranche of vehicle classes (KBA, 2012a, p. 1). Furthermore, for confidential reasons detailed statistics on regional origins and destinations for differing commodities transported by lorry are not open to the public.

Considering the small sample within the statistical population of road freight transports, the given data need to be considered as an approximation to the *real-world* data, only. In consequence, the indicated road freight total is questionable. Moreover, with a higher level of detail the validity of survey data is further limited, for instance a specification of transport volumes by CPA. That is why additional data specifications, such as a spatial allocation of transport volumes, are not published for road freight transport volumes.

Nevertheless, at least an allocation of mode specific annual transport totals to groups of goods – hence, commodity classes – is feasible along with the presented rail and IWW data as well as with the survey results for mode road.

[39] Although an even more detailed request is possible, a trade-off between a more detailed dataset in contrast to additional anonymised sections applies (cf. section 12.2).
[40] This element will be valuable for a modelling of combined transport alternatives in section 14.

In EUROSTAT (2014g), the volume for national road freight transport estimates (cf. next section) is presented. EUROSTAT (2014p) and EUROSTAT (2014q) offer the volume of goods that are sent and received in Germany by domestic freight forwarders.
The counterpart of sent and received commodity classes transported by international freight forwarders can be determined from a consolidation of EUROSTAT (2014b), EUROSTAT (2014p) and EUROSTAT (2014q) [41]. Results of this data collection are depicted as follows[42].

[41] Here, from EU-27 countries. Volumes from other countries are not presented.
[42] Note that not only road freight transports are performed by national as well as foreign forwarders, but also IWW transports. These transports are sufficiently reported to the Federal Bureau of Statistics for this differentiator. The respective total transport volume in tonne kilometres is depicted in Table G-8.

	National					International										
						sending					receiving					
	German forwarders		*foreign forwarders*		IWW total	*German forwarders*		*foreign forwarders*		IWW total	*German forwarders*		*foreign forwarders*		IWW total	
CPA	*road*	*rail*	*road*	*rail*		*road*	*rail*	*road*	*rail*		*road*	*rail*	*road*	*rail*		
1	6%	2%	(6%)		12%	(5%)	2%	(6%)		12%	(7%)	1%	(12%)		8%	
2	0%	6%	(0%)		8%	(1%)	0%	(1%)		0%	(0%)	15%	(0%)		27%	
3	10%	14%	(10%)		22%	(7%)	10%	(10%)		19%	(6%)	10%	(3%)		16%	
4	17%	1%	(17%)		5%	(12%)	1%	(10%)		6%	(14%)	1%	(10%)		4%	
5	1%	0%	(1%)		0%	(1%)	0%	(1%)		0%	(1%)	0%	(1%)		0%	
6	7%	4%	(7%)		1%	(8%)	6%	(9%)		1%	(6%)	5%	(10%)		2%	
7	3%	14%	(3%)		20%	(2%)	3%	(3%)		10%	(2%)	5%	(1%)		18%	
8	7%	12%	(7%)		10%	(13%)	7%	(10%)		18%	(14%)	5%	(11%)		12%	
9	9%	4%	(9%)		3%	(8%)	1%	(8%)		3%	(6%)	1%	(5%)		1%	
10	7%	11%	(7%)		5%	(8%)	9%	(10%)		9%	(9%)	12%	(13%)		4%	
11	3%	0%	(3%)		0%	(3%)	0%	(4%)		1%	(3%)	0%	(4%)		0%	
12	4%	6%	(4%)		0%	(4%)	4%	(5%)		2%	(5%)	4%	(6%)		0%	
13	1%	0%	(1%)		1%	(1%)	0%	(2%)		0%	(1%)	0%	(3%)		0%	
1 – 13	77% 188,003	72% 40,423	(77%) (6,368)		87% 9,540	(73%) 19,118	42% 8,558	(79%) 60,334		81% 10,309	(75%) 14,991	60% 13,799	(80%) 65,926		93% 20,738	76% 458,107
14	6%	3%	(6%)		11%	(4%)	3%	(2%)		6%	(5%)	2%	(3%)		2%	
15	3%	0%	(3%)		0%	(1%)	0%	(1%)		0%	(1%)	0%	(0%)		0%	
16	3%	1%	(3%)		0%	(2%)	1%	(3%)		0%	(4%)	1%	(3%)		1%	
17	2%	0%	(2%)		0%	(1%)	0%	(0%)		0%	(1%)	0%	(0%)		0%	
18	9%	1%	(9%)		0%	(7%)	1%	(8%)		0%	(7%)	0%	(8%)		0%	
19	0%	22%	(0%)		1%	(0%)	40%	(2%)		9%	(0%)	32%	(2%)		3%	
20	0%	1%	(0%)		0%	(0%)	0%	(3%)		0%	(0%)	0%	(3%)		0%	
Non-EU-27						(13%)	13%	(2%)		3%	(7%)	5%	(1%)		1%	
Total	245,267	56,326	8,308	0	10,912	26,352	20,310	76,424	0	12,688	20,030	23,159	82,369	0	22,228	**604,373**

Table A-3 Total transport volume per NST commodity division for Germany 2012 in thousands of tonnes

To further specify these transport totals within a spatial setting – a prerequisite for a qualified freight transport policy – the available statistical input data is not sufficient.

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