Measuring Service Quality in Freight Transport Networks

Author(s):
Mancera, Albert

Publication Date:
2017

Permanent Link:
https://doi.org/10.3929/ethz-b-000263136

DISS ETH NO. 24444

MEASURING SERVICE QUALITY IN FREIGHT TRANSPORT NETWORKS

A dissertation submitted to

ETH ZURICH

for the degree of

Doctor of Sciences

presented by

ALBERT MANCERA SUGRAÑES

Enginyer de Camins, Canals i Ports, UPC (Barcelona Tech)

born 3rd August 1985

citizen of Spain

accepted on the recommendation of

Prof. Dr. Ulrich Weidmann, examiner

Prof. Dr.-Ing Dirk Bruckmann, co-examiner

Prof. Dr.-Ing Bert Leerkamp, co-examiner

2017

Abstract

Freight transportation has been continuously growing since the disruption of containerization (European Commission, 2014). The implications of this growth on national and international freight networks are evident. Congestion and bottle necks lead to planning of new lines and terminals in times of budget restriction. Simultaneously, the EU aims to gain competitiveness within the European freight networks in order to ensure a long-term strategical position on the international market. Unfortunately, up to date there are no standards regarding quality-of-service on freight transportation that provide infrastructure planners, freight operators and shippers with clear descriptions for freight performance. On the meanwhile, quality scales as the Level-of-Service are used in several transport systems such as private mobility, public transportation, bicycle and pedestrian mobility.

Freight transport is mainly a business-to-business market (Bruhn, 2009). In any given geographic area there are a few important customers and a few important suppliers. In this environment losing a single important client has a high negative impact. Therefore, customer orientation is even more relevant for freight transport than for passenger transport (Muchiri, Pintelon, Martin, & De Meyer, 2010). Furthermore, freight markets usually struggle to provide a high level of satisfaction to shippers. For instance, 35% of shippers using the Canadian rail freight market are dissatisfied with service and 45% claimed their satisfaction level decreased over the last years (AARA-MPS, 2011); on the other hand, in the European rail freight market, 25% of customers have a low level of satisfaction (CER, 2013).

Therefore, shipper's perceived quality on freight transport services should be analysed quantitatively to understand the key factors that would enable the development of a measurement metric that quantifies quality of service on freight transportation. From this research gap the following research question was derived: Is it possible to evaluate the quality of a freight transport chain perceived by a shipper in a way that it takes into account commodity group and logistic network specific needs and to make it comparable to other transport chains?

In order to answer this question some standardization of the transport chain is needed as well as detailed analysis of the relationship between service provider and the customer, and the freight operations. Thus, the following questions were additionally included in this

research: Which is the right approach to evaluate a transport chain? Does a transport chain consist of generic elements? Is possible to evaluate it holistically or is it better to evaluate each of the existing activities of the transport chain? How to evaluate the quality of a transport chain? Which are the most suitable tools? How to grade and classify the quality of service in a transport chain? Is it possible to apply the concept of Level-of-Service to freight transport? At which parts of the transport chain the quality of service can be measured using this methodology? Are all types of goods homogeneous insofar as their quality standards? Is it possible to evaluate the overall quality of service of an entire intermodal freight shipment by using this methodology to evaluate the quality of each of its elements? Until which level of the freight network can such a quality measurement approach be applied?

First, a standardization of the transport chain was carried out, classifying all elements in two groups: logistic processes and transport processes. A transport process consists on the movement of goods by a transport mode. In this thesis are considered rail, road, IWT and SSS. A logistic process depends on the type of transport product and take place in a logistic facility. Combining transport and logistic processes Service providers can arrange transport services that fulfil the geographical and market needs of shippers.

Second, a definition of quality of service for freight transportation was developed, using as a reference the EN 13816 for passenger transportation (CEN, 2002) and adapting the quality loop to freight transportation. It stablishes a set of relationships between freight performance and level of satisfaction. As a result, it was defined that quality of service for freight transport is the shipper's perceived quality of a transport or a logistic process considering the transport and logistics performance and the service provider customer orientation.

Third, a customer-oriented measurement system for freight and logistics companies was developed. The measurement system was developed as part of research carried out for SBB Cargo in Switzerland and is based on professional expertise and data from stakeholders in all parts of the logistic chain. The proposed method is an indicator-based system built on a theoretical foundation, informed with the help of expert workshops and validated with real world data. The method can be used to measure the customer focus of logistics service providers over time, thus enabling them to improve, and/or to benchmark a pool of logistics companies. The proposed method can also be customized to evaluate other specific customer needs by adjusting weights and indicators within its computational structure.

Fourth, a quality scale named Level-of-Service for freight transportation was developed. The metric has been developed using shipper inputs on their service preferences and it uses transparent indicators that enable evaluation of freight corridors and networks. It also enables transport mode performance benchmarking through an intermodal quality scale of objective criteria. Method validation is illustrated with real test cases on the Swiss freight network (road and rail).

Finally, major contributions of the thesis are: a better understanding of the quality-of-service concept for freight transportation; a unified qualification method for unimodal and intermodal systems. Potential real-life applications for the Level-of-Service for freight transportation are diverse. For instance, supporting freight planners when designing lines, terminals or services; improving freight operator's performance; advising shippers when selecting service providers. The methods developed in this thesis indicate that quality of service evaluation tools for freight transportation could potentially be implemented. They have been validated as possible approaches to objectively analyse infrastructure and freight and logistics service providers. Since all elements are evaluated under the same parameters, the outcome of service logistics activities can be compared regardless of their company size, their location, the transport modes used, etc. Nevertheless, some challenges need to be underlined. Since most of the data necessary to do freight transportation experiments belongs to private bodies, such as service providers or shippers, it is really important to have some contact with the industry when planning to do some freight transportation research.

Zusammenfassung

Der Güterverkehr ist seit der Einführung des Containers kontinuierlich gewachsen (European Commission, 2014). Die Auswirkungen dieses Wachstums auf nationale und internationale Güterverkehrsnetze sind offensichtlich. Verkehrsüberlastung führt zur Planung neuer Verkehrswege und Terminals in Zeiten knapper öffentlicher Mittel. Gleichzeitig strebt die EU eine Erhöhung der Wettbewerbsfähigkeit Europäischer Güterverkehrsnetze an, um langfristig eine strategische Position im internationalen Markt zu sichern. Bis heute gibt es keine Standards zur Servicequalität im Güterverkehr welche Infrastrukturplaner, Logistikdienstleister und Verlader eine klare Beschreibung der Leistungsqualität im Güterverkehr liefern würde. Gleichzeitig werden Qualitätsstandards wie der „Level-of-Service“ in anderen Verkehrssystemen angewandt, beispielsweise im MIV, im ÖV sowie beim Fuss- und Veloverkehr.

Der Güterverkehr ist hauptsächlich ein Business-to-Business-Markt (Bruhn, 2009). In jedem geographischen Gebiet gibt es einige wenige wichtige Kunden und einige wenige wichtige Anbieter. In diesem Umfeld hat der Verlust eines einzigen wichtigen Kunden eine starke negative Auswirkung. Aus diesem Grund ist die Kundenorientierung im Güterverkehr noch wichtiger als im Personenverkehr (Muchiri et al., 2010). Zudem ist die Zufriedenheit der Verlader in Gütermärkten generell tief. Beispielsweise sind 35% der Verlader im kanadischen Schienengüterverkehrsmarkt unzufrieden mit der Leistung und 45% gaben an, dass ihre Zufriedenheit in den letzten Jahren sank (AARA-MPS, 2011); im Europäischen Güterverkehrsmarkt weisen 25% der Kunden eine geringe Zufriedenheit auf (CER, 2013).

Aus diesem Grund sollte die durch Verlader wahrgenommene Qualität von Güterverkehrsleistungen quantitativ analysiert werden. So könnten die Hauptfaktoren verstanden werden, welche die Entwicklung einer Messgrösse für die Servicequalität des Güterverkehrs quantifiziert erlaubten. Aus dieser Forschungslücke wurde die folgende Forschungsfrage abgeleitet: Ist es möglich, die durch einen Versender wahrgenommene Qualität einer Güterverkehrskette derart zu evaluieren, dass Gütergruppe und spezifische Anforderungen an das Logistiknetz berücksichtigt werden und das Resultat mit anderen Transportketten verglichen werden kann?

Um diese Frage zu beantworten werden eine Standardisierung der Transportkette und eine detaillierte Analyse der Beziehung zwischen Anbieter und Kunde sowie des Betriebs benötigt. Daher wurden die folgenden Fragen zusätzlich in dieser Forschungsarbeit behandelt: Welches ist der richtige Ansatz, um eine Transportkette zu beurteilen? Besteht eine Transportkette aus generischen Elementen? Ist es möglich, die Transportkette als Ganzes zu beurteilen oder ist es besser, jeden einzelnen Teil der Transportkette separat anzuschauen? Wie soll die Qualität der Transportkette beurteilt werden? Welches sind die geeignetsten Werkzeuge? Wie soll die Servicequalität in einer Transportkette benotet und klassifiziert werden? Ist es möglich, das Konzept des „Level-of-Service" auf den Güterverkehr anzuwenden? Auf welche Teile der Transportkette kann eine solche Methodik angewandt werden? Sind alle Arten von Gütern homogen hinsichtlich ihrer Qualitätsanforderungen? Ist es möglich, die Gesamtservicequalität einer gesamten intermodalen Gütersendung zu beurteilen, indem mit dieser Methodik die einzelnen Teile der Kette bewertet werden? Bis zu welcher Stufe des Güterverkehrsnetzes kann eine solche Qualitätsmessung angewandt werden?

Zuerst wurde eine Standardisierung der Transportkette vorgenommen, welche alle ihre Elemente in zwei Gruppen einteilt: Logistikprozesse und Transportprozesse. Ein Transportprozess besteht aus der Bewegung von Gütern mittels eines Transportsystems. In dieser Dissertation werden Schienenverkehr, Strassenverkehr, Binnenschifffahrt und Kurzstreckenseeverkehr berücksichtig. Ein Logistikprozess hängt von der Art des Transportprodukts ab und läuft in einer Logistikanlage ab. Durch die Kombination von Transport- und Logistikprozessen können Logistikdienstleister Transportleistungen organisieren welche die geographischen und die Marktanforderungen der Verlader erfüllen.

Als zweites wurde eine Definition für die Servicequalität im Güterverkehr entwickelt. Dafür wurde EN 13816 für den öffentlichen Personenverkehr (CEN, 2002) als Referenz verwendet und der Qualitätskreis an den Güterverkehr angepasst. Dieser angepasste Qualitätskreis führt ein Set von Beziehungen zwischen Güterverkehrsleistung und Kundenzufriedenheit ein. Als Resultat wurde definiert, dass die Leistungsqualität im Güterverkehr die durch den Verlader wahrgenommene Qualität eines Transport- oder eines Logistikprozesses unter Berücksichtigung der Transport- und Logistikleistungen und der Kundenorientierung des Logistikdienstleisters ist.

Als drittes wurde ein kundenorientiertes Messsystem für Logistikdienstleister entwickelt. Dieses Messsystem wurde als Teil eines Forschungsprojekts für SBB Cargo in der Schweiz entwickelt und basiert auf der Expertise und auf Daten von Stakeholdern in allen Teilen der Logistikkette. Die vorgeschlagene Methode ist ein Indikatorensystem, welches auf einer theoretischen Grundlage sowie auf Expertenworkshops aufbaut und mittels empirischer Daten validiert wurde. Die Methode kann verwendet werden, um den Grad der Kundenorientierung von Logistikdienstleistern über die Zeit zu messen. Dies ermöglicht Dienstleistern, sich zu verbessern. Zudem können damit Vergleiche zwischen Unternehmen vorgenommen werden. Die entwickelte Methode kann durch eine Veränderung der

Gewichte und der Indikatoren so angepasst werden, dass spezifische Kundenanforderungen berücksichtigt werden.

Als viertes wurde eine Qualitätsskala entwickelt, genannt „Level-of-Service für den Güterverkehr“. Für die Entwicklung diese Messgrösse wurden Aussagen von Verladern zu ihren Präferenzen hinsichtlich Service verwendet. Sie verwendet transparente Indikatoren, welche die Beurteilung von Güterverkehrskorridoren und –netzen ermöglichen. Ebenso erlaubt sie ein Benchmarking von verschiedenen Verkehrsträgern mittels einer intermodalen Qualitätsskala, welche auf objektiven Kriterien aufbaut. Die Validierung der Methode erfolgt mit Fallstudien auf dem Schweizer Güterverkehrsnetz (Strasse und Schiene).

Die Hauptbeiträge dieser Dissertation sind ein besseres Verständnis des Servicequalitätskonzeptes für den Güterverkehr sowie die Entwicklung einer einheitlichen Bewertungsmethode für unimodale und intermodale Systeme. Es gibt zahlreiche mögliche Anwendungen für den „Level-of-Service für den Güterverkehr“, wie zum Beispiel die Unterstützung von Güterverkehrsplanern beim Entwurf von Linien, Terminals, und Angeboten; die Verbesserung der Leistung von Logistikdienstleistern; Entscheidungsunterstützung für Verlader bei der Wahl von Anbietern. Die in dieser Dissertation entwickelten Methoden weisen darauf hin, dass Qualitätsbewertungswerkzeuge für den Güterverkehr Potenzial aufweisen. Sie wurden als mögliche Ansätze zur objektiven Analyse der Infrastruktur sowie von Fracht- und Logistikdienstleistern validiert. Da alle Elemente einer Transportkette mittels derselben Parameter beurteilt werden können die Ergebnisse von Logistikaktivitäten unabhängig von Unternehmensgrösse, Standort, Verkehrsträger, usw. verglichen werden. Allerdings muss einige Herausforderungen hervorgehoben werden. Da der grösste Teil der Daten, welche für eine Analyse des Güterverkehrs benötigt werden, privaten Akteuren wie Logistikdienstleistern oder Verladern gehören, ist ein guter Kontakt zu diesen essenziell für die Durchführung von Güterverkehrsforschung.

Acknowledgements

M’agradaria començar agraint al Prof. Weidmann el seu guiatge i el seu suport durant tot el desenvolupament d’aquesta tesi, així com al Prof. Buckmann, qui m’ha ajudat tant en la tesi com en diversos projectes aquests darrers anys a l’IVT. A més m’agradaria agrair al Prof. Leerkamp que acceptés de ser el meu tutor extern i que em procurés feedback constructiu per la culminació de la tesi. No voldria oblidar-me d’agrair a la Dr. Menéndez que em convidés a venir a Zuric a desenvolupar la meva carrera com a investigador i a en Santi que em donés la oportunitat, mentre treballava al CETMO, d’assistir a aquelles conferències que finalment em van fer anar a parar a Zuric.

Voldria esmentar també a tots els companys del departament, tant del grup VS, com del grup SVT i del grup VPL. Amb ells he passat gairebé sis any creixent com a professional i com a persona, i la seva petjada ja és per sempre inesborrable. Hem compartit moltes hores d’oficina però també pauses, conferències, viatges i aperitius. Gent de tots els orígens i costums que compartim passió pel món dels transports i la enginyeria. A més, no puc deixar d’esmentar les companyes del Sekretariat, amb qui sempre he pogut comptar i que m’han ajudat en tants i tants moments.

Per altra banda, em fa molta il·lusió esmentar les amistats que he fet durant aquests anys a Zuric, i que ja formen part de la meva vida per sempre. Grans amics com en Gerard, en Pablo o en Kyle, d’entre molts d’altres, que m’han ajudat a fer, de la meva estada a Zuric, una segona casa. Totes les aventures que hem viscut plegats seran per sempre part de mi. Finalment vull dir a la Cheri i a la meva família, que els hi estic molt agraït per tot el que han fet per mi i que no podria haver fet tot això sense ells ni el seu amor. Espero poder correspondre’ls com es mereixen.

Contents

List of Tables

List of Figures

1 Introduction

1.1 Motivation

One of the most important goals in any society is to satisfy its citizen needs. Due to the fact that not all the regions can be self-sufficient, regions trade goods amongst themselves in order to satisfy those needs. To accomplish this trade, goods are transported from one region to another, therefore developing a chain of distribution that gets more and more complicated over the pass of years and through production specialization, until becoming a basic part of our economic system. Nowadays the European Union aims to shift the share of road transport in favour to the alternative land transport modes such as rail, inland waterways and short sea shipping. This means that the intermodal transport should increase to allow this shift, although there are three main problems with intermodal transport: quality, price and coverage. Unfortunately, intermodal transport tends to be slower, less reliable and more expensive than road transport, and it is only offered in some corridors. Thus, a deeper knowledge of the quality concept in freight transport is needed.

Quality of transport services is perceived directly by the clients and crucial for their decision of the transport modes. Quality is highly influenced by the state of the transport infrastructure and operation, therefore measuring the quality of service according to some standards is important. In order to estimate quality, the Level of Service (LoS) concept has been broadly introduced in individual and collective transport. LoS is a discrete classification of the quality experienced by users. In passenger road transportation it evaluates, for instance, the quality of the traffic flow perceived by the users. It has been applied to pedestrian and public transport systems as well, but never in a comprehensive way to freight transport. However, there exist fundamental differences between passenger and freight transport systems. For instance, in terminal operation the differences are the most acute since they concern different facilities and often different locations. While each passenger is an independent decision-making unit, each load of freight must be managed from its origin to its destination (Weber, 2007). Along the whole transport chain, a strong organizational body is needed.

Nowadays it is not possible to compare the performance of different transport means in terms of quality in the same corridor, or to compare the performance of different corridors among them. It is neither possible to compare different variants of a freight corridor projects in terms of quality. So, the present state of the quality measurement systems does not support decision making of infrastructures investments. The aim of this research is to get a deep insight in measuring quality of service perceived by the shippers and based upon this to develop a freight LoS. Based on existing data and evaluation of selected European freight corridors, the approach will develop a freight transport quality scale directly related with the type of good shipped and the type of logistic network used. It will take into account the four main transport means in Europe (rail, road, inland waterway transport [IWT] and short sea shipping [SSS]), as well as the quality of the intermodal centres participating in the shipment process. A fixed set of transport attributes will be used to evaluate the quality of the transport in absolute values, regardless of the transport modes involved in the shipment. Different quality needs arise depending on the commodity group transported and the type of logistic network used, so each case will be studied separately, but from a holistic perspective. This methodology will be proven in a test case on a section of a European TEN-T corridor.

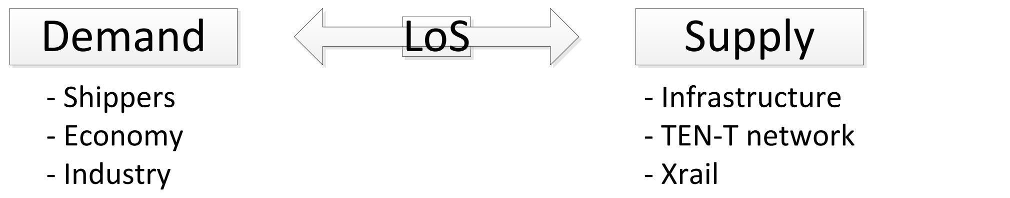
Table 1-1: Differences between freight and passenger transport

Freight	Passengers
• Must be loaded and transferred • Information must be processed through logistics managers • Logistics managers meet choices between transport modes "rationally" • Require limited travel accommodations • Exist risk of lost and damage	• Board, get off and transfer without assistance • Process information and act on it without assistance • Make choices between transport modes without assistance but often irrationally • Require travel accommodations related to comfort and safety

Source: (Weber, 2007)

The quality system will allow one to evaluate holistically the intermodal and intramodal freight transport in order to get a harmonized performance of the quality, and to compare different elements of the transport chain with different characteristics. Moreover, it aims to be used as a support of decision making in investment allocations and transport policy.

Figure 1-1: Level-of-Service as a link between demand and supply in freight transport



Source: Author

1.2 Goal and research question

Freight transport networks are strongly related with social-economic wealth distribution. They are key points of any country's production scheme and they are crucial for the industrial and the social development. Important parameters such as GDP are directly proportional to volumes of goods transported within a geographical territory (European Commission, 2014). Thus, they are not an isolated topic of study but, au contraire, they are linked with economy, sociology, industrial models and environmental policies. Even though all these mentioned ramifications of the freight transport networks influences exist, this research will focus only on the measurable aspects of transportation.

The goal of this research is to develop a methodology to measure the service quality in freight transport networks. It aims to further develop the service quality definition and classification in freight transport.

This research project aims to answer the following key question:

Is it possible to evaluate the quality of a freight transport chain perceived by a shipper in a way that it takes into account commodity group and logistic network specific needs and to make it comparable to other transport chains?

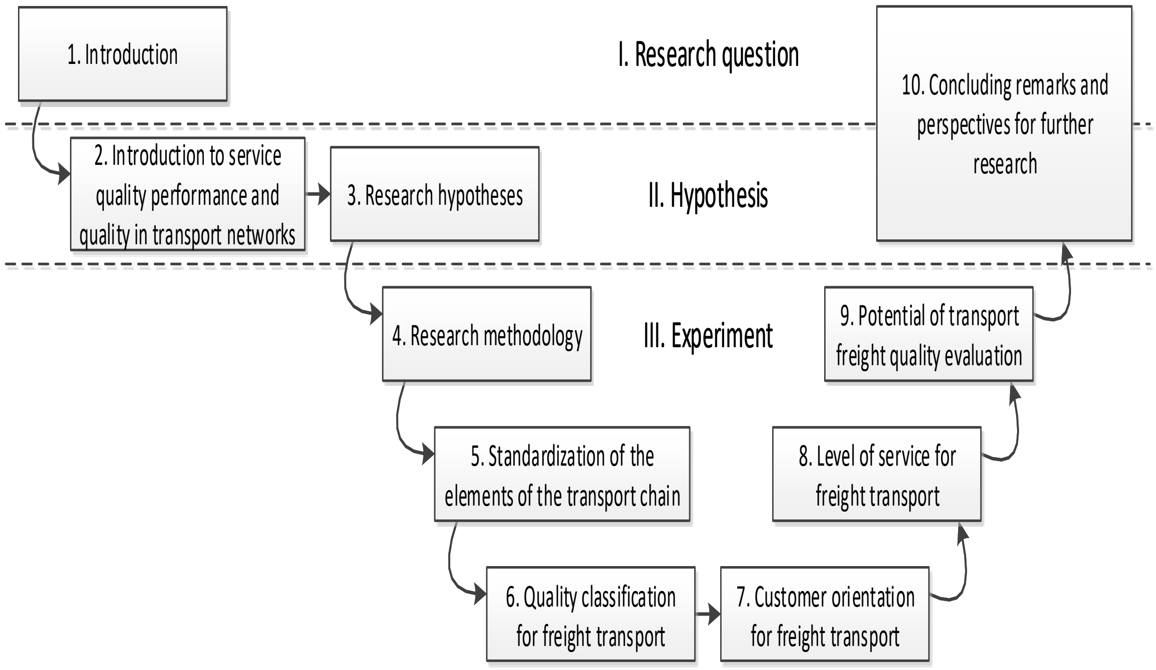
This implies the following detailed questions:

1. Which is the right approach to evaluate a transport chain? Does a transport chain consist of generic elements? Is possible to evaluate it holistically or is it better to evaluate each of the existing activities of the transport chain?
2. How to evaluate the quality of a transport chain? Which are the most suitable tools?
3. How to grade and classify the quality of service in a transport chain? Is it possible to apply the concept of Level-of-Service to freight transport? At which parts of the transport chain the quality of service can be measured using this methodology?
4. Are all types of goods homogeneous insofar as their quality standards?
5. Is it possible to evaluate the overall quality of service of an entire intermodal freight shipment by using this methodology to evaluate the quality of each of its elements?
6. Until which level of the freight network can such a quality measurement approach be applied?

1.3 Structure

The aforementioned research questions lead to the following basic structure of the study. Chapter 2 provides general introduction to the main topics of this research. This comprises an overview of the socio-economic context, “quality” definitions, quality measurements in industrial networks, service quality in transports, level of service concept, willingness to pay, price elasticity and freight market. The introduction is followed by chapter 3, which retakes the questions exposed in chapter 1.2 and links them to the set of research hypotheses of this study and the discussion of current gaps of the research. The methodological concept is subsequently presented in chapter 4. The research hypothesis are used to build up a set of experiments explained in Chapters 5 to 9. Chapter 5 is dedicated to analyses on the freight transport chain, while chapters 6 is dedicated to classification and measurement of freight transport quality. In Chapter 7, a methodology to evaluate customer orientation for freight transport is developed. Chapter 8 is dedicated to the development of the performance Level of Service for freight transport. The results of chapters 7 and 8 are brought together in chapter 9 and discussed in more detail by means of several case studies. These experiments are used to verify the hypothesis in Chapter 10. The study closes with the summary of key results and answers the research question, where are also mentioned the perspectives for further research.

Figure 1-2: Dissertation structure by chapters



Source: Author

1.4 Key words definitions

Along this dissertation the following key words are used recurrently. To clarify the intended meaning by the author, their meant meaning is described

- *Node*: Transport terminal where a freight transport shipment starts, ends, or tranships. It can be an access point to a network.
- *Link:* Transport infrastructure that connects two nodes with each other directly.
- *Corridor*: Group of links and nodes interrelated that share transport flows among the same axe connecting two main points of the network.
- *Network*: Group of nodes and links that connect all nodes of a geography, allowing the access to each node from any other by at least one route.

2 Introduction to service quality performance and quality in transport networks

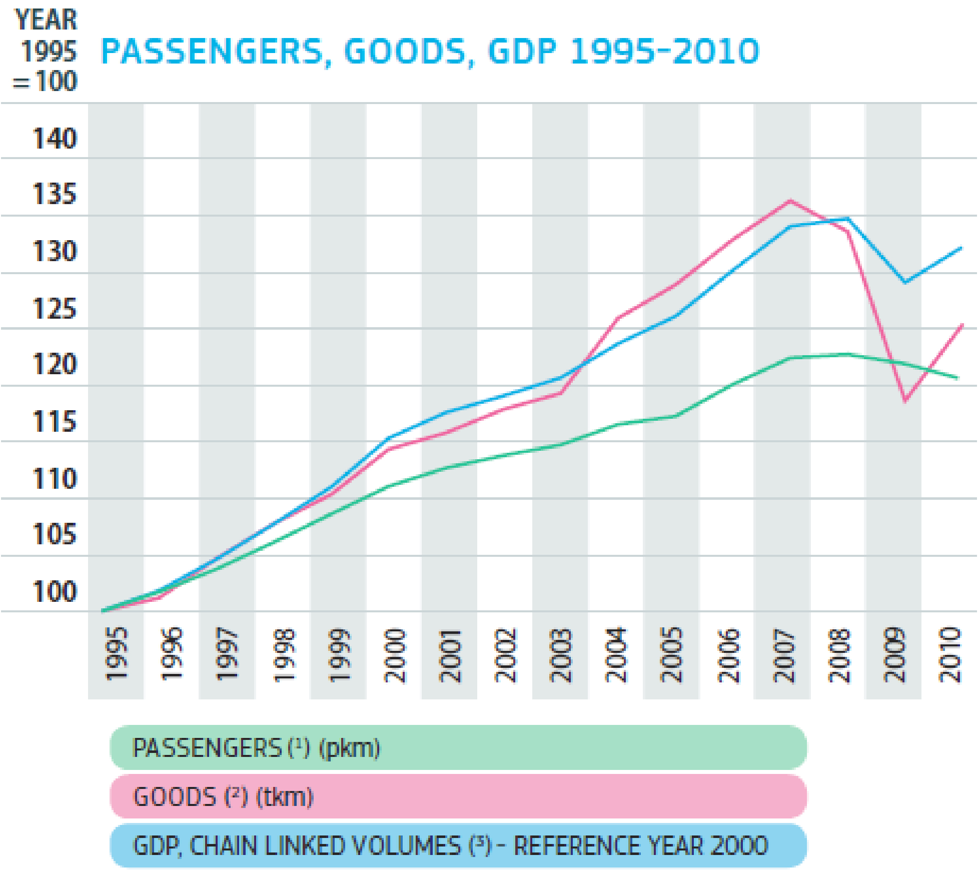
2.1 Socio-economic context

Trade and distribution are strongly linked to wealth in society. Freight transport systems have a strong relation with socio-economic dynamics. They can ensure access to markets and resources. Since the industrial revolution, and even before, the international, regional and local transport systems have been linked to economic activities. Besides the economic contribution to the GDP, these systems also produce negative impacts in society such as congestion, accidents and mobility gaps (Weber, 2007). International freight transport has increased for the last years. It is expected that growth on global freight trade will continue and some sources even predict that the trade flows will be doubled by 50 years (Sandberg, Spalding, Schweizer, & Associates, 2004). In the past 30 years global trade in EU has doubled, and it is expected that this trend will last (Kernohan, 2006).

The current situation of the European freight transport is challenging (Ruijgrok & Tavasszy, 2007):

- The transport market is highly fragmented due to the growth of smaller, customized shipments in higher frequencies, affecting the supply side in terms of market share and specialization.
- Increasing transport prices due to the increment of taxes to internalize the external costs of transport activities, and increasing labour and fuel costs.
- Increasing level of congestion in freight corridors and shared passenger-freight corridors.
- Steady increment of service quality requirements.

Figure 2-1: Growth rate of GDP, passengers and freight transport for EU 27



Source: (European Commission, 2014)

(1) The passengers measured in pkm correspond to those who traveled by cars, powered two-wheelers, buses & coaches, tram & metro, railways, intra-EU air and intra-EU sea.

(2) The transported goods measured in tkm correspond to road, rail, inland waterways, oil pipelines, intra-EU air and intra-EU sea.

Table 2-1: Annual growth rates for EU-27

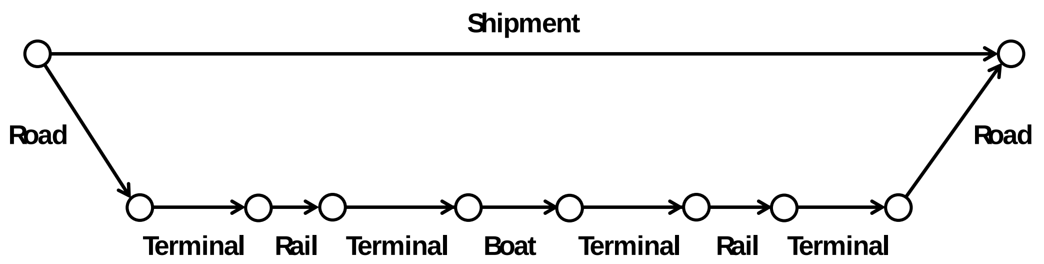
	1995-2010 p.a.	2000-2010 p.a.	2009-2010
GDP at year 2000 prices and exchange rates	1.9 %	1.4 %	2.0 %
Passenger transport (pkm)	1.3 %	0.9 %	-1.0 %
Freight transport (tkm)	1.5 %	0.9 %	5.3 %

Source: (European Commission, 2014)

This reality leads to the need to increase capacity and quality in order to better adjust to a globalizing economy. Flexibility and hybrid structures in freight transport systems will be needed to accommodate small and large scale, slow and just-in-time shipments (Ruijgrok & Tavasszy, 2007). Traditionally, this increase in quality and capacity was achieved by building new infrastructure, unfortunately the amount of resources that can be invested in developing new infrastructure is finite (Daehre, 2012). A more holistic approach is needed.

Therefore, it is crucial to measure freight transport quality on entire transport chains to identify the weak parts of network, so that the resources can be optimally allocated. But a tool that compares and evaluates the freight performance in such a way is missing. Nowadays, it even does not exist an international agreement for freight transport quality. Each national administration, shipper, operator, infrastructure manager, etc., has its own standards and quality measures, usually referred to different indicators and values. Moreover it does not exist a standardized method to compare quality of service by different transport modes (Islam & Zunder, 2014). Thus, this project aims to develop a method for quality assessment for freight in the European context. This method should be an innovative key that allows to evaluate holistically the quality provided by the freight corridors and the quality of freight shipments perceived by the shippers.

Figure 2-2: Example of an intermodal shipment schema



Source: Author

2.2 "Quality" definitions

The Oxford Dictionary of Construction, Surveying and Civil Engineering (Gorse, Johnston, & Pritchard, n.d.) defines "Quality" as:

1. *A standard of service or a product.*
2. *The degree that the characteristics of a product fulfil its requirements.*
3. *The product's fitness for use or purpose.*
4. *The expected characteristics of a product or service that are entirely defined by the end user, evolving and developing with customer requirements and expectations.*

Although these four definitions are implemented in the concept developed in this dissertation, the deep development of the Quality concept done by J. M. Juran is strongly taken into account in this dissertation. Juran defines Quality in two ways (Juran & Godfrey, 1998):

1. *"Quality" means those features of products which meet customer needs and thereby provide customer satisfaction. In this sense, the meaning of quality is oriented to income. The purpose of such higher quality is to provide greater customer satisfaction and, one hopes, to increase income. However, providing more and/or better quality features usually requires an investment and hence usually involves increases in costs. Higher quality in this sense usually "costs more."*
2. *"Quality" means freedom from deficiencies—freedom from errors that require doing work over again (rework) or that result in field failures, customer dissatisfaction, customer claims, and soon. In this sense, the meaning of quality is oriented to costs, and higher quality usually "costs less".* Table 2-2 elaborates on these two definitions:

Table 2-2: The meanings of quality

Product features that meet customer needs	**Freedom from deficiencies**
Higher quality enables companies to: • Increase customer satisfaction • Make products salable • Meet competition • Increase market share • Provide sales income • Secure premium prices The major effect is on sales. Usually, higher quality costs more.	Higher quality enables companies to: • Reduce error rates • Reduce rework, waste • Reduce field failures, • warranty charges • Reduce customer dissatisfaction • Reduce inspection, test • Shorten time to put new products on the market • Increase yields, capacity • Improve delivery performance Major effect is on costs. Usually, higher quality costs less.

Source: (Juran & Godfrey, 1998)

Juran also defines basic key words to describe what quality is (Juran & Godfrey, 1998):

- *Product: The output of any process. To many economists, products include both goods and services. However, under popular usage, "product" often means goods only.*
- *Product feature: A property possessed by goods or services that is intended to meet customer needs.*
- *Customer: Anyone who is affected by the product or by the process used to produce the product. Customers may be external or internal.*

- *Customer satisfaction: A state of affairs in which customers feel that their expectations have been met by the product features.*
- *Deficiency: Any fault (defect or error) that impairs a product's fitness for use. Deficiencies take such forms as office errors, factory scrap, power outages, failures to meet delivery dates, and inoperable goods.*
- *Customer dissatisfaction: A state of affairs in which deficiencies (in goods or services) result in customer annoyance, complaints, claims, and so on.*

Furthermore Juran emphasizes the distinctions between "Satisfaction" and "Dissatisfaction", underlining that this two concepts are not opposites (Juran & Godfrey, 1998): "*Customer satisfaction comes from those features which induce customers to buy the product. Dissatisfaction has its origin in deficiencies and is why customers complain. Some products give little or no dissatisfaction; they do what the producer said they would do. Yet they are not saleable because some competing product has features that provide greater customer satisfaction.*"

2.3 Quality measurements in industrial networks

Transportation networks have similarities in terms of quality estimation with other industrial networks such as telecommunication and electricity. Starting from the fact that it is not possible to store their product (transport, communication or electricity), major difference with other industrial networks such as gas or water supply networks. These networks provide a service usually consumed following a temporal pattern (e.g. peak hours, low peak hours, weekdays, and weekends). It also supposes an elevated initial investment (Knieps, 2006) in terms of infrastructure (e.g., cables, pipes, tracks, antennas, and control centres, security equipment). Due to these reasons, the costumers of these services make similar experiences consuming these services, and they complain about similar issues.

In the past years some research has been done in order to assess the Quality of Service (QoS) in these industries or economical activities (Albacete-Sáez, Mar Fuentes-Fuentes, & Javier Lloréns-Montes, 2007; Clements, 2004; Giannakis, Jamasb, & Pollitt, 2005; Growitsch, Jamasb, & Pollitt, 2009; Homburg & Rudolph, 2001; Lin, 2007; Lu, Zhang, & Wang, 2009; Martínez-Caro & Martínez-García, 2007; Martínez Caro & Martínez García, 2008). The concept of QoS has been discussed and implemented in several industrial networks, such as electricity distribution, telecommunication, leisure such as travel or accommodation, and industrial markets. Marketing literature underline the importance of QoS and states it is a critical success factor. There are many methods to measure QoS, such as SERVQUAL (SERVice QUALity), SERVPERF (SERVice PERFormance), and RSQS (Retail Service Quality Scale). Developed in the end of the 80's and during the 90's those methods consist of a scale of quality that compares the QoS expected by the costumers to the experienced quality. They take into account parameters such as tangibles, reliability, responsiveness, assurance and empathy. Nowadays there are new methods to evaluate the QoS in industrial networks such DEA (Data Envelopment Analysis) applied to those networks to improve their investments and keep a better position in the market.

Thanks to all the research on quality evaluation techniques and subsequent application on several industrial sectors, main findings have occurred. For some industrial sectors clear links between firm size, technical efficiency and QoS have been stated (Growitsch et al., 2009). Other studies show that "soft" facts such as interaction with the costumer and processes accompanying products have a deep impact in customer satisfaction, and alerts companies to not only focus in product optimization to improve QoS (Homburg & Rudolph, 2001; Lu et al., 2009). Furthermore these evaluation techniques allow to compare different companies of the same sector and state through certain indicators which are the ones that have a better performance and therefore a better level of satisfaction within their clients. The research in quality for industrial networks keeps ongoing and it is applied to other sectors due to its current positive results.

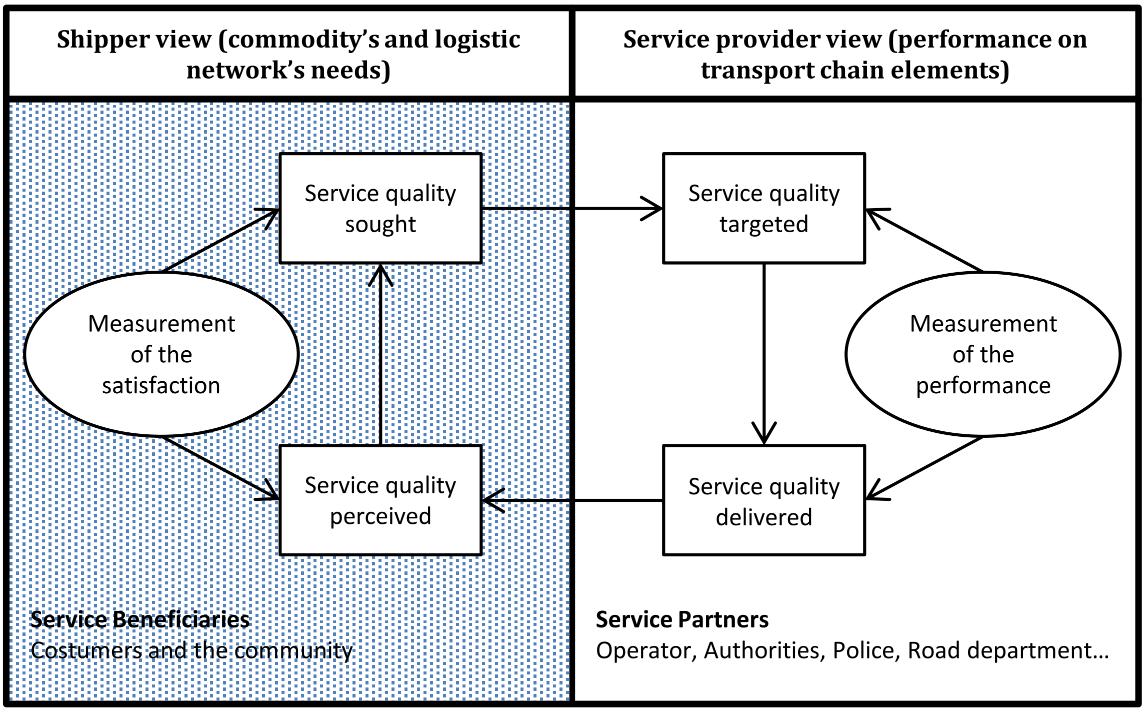
2.4 Service Quality in transport

It is needed to take into account that the quality of service can be perceived under different perspectives. Depending on the focus, one might define and quantify quality by different factors. The European Standard EN 13816 for Public passenger transport (CEN, 2002) explains different types of Service Quality (SQ) and the relationships between them. It aims to provide guidance for defining, targeting and measuring quality of service. In order to respect the exiting terminology in quality literature, SQ and QoS will be used according to the source used although they are a very similar concept and could be referred to by using the same term. The EN13816 norm defines four types of SQ:

- SQ sought, it is the one costumers would like to have.
- SQ perceived, it is the one costumers think they receive.
- SQ targeted, it is the one service providers would like to offer.
- SQ delivered, it is the one service providers really offer.

The first two SQ reflect the costumer view, and the other two the service provider's one. The difference between SQ sought and SQ perceived is the degree of customer satisfaction. The difference between SQ targeted and SQ delivered is a measure for service providers' efficiency. The difference between SQ sought and SQ targeted is a measure for the capability of the service provider to direct their efforts towards the costumer quality needs. The difference between the SQ perceived and the SQ delivered is a measure of the knowledge of the costumers about the real function of the service delivered.

Figure 2-3: Modification of the Service quality loop



Source: Adapted from (CEN, 2002)

The quality criteria are divided in 8 categories: availability, accessibility, information, time, customer care, comfort, security and environmental impact. Despite comfort (for obvious reasons) the other categories can be applicable to the freight transport systems. That will be the case, except for the environmental impact, which is not included in this research. Therefore, an adaption of the service quality loop to freight transport is below depicted to show general overview of the scope of the quality question for this research.

2.5 Level of Service concept

Level of Service (LoS) is a measure first developed for the U.S. High Capacity Manual (HCM) in 1965 in order to determine the quality of the service of a transportation infrastructure under given conditions (Highway Research Board, 1965). This concept was originally applied on highways and roads but nowadays is also applied in urban areas, intersections, and roundabouts, thanks to the updates of more recent experience and improved data (FDOT, 2002; TRB, 2000). In the last years a LoS concept has been adapted to other transport sectors such as public transport and pedestrians (Dorbritz & Scherer, 2011), and also intermodal freight terminals (Ballis, 2004), a topic strongly related with this project.

LoS is structured as a discrete classification that starts in maximum quality of service and goes down to the minimum quality at which a transport system is hardly useable. Every level is labelled by a letter (e.g., A, B, C, D, E, F), and qualitatively characterized by the perceived quality of the transportation flow (see citation below). This scale can be applied to any subject. In the HCM the subject transported are passengers as well as in the public transport or the pedestrian LoS. It is a generic and open concept to be applied also in the transportation of goods.

Citation 1: LoS description for road transport

LOS A describes free-flow operations. Free-flow speeds prevail. Vehicles are almost completely unimpeded in their ability to manoeuvre within the traffic stream. The effects of incidents or point breakdowns are easily absorbed at this level.

LOS B represents reasonably free flow, and free-flow speeds are maintained. The ability to manoeuvre within the traffic stream is only slightly restricted, and the general level of physical and psychological comfort provided to drivers is still high. The effects of minor incidents and point breakdowns are still easily absorbed.

LOS C provides for flow with speeds at or near the FFS of the freeway. Freedom to manoeuvre within the traffic stream is noticeably restricted, and lane changes require more care and vigilance on the part of the driver. Minor incidents may still be absorbed, but the local deterioration in service will be substantial. Queues may be expected to form behind any significant blockage.

LOS D is the level at which speeds begin to decline slightly with increasing flows and density begins to increase somewhat more quickly. Freedom to manoeuvre within the traffic stream is more noticeably limited, and the driver experiences reduced physical and psychological comfort levels. Even minor incidents can be expected to create queuing, because the traffic stream has little space to absorb disruptions.

At its highest density value, LOS E describes operation at capacity. Operations at this level are volatile, because there are virtually no usable gaps in the traffic stream. Vehicles are closely spaced, leaving little room to manoeuvre within the traffic stream at speeds that still exceed 80 km/h. Any disruption of the traffic stream, such as vehicles entering from a ramp or a vehicle changing lanes, can establish a disruption wave that propagates throughout the upstream traffic flow. At capacity, the traffic stream has no ability to dissipate even the most minor disruption, and any incident can be expected to produce a serious breakdown with extensive queuing. Manoeuvrability within the traffic stream is extremely limited, and the level of physical and psychological comfort afforded the driver is poor.

LOS F describes breakdowns in vehicular flow. Such conditions generally exist within queues forming behind breakdown points. Breakdowns occur for a number of reasons:

- *Traffic incidents can cause a temporary reduction in the capacity of a short segment, so that the number of vehicles arriving at the point is greater than the number of vehicles that can move through it.*
- *Points of recurring congestion, such as merge or weaving segments and lane drops, experience very high demand in which the number of vehicles arriving is greater than the number of vehicles discharged.*
- *In forecasting situations, the projected peak-hour (or other) flow rate can exceed the estimated capacity of the location.*

Note that in all cases, breakdown occurs when the ratio of existing demand to actual capacity or of forecast demand to estimated capacity exceeds 1.00. Operations immediately downstream of such a point, however, are generally at or near capacity, and downstream operations improve (assuming that there are no additional downstream bottlenecks) as discharging vehicles move away from the bottleneck.

LOS F operations within a queue are the result of a breakdown or bottleneck at a downstream point. LOS F is also used to describe conditions at the point of the breakdown or the bottleneck and the queue discharge flow that occurs at speeds lower than the lowest speed foe LOS E, as well as the operations within the queue that forms upstream. Whenever LOS F conditions exist, they have the potential to extend upstream for significant distances.

Source: (TRB, 2000)

As mentioned, the LoS concept has recently been applied to other transportation fields, such as public transport, and pedestrian and cycling mobility (Weidmann, Kirsch, et al., 2014; Weidmann, Orth, Dorbritz, Schwertner, & Carrasco, 2014). These two recent works have been developed by the Institute for Transport Planning and Systems (IVT in German initials) of ETH Zürich, in collaboration with the Swiss Association of Road and Transportation Experts (VSS in German initials). Basing their work in several quality studies and the original LoS developed in the HCM (Highway Research Board, 1965), IVT further developed the quality concept concerning public transport, pedestrians and bicycles.

Due to the fact that the operator takes several decisions in public transport systems, concerning for instance which type of vehicle will be used or how the travel time is planned, the introduction of indicators that measure the delivered quality, other than capacity and capacity utilization, are needed. Thus, the LoS takes into account key aspects that determine the quality perceived by the users such as on-time performance or headways. Furthermore, the methodology allows to calculate the LoS of an element (a transport link or a station), and it also allows to calculate the LoS of transport corridors and networks thanks to algorithms that combine the LoS of each of their elements.

Sometimes the LoS concept is misused or used under other meanings in the transportation field. This is the case of the European freight and passenger transport model TRANS-TOOLS, which incorporates a decision tool called Level-of-Service. Despite its name, it does not correspond to the LoS definition above explained. In fact, this LoS used in TRANS-TOOLS is a group of self-produced matrices that includes yearly values such as volume of tons, passengers, vehicles between origin and destination or on a link. These matrices and values are used as a decision tool during the mode choice phase in the simulation model (Nielsen & Burgess, 2008).

2.6 Quality in freight transports, willingness to pay, price elasticity and transport logistics

Until now, the main research has been focused in developing freight demand models (Bolis & Maggi, 2003; de Jong & Ben-Akiva, 2007; Leerkamp, Dahmen, Janßen, & Vollmer, 2013; Macharis & Bontekoning, 2004; Meyburg, 1979; Rich, Holmblad, & Hansen, 2009), freight market classification (Fries, 2009; Fries, Nash, Wichser, & Abay, 2008), studies about shipper needs (Danielis, Marcucci, & Rotaris, 2005; Gray, 2007; McGinnis, 1979; Patterson, Ewing, & Haider, 2007; Vellay & De Joung, 2003) and quality preferences (Bouffioux, Beuthe, & Pauwels, 2006; Instituto di Recerche Economiche & Rapp Trans AG, 2005; Roberts & Wang, 1979). In the field of multimodal LoS some progress has been done for passenger transport and pedestrians (CEN, 2002; Dorbritz & Scherer, 2011). Also, freight transport has been studied from industrial logistics point of view.

Few authors have already considered directly the question of quality in freight transportation and most of them agree in the main aspects that involve in quality of service (Gray, 2007). In the USA study of shipper's attributes (McGinnis, 1979) eight topics to define quality in freight transportation are considered: freight rates, speed, reliability, loss and damage, inventories, company policy, shipper market conditions and influence of the shipper's costumers. Out of these eight factors, those that were found most important were the ones associated with speed, reliability, freight rates and loss and damage.

In 1979 P. Roberts develops a first LoS for freight attributes in the USA context (Roberts & Wang, 1979). The aim of that work was to develop econometrically estimated disaggregated models of shipper and receiver response to various logistic situations. It proposes some methods to forecast four quality attributes (equipment availability, transit time and reliability, loss and damage, transport charges associated with shipment size), so an estimated LoS of a shipment should be known in advance. A distinction of needs is stated depending on the commodity type of the good. The results are based on real data. No further work is found in this direction.

Since then, many authors have used similar attributes and indicators on this field. (Danielis et al., 2005) measured quality in intermodal freight transport in two Italian regions as a combination of travel time, risk of delay and risk of loss and damage. He concludes that the shippers have a big willingness to pay for a good quality in freight transport services, especially for reliability and safety. Even though it should be taken into account that the concept of quality might vary depending on the type of good and the size of the company, because they have strong links with certain transport or economic needs.

Commodity groups have been proved to be key factors for freight transport quality satisfaction. Many authors (Bolis & Maggi, 2003; Bouffioux et al., 2006; Danielis et al., 2005; Fries, 2009; Fries et al., 2008; Instituto di Recerche Economiche & Rapp Trans AG, 2005; Patterson et al., 2007; Vellay & De Joung, 2003) have identified different priorities in shippers' behaviour, depending on the type of good shipped. As a consequence, shippers have different willingness to pay. This is due to the value and requirements of the items involved.

Currently, certain methodologies exist to analyse how shippers evaluate and select freight transport services. These methodologies are used to design models which aim to predict the freight demand depending on the time horizon and on the decision maker (Macharis & Bontekoning, 2004). According to (Meyburg, 1979) there are three approaches to evaluate the modal choice by the shippers: The economic positivism, the technological positivism, and the perceptual approach. More recent studies based their forecast methods on price elasticity (de Jong & Ben-Akiva, 2007; Rich, Kveiborg, & Hansen, 2011), and a combination of current infrastructure LoS for road infrastructure and unlimited capacity for rail or IWT and SSS (Rich et al., 2009).

On the other hand, freight transportation is also studied from transport logistics point of view. Transport logistics can be seen as an instrument to achieve time and space bridging operations within the subsystems of acquisition and distribution logistics of any company logistics. At the same time, transport logistics is one of the three layers on logistics systems, which also include production logistics and infrastructure systems (Mest, 2011). Within this scope, shipper's perception of freight transport quality is directly influenced by their logistic acquisition, production and distribution systems.

2.7 Synthesis

The quantification of quality for industrial and transportation networks has been a research topic for the last 40 years. Two main branches of study are underlined: measurement of customer satisfaction and measurement of performance. Many areas, such as road transport have been deeply studied, but there are others, such as intermodal freight transport networks, that probably due to their complexity, have not achieved the same degree of improvement. Although certain research has been done in LoS for freight logistic areas, or some freight model such as TRANS-TOOLS includes some decision matrices called LoS matrices, it is a fact that it does not exist a tool for freight transport as robust as LoS for passenger road transport, or the recently developed LoS for pedestrians and bicycles, and the LoS for public transport.

The study of concepts such as willingness to pay and the classification of goods in commodities are useful tools to study freight transportation demand, they show some light in shipper's preferences and state the diversity of the freight market. Unfortunately, the freight transport supply is not as studied, and some knowledge is missing. Moreover, shippers' acquisition and distribution logistics' needs are also an influencing factor on shippers' freight transport quality perception. Therefore, it is necessary to develop this knowledge to study the overall system. Thus, in chapter 5 and chapter 6 the author aims to develop certain knowledge in this direction by standardizing the elements of a transport chain, so they can be studied as units systematically.

Over the general idea of quality, it is important to underline the work developed by the European Union stating the quality loop. Besides being really clarifying, it also points which type of quality is relevant for each purpose. Thus, this research is focusing in the perceived quality by shippers which is the one affecting their level of satisfaction within the logistic service, and therefore the one that counts when shippers value the transportation product.

The methodologies used to study quality in industrial networks do not apply to freight transport systems, but nevertheless they introduce the concept of client satisfaction and furthermore give examples of methodologies to study quality perceived. So, although they are not useful for this research they state that quality measurements exist and are needed to better understand clients and therefor improve the service and consequently improve the market. This concept is relevant in the study because it sets precedents of practice that help to further develop sectors and improve their performance and efficiency.

3 Research Hypotheses

This chapter introduces the general hypotheses of this study, which stand behind the research questions raised in chapter 1.2.

3.1 Quality evaluation

Which is the right approach to evaluate a transport chain? Does a transport chain consist of generic elements? Is possible to evaluate it holistically or is it better to evaluate each of the existing activities of the transport chain?

In literature one can find several descriptions about transport chains and logistics which explain the different activities that take place during a shipment. These activities could be divided in two big groups, one that includes transport and carriage of goods between nodes, and another that includes temporal storage of the goods, loading and unloading activities in transhipment points.

Hypothesis

- **It is possible to divide a transport chain in standardized elements (transport modes and transhipment points).**

How to evaluate the quality of a transport chain? Which are the most suitable tools?

Literature shows several examples of quality measurements either in industrial networks and transport networks. There also exist some studies about freight transport quality measurements. In all these studies a set of measurable indicators are used to evaluate the performance of the activity and therefore quantify, and later classify, the quality delivered or perceived.

Hypothesis

- **It is possible to evaluate each part of the transport chain by measurable quality indicators.**
- **Perceived Quality of Service is dependent on service provider’s freight performance and customer orientation.**

3.2 Quality classification

How to grade and classify the quality of service in a transport chain? Is it possible to apply the concept of Level-of-Service to freight transport? At which parts of the transport chain the quality of service can be measured using this methodology?

According to literature there are quality classifications for many types of industrial and transport network. One of the major examples is the Level-of-Service methodology developed in 1965 in the Highway Capacity Manual in the United States. It is a scale of quality (from A to F) that allows to grade the quality of a road infrastructure according to indicators such as capacity or speed limits. This same methodology has been applied in the past years also to public transport, pedestrian and bicycle mobility. The methodology is used to measure quality in any part of those transport networks.

Hypothesis

- **It is possible to define a measurable index for freight transport customer orientation to evaluate the quality of service not dependent from freight transport performance.**
- **It is possible to define a measurable LoS for each of the quality indicators of any part of the transport chain and they can be combined to evaluate a bigger section of the transport chain.**

Are all types of goods homogeneous insofar as their quality standards?

Some recent studies point out the link between type of good transported, price elasticity and mode choice. There are also studies that conclude that certain costumers have different willingness to pay for certain transport attributes depending on the type of good they need to transport.

Hypothesis

- **The LoS of a given shipment varies depending on the type of good transported.**

3.3 Level of implementation

Is it possible to evaluate the overall quality of service of an entire intermodal freight shipment by using this methodology to evaluate the quality of each of its elements?

The overall quality of a service is a function of the individual quality of all its parts. This is the reason why certain methodologies, in order to calculate clients' degree of satisfaction for certain services, are based on analyzing individually each element involved in those services. Therefore, seems reasonable to presume that a similar relationship might exist between an overall freight transport service, and its single elements.

Hypothesis

- **It is possible to evaluate the quality of service of an entire intermodal freight shipment by evaluating individually all its single parts.**

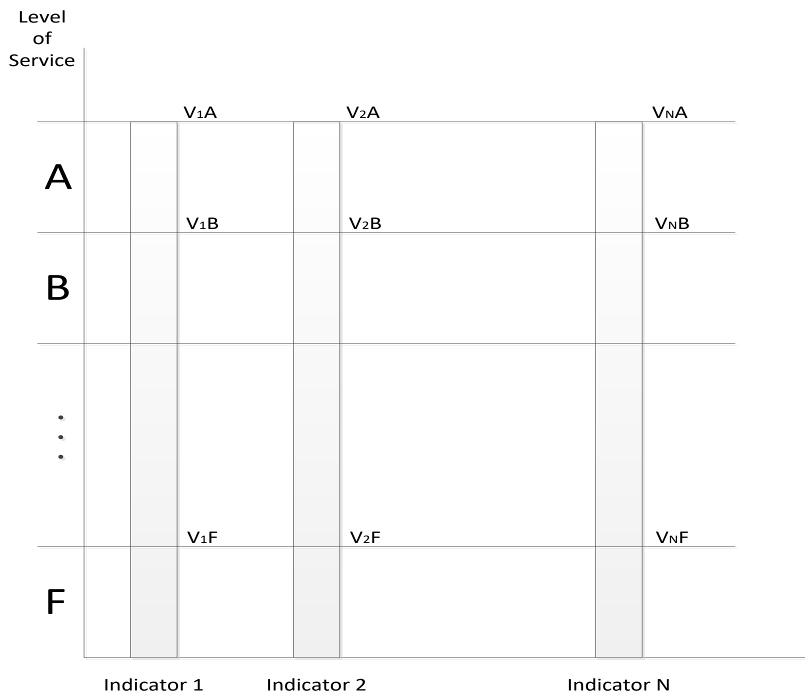
Until which level of the freight network can such a quality measurement approach be applied?

There exist certain conceptual differences between a transport link, a corridor and a network. The quality of a link has a narrower optic than the corridor, it takes into account the transport mode performance and the logistic are performance. On the other hand the quality of a corridor needs to integrate intermodal issues such as coordination and management. The quality concept for a network needs to integrate concepts such as connectivity, accessibility and interoperability. Therefore, to do a bottom up approach to calculate a LoS for freight transport on links and corridors, those concepts need to be integrated on the calculation process.

Hypothesis

- **It is possible to evaluate the LoS of a corridor based upon the values of the LoS of all its links.**
- **It is possible to evaluate the LoS of a full network based upon the values of the LoS of all its corridors in the infrastructure level and in the capacity level.**

Figure 3-1: Schema of the LoS for freight transport. V_iJ are the values between one level and the next one



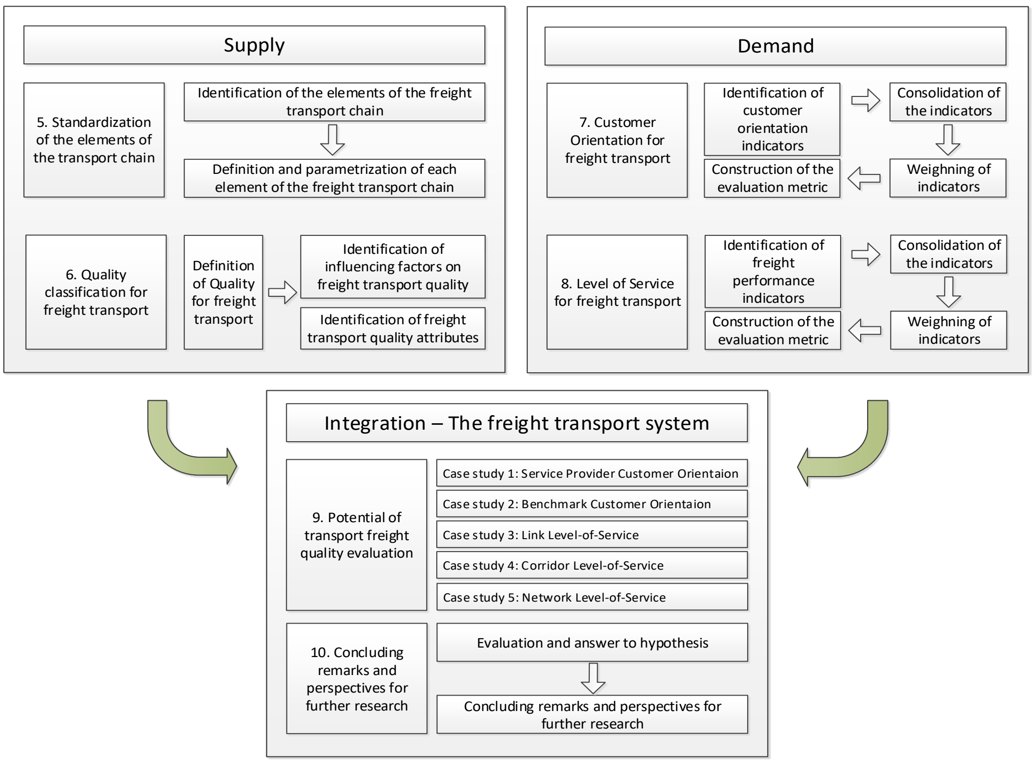
Source: Author

4 Research methodology

4.1 Methodological concept

To answer the questions formulated in chapter 3 and verify the hypothesis the following research work has been structured as Figure 4-1 illustrates. The main research is divided in three groups (Supply, Demand, and Integration – The freight transport system). The first block, “Supply” seeks to verify the hypothesis on standardization of the transport chain and quality attributes. The second block is labelled “Demand” and seeks to verify the hypothesis related with the LoS concept as well as the quality indicators and commodity groups. In the third block, through the case studies, the goal is to proof the concept and verify the hypothesis about the level of implementation of the LoS in a freight network. This structure should enable to answer all the questions of Chapter 3.

Figure 4-1: Methodological concept



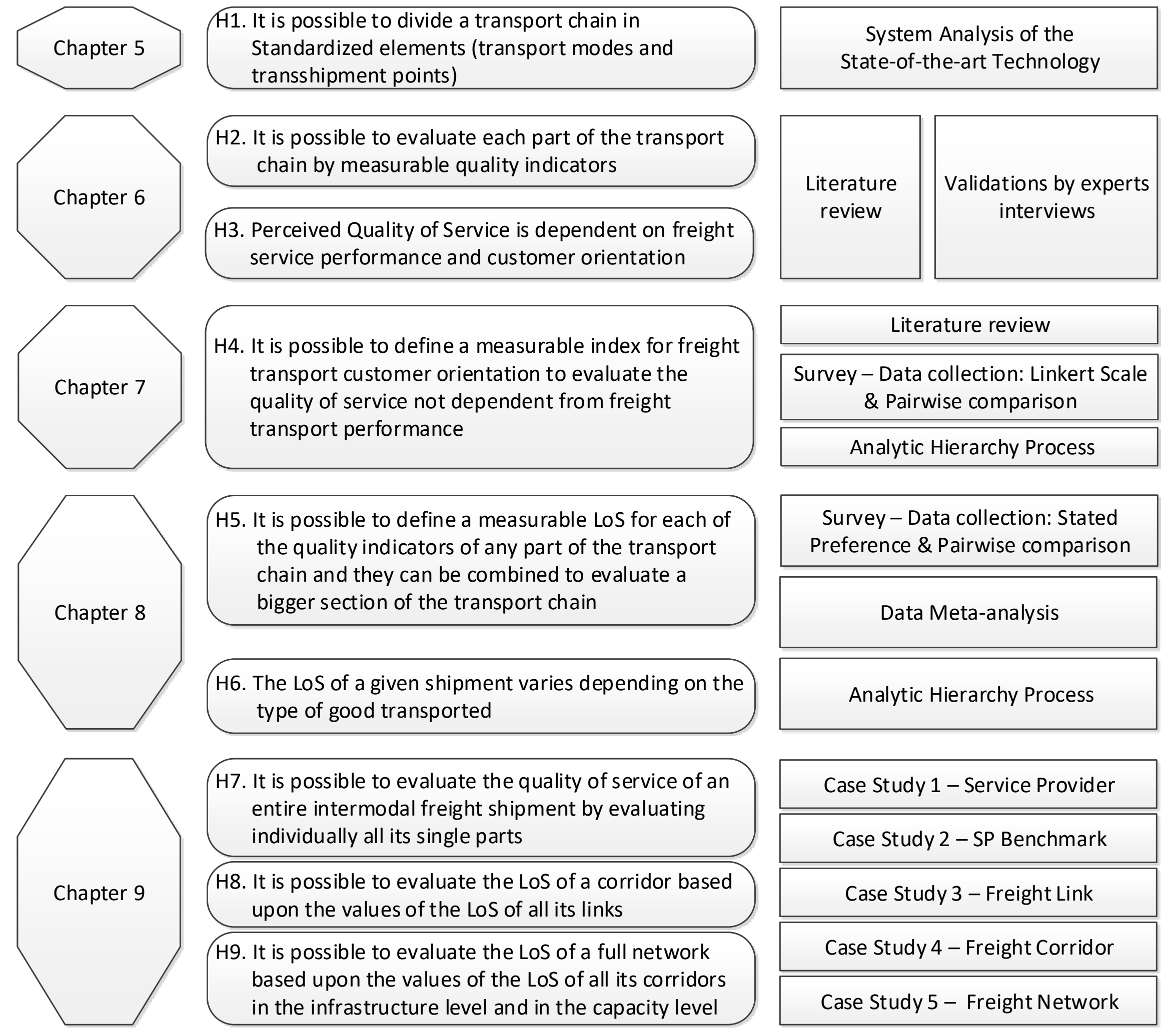
Source: Author

4.2 Applied methods

4.2.1 Overview

In order to verify the hypothesis, a number of methods are applied in this thesis. These methods are used in each chapter as Figure 4-2 indicates, depicting from left to right, the chapter, the hypothesis and the method applied.

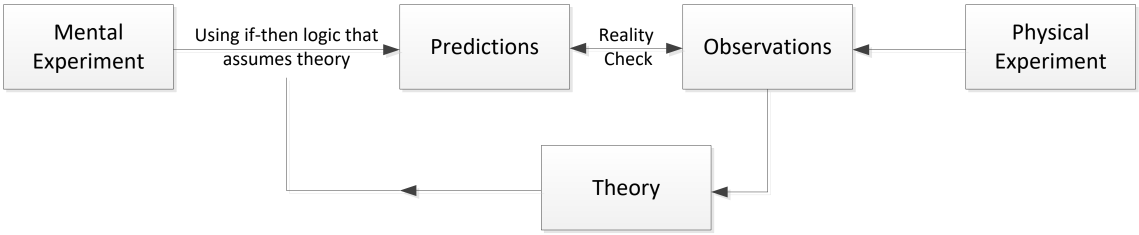
Figure 4-2: Methods distribution by chapters and hypothesis



Source: Author

The essence of scientific method has four main elements: Theory, observation, experiment and simulation. Observations from an experiment and predictions based on theory are compared in a reality check.

Figure 4-3: Scientific method



Source: Author

4.2.2 System analysis of the state-of-the-art technology

Chapter 5 aims to standardize the elements of the transport chain one by one, providing standard definitions for each process and each activity involved within the transport chain. Therefore it is needed a general method that applies a 'systems' or 'holistic' perspective by taking all aspects of the current freight transport chain situation into account, and by concentrating on the interactions between its different elements. Thus a system analysis of the state-of-the-art technology is the appropriate method to be used.

4.2.3 Freight transport quality attributes - Literature review

Literature review is a survey of a specific topic to contextualize and frame a research. It also implies an evaluation of the worth and validity of the publications for the specific research, considering that some of them might be contrary at ones hypothesis. This method will be applied in chapter 6 and chapter 7, to summarize the freight transport quality attributes that researchers have already highlighted as the more relevant ones according to certain parameters such as shipment distance, shipment size, commodity group, willingness to pay, national and international shipment, etc. This method will be used to decide which attributes will be taken into account to develop the LoS and the index for customer orientation. It belongs to the observation category and it is used to check the hypothesis H2, H3 and partially the hypothesis H4.

4.2.4 Survey - Data collection

The United Nations define Data Collection as: "*The process of gathering data. Data maybe observed, measured, or collected by means of questioning, as in a survey or census response"* (UNECE, 2000). Although methods might vary from discipline to discipline, the emphasis on ensuring accurate and honest collection remains the same. The main goal of collecting data is to obtain quality evidence that derive to rich data analysis and allows the construction of a convincing and credible answer to the research questions. Selection of appropriate data collection instruments and clearly delineated instructions for their correct use reduce the likelihood of errors occurring (Sapsford & Jupp, 2006). In this dissertation the three methods used to collect data are the Linkert Scale, the Pairwise Comparison and the Stated preference (SP).

Linkert Scale is a well-known data collection assessment or rating method (Likert, 1932). It uses a psychometric response scale to rank preferences or degree of agreement of survey participants regarding a set of statements. Usually, the scale used is the 5-point scale, where the extremes are “strongly agree” and “strongly disagree”, and in the middle “neither”, agree” or “disagree”. Linkert scales are summative scales, because responses can be analysed separately or together with the other related ones (Bertram, 2008). It has recently been concluded that the responses can be treated as ordinal data or as interval data. Moreover, the method can be used with small sample sizes, with unequal variances and with non-normal distributions (Norman, 2010).

Pairwise comparison is a method for comparing indicators one-on-one. Usually a group of experts judge the relative importance of each couple of indicators, whose results are used to calculate relative weights for the indicators. This method measures at the same time ordinal and cardinal importance and the results can be analysed for consistency using the consistency index, in case some inconsistencies occurred, increasing the reliability and accuracy of the analysis (Mendoza & Macoun, 1999). Among the different methods for analysing the data, the Analytical Hierarchic Process is the selected one for this particular dissertation (see Chapter 4.2.5).

Stated preference methods are a group of techniques to estimate utility functions by collecting statements from transport users about their preferences on different transport scenarios consisting on a set of alternatives pre-specified by some attributes. In those scenarios the researcher displays a set of situations to find out certain particularities about the reason behind transport user consumer’s preference. These methods were developed in 1970s (Kroes, Sheldon, & Sheldont, 1988). The survey techniques belong also to the observation category and it is applied to check the hypothesis H4, H5 and H6.

4.2.5 Analysis of the Survey – The analytic Hierarchy Process

The Analytic Hierarchy Process is a measurement method to set priorities or relative importance between a group of actions or alternatives. It is a special case of the analytic network process (ANP). The AHP was firstly developed by Saaty in 1980 and it enables to perform high-level quality analysis. Since then many authors used it to evaluate and compare decisions and strategies in a diverse group of applied fields, such as government, business, industry, healthcare, and education (Saaty, 1988, 1990; Shepard, 1972; Thurstone, 1927). According to (Saaty, 1990) the result of the AHP is a method of scaling between a group of actions or alternatives, and it can provide guidelines for the allocation of resources.

This methodology subdivides a complex decision-making or planning into its components or levels, and arranges them into an ascending hierarchic order. Afterwards, through pairwise comparisons (Saaty, 1988) between the different indicators, it compares and evaluates the hierarchical structure of the different elements that conform the decision thinking structure. This pairwise matrix is generated by establishing priorities for the main criteria by judging them in pairs for their relative importance. The procedure is based in stating how much more important is one element to another. The resulting matrix of order n compares $n(n-1)/2$ elements due to its reciprocal quality where all elements in the diagonal are equal to 1 (Saaty, 1988).

$$\begin{pmatrix} 1 & a_{1,2} & \cdots & a_{1,n-1} & a_{1,n} \\ (a_{1,2})^{-1} & 1 & & a_{2,n-1} & a_{2,n} \\ \vdots & & \ddots & \vdots & \\ (a_{1,n-1})^{-1} & (a_{2,n-1})^{-1} & \cdots & 1 & a_{n-1,n} \\ (a_{1,n})^{-1} & (a_{2,n})^{-1} & & (a_{n-1,n})^{-1} & 1 \end{pmatrix}$$

For a given level in the hierarchy the solution technique results in a n-element eigenvector of priorities by solving the eigenvalue problem $(A-\lambda I)X=0$. The components of the eigenvector correspond to the relative importance of each element (Saaty, 1990).

The axioms of this methodology are (Saaty, 1988):

- Reciprocal property, an element is equally important as itself, therefore $a_{i,i}=1$.
- Homogeneity that is characteristic of people's ability for making comparisons among things that are not too dissimilar with respect to a common property and, hence, the need for arranging them within an order preserving hierarchy.
- Dependence of a lower level on the adjacent higher level.
- An outcome can only reflect expectations when the latter are well represented in the hierarchy.

The AHP neither assumes transitivity (or the stronger condition of consistency) nor does it include strong assumptions of the usual notions of rationality.

The approach for this dissertation is to develop a hierarchy of key indicators that affect the quality performance for freight transport and analyse this structure with the AHP. To do so previously is needed to concrete the pairwise comparisons of each pair of indicators. This information will be extracted from the current state of art of the freight market, the studies of shippers' willingness to pay and price elasticity of freight transport products, and complemented with the shippers survey conducted during the development of this research.

The statistical analysis belong to the experiment category and it is used to check hypothesis H4, H5 and H6.

4.2.6 Proof-of-concept - Case study

To test and proof the developed concepts along the thesis case studies will be conducted. A case study is a methodology that analyse systems or events that are studied holistically by one or more methods. The case that is subject of study will provide an analytical frame within which the study is conducted and which the case illuminates and explicates (Johansson, 2003).

Several case studies will be conducted to evaluate the LoS methodology developed in this research. The allocation of this case studies will be real corridors of the TEN-T network that fulfil the requirements of intermodality, border-crossing, diversity of commodities and geography. Furthermore, a small network will also be tested in a case study to validate the last hypothesis of the research. The allocation of the case studies will depend on the data collected.

The test case belongs to the simulation category and it is used to check hypothesis H7, H8 and H9.

5 Standardization of the elements of the transport chain

5.1 The transport chain

Freight transportation is the physical process of transporting goods from an origin to an intended destination. The process is divided in two different partial processes: transportation processes and logistic processes. By combining transportation processes and logistic processes the freight transport operators transport goods. The combination of these processes is called transport chain (see Figure 5-1).

Figure 5-1: Schema of a transport chain

Source: Author

The Economic Commission for Europe defines Intermodal Transport as “The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes” (UNECE, 2001). It is important to distinguish it from Multimodal Transport, which consists in conveying one commodity with at least two different transport modes in an integrated manner. In this project four transport modes, and their transhipment points, will be considered: road, rail, waterways and short sea shipping, main transport modes in the European network, and intermodal terminals as transhipment points.

Figure 5-2: Examples of transport chains (traditional schemas)

Abbildung 1: Direktzug

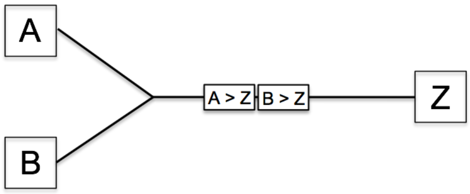


Abbildung 2: Feeder System

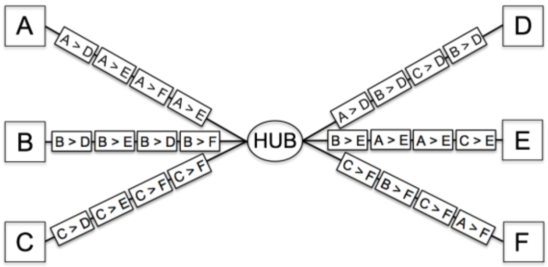


Abbildung 3: Hub & Spoke System

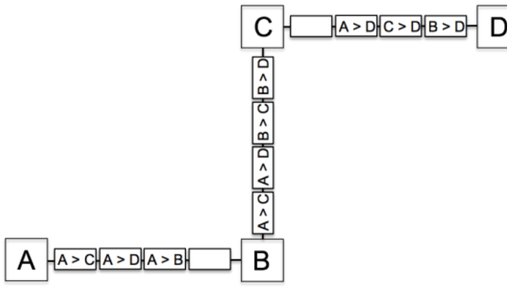
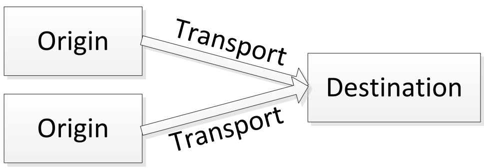


Abbildung 4: Linienzug

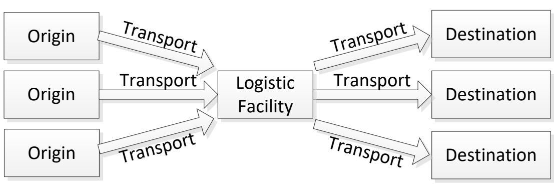
Source: (Wichser, 2010)

Figure 5-3: Examples of transport chains (proposed schemas)

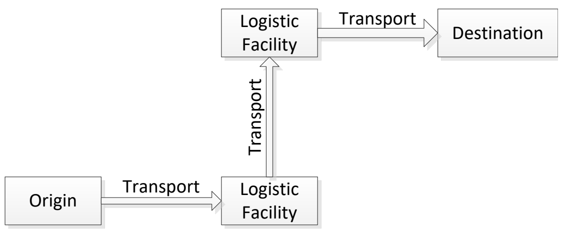
Direct Train



Feeder System



Hub & Spoke System



Linear Train

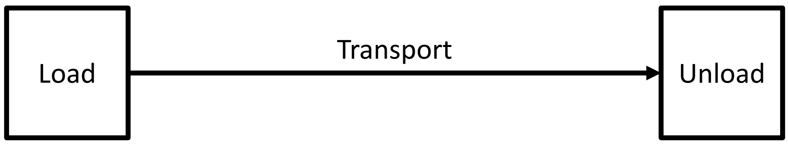
Source: Author

5.2 Logistic processes and logistic facilities

The logistic processes depend on the type of transport product (e.g., single wagon load, intermodal transport, full trains, etc.) and take place in a logistic facility. They can be simplified as: loading, unloading, transhipping, storing and shunting.

- *Loading* and *unloading* processes are those logistic processes responsible of moving the goods in and out the transport vehicle. These activities might be done manually or using mechanical devices such as cranes, forklifts, pipes (for liquids or bulk), etc., depending on the type of good and the equipment available. Operational standards must be followed to ensure safety and security requirements for the goods and the operators.

Figure 5-4: Shipment schema with only loading and unloading processes



Source: Author

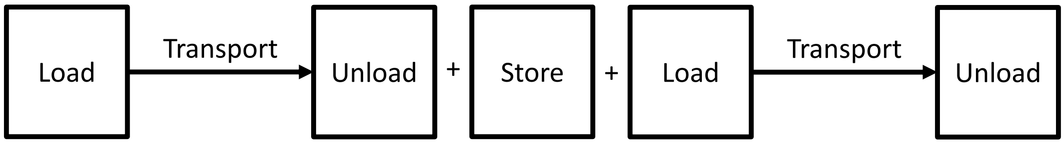
- *Transhipping processes* are those intended to shift the location of a good from one vehicle to another, so the shipment can proceed. This activity can also be done either manually or by mechanical devices such as cranes, forklifts, pipes (for liquids or bulk), etc., depending on the type of good and the equipment available. As well there are operational standards to be followed in order to ensure safety and security requirements for the goods and the operators. One special case of transhipment is Cross-docking. While transhipments processes usually include temporal storing of the cargo in some warehouse, cross-docking consists in transhipping cargo directly from one vehicle to the next one, including reassembling of the cargo.

Figure 5-5: Shipment schema with transhipment process between loading and unloading point

Source: Author

- *Storing* is a logistic process that consist on place a set of goods in a dedicated location where they can be safely saved from any type of weather or criminal action. This location need to be equipped properly so the goods are saved according to their specific requirements. The storing can be also done either manually or by mechanical devices such as cranes, forklifts, pipes (for liquids or bulk), etc., depending on the type of good and the equipment available.

Figure 5-6: Shipment schema with storing process between loading and unloading point



Source: Author

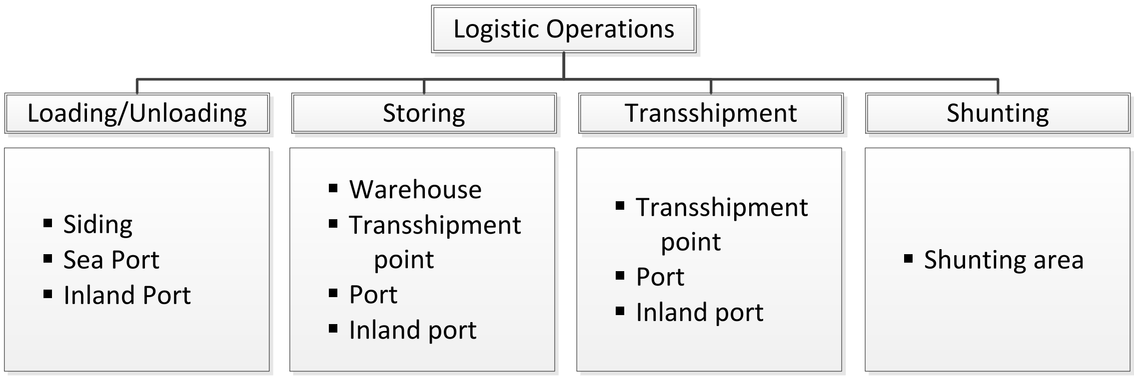
- *Shunting* is a vehicle sorting operation, which consists on exchanging position of non-motorized vehicles within the same transport formation connected to a tractor vehicle or, switching a non-motorized vehicle from on transport formation connected to a tractor vehicle to a different one. This operation is mostly used in hub-and-spoke networks, either in rail, road or IWT.
  - In road transport shunting is used to group, ungroup or sort combinations of tractor-trailer- semitrailer, tractor-trailer, tractor-semitrailer and tractor-semitrailer-semitrailer.
  - In rail transport shunting is mostly used in Single Wagon Load networks to sort wagons in shunting yards either by gravity procedures or by using shunting locomotives.
  - In IWT shunting is used as well to sort combination of push boat and barge(s) by the same principle. Some authors (Konings, Kreutzberger, & Maras, 2013) name this operation also horizontal handling process.

Figure 5-7: Shipment schema with shunting process between loading and unloading point

Source: Author

These logistic processes are carried out in logistic facilities that can be classified as: warehouse, siding, transhipment point, shunting area, seaport, and inland port, etc. Figure 5-8 shows the existing logistic processes and indicates the logistic facilities where they usually take place.

Figure 5-8: Logistic operations, logistic areas and facilities



Source: Author

Transhipment facilities are nodes of the freight network where cargo is assembled and/or dispersed. There is equipment for loading and unloading goods and areas dedicated to allocating the transport means. Usually these facilities are classified according to the type of cargo they handle (bulk, general or containers) and the type of transport mode allowed (only rail, only road, only IWT, only SSS and intermodal) (Weber, 2007). Intermodal terminals are strategic areas where the different freight transport modes gather. The intermodal material (i.e., containers or swap bodies) are stored or transhipped from one mode to another. They are equipped with mobile or fixed equipment to load and unload the cargo and realize different logistic operations. Storing area for the cargo might be required (Ghaus Younossi, 2009).

Table 5-1: Factors influencing quality to evaluate in transhipment facilities

		Road	Rail	IWT	SSS
Road	Resources	E,P, C			
	Processes	L, S, T, Sh			
Rail	Resources	E,P, C	E,P, C		
	Processes	L, S, T	L, S, T, Sh		
IWT	Resources	E,P, C	E,P, C	E,P, C	
	Processes	L, S, T	L, S, T	L, S, T, Sh	
SSS	Resources	E,P, C	E,P, C	E,P, C	E,P, C
	Processes	L, S, T	L, S, T	L, S, T	L, S, T, Sh

E = Equipment; P = Personnel; C = Capacity; L = Loading/unloading;
S = Storing; T = Transhipment; Sh = Shunting

Source: Author

Table 5-1 shows the relevant factors for the evaluation of the performance of the transhipment facilities. It sorts the transport modes available in the terminal by pairs. The case of Road—Road terminal describes a transhipment terminal only for road transport. A Road—Rail terminal is an intermodal transhipment terminal for road and rail transport. Trimodal terminals are not explicitly included in the table but the factors that need to be taken into account are stated for each type of transhipment. For instance a trimodal terminal Road—Rail—SSS like at Basel Port in Switzerland, can be evaluated by the factors of each individual transhipment (e.g., Road—Rail transhipment, plus Road –SSS transhipment, plus Rail—SSS transhipment).

Table 5-2: Classification of existing and foreseen intermodal transport terminals in Europe

Type	**Modes**	**Unit types**	**Current volume range [units per year]** **Small terminal** **Medium terminal** **Large terminal**	**Future volume range [units per year]** **Small terminal** **Medium terminal** **Large terminal**
Existing				
I	Road-Rail Combiterminal	Swap bodies Semitrailers Containers	< 20,000 20,000 – 100,000 > 100,000	< 30,000 30,000 – 150,000 > 150,000
IIa	Road-IWT Container terminal	Containers	< 30,000 30,000 –50,000 > 50,000	< 50,000 > 50,000 Not foreseen
IIb	Road-Rail-IWT Container terminal	Containers	< 50,000 > 50,000 Not foreseen	< 100,000 > 100,000 Not foreseen
IIIa	Maritime full-Container terminal with Road and Rail Connection	Containers	< 100,000 > 100,000 Not foreseen	< 200,000 > 200,000 Not foreseen
IIIb	Maritime full-Container terminal with Road-Rail-IWT connection	Containers	< 200,000 200,000 – 500,000 > 500,000	< 300,000 300,000 – 500,000 > 500,000
Foreseen				
Type	Modes/description	Unite types	Future volume range [units per year]	
IV	Road-Rail Bimodal terminal	Bimodal Units (special semitrailers)	10,000 (small terminals)	
V	Road-Rail Transfer terminal	Swap bodies Semitrailers Containers	< 300,000 (small terminals) > 300,000 (large terminals)	

Source: (DG Transport, 1999)

5.3 Transport processes and transport modes

Transport processes are carried out, in a continental context, along continental transport networks of different transport modes, e.g., road, rail, IWT and SSS. On the European level the requirements for transport infrastructure are defined in the TEN-T Guidelines.

5.3.1 Road

According to the TEN-T Guidelines, the TEN-T roads is composed of motorways and high-quality roads – existing, new, to be build or to be adapted. Road freight transport's strengths are more dominant in the short and medium distance transport, mainly in door-to-door transport. It also covers last mile shipments in the intermodal long-distance shipments. Its weaknesses are mainly the elevated costs per unit transported, smaller capacity and need of more personnel (compared to the other transport modes). It also produces a higher pollution per unit than other modes.

Usually road freight transport is structured in Full-Truck-Load shipments (FTL), Less-Than-Truck-Load shipments (LTL) and intermodal containers. Using this load configurations several schemas of delivery can be organized. Each of them serves better different client interests and commercial strategies, depending on the type of business they provide the service to. The main system types are:

- Door to door shipment: A FTL or container shipment goes from origin to destination on the same road transport vehicle without transhipping or getting stored anywhere.
- Feeder shipment: LTL shipments with different origins and same destination get shipped by different trucks until a specific location on their routes. The cargo gets reorganized in a bigger truck that can carry the full load of the resulting FTL shipment and it is shipped until the destination point.
- Liner shipment: LTL trucks that ship under regular schedules and load and unload cargo in commercial stops along their commercial route.
- Hub-and-Spoke: a set of road shipments containing cargo with different origins and destinations are organized by intermediate stops in hubs, where the cargo is redistributed by shunting procedures in case of FTL, or loading and unloading procedures in case of LTL or intermodal containers, so the trucks that exit the hub ship the goods with identic destination point.

5.3.2 Rail

Rail is the strategic sector that offers the broadest possibility for the integration of transport in sustainable development. The guidelines define the TEN-T for railways of the 27 Member States as comprising high-speed lines and conventional lines. Rail freight strengths are in long distance transport, costs per unit transported, capacity, risk of accidents and pollution (compared to the other transport modes). Its weaknesses are mainly in the short distances and door-to-door as well as last mile shipments.

Rail freight transport uses freight wagons, and flat wagons carrying intermodal containers, swap bodies, and entire road vehicles (rolling highway). Within these possibilities different rail freight strategies can be offered:

- Block train: trains that ship goods between two terminals. The number of wagons may depend on the demand (block trains), or it can be a fixed formation (shuttle trains).
- Feeder train: Also called group trains, they are a combination of small trains of the same region that travel as a unique train for a long distance, although in a previous step of the shipment they were moving as independent trains from different origins.
- Liner train: regular service trains that can incorporate small terminal operations of intermodal transport such as loading and unloading intermodal containers on a fixed composition of wagons or coupling and uncoupling some wagons to and from the liner train.
- Single Wagonload (or Hub-and-Spoke system): rail freight system that assembles customer sidings, collection fields, shunting areas, and distributions fields. Small groups of wagons are taken from private sidings to collection fields where they are coupled to other wagons coming from the same area. Afterwards, the wagons are shipped to shunting areas where they are sorted according to their destination and coupled to a locomotive. Later, the wagons composition is shipped to another shunting area where the composition is now broken up in smaller trains which are shipped to distribution fields. Finally from these distribution fields the wagons are transported to their destination sidings. This process usually involves different types of locomotives and power engines.

5.3.3 Inland Waterways (IWT)

Consists of rivers, canals and its various branches which connect them. The TEN-T inland waterway projects aim to help connect industrial regions and urban areas and link them to ports. Its strengths are a high level of safety, less harmful to the environment than road and rail transport, fuel efficiency, reliability and cost, if distances are significantly long. The weaknesses are low speed, lack of flexibility, lack of accessibility, high investments in new barges and waterways, natural constrains and limited lock operating hours (Wiegmans, 2005).

- Direct ship: traditionally barges and push boats containing bulk material that sail from one terminal to another directly.
- Liner ships: periodic IWT shipments that have a fixed route and that allow transhipment of containers in their commercial stops and allow shunting of the barges attached to the push boat.
- Hub-and-Spoke: Although this system is not applied yet to IWT, there is some recent research done in this field that points out its potential. According to (Konings et al., 2013) potential benefits in economies of scale, reducing costs, reducing operations, and an effective way to enhance the hinterland of seaports.

5.3.4 Short Sea Shipping (SSS)

Maritime transport is the backbone of international trade, yet its capacity has not been fully exploited in Europe. SSS strengths are lower freight rates due to inherent economies of scale and distance, unlimited capacity, safety of navigation, and lack of necessity for additional investment and superstructure except the harbours. Additionally, it can contribute to reduce the energy consumption levels. The weaknesses are the impossibility of a door-to-door transport service (the exception being for liquid and dry bulk cargoes), and the use of dedicated terminals and a network of well-located inland terminals (Paixão & Marlow, 2002).

Table 5-3 summarizes the existing delivery strategies of the different transport modes. Although there exist operational differences within modes, the delivery concepts are similar. Therefore, these similarities will be used in this study to standardize the elements of the transport chain to obtain a systematic approach to freight operations so the evaluation tool can be robust.

The performance of the processes is in both cases, transport processes and logistic processes, dependent of the infrastructure and the operations. Therefore, the quality resulting from each process needs to be calculated counting on those parameters.

Table 5-3: Summary of shipment types per mode

	Road	Rail	IWT	SSS
Direct shipment	FTL	Bloc train Shuttle train	Direct ship	Direct ship
Feeder shipment	LTL+FTL	Feeder train		
Liner shipment	LTL+FTL	Liner train	Liner ship	Liner ship
Hub-and-Spoke	Hub-and-Spoke	SWL	Hub-and-Spoke	

Source: Author

6 Quality concept for freight transport and quality attributes

6.1 Introduction

As described in Chapter 2.6, several authors researched on the concept of freight transport quality. While in the early research projects the focus was centred on the econometrics of freight transport, later on some researchers realized the relevance of commodity groups roles. Studies on willingness to pay of shippers show that relevance of different aspects of the transport services vary depending on the type of good transported. Thus, Chapter 6.3 introduces some of the existing classifications for goods and a discussion about which is the one that should be adopted when evaluating quality for freight transport.

Furthermore, some other researchers focused on developing demand freight models to better understand the behaviour of freight transport systems. Finally, some attempts to link LoS concept and freight and logistic activities were carried on. From previous research one finds that although freight transport and logistic activities are complicated operations depending on several variables, it is possible to reproduce and forecast these activities with certain level of accuracy. Therefore, LoS measurements could be done if freight performance is properly parameterized.

A way to parameterize freight performance is to select attributes and indicators that help to evaluate and quantify different particularities of the transport chain and its processes. Therefore, Chapter 6.4 presents the attributes used according to literature to define quality in freight transportation and freight logistics. These attributes will be used to develop frame to evaluate freight transport quality in the following chapters and to build up a LoS metric.

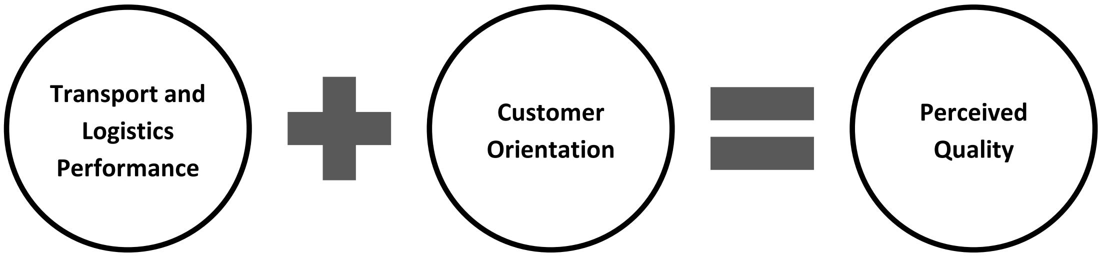
A collection of data about shipments and shipper's preferences will be conducted, by running a survey to freight professionals. This survey will include the goods classification of Chapter 6.3, and the attributes selected in Chapter 6.4. The data collection will be used to classify the importance of the freight quality attributes, as well as to state similarities and differences between the commodity groups in terms of quality priorities.

In Chapter 6.2, the author defines quality of service for freight transport, as well as the different levels of quality of service that a transport chain, or an element of the transport chain can have. Theses definitions are based on existing definitions of LoS levels such as the ones included in HCM or HBS, but also related with LoS papers recently published for several transportation disciplines that are currently incorporating this traditional classification into new areas. It states the suitability of this type of classification for this particular matter.

6.2 Definition of Quality of Service for freight transport

Based on the logic presented in Chapter 2.4 about types of QoS in public transport defined by the EC, in this thesis Quality of Service for freight transport is defined by the author as the "shipper's perceived quality of a transport or a logistic process considering the transport and logistics performance and the service provider customer orientation ". The perceived quality it is influenced by the quality delivered, which includes the actual transport and logistics performance of the service provider, and the customer orientation the service provider offers. Therefore, QoS for a given shipment is an overall shipper's perception resulting from a combination of the perceived quality of each processes (transportation and logistics operations) intervening in the transport chain and the customer orientation the service provider offered since the first contact with the shipper until the last one.

Figure 6-1: Elements influencing Perceived Quality



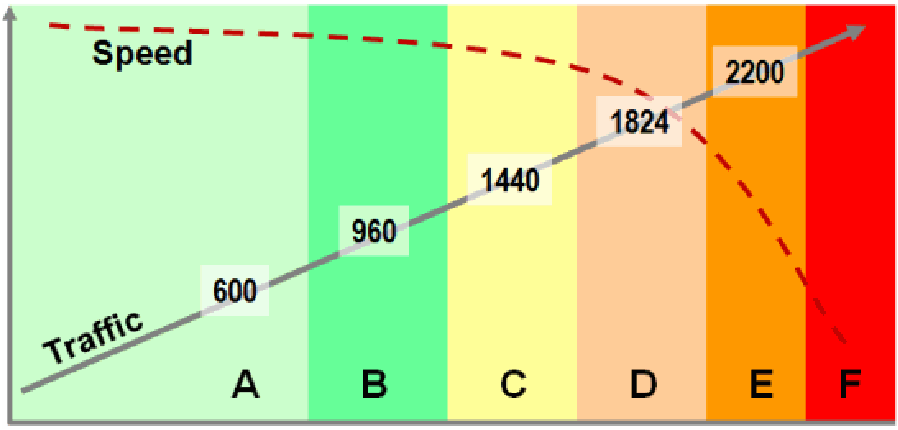
Source: Author

Indicators allow to quantify freight transport performance, by evaluating certain attributes of the freight service. Standards need to be set so different activities of the transport chain can be compared in terms of quality. Many transportation researchers agree on using the LoS concept to set quality standards in similar systems, such as road transportation (FGSV, 2001; TRB, 2000), public transportation (Orth, Carrasco, Schwertner, & Weidmann, 2013; Orth, Weidmann, & Dorbritz, 2012), pedestrian and cycling transportation (Dorbritz & Scherer, 2011), or even freight terminals (Ballis, 2004). It is aimed to use the LoS classification due to its great acceptation on the sector and its clearness. This is the quality perspective used in this dissertation to elaborate a LoS, which is a scale of qualities, or quality classification.

The quality classification in handbooks such as HCM (TRB, 2000) or HBS (FGSV, 2001), follow a six level structure, from A to F, being A the highest quality and F the lowest. This six-level-structure for quality classification has been also used in multiple papers and studies to develop new LoS for different matters related or not to transportation. In this dissertation it is aimed to use the same classification due to its great acceptation on the sector and its clearness. The levels A to F depend on the attributes selected to calculate the quality. Given a value of an indicator that quantifies an attribute, this attribute may fall into one level or another. The combination of the levels of each attribute used to determine the quality of a segment of the transport chain provide the quality of the segment.

For instance, we can take a look at the road LoS diagram from the HCM (TRB, 2000) (see Figure 6-1). On the vertical axis there are the speeds that a driver can reach on the lane, and on the horizontal numbers there are the levels (A-F). In diagonal there is the density of cars on the lane. It can be observed that when de density of the lane increases, the speed decreases (red discontinuous line), and the LoS decreases as well. In that case, the LoS is represented by 2 indicators, speed and density.

Figure 6-2: Levels-of-Service



Source: (TRB, 2000)

Usually, for any A-F LoS classification, values from A to D are acceptable values of performance and E and F are not acceptable. Therefore, if an infrastructure or service rank E or F means that they are not suitable for the service they have been designed to. In this dissertation the levels of the LoS are described as follows:

- A – This level describes the best quality of service. The indicators used to evaluate the relevant attributes for the process rank in the best 10% performance possible.
- B – This level is slightly below the best quality of service. The indicators used to evaluate the relevant attributes for the process rank just between the best 10% performance possible and the best 20%.

- C – This level implies some minor disruptions on the quality of service. Some of the indicators used to evaluate the relevant attributes for the process rank poorly but still manage to be between the best 20% and the best 35%.
- D – This level offers the last acceptable quality of service. Some of the indicators used to evaluate the relevant attributes for the process rank poorly (below the best 35%) but still manage to be above the average.
- E – This level offers a quality of service not acceptable. The indicators used to evaluate the relevant attributes for the process rank below the average performance.
- F – This level implies that the service is not offered anymore. Total disruption of the service.

This general description of the LoS will be more specific in chapter 8 when the indicators are selected. Then, for each indicator specific values will be given, based on data analysis of travel times, delays, percentage of damage, etc.

On the other hand, usually shippers and service providers are not the same entity. Therefore, it is needed to take into account the information flow between shippers and service providers so SQ targeted can be as close as possible to SQ sought and SQ perceived can rate as high as possible. For that purpose, it is intended to develop a method, parallel to the aforementioned, to calculate customer orientation for logistic companies. it would rank by relevance the customer service attributes from shipper's point of view. It measures therefore the relation between SQ sought and SQ targeted, and SQ delivered and SQ perceived, since it is mostly focused in communication between the shipper and the service provider.

6.3 Structure of freight commodities

A commodity is an economical term for any item produced for commercial use. In freight transport these items are goods and receive the name of freight commodities. These commodities have full or partial fungibility, i.e., the individual units of each commodity are capable of mutual substitution in the market, e.g., coal, gold or oil are fully fungible because the substitution of a piece of coal for another makes no difference for the end consumer. Usually in freight transportation commodities are terms to describe homogeneous groups of products, or groups of products that share certain similarities.

Several studies (Bolis & Maggi, 2003; Bouffioux et al., 2006; Danielis et al., 2005; Fries, 2009; Fries et al., 2008; Instituto di Recerche Economiche & Rapp Trans AG, 2005; Patterson et al., 2007; Vellay & De Joung, 2003) have identified different priorities in shippers' behaviour, depending on the type of good. This phenomenon is known as "willingness to pay". In these studies shippers are asked to state which transports attributes they value the most when shipping a certain commodity. The results show that shippers shipping similar commodities have similar willingness-to-pay patterns, but that differ with shippers shipping other commodities. For instance, there are commodities like perishable goods, which need to be transported as fast as possible to avoid damage. There are other commodities that need to arrive at a precise time to destination due to a production schedule. Stablishing a parallelism between freight transport and passenger transport, commuter travellers have similar travel needs among them, and leisure travellers have also similar travel needs among them, but both groups have different travel needs.

Therefore, it might be that some transport modes, due to transport attributes, offer higher quality of service for certain commodities. As it is intended to develop a LoS for freight transport from the shipper's point of view, which appears to be non-homogeneous, it is necessary to study the quality of service taking into account the commodity. For that matter it is intended to select a classification of commodities that groups goods with similar needs. The segmentation criteria for achieving consolidated groups with similar transportation needs falls to two conditions (Fries, 2009):

- Modal-split values of the commodities within each group should be as similar as possible to avoid one mode dominated products in the group.
- Demand characteristics of shippers should be as similar as possible to augment statistical significance of the relevant criteria in the resulting model.

If one take for instance the European freight market, which is complex and diverse, one finds a detailed goods classification. The Commission Regulation (EC) No 1304/2007 of 7 November 2007 amending Council Directive 95/64/EC, Council Regulation (EC) No 1172/98, Regulations (EC) No 91/2003 and (EC) No 1365/2006 of the European Parliament and of the Council with respect to the establishment of Standard goods classification for transport statistics (NST) 2007 as the unique classification for transported goods in certain transport modes (road, rail, inland waterways and maritime):

This classification presents the variety of types of goods that are shipped continuously on the European market. It is quite detailed in terms of commodity description, but it does not take into account logistic processes neither how these goods are usually shipped. As stated in chapter 5 transport chains are divided into transport processes and logistic processes. The logistic processes, as well as the transport processes, can be analysed with quality attributes (Ballis, 2004). Thus, the structure of freight commodities to build up the LoS needs to bundle commodity groups having similar logistic processes from the shipper's perspective. Following this logic, there are classifications of freight market by logistic services, like the Swiss logistic market study "Logistikmarktstudie", which classifies the Swiss freight market in types of services since 2007 (see Table 6-1). Therefore, regardless the type of good, it organizes the freight market focusing on the operational activities transport companies carry on.

Table 6-1: First level classification of the NST 2007

Group	NST 2007
01	Products of agriculture, hunting, and forestry; fish and other fishing products
02	Coal and lignite; crude petroleum and natural gas
03	Metal ores and other mining and quarrying products; peat; uranium and thorium
04	Food products, beverages and tobacco
05	Textiles and textile products; leather and leather products
06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
07	Coke and refined petroleum products
08	Chemicals, chemical products, and man-made fibers; rubber and plastic products ; nuclear fuel
09	Other non-metallic mineral products
10	Basic metals; fabricated metal products, except machinery and equipment
11	Machinery and equipment n.e.c.[1]; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
12	Transport equipment
13	Furniture; other manufactured goods n.e.c.
14	Secondary raw materials; municipal wastes and other wastes
15	Mail, parcels
16	Equipment and material utilized in the transport of goods
17	Goods moved in the course of household and office removals; baggage and articles accompanying travelers; motor vehicles being moved for repair; other non-market goods n.e.c.
18	Grouped goods: a mixture of types of goods which are transported together
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.
20	Other goods n.e.c.

Source: (UNECE, 2008)

Table 6-2: Service classification according to Logistikmarkstudie 2014

Group	Services
01	Tank & Silo services (gas, fluids and solids)
02	Bulk logistics (raw materials and waste disposal)
03	Heavy cargo logistics and crane services (more than 25 tons)
04	FTL logistics (no bundling neither transshipments)
05	Cargo logistics (from 31,5 kg to 3 tons)
06	CEP services (from 2 to 31,5 kg)
07	Postal and mail services (less than 2 kg)

Source: (Stölze, Hofmann, & Lampe, 2014)

[1] Not else classified

Although this classification divides the market in groups of similar logistic processes it does not include enough information about the properties of the goods transported. If it will be used to group shipper's perspective about quality in freight transportation, the results would have high dispersion. Therefore, this classification is not fully appropriate to evaluate quality requirements of a shipment.

On the other hand, (Fries, 2009) developed a classification that groups commodities of similar transport needs and transport logistics. This classification keeps the logic of the NST classification but reduces the number of groups to 7. The reduction of groups is based on bundling groups with similarities in terms of transport logistics, which follows the logic of chapter 5. Therefore, this classification of goods is perceived as the appropriate one to analyse the freight market quality needs and to be used to build up a metric to evaluate quality of service in freight transport networks. Furthermore, using this classification will allow the author to compare results with Fries work once the data analysis is done.

Table 6-3: Goods classification according to Fries 2009

Group	Commodity groups	NST 2007
01	Agricultural raw material	Any type of agricultural and forestall material as well as textiles and waste paper. This group is characterized by low value products which NST classifies in groups 1, 6 and 14.
02	Food and animal feed products	All kind of food products and fodder. Typically, shippers of these commodities value on-time reliability and transit times due to perishable goods. NST group 4 as well as part of group 1 belongs to this group.
03	Chemical and mineral products	NST groups 2, part of 3, 7, 8, and 9, which belong to the chemical industry and usually have similarities in their logistics and travel needs.
04	Iron and metal products	Metal ores and other mining and quarrying products, basic metals and fabricated metal products. Most of the products have low specific value and are non-finished products, directly sold to end-costumers. It contains parts of group 3 and parts of 10 of NST classification.
05	Building products	Parts of group 9 and 10 of the NST classification and that has specific logistic needs.
06	Manufactured goods	Manufactured goods including general machinery and vehicles. The group is characterized by high value goods which shippers mostly worry about damage/loss and on-time reliability aspects of the shipment. The NST groups that are part of this commodity group are 5, 11, 12, 13 and 16.
07	Other products and containers	All products that don't fit in any of the previous categories, which in NST classification are groups 15, 17, 18, 19 and 20. General not specific cargo falls into this category.

Source: (Fries, 2009)

6.4 Identification of freight transport quality attributes

Research in freight transport has been using freight attributes since the very first attempts to describe freight behaviour. The attributes are elements used to quantify transport qualities. They define a specific aspect of the transport or the logistic process and by linking those to some indicators allow researchers to quantify those specific aspects. In order to quantify quality in these research, the author has conducted a literature review of the attributes that have been used on previous works and presents them in a summarized Table 6-4. These table will be used to select which indicators are going to be used to run the shippers survey on freight quality.

1. Among literature there is a variety of outstanding freight transport attributes according to different authors and studies. For instance, a stated preference experiment with transport managers conducted on 2006 by Association for European Transport and contributors provided a sample of preference orders among hypothetical transport solutions. They estimated the relative importance and value for freight shippers of qualitative attributes: service frequency, transport time, reliability of delivery, carrier’s flexibility, and safety. The analysis concluded that different attributes play important and differentiated roles in the choice of a transport solution (Bouffioux et al., 2006) (see column 1 in Table 6-4).
2. A report from the European Commission that seeks to improve the quality, efficiency and transparency of intermodal transport chains selected a group of indicators to evaluate the quality of service in intermodal freight terminals (Ruesch et al., 2005).Task D develops of a set of quality indicators and a benchmark system. The following quality indicators have been identified: Cut-of, waiting and turnaround times, opening hours, accessibility, hinterland connection, damage frequency, security, and terminal and labour productivity (see column 2 in Table 6-4).
3. The Logistics Performance Index measures the on-the-ground efficiency of trade supply chains, or logistics performance. Published biannually, it covers 160 countries in the 4th edition of 2014 (Arvis et al., 2014). It uses a set of attributes on the survey conducted to measure the logistic performance: efficiency of customs, border clearance, quality of trade, transport infrastructure, ease of arranging competitively priced shipments, competence and quality of logistics services, ability to track and trace consignments, and frequency with which shipments reach consignees within scheduled or expected delivery time (see column 3 in Table 6-4).
4. Ballis suggested in 2004 a methodology to calculate the Level-of-Service standards for intermodal freight terminals (Ballis, 2004). It stablishes differences between types of terminals and the modes they serve. It includes the following attributes:

waiting time of users in the system, reliability, flexibility, qualification, safety and security, and terminal accessibility during the day (see column 4 in Table 6-4).

5. A recent paper from 2014 suggest Quality-of-service indicators for planning intermodal barge transportation systems (Wang, Bilegan, Crainic, & Artiba, 2014). These indicators are: number of contracts served, waiting time in intermodal terminals, waiting time at other terminals, average turnaround time, time on intermodal services, handling in intermodal terminals, waiting time at borders, containers transported by barge, and empty containers transported. These indicators can be summarized as attributes of operation time, safety and efficiency (see column 5 in Table 6-4).
6. In 2005 Danielis and Marcucci (Danielis et al., 2005) published a choice model paper to evaluate shippers' preferences for freight service attributes. They used a stated preference experiment on a sample of Italian manufacturing firms and the attributes used were: cost, transit time, punctuality, loss and damage, flexibility, frequency and transport mode (see column 6 in Table 6-4).
7. An analysis of attributes for rail and road freight transport in Spain was carried out using a stated preference experiment by Feo-Valero, García-Menéndez and Del Saz-Salazar in 2014 (Feo-Valero, García-Menéndez, & Saz-Salazar, 2016). The attributes used were: transport cost, transit time, frequency of the transport service, punctuality, Notice for contracting, variable that combines the notice for contracting the transport service before the scheduled time of departure with the probability of the shipment being finally transported in that service (rapidness) (see column 7 in Table 6-4).

Table 6-4: Freight quality attributes used in different studies

Attributes	Document / Paper / Study						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Frequency	X		X			X	X
Reliability	X			X		X	X
Safety	X	X		X	X	X	
Transport or transit time	X	X		X	X	X	X
Flexibility	X			X		X	
Accessibility		X	X	X			
Efficiency		X	X		X		
Rapidness							X
Information			X				

Source: Author

The most used attributes are transport or transit time, reliability, safety, frequency, flexibility and accessibility (mostly for freight terminals). Selecting this group of attributes as relevant for freight transport, a LoS for freight transport can be build up on them. It is needed to estimate if all these attributes are relevant for each commodity group and if so, which preference has each attribute for each commodity.

Indicators need to be selected to quantify each attribute. For a given attribute, different indicators might apply depending on process (logistic or transport wise) or transport mode. Measuring performance to quantify an attribute needs to be adapted to the circumstances of the shipment, e.g., transport mode, commodity group and process.

7 Customer orientation in freight transport

7.1 Introduction

This chapter about customer orientation in freight transport was developed in parallel to a research project on building an index for customer orientation for SBB Cargo in 2015. The project was carried out by the author and other members of the IVT in collaboration with Universität St. Gallen.

Figure 7-1: Customer orientation causal chain

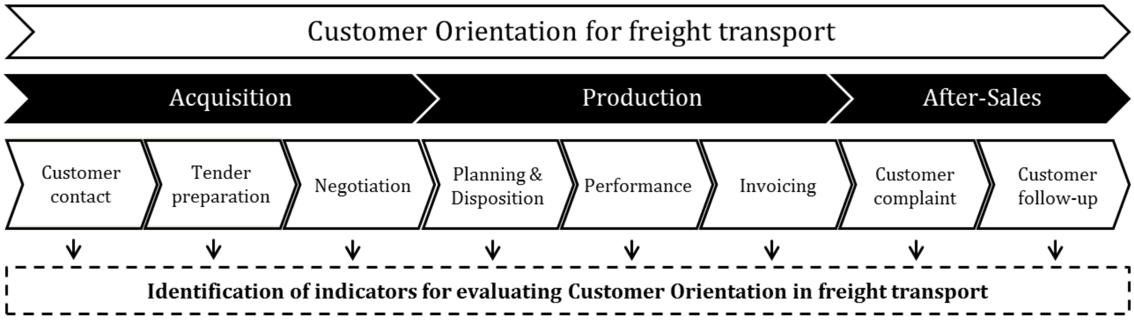
Source: (Bruhn, 2009)

Freight transport is mainly a business-to-business market (Bruhn, 2009). In any given geographic area there are a few important customers and a few important suppliers. In this environment losing a single important client has a high negative impact. Therefore, customer orientation is even more relevant for freight transport than for passenger transport (Muchiri et al., 2010). Furthermore, freight markets usually struggle to provide a high level of satisfaction to shippers. For instance, 35% of shippers using the Canadian rail freight market are dissatisfied with service and 45% claimed their satisfaction level decreased over the last years (AARA-MPS, 2011); on the other hand, in the European rail freight market, 25% of customers have a low level of satisfaction (CER, 2013).

Given strong competition in the freight sector and the consequently high expectations of shippers and receivers, logistics service providers must continuously improve service and performance quality. When service providers improve customer satisfaction, they strengthen customer loyalty, which ultimately helps increase market share. Furthermore, stronger customer orientation can help mitigate price competition and thus lead to an improved market position vis-à-vis the competition.

Customer orientation and the resulting customer satisfaction are therefore important measures of performance in the logistics market. However, customer expectations are becoming increasingly heterogeneous and it is becoming more difficult to scientifically measure customer orientation. The challenge for freight service providers lies in developing customer orientation evaluation measures and protocols, and then using them to provide more client-oriented services.

Figure 7-2: Indicator-based-system for evaluating Customer orientation for freight transport



Source: Author

The adaption of the public transportation service quality loop to freight transportation was presented in Chapter 2.4. One of the eight criteria used on the EN 13816 is customer care, while most of the other criteria measure transportation performance. In Chapter 6.2 it is expounded that service quality perceived by the shippers could be understood as the combination of the service provider transport and logistics performance and its customer orientation. Customer orientation influences the Service quality loop along the three phases.

- First, during the acquisition phase, actions such as contacting the customer, preparing the tender or negotiating terms and conditions of the service are executed. Effective customer orientation actions during the acquisition phase increase customer satisfaction and help the service provider to set accurate goals for the service quality targeted.
- Second, during the production phase, planning and disposition of the service, performance and invoicing are carried out. These actions take place before, during, and after the shipment. Customer orientation measures support the performance of the shipment during this phase, improving quality perceived by the shipper.
- Third, during after-sales phase, management of customer complaints and customer follow-up take place. Effective customer orientation actions during after-sales phases increase customer satisfaction and might improve the service quality perceived for a given transport and logistics performance.

In this chapter, a measurement and evaluation method for customer orientation for freight transport is developed. For that purpose, a set of theoretical considerations regarding quality aspects are harnessed with the help of expert workshops and finally validated with real world data. The model serves two basic application priorities. On the one hand, it measures customer focus of logistics service providers, so it can be improved on basis long-term. On the other hand, using a benchmarking approach, the model can be used to compare a pool of freight transport companies. Therefore, the model can serve as a building block of a customer-oriented corporate management tool. Furthermore, this model underlies an indicator-based-system that could be customized to any specific business needs. The collaboration of freight expertise and the validation with real world data through an on-line survey to freight professionals were possible thanks to the industrial contacts of Universität St. Gallen and SBB Cargo.

7.2 Research design

7.2.1 Research steps

Hypothesis 4 of this thesis says: *It is possible to define a measurable index for freight transport customer orientation to evaluate the quality of service not dependent from freight transport performance*. In order to prove this hypothesis, the following research design is developed. The goal is to build an indicator-based-system to measure for customer orientation in freight transport. The research design is depicted in Figure 7-3. It consists of five steps:

1. A literature review of general customer orientation measurement methods to collect indicators that might be relevant on the field of freight transportation.
2. A top-down matrix classification of those indicators into the phases of the service (acquisition, production and after-sales) and activities they belong to and the criteria they measure.
3. A freight and logistics expert's workshop to identify which indicators of the matrix are considered relevant and suitable to build the measurement method's metric.
4. A bottom-up classification of workshop's output to build a 2-level metric (attributes and criteria).
5. A freight and logistics professional's survey to quantify the relative importance of metric's attributes and criteria.

Figure 7-3: Process for building a measurement method for customer orientation in freight transportation

Source: Author

7.2.2 Discussion of the applied methods

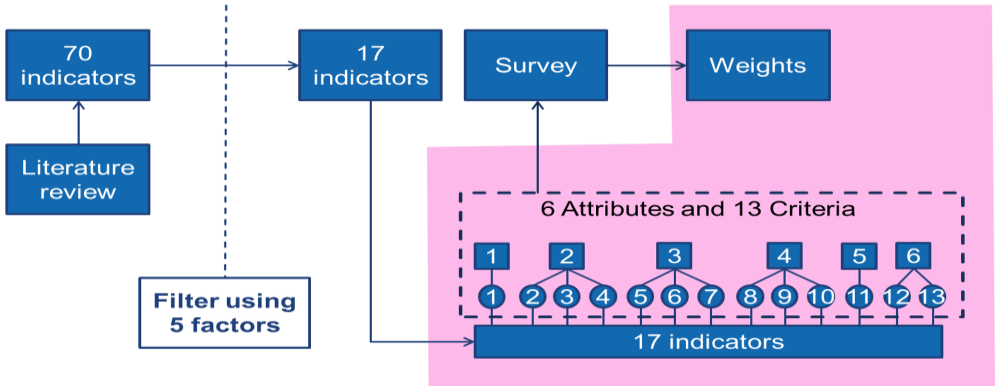
Literature review provides information about quality indicators that are already accepted by the scientific and industrial community. Therefore, this method ensures a solid base on which the indicator-based-system measurement method will be built. On the other hand, as this is the only chosen method to create the pool of indicators, there is no room for developing new indicators to measure customer orientation. An alternative or a complementary method to develop new indicators could have also been applied, but that would require a later validation of indicators, implying several efforts with a not clear success rate. Thus, literature review was selected as the only method to create a scientifically and industrially well-accepted pool of indicators, risking leaving out the possibility of developing new indicators.

After collecting indicators through literature review, they are top-down classified in a matrix using the phases and activities structure shown in Figure 7-2. The matrix constitutes the material used during the expert's workshop in order to have a comprehensive discussion about each indicator. The workshop method is applied to sieve customer orientation indicators, using freight and logistics expertise. To minimize method's subjectivity, experts are divided in 3 working groups, allowing three parallel discussions and providing three independent conclusions. Furthermore, five well-defined factors (see Table 7-2) are provided to participants to discuss each indicator, ensuring systematization and robustness on the discussion. Finally, a comparison of the independent conclusions of each working group is carried out to provide the definitive results. Concluding, although workshops are subjective methods, participants expertise plus parallel working groups strategy and well-defined factors, drastically reduce subjectivity, increasing results' reliability.

The group of twenty indicators resulting from the workshop is bottom-up structured in a 2-level metric. Six attributes make up the first level: accessibility, information, reliability, celerity, finding solutions and customer understanding, and thirteen criteria as make up the second one. Attributes contain from one to three criteria and each criterion is evaluated by at least one indicator.

The on-line survey is applied to calibrate weights of attributes and criteria, since the measurement method's metric is weighed additive (see discussion on Chapter 7.5.2). This method is selected because there is no information on specialized literature about relative importance of different attributes on customer orientation for freight transports. The survey provides empirical data that can be statistically analysed to conclude the weights. The major drawback of this method is the sample size. If it is too small, the reliability of the results is also small. Unfortunately, sample size is a recurrent issue for freight research. To overcome the sample issue, quality data needs to be ensured. One option would be to conduct the survey face-to-face with each respondent or run a telephone survey, but those were logistically not possible. Therefore, the internet survey was the best alternative. Efforts were directed on making the on-line survey self-explanatory, so respondents would have as much certainty as possible when answering the survey.

Figure 7-4: Schema of the construction of the 2-level metric with 17 indicators and its weights calibration



Source: Author

7.3 Indicators, attributes and criteria

Literature provides more than 70 indicators for measuring customer orientation (Parasuraman, Zeithaml, & Berry, 1988), including all activities from customer contact to customer follow-up (see Figure 7-2). At the same time, these activities can be divided into several criteria, which would be measured by the indicators. Table 7-1 illustrates how one activity (customer contact) is divided into several criteria, and which indicators could be used to measure them. This is part of the table with 70 indicators (see appendix) created to be used during the workshops with experts from the freight and logistics sector. This matrix divides all customer orientation activities into criteria. It classifies all indicators found through literature review.

Table 7-1: Classification of indicators for measuring customer orientation during customer contact

Criteria	Indicators
Customer contacts actively addressed by the Service Provider (SP)	Number of actively concerned customer contacts
	Number / type of proactive customer information
Customer contacts passively received by the SP	Number of customers that contacted with the SP
Transparency of the SP contact person	Reaction time of the SP (in case of email inquiry or non-availability)
	Percentage of customer contacts that have directly found the right contact person
Reliability of communication channels	Number of possible communication channels
Trait of the SP contact person	Affability

Source: Author

7.4 Procedure

A workshop with 20 experts from the freight and logistics sector was organized on the headquarters of SBB in Basel (Switzerland). The goal of the workshop was to use participants' expertise to evaluate each indicator found in literature and decide over its suitability for being included in a measurement method for customer orientation in freight transport. Experts were provided with the matrix where indicators were classified according to phase of service, activity and criteria. The experts were divided in three parallel working groups and asked to label the suitability of each indicator through group discussion using the factors of Table 7-2. The meaning of factors to label the suitability of the indicators are:

- Acquisition effort: how much effort is required in order to collect data to measure the indicator.
- Usefulness: how useful is the information the indicator provides in terms of customer orientation.
- Data source: which data base can contain the information needed to measure the indicator.
- Measurability: which type of information can be measured (qualitative or quantitative).
- Degree of influence: how much influence the indicator has on customer orientation.

Table 7-2: Factors to label indicators for customer orientation for freight transport

Acquisition effort	Usefulness	Data source	Measurability	Degree of influence
- High - Medium - Low - Automatic	- High - Medium - Low	- Intern - Extern - SAP/ CRM/ Homepage	- Qualitative - Quantitative - Not measurable	- High - Medium - Low

Source: Author

After the workshop, the output of the three parallel working groups were compared. The output indicated that 20 of the 70 indicators were suitable for the measurement of customer orientation in freight transportation. Obviously, the selected indicators correspond to those which better rank according to the aforementioned factors, i.e., low acquisition effort, high usefulness, internal data source, quantitative measurability and high degree of influence. Those 17 indicators were consolidated in a more compact matrix which consists of 6 attributes and 13 criteria (see Table 7-3 and Table 7-4). The six attributes are:

- Accessibility: Service provider's staff are always reachable and the exchange of information between customer and service provider is reliable.
- Information: The service provider proactively informs the client about important events.

  - Reliability: The promised service is performed reliably and accurately. Customer needs are served dutifully. Quality requirements are met.
  - Celerity: The service provider responds immediately and without delay to customer requests.
  - Finding solutions: The service provider offers customized solutions within its service portfolio or can develop them for the customer.
- Customer understanding: When dealing with the customers, the employees of the service provider show expertise, professionalism and empathy.

Table 7-3: Attributes and criteria classification for CO for freight transport

Attributes	Criteria
Accessibility	C 01: Availability of the appropriate contact person by the service provider
Information	C 02: Personal contact with the sales staff
	C 03: Use of a web service portal by the service provider
	C 04: To be informed on time about exceptional events
Reliability	C 05: Reliability of the service provider when submitting an offer
	C 06: Reliable execution of order processing
	C 07: Reliable handling of complaints
Celerity	C 08: Rapid reaction of the contact person from the service provider
	C 09: Rapid processing until the order confirmation
	C 10: Prompt handling of a complaint
Finding solutions	C 11: Customization of service providers when offering solutions
Customer understanding	C 12: Expertise and readiness of responsible staff by the service provider
	C 13: Random collection of customer feedback after handling orders

Source: Author

Table 7-4: Indicators to measure customer orientation in freight transport

Criteria	Indicators
C 01	I 01: $\frac{Actual\ service\ time\ [hours\ per\ day]}{Maximum\ service\ time\ [24\ hours]} \times 100$
	I 02: $\frac{Actual\ accessibility\ potential\ [hours\ per\ month]}{Maximum\ accessibity\ potential\ [hours\ per\ month]} \times 100$
	I 03: $\frac{Number\ of\ customer\ calls\ answered}{Total\ number\ of\ customer\ calls} \times 100$
C 02	I 04: $\frac{Number\ of\ calls\ to\ customers\ by\ SR^1 + Number\ of\ personal\ customer\ contacts}{Number\ of\ SR^1}$
C 03	I 05: $\frac{Number\ of\ customers\ connected\ to\ the\ IT\ system\ of\ the\ service\ provider}{Total\ number\ of\ active\ customers} \times 100$
C 04	I 06: $\frac{Number\ of\ cases\ informed\ about\ a\ delay}{Number\ of\ cases\ affected\ by\ exceptional\ events,\ in\ particular\ delays} \times 100$
C 05	I 07: $\frac{Number\ of\ all\ complied\ offers}{Number\ of\ all\ offer\ requests} \times 100$
C 06	I 08: $\left(1 - \frac{Number\ of\ all\ transport\ complains}{Number\ of\ all\ transport\ contracts}\right) \times 100$
	I 09: $\left(1 - \frac{Number\ of\ trains\ with\ a\ +3\ minutes\ delay}{Number\ of\ all\ trains}\right) \times 100$
	I 10: $\frac{Number\ of\ invoice\ adjustments}{Number\ of\ all\ issued\ invoices} \times 100$

C 07	I 11: $\frac{Value\ of\ all\ credits\ (reimbursement)}{Number\ of\ payments\ to\ customers}$
C 10	I 12: $\frac{Effort\ of\ replying\ all\ complains\ [hours\ per\ month]}{Number\ of\ complains}$
C 11	I 13: $\frac{Number\ of\ all\ offers\ that\ lead\ to\ transport\ orders}{Number\ of\ all\ complied\ offers} \times 100$
C 12	I 14: $\frac{Number\ of\ customers\ that\ participate\ in\ product\ development}{Total\ number\ of\ active\ customers} \times 100$
	I 15: $\frac{Cumulative\ number\ of\ training\ hours\ of\ all\ internal\ and\ external\ trainings\ [hours]}{Number\ of\ SR^1}$
	I 16: $\frac{Number\ of\ all\ customer\ records\ that\ have\ been\ active\ for\ 18\ months\ in\ CRM}{Number\ of\ customer\ records\ in\ CRM} \times 100$
C 13	I 17: $\frac{Number\ of\ all\ personal\ after-sales\ customer\ contacts}{Number\ of\ all\ transport\ contracts} \times 100$

[1] Sales representative

Source: Author

7.5 Structure of the metric

7.5.1 Existing structures

Three possible structures can be adopted for building the metric of the indicator-based-system to evaluate customer orientation for freight transport: additive, multiplicative and additive weighed structures.

1. The additive approach is the simplest structure (Bortz & Döring, 2006). The overall value is calculated by adding the values of individual indicators. Indicators must be shaped in the same range of values and in balanced scales to allow direct comparisons and to prevent indicators taking greater weights than others (Schnell, Hill, & Esser, 2008). In that structure, a low value of an indicator can be compensated by a high value of another indicator. The application is suitable for studies in which the individual indicators behave quite independently from each other. Furthermore, indicator values must ensure comparability, i.e. they must be transformed to dimensionless variables by means of a reference value.

$$Overall\ value_{additive} = Indicator_1 + Indicator_2 + \cdots + Indicator_n$$

2. The multiplicative approach is applicable when there are indicators with a minimum value required and when various indicators cannot be compensated. This structure is determined by a multiplicative combination of indicators which already brings an indirect weighing with it. When one of the indicators does not reach an explicit value, the overall value automatically equals zero. Therefore a thorough choice of indicators is an important prerequisite for the application of a multiplicative structure (Bortz & Döring, 2006; Schnell et al., 2008).

$$Overall\ value_{multiplicative} = Indicator_1 \cdot Indicator_2 \cdot \ldots \cdot Indicator_n$$

3. A weighed additive structure offers the possibility to incorporate indicators with different levels of significance, providing higher level of information. The prerequisite for applying this structure is an individual weighing of the indicators using the constants $a_1, \dots, a_n$ to include their relative significance on the calculation method. The weighing can be calculated using empirical studies, statistical analysis, or theoretical considerations from experts on the field (Schnell et al., 2008).

$$Overall\ value_{weighed\ additive} = a_1 \cdot Indicator_1 + a_2 \cdot Indicator_2 + \cdots + a_n \cdot Indicator_n$$

7.5.2 Selection of the appropriate structure

The assumption on the structure of the metric is that the six attributes and thirteen criteria selected to build this measurement method are interdependent from each other and they have different relative values. The research has been designed in a way that weights for criteria and attributes will be calculated by analysing the results of an on-line survey designed especially for this research. Therefore, the structure of the metric is foreseen to be the weighed additive; the addition of attributes times their coefficients provide the level of customer orientation (7.1). At the same time, each attribute value is calculated by the addition of criteria times their coefficients (7.3). The coefficients equal the relative importance of the attributes and of the criteria. Furthermore, the sum of all attributes coefficient equals to one (7.2), as well as the sum of each criterion coefficient belonging to one attribute (7.4). The reason is to keep a decimal base on the measurement method.

$$Level\ of\ customer\ orientation = a_1 \cdot Attribute_1 + a_2 \cdot Attribute_2 + \cdots + a_n \cdot Attribute_n \quad (7.1)$$

Where $\sum_{i=1}^{n} a_i = 1$ (7.2)

$$Attribute_i = b_i^1 \cdot Criterion_1 + b_i^2 \cdot Criterion_2 + \cdots + b_i^m \cdot Criterion_m \quad (7.3)$$

Where $\sum_{j=1}^{m} b_i^j = 1$ (7.4)

7.6 Weighing of attributes and criteria

7.6.1 Design of the on-line Survey (methods)

Once the selection of indicators is made and they are consolidated within the criteria and attributes metric, it is needed to weigh the importance of each criterion and attribute. Therefore, an on-line survey is designed to collect freight actors’ professional knowledge about the criteria and the attributes.

For the construction of the survey three groups of questions are designed:

1. Pairwise comparison of the customer orientation attributes: The six attributes (see Chapter 7.3) are sorted by pairs and respondents need to indicate, according to their professional expertise, whether they are equally important, or one attribute is more important than the other. All attributes are paired with each other, therefore there are 15 questions in this question group. The questions are randomly ordered to minimize observational error from the respondents.
2. Five-point Likert Scale for the customer orientation criteria: The importance of each of the 13 criteria (see Chapter 7.3) is asked individually using a Likert Scale from 1 to 5, being 5 very important and 1 not important at all. Each criterion is linked to a general aspect of the customer service or to an aspect of a specific phase (acquisition, production and after-sales). There are 13 questions in this question group and they are randomly ordered to minimize observational error.
3. General questions about the respondent's profile: Questions concerning the role on the logistic chain of the respondent's company, the respondent role inside the company, transport modes the company uses in number of shipments and commodities shipped by the company also in number of shipments. These questions are used to classify the answers of the survey in different clusters to identify possible different behaviours with respect to the customer satisfaction.

The software used for running the on-line survey is LimeSurvey. LimeSurvey is a free and open source on-line survey application written in PHP and based on a MySQL, PostgreSQL or MSSQL database. As a web server-based software it enables users using a web interface to develop and publish on-line surveys, collect responses, create statistics, and export the resulting data to other applications (Carsten Schmitz, 2015). It was selected because of its question design flexibility and its free service. If predefined question types are not powerful enough for an intended question, LimeSurvey allows users to program new type of questions or modify existing question types using PHP language.

7.6.2Execution of the on-line survey

The survey for costumer orientation in freight transport was conducted on-line for two weeks, between June 2nd and June 18th, 2015. 1037 professionals from the freight sector in Germany and Switzerland were invited to participate. The contacts data set used for the survey belongs to the Chair of Logistics Management from Universtiät St. Gallen (project partner of the customer orientation research project in which frame this survey was conducted). After the two weeks period, the total number of answers was 198. Out of them 140 were completed answers, therefore the statistical analysis was conducted using the 140 complete answers. Out of the 140 answers, respondents classify their company role on the logistic sector in four possible categories:

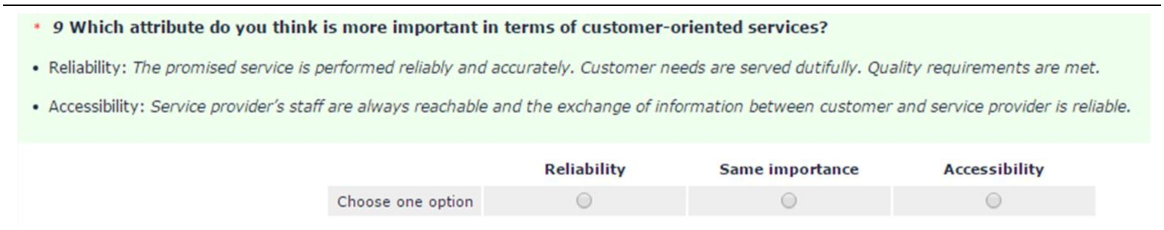
- Shipper
- Carrier
- Forwarder
- Other

Respondents had the possibility to select more than one of the aforementioned categories to define their company's role. It allowed those respondents who have more than one role in the logistic chain to properly define themselves. This helped to obtain a more accurate answers' classification in terms of role.

7.6.2.1 Attribute's pairwise comparison

For analysing the answers on the attribute's pairwise comparison the Analytic Hierarchy Process is applied. Using that method, it is possible to set priorities or relative importance between a group of actions or alternatives (see Chapter 4.2.5). All questions include the definitions of the two attributes that need to be compared (see an example of an attribute pairwise comparison question in Figure 7-5).

Figure 7-5: Example of an attribute pairwise comparison question


* 9 Which attribute do you think is more important in terms of customer-oriented services?
- Reliability: *The promised service is performed reliably and accurately. Customer needs are served dutifully. Quality requirements are met.*
- Accessibility: *Service provider's staff are always reachable and the exchange of information between customer and service provider is reliable.*

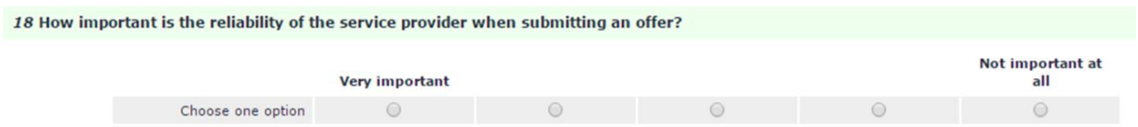
	Reliability	Same importance	Accessibility
Choose one option	○	○	○

Source: Author

7.6.2.2 Criteria Likert Scale

For analysing the answers of the 13 criteria, the Likert Scale method was applied. It is a psychometric response scale primarily used in questionnaires to obtain participant's preferences or degree of agreement with a statement or set of statements (see Chapter 4.2.4). Intermediate options are not labelled to increase respondent's psychometric response (see an example of a criterion Likert scale in Figure 7-6).

Figure 7-6: Example of a criterion Likert scale question


18 How important is the reliability of the service provider when submitting an offer?

	Very important				Not important at all
Choose one option	○	○	○	○	○

Source: Author

7.6.3Results of the on-line survey

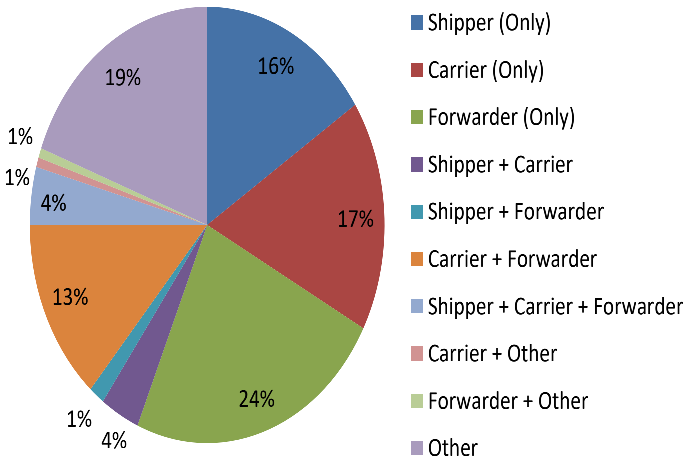
The results of the on-line survey are presented organized by question type.

7.6.3.1 Company's role

Table 7-5. Respondents roles in freight supply chain

Company's role	Count
Shipper (Only)	22
Carrier (Only)	24
Forwarder (Only)	33
Shipper + Carrier	5
Shipper + Forwarder	2
Carrier + Forwarder	19
Shipper + Carrier + Forwarder	6
Carrier + Other	1
Forwarder + Other	1
Other	27
Total	***140***

Figure 7-7. Respondents roles in freight supply chain

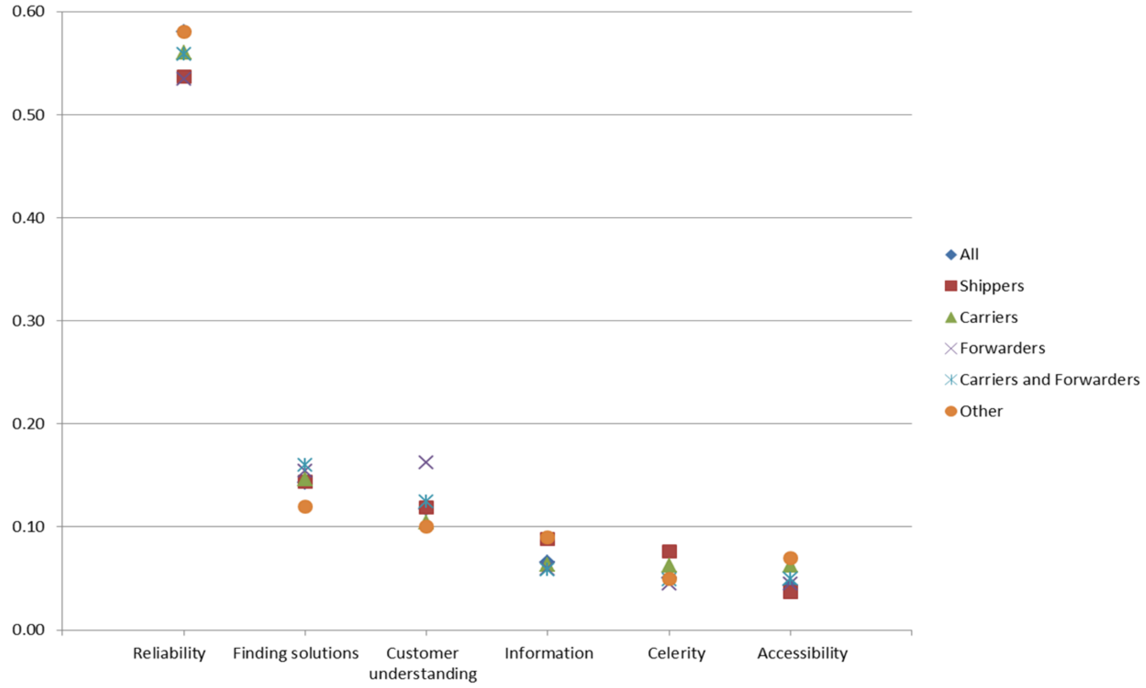


Considering the company's role, the answers can be classified in different sets. The answers of the survey were analysed using a set of methods and the results were used as input data to calibrate the weighing of the attributes and criteria. Furthermore, answers were classified in six sets to spot different behaviours among different roles: all answers of the survey (140), shipper answers (35), carrier answers (55), forwarder answers (61), carrier and forwarder answers (35), and other answers (27). In the "other" category the respondent backgrounds are quite diverse: academic experts in freight and logistics, terminal operators, 3PL and 4PL companies, etc.

7.6.3.2 Attribute's pairwise comparison

Among the six sets of answers, the results of the analysis coincide in several points. Reliability is the most valued attribute and considered to represent more than 50% of the importance on customer orientation for freight transportation. Finding solutions and customer understanding are considered as a second rank of importance and valued from 20 to 30% of importance when combined. Information, celerity and accessibility are considered as a third rank of importance and receive between 15 to 20% of the importance when combined. In Table 7-6 the weighing of the attributes (in a scale from 0 to 1) is presented for all the data sets. It can be observed that Reliability is by far the most valued attribute by professionals of the freight sector. Moreover, "Reliability", "Finding solutions" and "Customer understanding" represent more than 80% of the weighing of the attributes for customer orientation for freight transport.

Figure 7-8: Attributes weights



Source: Author

Table 7-6: Attributes weights

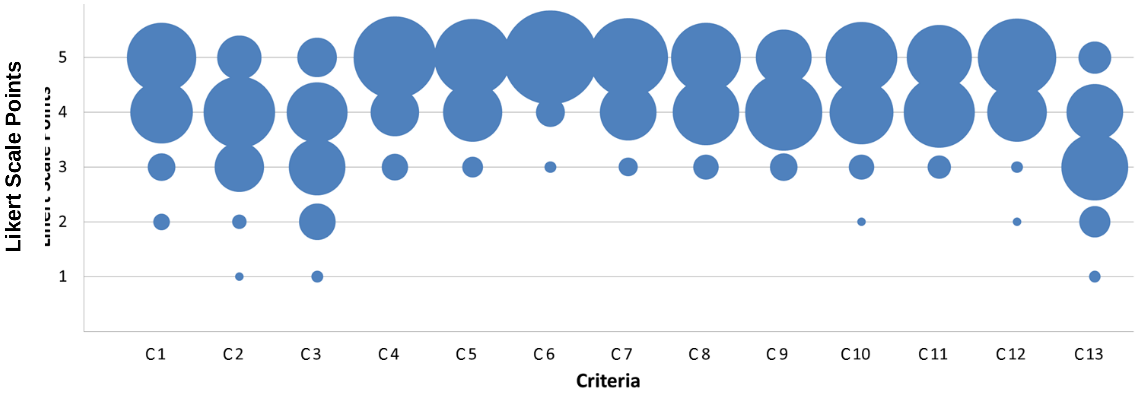
Attributes	All	Shippers	Carriers	Forwarders	Carriers and Forwarders	Other
Reliability	0.58	0.54	0.56	0.53	0.56	0.58
Finding solutions	0.14	0.14	0.15	0.15	0.16	0.12
Customer understanding	0.12	0.12	0.10	0.16	0.12	0.10
Information	0.07	0.09	0.06	0.06	0.06	0.09
Celerity	0.05	0.08	0.06	0.04	0.05	0.05
Accessibility	0.04	0.04	0.06	0.05	0.05	0.07

Source: Author

7.6.3.3 Criteria Likert Scale

The analysis was also conducted on the six sets of answers based on logistics roles and several findings need to be stated. Frist, most of the respondents valued most of the criteria with a 4 or a 5 (see Figure 7-9), meaning the criteria considered in the study were found very important for customer orientation in freight transportation. This fact reinforces the selection of criteria carried on during the expert's workshop (see Chapter 7.3). Figure 7-9 presents all the answers of the survey for the 13 criteria. The diameter of the circles indicates the amount of answers each criterion had for each level of the scale, where 5 means "really important" and 1 means "not important at all".

Figure 7-9: Density of answers on Likert-Scale evaluation of the 13 criteria



Source: Author

Second, as found during the analysis of the attributes pairwise comparison, the six groups of answers provide similar results for each criterion (see Table 7-7). Regarding the coefficients' calculation, the median values of each criteria have been used in each data set to establish the relative weighing of the criteria inside each attribute. In Table 7-7 the weight of each criterion within its attribute and for each set of answers is presented. Furthermore, it needs to be underlined that criteria belonging to the Reliability attribute are again the most valued among the respondents. This fact verifies the results of the AHP analysis of the costumer orientation attributes, reinforcing that reliability is the key attribute for customer orientation in freight transportation.

Table 7-7: Relative weighing of criteria for each attribute

		Weights					
Attribute	Criterion	All	Shippers	Carriers	Forwarders	Carriers and Forwarders	Other
Accessibility	C 01	1.00	1.00	1.00	1.00	1.00	1.00
Information	C 02	0.32	0.30	0.32	0.33	0.33	0.32
	C 03	0.29	0.30	0.30	0.28	0.29	0.29
	C 04	0.39	0.40	0.38	0.39	0.38	0.39
Reliability	C 05	0.32	0.33	0.32	0.32	0.32	0.33
	C 06	0.35	0.35	0.35	0.35	0.35	0.34
	C 07	0.33	0.32	0.33	0.33	0.33	0.33
Celerity	C 08	0.34	0.34	0.33	0.34	0.34	0.33
	C 09	0.32	0.32	0.33	0.32	0.32	0.32
	C 10	0.34	0.34	0.34	0.34	0.34	0.35
Finding solutions	C 11	1.00	1.00	1.00	1.00	1.00	1.00
Customer understanding	C 12	0.57	0.59	0.57	0.57	0.56	0.59
	C 13	0.43	0.41	0.43	0.43	0.44	0.41

Source: Author

7.6.4 Discussion of methods and results of the on-line survey

1. The response rate of the survey is higher than 10% (198 total answers, 140 complete answers, out of 1037 invitations). Furthermore, an unknown percentage of the invitations might have not been properly delivered since the contacts databases has not been updated recently. Therefore, the response rate might be even higher, unusual fact on freight and logistics surveys.
2. AHP and Likert scale are methods to evaluate subjective data and convert it into reliable data. Furthermore, the data used in each method comes from different question sets (attributes' pairwise comparison and criteria Likert scale evaluation). Nevertheless, the output of both groups of questions converge in several topics:
   - No major differences are found between answers of different logistics players (shippers, carriers and forwarders). Despite classifying answers on 6 different sets, no major differences among sets are found.
   - Reliability is by far the most important attribute in customer orientation in freight transportation. Whereas in the pairwise comparison questions, reliability accumulates more than 50% of the weight, in the Likert scale questions, criteria belonging to reliability attribute are also the best valued.
3. Furthermore, the AHP results provide a 3-level attributes classification in all the sets: Reliability (+50% of weight), finding solutions and customer understanding (22% – 30% of the weight), and information, celerity and accessibility (11% - 21% of the weight).
4. Groups of criteria belonging to one attribute get usually equally distributed weights (around 1/3 in attributes with 3 criteria) except in two cases, C04 and C12.

7.7 Synthesis of the chapter

7.7.1 Results

Substituting the values found in the set of "all answers" of Table 7-6 and Table 7-7 in equation (7.1) and (7.3):

$$\begin{aligned} &Level\ of\ customer\ orientation\ of\ a\ freight\ service\ provider\ = \\ &= 0.04xC01 + 0.02xC02 + 0.02xC03 + 0.03xC04 + 0.19xC05 \\ &+ 0.20xC06 + 0.19xC07 + 0.02xC08 + 0.02xC09 + 0.02xC10 \\ &+ 0.14xC11 + 0.07xC12 + 0.05xC13 \end{aligned} \tag{7.5}$$

7.7.2Discussion of methods and results

Customer orientation is relevant for measuring service quality in freight transport networks because it influences the perceived quality by the shippers on the service quality loop. Therefore, measuring customer orientation is crucial to understand service quality interactions between the shipper and the service provider. After the work presented in chapter 7, it can be concluded that customer orientation in freight transportation is measurable. An index to calculate costumer orientation in freight transportation is built (7.5) and explained in detail. Therefore, hypothesis H4 is considered proved.

The selected structure for the metric is the weighed additive structure. It brings together the weighing of the indicators and the compensation characteristic (a good performance on one indicator might partially compensate the bad performance of another one). Furthermore, it does not minimize the result of the calculation just because one indicator, unless this indicator has a really high weight, like reliability, which then it becomes an even more realistic result. The other two possible structures are not found applicable for this method. The additive structure in not optimal for evaluating the customer orientation because the indicators are proved to have uneven weights (see the results on chapter7.6.3), which conflicts with the equal weight of the additive structure. The multiplicative structure emphasizes the interdependence of indicators in the overall result. Although it includes certain weight measures, it cannot be stated that the level of customer orientation of a company is really low just because one indicator might rank that low.

On the other hand, some more major findings can be outlined. After a workshop with freight and logistics expertise, a two-level structure (attributes and criteria) is considered to be the most appropriate one to group the indicators that measure customer orientation. Given that, weights need to be calculated. The different actors on the logistics chain value similarly the different attributes and criteria selected to measure customer orientation. Reliability outstands as the most important attribute for customer orientation, and it is considered to represent more than 50% of the weight. Finding solutions and Customer understanding seem to have a second level of relevance and together represent between the 20 and the 30% of the weight. Finally, Information, celerity and accessibility are between a 15 and 20% of the weight.

Finally, to calculate the Level of customer orientation of a freight service provider, the values measured using the selected indicators need to be introduced in each criterion. The indicators need to be dimensionless and equally scaled, e.g. from 0 to 100. Then, the level of customer orientation will oscillate between 0 and 100, being 0 the worst possible and 100 the best possible. Each service provider should adapt the measurement of indicators to its own resources.

8 Level-of-Service for freight transport

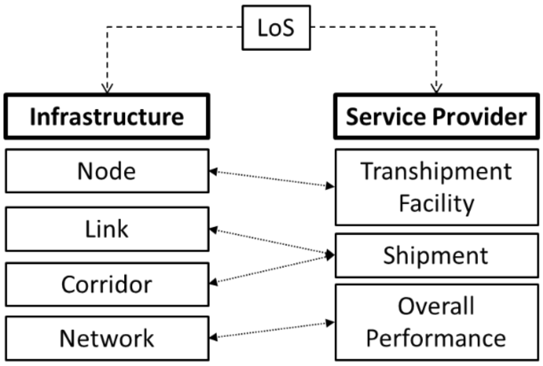
8.1 Introduction

Level-of-Service (LoS) has been identified as an appropriate method to evaluate and quantify quality on freight transportation. The method evaluates freight transportation performance according to some attributes that define features of transportation or logistics processes. Each attribute converts numerical inputs (indicators) into an A - F quality grade. The selection of attributes was conducted on chapter 6.4, and their exact definitions are found in chapter 8.3.1. The indicators are defined in chapter 6.4 and classified according to the attributes they measure and their field of application.

The LoS can be applied onto two major fields: infrastructure and service provider performance. On the one hand, infrastructure refers to elements that influence freight performance such as the layout, safety and security measures, traffic restrictions, the availability of slots, technical requirements to access the infrastructure, and so on. The indicators to measure quality might vary depending on the scale used to look at the infrastructure, e.g. a small scale would be a node or a link, middle scale would be a corridor, and big scale means the full network.

On the other hand, service provider performance refers to operators management elements such as shipment travel time, delay and punctuality rates, rates of damaged and lost cargo, frequency of a given service, time in advance needed for contracting a shipment service, etc. the indicators associated to this field might also vary depending on the scale, e.g. a single shipment or the overall performance of a shipping company. Nevertheless, the LoS of a given service provider performance and the LoS of the infrastructure used during that service are related. Relations between infrastructure and service provider will be explained later.

Figure 8-1: Fields of application of the LoS for freight transport



Source: Author

8.2 Research design

8.2.1 Research steps

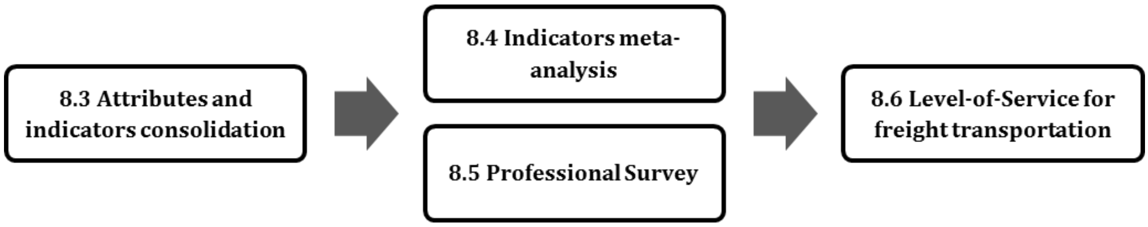
Chapter 8 aims to prove Hypothesis 5 and 6:

- *Hypothesis 5 of this thesis says: It is possible to define a measurable LoS for each of the quality indicators of any part of the transport chain and they can be combined to evaluate a bigger section of the transport chain.*
- *Hypothesis 6 of this thesis says: The LoS of a given shipment varies depending on the type of good transported.*

In order to prove these hypothesis, the following research design is developed. The goal is to build an indicator-based-system to measure logistics performance either on the service provider performance as on the infrastructure features. Collected data during the professional survey will be clustered by commodities and by logistics networks to search for different needs. The research design is depicted in Figure 8-2 and it consists of 3 steps:

1. A consolidation of selected attributes and indicators into a 2-level metric with 6 parallel cases; 3 infrastructure cases (link, corridor and network), 2 operator cases (shipment and overall performance of service provider), and 1 case of infrastructure and operator (nodes).
2. A meta-analysis of logistics and freight transportation data to calibrate the indicator limit values.
3. A freight and logistics professional's survey to quantify the relative importance of metric's attributes and spot difference on commodities.

Figure 8-2: Process for building a measurement method for logistics performance in freight transportation



Source: Author

8.3 Design of the frame for a Level of Service for freight transport

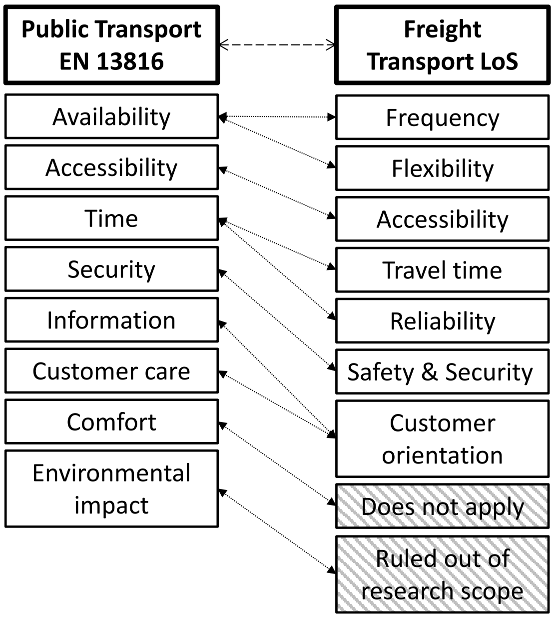
8.3.1 Attributes definitions

The attributes for developing a LoS method for freight transport have been selected in Chapter 6.4 by benchmarking 7 freight quality studies. A definition for each attribute has been adapted to the frame of this research. They have been kept as simple and as specific as possible:

- Travel time: door-to-door transport time.
- Reliability: probability of conducting the shipment on time.
- Safety and Security: probability that cargo does not get lost, damage or stolen during the shipment.
- Frequency: how often one shipment is available.
- Flexibility: capability to organize a shipment in short notice.
- Accessibility: Opening hours of service provider and other technical requirements for service availability.

Certain degree of consistence can be found between the selected attributes for measuring LoS for freight transportation, and the ones of the EN 13816 presented on Chapter 2.4. Leaving aside the "comfort" attribute for obvious reasons, and the environmental impact (ruled out of this research's scope), the attributes used to evaluate quality of service in the EN 13816 for public transportation are correlated with the attributes used on the LoS for freight transportation and the customer orientation for freight transport developed on Chapter 7. Therefore, this might be considered as a validation of the selected attributes to measure quality of service from shipper's point of view in a generic way.

Figure 8-3: Reciprocity between EN 13816 and LoS for freight transport



Source: Author

8.3.2Selection of freight transport quality indicators

The LoS method is designed to be applied either onto infrastructure or onto Service Provider performance (see Figure 8-1). Therefore, for each attribute, several indicators need to be selected. In this chapter, the reasoning for the selection of each indicator is presented. At the end of the chapter, Table 8-14 and Table 8-15 summarize the indicators selected for building the metric, and organize them by attribute and by field of application.

8.3.2.1 Travel time indicators

As seen in Chapter 5, a shipment can be as simple as a direct shipment or complex as several combinations of logistics and transportation processes. Each of these processes has an associated dwell time (Dt_i), i.e. time spent since the beginning of the process until its end. For instance, according to the description given in Chapter 5, the total travel time (TTt) of a direct shipment would be the sum of the dwell time of loading the vehicle, the time the vehicle takes to travel from origin to destination point and the dwell time of unloading the vehicle. Therefore, if the dwell time of each activity is known, the total travel time can be calculated as:

$$TTt = \sum_{i=1}^{n} Dt_i \tag{8.1}$$

Infrastructure has an impact on travel time (Tt). Capacity, level of usage, traffic restrictions, etc., influence travel time to a greater or lesser extent. Since calculating and parameterizing each of those influences on the travel time would demand excessive quantities of data, which are not accessible for such a research project, it is decided to develop the infrastructure travel time indicator with existent and available data: average speed (v), length of link (L_L) or corridor (L_C) and type of freight vehicle (ϑ). Therefore, we can calculate average travel time per type of vehicle in a given link (L), corridor (C) or network (N), as the fraction of the length of the element and the average speed of a type of vehicle in that infrastructure. To calculate corridor or network average speed, it is needed to also use the volumes (V).

$$Tt_{L,\vartheta} = \frac{L_L}{\overline{v}_{L,\vartheta}} \tag{8.2}$$

$$Tt_{C,\vartheta} = \frac{L_C}{\overline{v}_{C,\vartheta}} \tag{8.3}$$

$$\overline{v}_{C,\vartheta} = \frac{\sum L_{L_i} \times V_{L_i}}{\sum \frac{L_{L_i} \times V_{L_i}}{\overline{v}_{L,\vartheta_i}}} \tag{8.4}$$

$$Tt_{N,\vartheta} = \frac{L_N}{\overline{v}_{N,\vartheta}} \tag{8.5}$$

$$\overline{v}_{N,\vartheta} = \frac{\sum L_{L_i} \times V_{L_i}}{\sum \frac{L_{L_i} \times V_{L_i}}{\overline{v}_{L,\vartheta_i}}} \tag{8.6}$$

To measure the LoS of the Service Provider two areas must be considered: the overall performance of the company and the performance of a specific shipment. For a specific shipment, the travel time is calculated as mentioned above; the sum of dwell times of all processes executed from origin to destination. Since that specific information might not be available, the shipment's total travel time might be calculated as the time passed since the goods were set to be collected by the transporter on origin point until they were unloaded at destinations' point.

On the other hand, to evaluate the overall performance of the shipping company a general approach is needed. Instead of focusing in single shipments, it is needed to evaluate the mean travel time of general shipments the company performs. This could be calculated as the average lead time over several shipments, as suggested on (Ruesch et al., 2005).

$$Tt_{OP} = \frac{1}{n} \sum Tt_S \tag{8.7}$$

8.3.2.2 Reliability indicators

Reliability (R) has been defined in this research as the capability of conducting a shipment within an acceptable time threshold. According to that definition, the indicators that measure this attribute should focus on the factors that influence travel time and allow or prevent stable conditions for a reliable service. Regarding infrastructure, its effects on reliability could be observed on the variability of freight commercial speeds. If a link, a corridor or a network offer low variability on commercial speeds, a service provider will be able to plan the route under a high travel time reliability, increasing the chances of delivering on time. If, instead, a piece of infrastructure offers high variability on commercial speeds, the service provider would prefer to avoid this path on his routing, otherwise he will be exposed to high variability on the travel time, risking low reliability and delays.

The variables that measure this phenomenon are speed, its mean and its standard deviation. The variance of a commercial speed on a given link, corridor or network can be calculated as indicated below, were v_i is each measure of the commercial speed in the infrastructure, and $\bar{v}$ is the arithmetic mean of all the data set. Standard deviation (σ_n) is the square root of the variance. Finally, using σ_n and $\bar{v}$ the variance coefficient can be calculated. If the variance coefficient is low, the infrastructure has a high level of reliability.

$$\sigma_n(v) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(v_i - \bar{v})^2} \tag{8.8}$$

$$R_L = \frac{\sigma_n(v)_L}{\bar{v}_L} \tag{8.9}$$

$$R_C = \frac{\sigma_n(v)_C}{\bar{v}_C} \tag{8.10}$$

$$R_N = \frac{\sigma_n(v)_N}{\bar{v}_N} \tag{8.11}$$

Regarding the freight operator, reliability is usually measured by delay indicators. For instance, if a shipment is performed on time (S^*), reliability attribute would rank its best, whereas if there is some delay ($D > 0$), quality perceived by the shipper would be lower. As for the overall performance (OP) of the operator, the indicator should provide information concerning all the shipments of the company ($\sum S$).

$$R_S = D \tag{8.12}$$

$$R_{OP} = \frac{\sum S^*}{\sum S} \tag{8.13}$$

8.3.2.3 Safety and Security indicators

To calculate quality of service regarding safety and security ($S\&S$), three variables are relevant: cargo damaged (cd), cargo lost (cl) and cargo stolen (cs). The role infrastructure could play on this matter is complex. For instance, several factors could influence an accident occurrence (e.g. layout, illumination, signalling, vehicle density, weather, visibility, etc.). Since quantifying all these factors could not be achievable in this research, it is decided to focus on the amount of accidents (a) in a given link, corridor or network. Therefore, an infrastructure with an elevated number of freight accidents would provide a low quality of service, and an infrastructure with a low number of accidents would provide a high level of service. Nevertheless, these values need to be normalized by freight traffic volumes, so they could be comparable.

Another problem affecting freight shipments in terms of safety and security is crime and vandalism. Again, since the factors favouring or discouraging a criminal or a loutish act are several and very diverse, they escape from the scope of this research. Therefore, it is decided to count the amount of robberies (r) that take place on an infrastructure and normalize it with the freight volume (V). Furthermore, it is needed to include a coefficient for each element (α and β) so accidents and robberies could be compared. The discussion of the values of α and β should be justified with real data about quality loss perception from shippers for each type of action.

$$S\&S_{I} = \frac{\alpha \sum_{i}^{n} a + \beta \sum_{j}^{m} r}{V} \tag{8.14}$$

With regard to the freight operator, the attribute safety and security should also be measured by the amount of cargo damaged, lost, and/or stolen. Therefore, for a single shipment the indicator should measure the amount of cargo affected, weighted by the perception factor of the shippers (α, β and γ), and normalized by the total cargo of the shipment ($\sum c_{S}$).

$$S\&S_{S} = \frac{\alpha \cdot cd + \beta \cdot cs + \gamma \cdot cl}{\sum c_{S}} \tag{8.15}$$

As for the overall performance of the service provider, the indicator needs to consider the performance of all the shipments the company carries out, or all the shipments of the same type, if the operator is offering different services. Therefore, the indicator should be:

$$S\&S_{OP} = \frac{\alpha \cdot Sd + \beta \cdot Ss + \gamma \cdot Sl}{\sum S_{i}} \tag{8.16}$$

8.3.2.4 Frequency indicators

The role of the infrastructure on the frequency (Fr) of the service it is less straightforward than for the other attributes. Nevertheless, there are some aspects of the infrastructure manager that influence the frequency of service. For instance, the existence and the availability of dedicated freight slots (FS) on a rail network, may influence the service.

$$Fr_{Rail,I} = \frac{FS}{day} \tag{8.17}$$

The overall performance of the operator can be measured by the weekly departures (wd) the company offers (Feo-Valero et al., 2016; Ruesch et al., 2005).

$$Fr_{OP} = wd \tag{8.18}$$

8.3.2.5 Flexibility indicators

This attribute is defined as the capability to organize a shipment in short notice. By definition, this attribute is not related to infrastructure but to the service provider. For a shipment, the flexibility could be measured as the time in advanced (ta) needed for booking the service. Whereas for the overall performance of the service provider, the literature (Arvis et al., 2014) indicate that the most suitable indicator is the combination of the mean time in advance needed for booking a shipment ($\overline{ta_S}$) and the request acceptance rate, i.e., the ratio of shipments requested (Sr) and shipment accepted (Sa).

$$Fl_S = ta_S \tag{8.19}$$

$$Fl_{OP} = \overline{ta_S} + \frac{\sum Sa}{\sum Sr} \tag{8.20}$$

8.3.2.6 Accessibility indicators

Accessibility is defined in this research as the opening hours of a service provider and other technical requirements for service availability. Regarding infrastructure, this attribute evaluates two aspects: the limitations to access a network and the vehicle requirements to transit a way. By limitations to access a network we understand the amount of access points a network has, i.e. how permeable (p) it is, the legal regulations (lr), i.e. time frame when freight is allowed on the infrastructure, and the need to book a right of way (rw). By vehicle requirements we understand size and weight requirements (sw), type of goods (tg), etc. Therefore, accessibility is a function of several elements:

$$A = f(p, lr, rw, sw, tg) \tag{8.21}$$

- Road infrastructure: Road is 100% permeable, any point of the network can be accessed from every point to the network. Nevertheless, there are certain roads, mostly urban, where freight is not allowed at certain times of the day for congestion reasons or other reasons. On the other hand, it is not needed to book a right of way to travel on road infrastructure. Nevertheless, there are some size and weight restrictions on some roads, as well as on dangerous goods.

- Rail and IWT infrastructure: It is a closed system. A convoy can only enter the network in fixed points and infrastructure operator permission is required. It is not possible to access all points of the network from everywhere and booking time slots is necessary. There are also some restrictions on size and weight that depend on the system and on specific surrounding infrastructure, e.g. tunnels, bridges, etc. Specific permissions must be ask for shipping dangerous goods on the infrastructure. For inland waterways, the frequency on the service might be influenced by the opening hours (OH) of locks and lift bridges. These elements that block the flow out of the opening hours restrict the service that freight operators could offer.

$$A_{IWT,I} = \frac{OH}{168} \tag{8.22}$$

Table 8-1 summarizes all indicators presented described in this chapter.

Table 8-1: Indicators for evaluating quality of service on freight transportation

		Infrastructure			Operator		
		Link	**Corridor**	**Network**	**Shipment**	**Overall performance**	
Travel time	Road	$\frac{L_L}{\bar{v}_{L,\vartheta}}$	$\frac{L_C}{\bar{v}_{C,\vartheta}}$	$\frac{L_N}{\bar{v}_{N,\vartheta}}$	$\sum_{i=1}^{n} Dt_i$	$\frac{1}{n}\sum Tt_S$	
	Rail						
	IWT						
	SSS						
Reliability	Road	$\frac{\sigma_n(v)_L}{\bar{v}_{L,\vartheta}}$	$\frac{\sigma_n(v)_C}{\bar{v}_{C,\vartheta}}$	$\frac{\sigma_n(v)_N}{\bar{v}_{N,\vartheta}}$	D	$\frac{\sum S^*}{\sum S}$	
	Rail						
	IWT						
	SSS						
Safety and security	Road	$\frac{\alpha\sum_i^n a + \beta\sum_j^m r}{V_L}$	$\frac{\alpha\sum_i^n a + \beta\sum_j^m r}{V_C}$	$\frac{\alpha\sum_i^n a + \beta\sum_j^m r}{V_N}$	$\frac{\alpha \cdot cd + \beta \cdot cs + \gamma \cdot cl}{\sum c_S}$	$\frac{\alpha \cdot Sd + \beta \cdot Ss + \gamma \cdot Sl}{\sum S_i}$	
	Rail						
	IWT						
	SSS						
Frequency	Road					wd	
	Rail	FS/day					
	IWT						
	SSS						
Flexibility	Road				ta_S	$\overline{ta_S}$	$\frac{\sum Sa}{\sum Sr}$
	Rail						
	IWT						
	SSS						
Accessibility	Road	$f(p, lr, rw, sw, tg)$					
	Rail						
	IWT						
	SSS						

Source: Author

Regarding the nodes or transhipment facilities, there exist a suggested LoS. (Ballis, 2004) suggested a set of indicators to calculate LoS in intermodal freight facilities. Ballis argues that the number of attributes is limited in order to ease their implementation. For each attribute, one or more quantifiable indicators are defined. The following table summarizes the indicators suggested for evaluating intermodals facilities:

Table 8-2: Indicators for LoS on freight intermodal terminals suggested by Ballis

Attributes	Indicators
Dwell Time	Waiting time of users in the system. It includes waiting time in the queue and service time (minutes)
Reliability	Incidents of vehicle delay in departure (%)
	Duration of delay (minutes)
Safety and Security	Loss of goods (% of cases)
	Loss of loading units (% of cases)
	Loss of documents (% of cases)
Flexibility	Cut off time (hours): time interval between the latest container delivery at the terminal entrance and the departure time of the vessel or train.
Accessibility	Working hours per day
	Handling of hazardous goods
	Handling of perishable goods

Source: (Ballis, 2004)

- Waiting time for road transport: Total truck time between entry to and departure from terminal.
- Waiting time for rail transport: Total train time between entry to and departure from terminal.
- Waiting time for SSS and IWT: Total vessel time between entry to and departure from terminal.

8.3.3 Optimal calibration of indicator values – Meta-analysis

For the calibration of the indicator values, a geo-referenced map of Switzerland has been elaborated. Based on the road and rail Swiss network, data from different sources has been implemented to develop a working space to analyse the selected indicators. In this way, analysis of links and corridors could be conducted, concluding different quality levels for each indicator.

8.3.3.1 Travel time indicators

To calibrate the travel time indicator different data sets have been used. For road, data from the Nationales Personenverkehrsmodell des UVEK (NPVM) has been used. The Federal Office for Spatial Development of Switzerland (ARE) was willing to collaborate with this research by sharing the demanded data. This model allocates all traffic demand on the Swiss road network and provides information on speeds and volumes for each link and per type of vehicle among other information. This model classifies freight vehicles in three categories:

- Van, which besides this type of vehicle, it also includes van with trailer and van with semi-trailer.
- Truck (>3.500 Kg)
- Trailer truck (articulated) or freight train.

For rail, original data from a recently proposed methodology to asses capacity problems in the Swiss rail network (Frank, 2013) has been used. Its author was willing to share the original data, so it could be also used for this research. The data includes speed data of different sections of the Swiss rail network and it is classified according to three types of services:

- Full train
- Single Wagonload (SWL)
- Express train

For IWT, the data used was obtained through literature review. Several publications provide numbers on speeds (Pršić, Carević, & Brčić, 2011) and their standard deviations (Xiao, Ligteringen, Van Gulijk, & Ale, 2015) for IWT services. Literature provides values for two types of ship categories:

- Self-propelled ships
- Pushing convoy

Finally, for SSS, a database from a publication (Martínez de Osés & Castells, 2006) has been used to calculate speed and its standard deviation. It analyses several international SSS services with at least one Spanish port on their route. Data include information of two types of ships:

- Conventional merchant ship (speed below 23 knots), 80.6% of the data set.
- Fast conventional merchant ship (speed between 23 and 30 knots), 19.4% of the data set.

In this case, speed and standard deviation have been calculated as an average of all data because it was not clear which data belonged to which ship type.

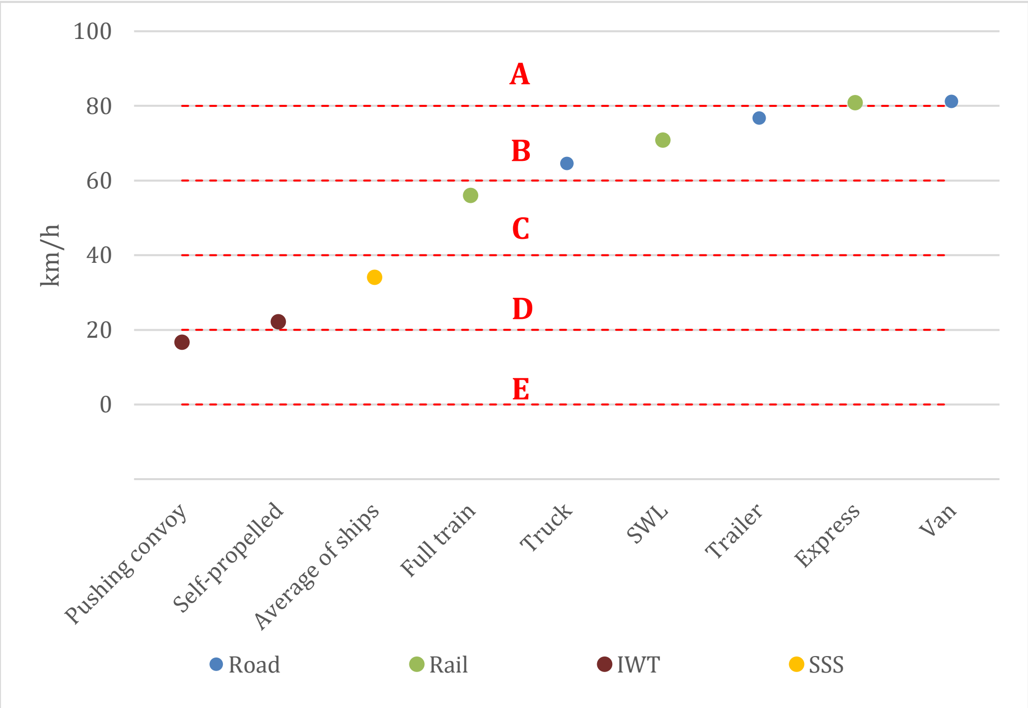
Table 8-3: Average speeds and standard deviations per transport mode

Mode	Type of vehicle or service	Speed (km/h)	Standard deviation
Road	Truck (>3.500 Kg)	64.59	18.67
	Van (<3.500 Kg)	81.24	29.93
	Trailer truck (articulated)	76.81	14.91
Rail	Full train	56.05	3.26
	SWL	70.9	7.55
	Express	80.85	15.89
IWT	Self-propelled ship	22.22	2.22
	Pushing convoy	16.67	2.22
SSS	Average of ship types	34.08	6.64

Source: Author

Combining the speed data from all transport modes, a speed correlation can be calculated, where speeds increase from the water transports to land transports (from 20 to 80 km/h approximately). Given that this data is a summary of average speeds, it can be concluded that speeds on that range are common. Therefore, the LoS level of this range should be between B and D, according to its definitions. Thus, the following classification is suggested, Where LOS A is for $v > 80km/h$, LOS B to LOS D is for $20km/h < v < 80km/h$, LOS E is for $v < 20km/h$, and LOS F is for $v = 0km/h$. LOS B to LOS D are equally distributed since there is no data available that indicates otherwise.

Figure 8-4: Calibration of Travel Time indicator



Source: Author

It needs be underlined that these speeds are average speeds on infrastructure and not commercial speeds. Commercial speeds (average speed of a door to door service.) are considerable lower, since they include time spent on freight terminals, marshalling yards, etc. For instance, international freight trains run at an average speed between 20 and 30 km/h in central and eastern European countries (European Court of Auditors, 2016).

8.3.3.2 Reliability indicators

As presented in Chapter 8.3.2, reliability indicators are: $R_L = \frac{\sigma_n(v)_L}{\bar{v}_L}$ for a link, $R_C = \frac{\sigma_n(v)_C}{\bar{v}_C}$ for a corridor, and $R_N = \frac{\sigma_n(v)_N}{\bar{v}_N}$ for a network. By definition: $\sigma_n(v) \geq 0$, $\overline{v} > 0$ and $\overline{v} \geq \sigma_n(v)$. Therefore, $R \in [0,1]$. The closer R is to zero the higher the quality of service regarding reliability; the closer R is to 1 the lower the quality of service regarding reliability. To calculate $\frac{\sigma_n(v)}{v}$ data presented above (see Table 8-3) has been used. Results are presented on Table 8-4.

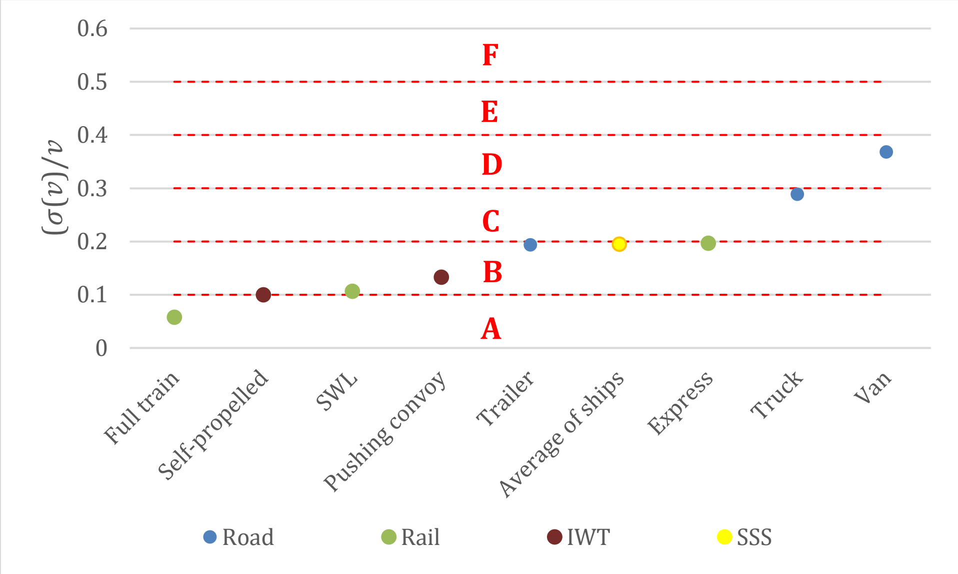
Table 8-4: Reliability indicator values

Mode	Type of vehicle or service	$\frac{\sigma_n(v)}{v}$
Road	Truck (>3.500 Kg)	0.289
	Van (<3.500 Kg) -	0.368
	Trailer truck (articulated)	0.194
Rail	Full train	0.058
	SWL	0.106
	Express	0.197
IWT	Self-propelled ship	0.100
	Pushing convoy	0.133
SSS	Average of ship types	0.195

Source: Author

Combining the values of all modes for the reliability indicators it can be stated that the less reliable mode in terms of speed is the road transport. Rail and IWT, since they have dedicated slots or paths on their networks, it is understandable that they register a higher level of reliability per section of infrastructure. Most of the values are between 0.1 and 0.4. Therefore, LOS B and LOS D should cover this range of values by definition. It is decided to distribute this range in homogenous segments for the same reasoning than on the previous indicator. LoS A is then for values lower than 0.1. LoS E is for values bigger than 0,4 and finally LoS F for values bigger than 0,5.

Figure 8-5: Calibration of Reliability indicator

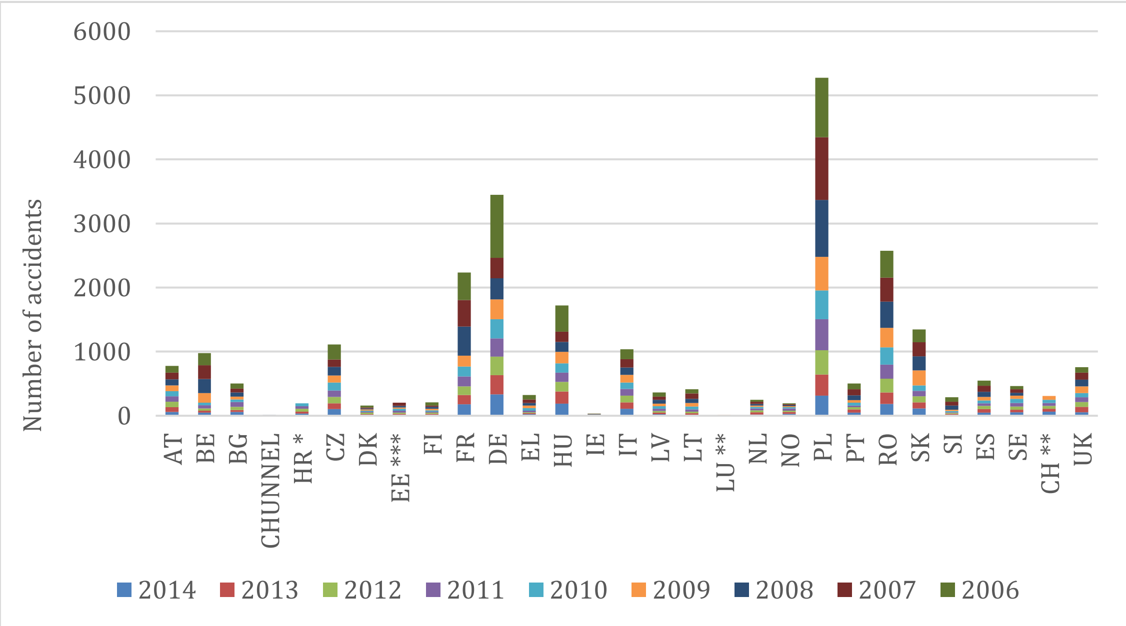


Source: Author

8.3.3.3 Safety and security indicators

The number of accidents on a network depends on the country and on the type of mode. For instance, on rail freight transport between 2006 and 2014, Poland had a considerably higher number of accidents than the other countries of the EU (see Figure 8-6).

Figure 8-6: Rail accidents in Europe 28 (2006-2014)



* Data from 2010 to 2014; ** Data from 2009 to 2014; *** Data from 2007 to 2014

Source: (EC, 2016)

To calibrate the indicators of safety and security, data on accidents from the Swiss rail and road networks has been obtained. For both modes, detailed database with all accidents from 2013 to 2015. For rail, the data comes from the Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK, Bundesamt für Verkehr BAV, Abteilung Sicherheit, Sektion Grundlagen. For road, the data comes from the Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK, Bundesamt für Strassen ASTRA, Abteilung Strassennetze. The total number of accidents per mode has been normalized by the volume of its freight network (FGSV, 1997) (eq. 8.23). The network volume has been calculated using data of BAV, concerning annual values of vehicle-kilometres of the Swiss road and rail network.

$$Safety\ and\ security\ Indicator = \frac{Accidents\ per\ year}{Milions\ of\ feight\ vehicles\ \times\ kilometers} \tag{8.23}$$

Table 8-5: Accidents with freight vehicles involved

	Mode	2013	2014	2015
Total number of accidents per year	Road	7094	7161	7419
	Rail	77	103	83
Annual volume in millions of vehicle-kilometers	Road	6117	6234	6364
	Rail	29.6	33.6	34.5
Accidents normalized by annual volume in vehicle-kilometers	Road	1.160	1.149	1.166
	Rail	2.601	3.066	2.406

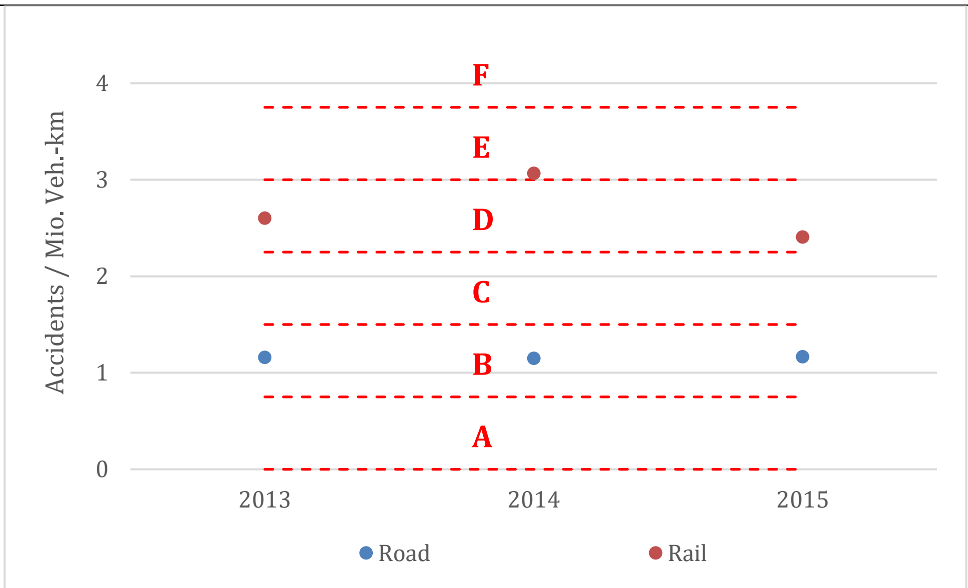
Source: UVEK 2013-2015 and ASTRA 2013-2015

By analysing the data provided, it can be stated that the absolute difference between accident rates on both networks is remarkable. This could be explained by a number of reasons. On one hand, interaction among vehicles is more likely on road due to lane changing manoeuvres, ramp access acceleration and deceleration, mixed trajectories on crossroads, overtaking manoeuvres, etc. These common driving situations increase the possibilities that accident occurs. Moreover, on the Swiss road network mixed traffic is allowed. This also increases the likelihood of an accident to occur due to visibility issues and different flow speeds.

On the other hand, rail systems behave mostly on a linear fashion. All train manoeuvres are supervised and technically controlled. Only speed is in the responsibility of man (under ECTS 2, even this is technically controlled). Therefore, the likelihood of an accident to occur is reduced considerably, and most of the collisions take place inside rail freight terminals during shunting procedures. Furthermore, on the Swiss rail network safety checks on freight trains are conducted periodically. When a freight train crosses a safety check section on the network sensors collect critical information and it is analysed right away. For instance, on 2015, around 1700 "obvious dangerous" events where detected on freight trains of the Swiss network. These events are stipulated on the article 24 of the Eisenbahn-Netzzugangsverordnung. An example of “obvious danger” event is when cargo weight is not well-balanced inside the wagon. This could be due to a bad loading procedure or to displacement of cargo because of train movement. This event is considered dangerous because it might induce to a later accident. When detected, the train is stopped, and cargo is readjusted.

After normalizing the accidents by the total vehicle kilometres on the network, values come closer and reach the same order of magnitude (see Table 8-5). Taking these values as representative of the Swiss freight system, by definition of the LoS they should fit between LoS A and LoS D. Therefore, the scale of values is built using values of Table 8-5 as main reference. The range selected is from 0 to 3 and divided in homogenous quality steps of 0.75 each. LoS E and LoS F are built as a continuation of these homogenous steps.

Figure 8-7: Calibration of Safety and Security indicator



Source: Author

8.3.3.4 Frequency indicators

Frequency indicator for infrastructure is understood in this research as how often it is allowed to run a freight service on an infrastructure. On road infrastructure, freight services are always allowed except for special goods (ECE, 2015; SBB Cargo International, 2013) and temporal interdictions such as the *night driving ban* “Nachtfahrverbot” and the *Sunday driving ban* “Sonntagsfahrverbot” (Art.9 Abs. 2 VRV), topics dealt with on the accessibility indicator. However, on rail, despite the absence of general restrictions, freight service is limited to a given number of slots at several dedicated times. This time structure of freight slots is given by the passenger timetable structure. It is designed by the infrastructure manager and operators need to book those paths in advanced. Therefore, this indicator illustrates one challenge of rail freight when competing with road freight. The theoretical capacity of a rail line (Bischofberger, 1997) can be calculated as follows:

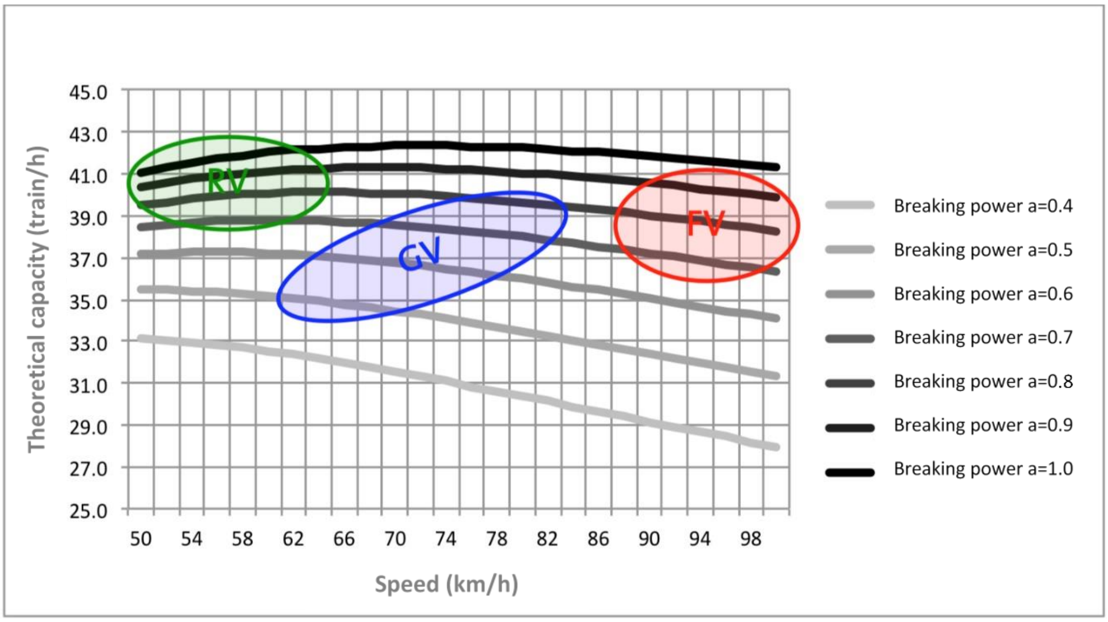
$$L_{theo,max} = \frac{2av}{Bv^2 + 2av(t_A + t_R) + 2aL} \quad (8.24)$$

Where:

- a - Breaking power in [m/s2]
- v - Speed in [m/s]
- B - Slot factor [-]
- t_A - Approximation time in [s]
- t_R - Evacuation time in [s]
- L - Train length in [m]

Therefore, the capacity depends on several parameters. The range of possible maximal theoretical capacities for rail freight have been studied before (Weidmann, Frank, Fumasoli, & Moll, 2012) and it oscillates between 35 and 40 trains/h. This value needs to be reduced to its 75% to ensure stable operations (UIC, 2004). Therefore, the maximal stable capacity oscillated from 26 to 30 trains per hour depending on the type of train and composition (more than 600 trains/day).

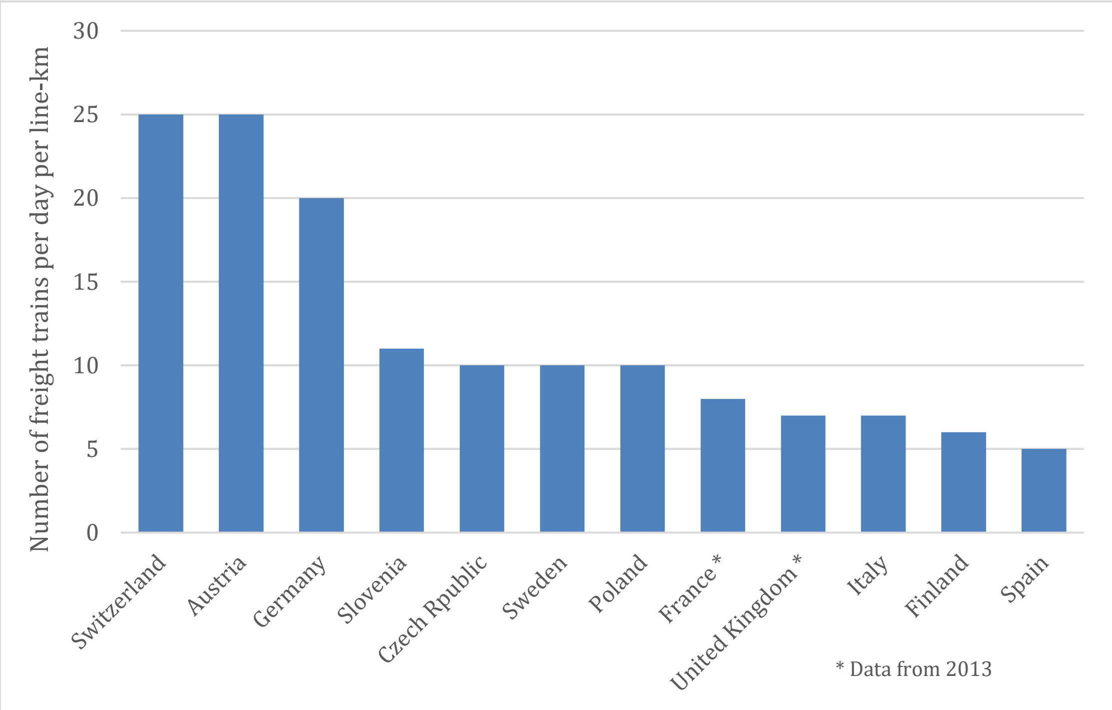
Figure 8-8: Rail line theoretical maximal capacity



Source: (Weidmann et al., 2012)

The current frequencies in European rail freight networks are depicted in Figure 8-9. Switzerland and Austria are the networks with a higher frequency of freight trains per day, although all networks work considerably below their maximal stable freight capacity. First, it might well be that there is not enough demand that justifies much bigger average loads than the ones here presented. Second, it needs to be stated that all those networks are also used for passenger transportation, which reduces capacity for freight. Third, despite the average load of the network, most likely, important freight corridors operate higher number of freight trains per day within those networks, e.g., on the link Basel-Olten there are more than 100 freight trains per day, and on the Gotthard tunnel there are around 120 freight trains per day (SBB, 2016a).

Figure 8-9: Freight trains per day and km on 2014 in European countries



Source: (EC, 2016)

Taking Switzerland as an example of well-performing rail freight network, frequency of service on its lines has been evaluated using SBB data from freight traffic in 2016 (SBB, 2016a). Data analysis shows an asymptotic distribution of frequency, where few lines are highly used for freight services, some have a moderate amount of service and other are barely used. This data is used to calibrate the frequency indicator presented on chapter 8.3.2. Since the data distribution is not linear, instead of a applying a linear LoS scale as in other indicators, a quartile scale is used. Thus, this scale better represents the behaviour of the network. For LoS A, the theoretical scenario of a full rail freight network is selected. This value has been calculated above and allows up to 600 freight trains per day. For LoS B to E, the quartiles of the Swiss rail network are adopted. Finally, LoS F is disruption of the system, i.e., no freight trains.

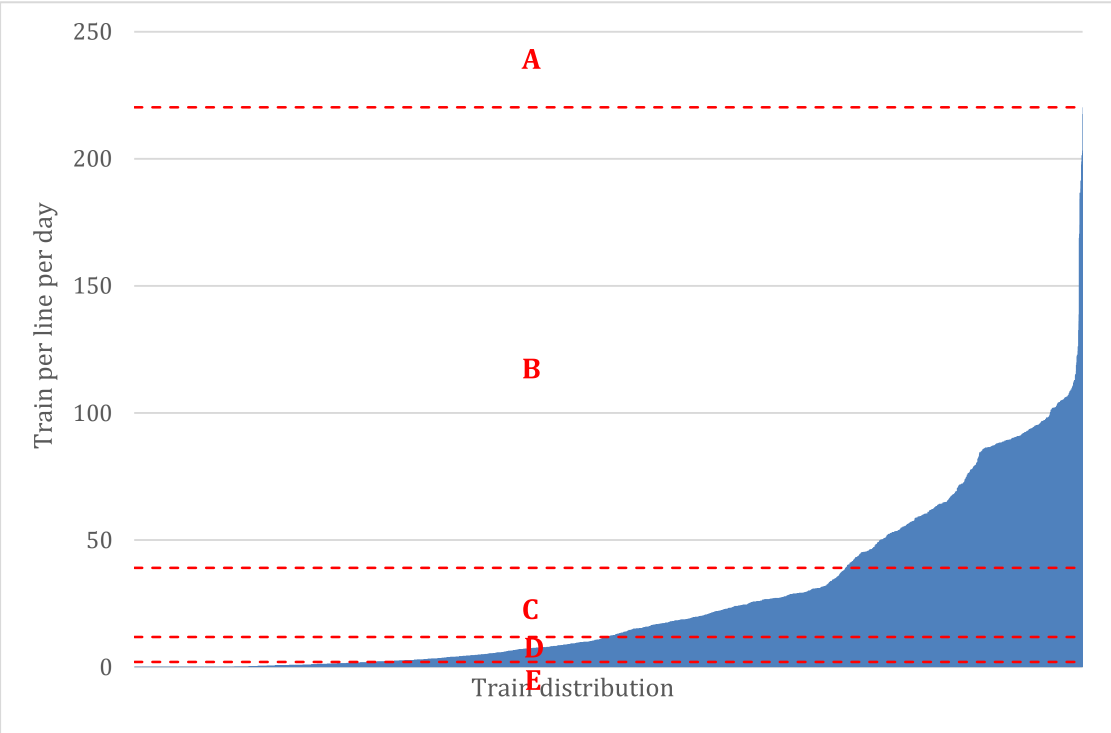
$$Fr_{Rail,I} = \frac{FS}{day}$$

Table 8-6: Frequency scale LoS

LoS	Freight trains paths per day
A	221 - 600
B	40 - 220
C	12-39
D	3-11
E	0-2
F	No service

Source: Author

Figure 8-10: Calibration of Frequency indicator



Source: Author

8.3.3.5 Accessibility indicators

Accessibility is evaluated in this research using three indicators: opening hours, vehicle restrictions and cargo restrictions. Concerning opening hours, road transportation has some restrictions in Switzerland such as the *night driving ban* and *Sunday driving ban* (Art.9 Abs. 2 VRV). On SSS, the ways are always open to traffic. Concerning rail it depends on the paths available on the schedule. Finally, for IWT it depends on the canal opening hours. The standard operating regimes for IWT establishes 5 types of waterways depending on the time they are open, from all the time (168 hours per week) to only 60 hours per week; and depending on their cargo capacity.

Table 8-7: Standard operating regimes for commercial navigation

Regime	Monday	Tuesday-Friday	Saturday	Sunday	Total weekly hours
1	0 - 24	0 - 24	0 - 24	0 - 24	168
2	6 - 24	0 - 24	0 – 20	8 – 20	146
3	6 – 22	6 – 22	8 – 20	9 - 17	100
4	6 – 22	6 – 22	8 – 18	--	90
5	7 – 19	7 – 19	--	--	60

Source: (Brolsma & Roelse, 2011)

- Regime 1. Trunk routes and other waterways regarded as crucially important.
- Regime 2. Waterways carrying more than 15 million tons of cargo capacity a year.
- Regime 3. Waterways carrying 5 to 15 million tons of cargo capacity a year.
- Regime 4. Waterways carrying 2 to 5 million tons of cargo capacity a year.
- Regime 5. Waterways carrying less than 2 million tons of cargo capacity a year.

This classification seams suitable for evaluating the quality of opening hours of a transportation infrastructure. Therefore, it is adopted in this research for building the quality scale for the opening hours indicator on accessibility.

Table 8-8: Opening hours LoS

LoS	Total weekly hours
A	168
B	146-167
C	100-145
D	90-99
E	60-89
F	<60

Source: Author

In terms of cargo restriction, the same criteria as for freight terminals is adopted (Ballis, 2004). If an infrastructure allows hazardous and perishable goods to be transported or not.

Table 8-9: Cargo restriction LoS

LoS	Hazardous goods	Perishable goods
A	Yes	Yes
B	Yes	Yes
C	Yes	No
D	No	No
E	No	No
F	No	No

Source: Author

Regarding vehicle restriction, specific regulation for each mode is needed. For instance, on IWT the type of canal determines which formation of barges are allowed (see Table 8-11). The following classification is suggested:

Table 8-10: IWT vehicle restriction LoS

LoS	Inland waterway class
A	VI and VII
B	VI a and VI b
C	V a and V b
D	IV
E	none
F	none

Source: Author

Table 8-11: Classification of international Inland waterways

Class Inland waterway	Motor vessels and barges				Pushed convoys					Air draught
	Length (m)	Width (m)	Depth (m)	Tonnage (T)	Formation	Length (m)	Width (m)	Depth (m)	Tonnage	
IV	80-85	9.5	2.5	1000-1500		85	9.50	2.50-2.80	1250-1450	5.25 or 7.00
V a	95-110	11.4	2.5-2.8	1500-3000		95-110	11.40	2.50-4.50	1600-3000	5.25 or 7.00 or 9.10
V b						172-185	11.40	2.50-4.50	3200-6000	
VI a						95-110	22.80	2.50-4.50	3200-6000	7.00 or 9.10
VI b	140	15	3.9			185-195	22.80	2.50-4.50	6400-12000	7.00 or 9.10
VI c						270-280 195-200	22.80 33.00-34.20	2.50-4.50 2.50-4.50	9600-18000 9600-18000	9.10
VII						285 195	33.00 34.20	2.50-4.50	14500-27000	9.10

Source: (Binnenschiffahrts-Verlag Gmbh, 2006)

8.4 Structure of the metric

8.4.1 Existing structures

The three existing structures for a metric based on indicators and attributes have been presented in chapter 7.5.1. Therefore, the definitions will not be repeated in this chapter.

8.4.2 Selection of the appropriate structure

For the same reasons as in chapter 7.5.2, the assumption on the structure of the metric is that the six attributes are independent from each other and they have different relative values. The research has been designed in a way that weights of attributes will be calculated by analysing the results of an on-line survey designed Ad-hoc. As a result, the structure of the metric is the weighed additive one (1). The coefficients equal the relative importance of the attributes. The sum of all attributes coefficient equals to one (2). The reason is to keep a decimal base on the measurement method.

$$Level\ of\ Service = a_1 \cdot Attribute_1 + a_2 \cdot Attribute_2 + \cdots + a_n \cdot Attribute_n \quad (8.24)$$

Where $\sum_{i=1}^{n} a_i = 1$ (8.25)

8.5 Weighing of freight attributes – Survey results

8.5.1 Methods and execution

An on-line survey has been developed to collect data in order to calibrate the metric of the method. Six attributes have been identified as the more relevant attributes for evaluating freight performance through literature review (see Chapter 6). The survey is divided in three parts:

1. First, respondents are asked general questions to classify the answers. For instance, they are asked about their company's role in the freight transport chain, the volume or the type of goods they move per year, or their personal role inside the company. The goal of these questions it to spot differences among different answer clusters.

Figure 8-11: General questions of the respondent's profile on-line survey

1. What role does your company play within the logistics chain? Please mark.
   - ☐ Shipper
   - ☐ Carrier
   - ☐ Forwarder
   - ☐ Terminal operator
   - ☐ Other, please specify

2. What is your role in the company? Please indicate.
   - ☐ Sales representative
   - ☐ Dispatcher
   - ☐ Other operational job
   - ☐ Business development
   - ☐ Quality management
   - ☐ CEO
   - ☐ Controlling
   - ☐ Other, please specify

3. Please indicate for each commodity group the number of shipments your company handles every year.

Agricultural raw materials	Food and animal feed products	Chemical and mineral products	Iron and metal products	Building products	Manufactured goods	Postal and mail services	Other
0-1000000	0-1000000	0-1000000	0-1000000	0-1000000	0-1000000	0-1000000	0-1000000

4. Please indicate for each transport mode, the number of shipments your company handles every year.

Rail (Door-to-door service)	Road (Door-to-door service)	Rail + Road (Combined transport)	Intermodal (other than Rail + Road)
0-1000000	0-1000000	0-1000000	0-1000000

Source: Author

2. Afterwards, the respondents should compare by pairs the six freight quality attributes. A ruler is provided, and respondents shall move the roller left or right to indicate which attribute is more relevant according to their professional expertise. The further from the centre they move the roller, the bigger the relative importance between the two attributes. The goal of this questions is to collect the relative weighs of the attributes, so these can be used as input data to run an AHP analysis and conclude absolute weighs of the attributes.

Figure 8-12: Pairwise comparison of attributes on the on-line survey

5. According to the description above, compare the two following freight performance attributes:
   - **Attribute 1**: *Reliability* - Probability of conducting the shipment on time
   - **Attribute 2**: *Travel time* - Door-to-door transport time

(negative values) 0 (positive values)
Reliability <--------¦--------> Travel time

0

Source: Author

3. Finally, respondents are asked to describe three of their last shipments. They need to give in information such as origin and destination of the shipment, distance, travel time, percentage of damaged and lost cargo, type of cargo, type of packaging, etc. Furthermore, they need to express their satisfaction about some of the given

information. If they are not satisfied they are ask to specify which threshold would be acceptable for them. The goal of this section is to detect certain boundaries between what it is considered acceptable and not acceptable in terms of quality for certain attributes and commodities.

Figure 8-13: Questions to describe one shipment

Shipment 1

Please describe one of your last shipments by answering the following questions.

20. Indicate which transport mode was used during the shipment.
    - ○ Rail (Door-to-door service)
    - ○ Road (Door-to-door service)
    - ○ Rail + Road (Combined transport)
    - ○ Intermodal (other than Rail + Road)

21. Indicate to which commodity group the transported cargo belongs.
    - ○ Agricultural raw materials
    - ○ Food and animal feed products
    - ○ Chemical and mineral products
    - ○ Iron and metal products
    - ○ Building products
    - ○ Manufactured goods
    - ○ Postal and mail services
    - ○ Other, please specify

22. Indicate the origin of the shipment (city, country).

23. Indicate the destination of the shipment (city, country).

24. Indicate the total distance of the shipment (km). The value must be greater than or equal to 0.

    0

25. Indicate the net weight of the shipment (kg). The value must be greater than or equal to 0.

    0

26. Indicate the type of cargo of this shipment.
    - ☐ Liquid bulk goods
    - ☐ Dry bulk goods
    - ☐ Containers and swap bodies
    - ☐ Palletised goods
    - ☐ Pre-slung goods
    - ☐ Mobile, self-propelled units
    - ☐ Mobile, non self-propelled units
    - ☐ Other, please specify

Source: Author

Figure 8-14: Questions to describe one shipment and express satisfaction

27. Indicate the time in advanced needed to book such a shipment (hours). The value must be greater than or equal to 0.

0

28. Were you satisfied with the time in advanced needed for booking such a shipment?

☐ Yes
☐ No. Please indicate which time in advanced needed for booking would have been acceptable in your opinion

29. Indicate the expected travel time for this shipment (hours). The value must be greater than or equal to 0.

0

30. Were you satisfied with the expected travel time?

☐ Yes
☐ No. Please indicate which expected travel time would have been acceptable in your opinion

31. Indicate the delay of this shipment (hours). The value must be greater than or equal to 0.

0

32. Was the delay acceptable in your opinion?

☐ Yes
☐ No. Please indicate which delay would have been acceptable in your opinion

33. Indicate the percentage of damaged and lost cargo during this shipment (%). The value must be between 0 and 100, inclusive.

0

34. Was the amount of damaged and lost cargo acceptable in your opinion?

☐ Yes
☐ No. Please indicate which amount of damaged and lost cargo would have been acceptable in your opinion

35. Were you satisfied with the overall performance of the shipment?

☐ Yes
☐ No. Please explain why

Source: Author

8.5.2 Results

Visits and answers took place between April 2016 and July 2016. Although the total number of visits was 122, the number of complete answers was 6 for the first and the second part of the survey, and 3 for the third part (see detailed numbers on Table 8-12).

Table 8-12: Survey's response summary

	Visits without answer	Partial Answers	Complete Answers
General questions	107	9	6
Attributes comparison	92	24	6
Shipment descriptions	1	1	3

Source: Author

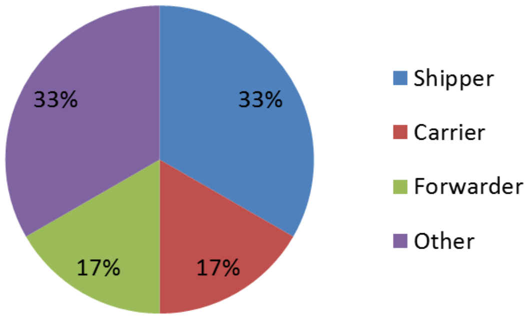
8.5.2.1 Respondent's role

The first two sections of the survey were completely answered by the same group of respondents. On the other hand, the third section was only fully answered by a part of that group of respondents. Below, respondent's profiles are presented:

- Respondent's roles of the complete answers on sections "General questions" and "Attributes comparison" are plotted on Figure 8-15.

Figure 8-15: Respondents roles for first and second section of the survey

Role	Count
Shipper	2
Carrier	1
Forwarder	1
Other	2
Total	***6***

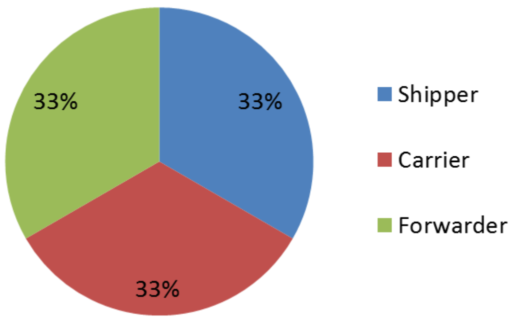


Source: Author

- Respondent's roles of the complete answers on section "Shipment descriptions" are plotted on Figure 8-16.

Figure 8-16: Respondents roles for the third section of the survey

Role	Count
Shipper	1
Carrier	1
Forwarder	1
Total	***3***



Source: Author

8.5.2.2 Attributes comparison

For the attributes comparison, the answers have been clustered in six groups: All answers together, shippers, carriers, forwarders, carriers and forwarders, and others. Carriers and forwarders cluster is designed to analyse the service provider point of view. The cluster "other" includes answers from the administration body and academics. These respondents are good representatives of the industry, they have good knowledge of the freight sector due to their professional experience and their job responsibilities. These answers have been analysed using the AHP method. The overall results are summarized on Table 8-13, and plotted on Figure 8-17. It illustrates the weights of the six freight quality attributes according to the survey answers of the different logistics roles of the supply chain.

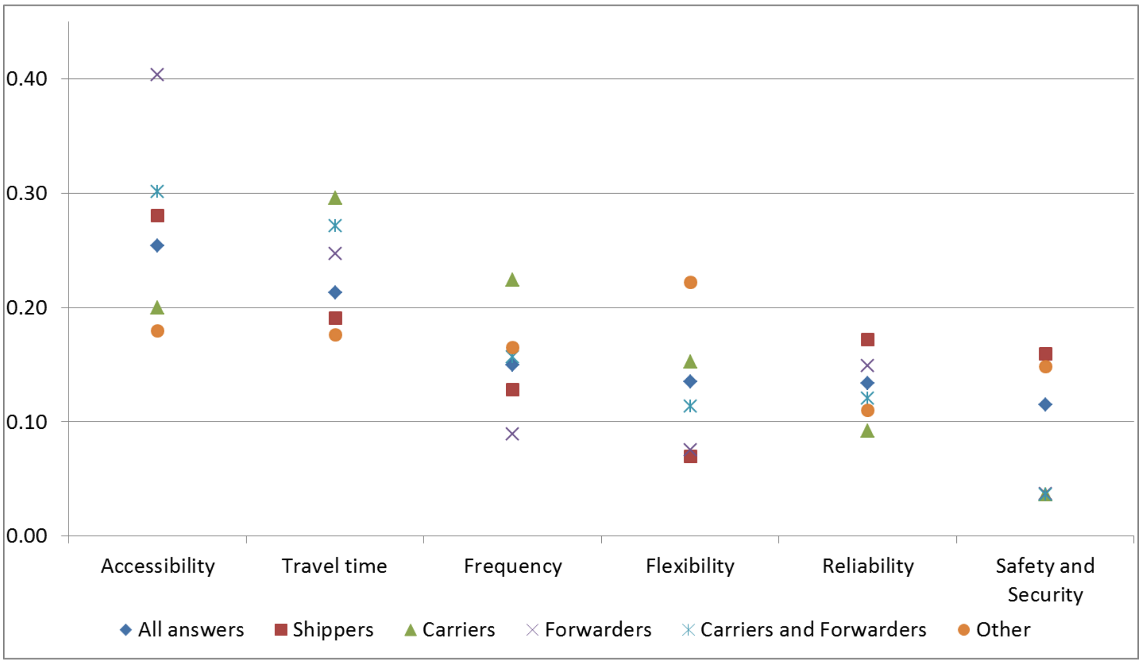
Table 8-13: Attributes weights resulting from the AHP analysis

	All	Shippers	Carriers	Forwarders	Carriers and Forwarders	Other
Accessibility	0.25	0.28	0.20	0.40	0.30	0.18
Travel time	0.21	0.19	0.30	0.25	0.27	0.18
Frequency	0.15	0.13	0.22	0.09	0.16	0.16
Flexibility	0.14	0.07	0.15	0.08	0.11	0.22
Reliability	0.13	0.17	0.09	0.15	0.12	0.11
Safety and Security	0.11	0.16	0.04	0.04	0.04	0.15

Source: Author

Results show respondents consider two levels of attributes. Except "Other" respondents, who consider Flexibility the most important attribute, Accessibility and Travel time are considered the most relevant attributes and each rank mostly between 20 and 30 % of the total weight. On the second level, respondents consider Frequency, Flexibility, Reliability and Safety and Security. Each rank between 10 and 20%, besides Safety and Security, which Service providers consider the least important, and they rank it around 4%.

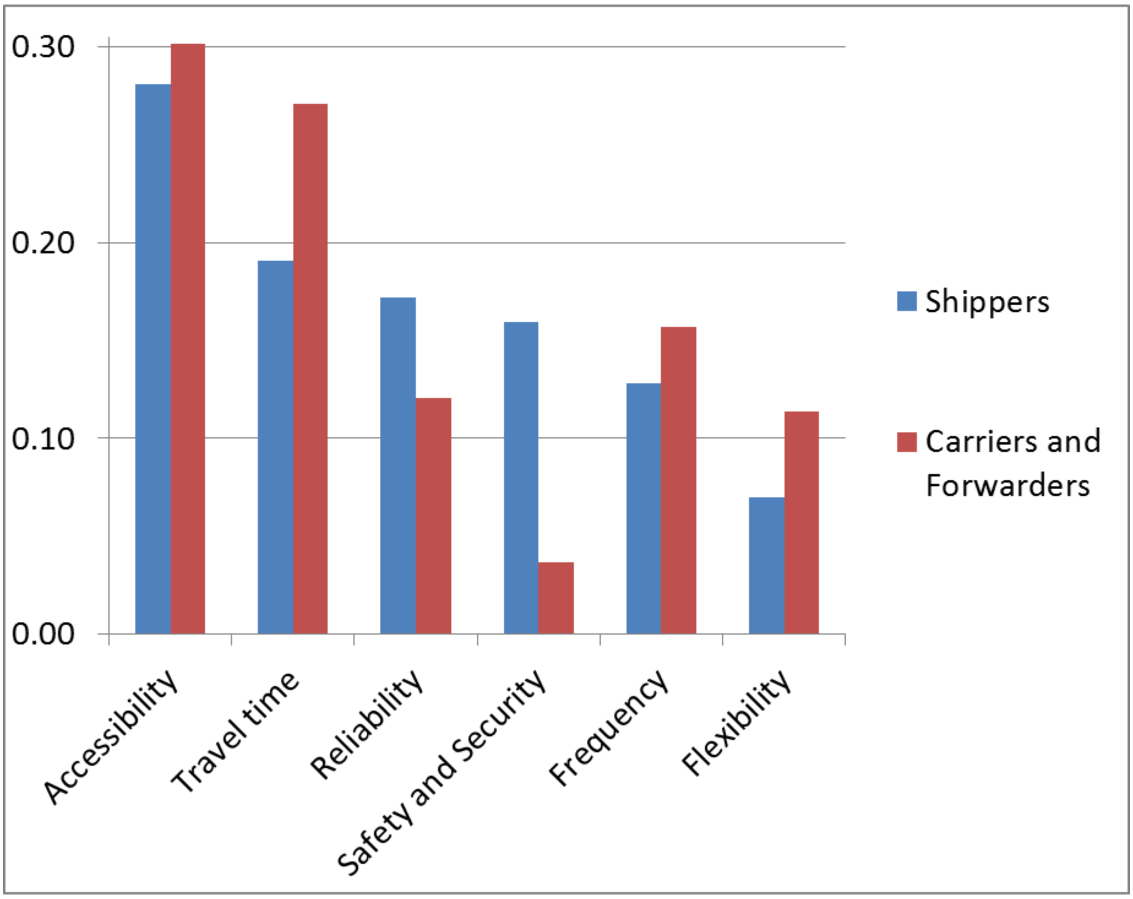
Figure 8-17: Attributes weights resulting from the AHP analysis



Source: Author

Considering only the respondents that intervene on the Service quality loop (see Figure 2-3), shippers and service providers (carriers and forwarders), some similarities and some differences can be observed. Both agree on the most important attributes, Accessibility and Travel time. Nevertheless, they disagree on the importance of safety and security. Whereas for shippers, it is an important attribute, almost as important as reliability and more important than frequency and flexibility, service providers consider it the least important.

Figure 8-18: Comparison of shippers and service providers opinions on weights of freight transportation attributes



Source: Author

8.5.3 Discussion of methods and results

The survey had a low rate of answers and it might be explained by different reasons:

- First, as opposed to the survey conducted in Chapter 7, there was none potential respondents' database available. That limited considerably the total amount of contacts the survey invitations could be sent to. Being known that, on the customer orientation survey there was a 19% of response (198 partial or complete answers out of 1037 invitations), and a 13,5% of complete answers rate (140 out of 1037). Thus, when the number of invitations drops down considerably (two orders of magnitude), it seems logical that the answers drop down on the same magnitude.
- Second, the total time required to answer the survey might have been too long (about 45 minutes). The general questions and the attribute comparison exercise were similar in length as in the previous survey, but the shipment description required more effort. That might explain why the number of complete answers drop from the second to the third part of the survey.
- Third, it is known that freight companies tend to be reserved about sharing information on company interests or performance, since it is sometimes perceived as a risk in terms of market competition. Therefore, the willingness to contribute altruistically to the survey might be affected by this fact, since there is no incentive from the respondents to answer.

The AHP analysis indicates that there are different opinions on the relevance of the attributes depending on the actor of the supply chain. These differences are reasonable because shippers value more reliability and safety and security than service providers, who value more flexibility. Recent studies show that thefts are a growing concern for shippers (Brüls & Wyer, 2016), due to an increase of these events in Europe, whereas for service providers flexibility is important to deal with unexpected events during operation. Nevertheless, these differences can also be the consequence of the small sample of answers. There is the possibility than a bigger pool of answers would reduce differences on the AHP results.

8.6 Level-of-Service for freight transportation

8.6.1 Results

The indicators used on the suggested LoS for freight terminals (Ballis, 2004), were presented on Table 8-2. The calibration of those indicators is presented on Table 8-14. The numbers for each level are based on shipper's perception. LoS A refers to an ideal situation according to shippers' perspective, although it might not meet existing terminal operation performance. On the other hand, LoS B values are based on existing performance with high LoS. Finally, LoS F values are based on unacceptable performance, according to shippers' perspective.

Table 8-14: Proposed LoS standards for freight terminals

			Level of Service					
Attribute	**Indicator**	**Mode**	**A**	**B**	**C**	**D**	**E**	**F**
Dwell time	Waiting time	All	0-19	20-30	31-40	41-60	61-120	SYSTEM BREAKDOWN
Reliability	Vessel delays (%)	SSS, IWT	0-2	3-5	6-15	16-30	31-60	
	Duration (min)		0-30	31-45	46-60	61-90	91-180	
	Train delays (%)	Rail	0-2	3-5	6-10	11-20	21-40	
	Duration (min)		0-10	11-20	21-30	31-40	41-60	
Flexibility	Cutoff time (hours)	SSS, IWT	0-2	3-4	5-6	7-8	9-24	
		Rail	0-0.5	1-2	3-4	5-6	7-8	
Safety and security	Loss of goods (%)	All	0	0	0-0.5	0.5-1	1-2	
	Loss of loading units (%)		0	0	0	0-0.5	0.5-1	
	Loss of documents (%)		0	0	0-5	5-10	10-15	
Accessibility	Working hours (seaside) (hours)	SSS, IWT	24	24	24	16	16	
	Working hours (yardside) (hours)		24	24	16	16	8	
	Working hours (hours)	Rail	24	24	16	16	8	
	Hazardous goods	All	yes	yes	no	no	no	
	Perishable goods		yes	yes	yes	no	no	

Source: (Ballis, 2004)

LoS for freight transport infrastructure is presented on Table 8-15. Attributes are defined on chapter 8.3.1, indicators are explained on chapter 8.3.2 and calibration values are presented on Chapter 8.3.3.

Table 8-15: Proposed LoS standard for freight transport infrastructure

			Level of Service					
Attribute	**Indicator**	**Unit**	**A**	**B**	**C**	**D**	**E**	**F**
Travel time	$\bar{v}_{\vartheta}$	Km/h	>80	60-80	40-60	20-40	<20	SYSTEM BREAKDOWN
Reliability	$\frac{\sigma_n(v)_L}{\bar{v}_{L,\vartheta}}$	-	<0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	
Safety and security	$\frac{\alpha \sum_i^n a + \beta \sum_j^m r}{V_L}$	$\frac{Accidents}{Mio.Veh-km}$	0-0.75	0.75-1.5	1.5-2.25	2.25-3	3-3.75	
Frequency	$\frac{FS}{day}$	Trains/day	221 - 600	40 - 220	12-39	3-11	0-2	
Accessibility	Opening hours	h/week	168	146-167	100-145	90-99	60-89	
	Hazardous goods	-	yes	yes	no	no	no	
	Perishable goods	-	yes	yes	yes	no	no	

Source: Author

Shipper's perception on how important each attribute is (Table 8-16) is one result of the shipper's survey presented on chapter 8.5. These weights are used to calculate the overall LoS of a transport element by using a weighted additive metric.

Table 8-16: Shipper's attribute weights

Attribute	Weight
Accessibility	0.28
Travel time	0.19
Frequency	0.13
Flexibility	0.07
Reliability	0.17
Safety and Security	0.16

Source: Author

Numerical equivalent of LoS for calculation overall LoS of an element in a scale from 0 to 1. From A to D, LoS is acceptable for service, therefore it is evenly distributed between 0.5 and 1, being 0.5 the minimum quality accepted for service. The LoS F is total disruption of service and therefor the lowest numerical qualification is given. LoS E is on the middle between total disruption and minimum quality accepted

Table 8-17: LoS numerical values

LoS	Value
A	1
B	0.833
C	0.666
D	0.5
E	0.25
F	0

Source: Author

8.6.2 Discussion of methods and results

The A-F scale has been adopted for this study because of its general acceptance in the transportation scientific and technical community regarding Level-of-Service metrics. Since it was first implemented on the Highway Capacity manual in the 1960s decade, its use has been enhanced and spread to other transportation fields such as public transport or human powered mobility such as pedestrian or cycling manuals. Furthermore, some contributions on Level-of-Service metrics for freight terminals also implemented this scale. Thus, this scale seems the appropriate choice to build a Level-of-Service metric for freight transportation. Adoption of this system also allows some cross-comparisons between transport systems and get general evaluation of transport quality in an area.

The results suggested in this chapter are based upon the available data that the author could have access to. Thus, with different data sets or bigger data sets, values could vary. Further research should consider including data from other countries and complete the study with currently inaccessible information such as robbery data, which was not accessible by the author.

9 Potential of transport freight quality evaluation

In this chapter there are 5 cases studies to validate the methodologies developed on chapter 7 and chapter 8. On chapter 7, a methodology to evaluate customer orientation for freight and logistics service providers was exposed. On chapter 8, a methodology to calculate Level-of-Service on freight networks was presented. Case Study 1 and 2 validate two applications of the customer orientation measurement methodology: measure customer orientation on freight and logistics service providers; and benchmark different freight and logistics service providers in terms of their customer orientation performance. Case Studies 3, 4 and 5 validate the application of the methodology to calculate Level-of-Service for freight transportation. Case 3 evaluates a link, Case 4 evaluates a corridor and Case 5 evaluates a network.

9.1 Case study 1: Customer orientation evaluation of a service provider

9.1.1Description of the case

The proposed methodology presented on chapter 7 for evaluating freight and logistics companies regarding customer orientation was validated using real data of a Swiss rail freight operator (SBB Cargo). The validation was done on the frame of the research project "*Erarbeitung eines Index zur Messung der Kundenorientierung in der Logistikbranche"* carried out by IVT and USG. The author of this thesis was responsible for developing IVT's contribution on the project. SBB Cargo was interested in a metric to evaluate the degree of customer orientation, a tool for company's self-evaluation and a benchmark with other freight and logistics providers of the market. Therefore, they provided specific data so the indicator-based-system could be applied.

9.1.2Application of the metrics

Below, the results of the validation are presented. Table 9-1 presents all calculations following the methodology developed on chapter 7 (6 attributes and 13 indicators). Each indicator has an associated frequency which indicates how often data is collected and computed. For each indicator, some variables are presented. These variables are used to calculate indicator calculation (in bold). The score for each indicator (in bold) are the result of calculations and comparison with the base value. The base value is a reference value defined by the company according to its goals and its past performance. Performing this evaluation over time can provide new base values for the company as a self-learning algorithm would.

$$Indicator\ score = \frac{Value\ of\ Indicator\ calculation}{Base\ value\ of\ Indicator\ calculation}\ x\ 100 \tag{9.1}$$

Table 9-1: Calculation customer orientation of a rail freight service provider

Attributes	Indicator	Frequency	Variables	Value	Base value
Accessibility	I 01	yearly	Maximum service time (24 h)	24	24
			Actual service time (h per day)	12	12
			Indicator calculation	*50%*	*50%*
			Indicator score	*100*	
	I 02	monthly	Maximum accessibility (h per month)	720	720
			Actual accessibility (h per month)	717	720
			Indicator calculation	*99.58%*	*100%*
			Indicator score	*99.58*	
	I 03	monthly	Number of all customer calls	2900	2900
			Answered customer calls	2749	2842
			Indicator calculation	*94.79%*	*98%*
			Indicator score	*96.73*	
Information	I 04	monthly	Number of sales staff	111	115.33
			Number of calls to customers by sales staff	86	250
			Customer calls per sales representative	0.78	2.17
			Number of personal customer contacts	1674	1674

			Personal customer contacts per sales representative	15.08	14.51
			Indicator calculation	*15.86*	*16.68*
			Indicator score	*95.06*	
	I 05	yearly	Number of active customers	1741	1741
			Number of customers connected to the IT system	1400	1452
			Indicator calculation	*80.41%*	*83.38%*
			Indicator score	*96.44*	
	I 06	monthly	Number of cases affected by exceptional events, in particular delays	1824	1824
			Number of cases informed about a delay	1750	1750
			Indicator calculation	*95.94%*	*95.94%*
			Indicator score	*100*	
Reliability	I 07	monthly	Number of all offer requests	1072	1278
			Number of all complied offers	904	1118
			Indicator calculation	*84.33%*	*87.48%*
			Indicator score	*96.40*	
	I 08	monthly	Number of all transport contracts	57250	57250
			Number of all complains	465	465
			Indicator calculation	*99.19%*	*99.19%*
			Indicator score	*100*	
	I 09	monthly	Number of all trains	11366	11366
			Number of all trains with +3 minutes delay	3741	3741
			Indicator calculation	*67.09%*	*67.09%*
			Indicator score	*100*	
	I 10	monthly	Number of all issued invoices	3012	3012
			Number of invoice adjustments	250	250
			Indicator calculation	*91.70%*	*91.70%*
			Indicator score	*100*	
	I 11	monthly	Value of all credits (reimbursement)	40000	40000
			Number of payments to customers	5	5.33
			Indicator calculation	*8000*	*7500*
			Indicator score	*106.67*	
Celerity	I 12	monthly	Number of complains	349	349
			Number of all offers that lead to transport orders	8759.52	8759.52
			Indicator calculation	*25.10*	*25.10*
			Indicator score	*100*	

Finding solutions	I 13	monthly	Number of all complied offers	904	904
			Number of all offers that lead to transport offers	301	301
			Indicator calculation	*33.30%*	*33.30%*
			Indicator score	*100*	
Customer understanding	I 14	yearly	Total number of active customers	1741	1741
			Number of customers that participate in product development	56	56
			Indicator calculation	*3.22%*	*3.22%*
			Indicator score	*100*	
	I 15	yearly	Number of sales staff	111	115.33
			Cumulative number of training hours of all internal and external trainings	3200	3200
			Indicator calculation	*28.83*	*27.75*
			Indicator score	*103.90*	
	I 16	yearly	Number of al customer records in CRM	13202	13202
			Number of all customer records that have been active for 18 months in CRM	4625	4625
			Indicator calculation	*35.03%*	*35.03%*
			Indicator score	*100*	
	I 17	yearly	Number of all transport contacts	687000	687000
			Number of all personal aftersales customer contacts	264	264
			Indicator calculation	*0.04%*	*0.04%*
			Indicator score	*100*	

Source: Author

9.1.3Evaluation and rating

After calculating the score for each indicator, and in order to calculate the overall level of customer orientation, the weighting of each attribute and indicator needs to be applied. Attribute scores are calculated using the indicator scores and its weights presented on chapter 7. Table 9-2 presents the weighing of each attribute as well as the attributes scores. Furthermore, it presents the Level of customer orientation of the company calculated with the aforementioned values. As it is indicated, the company provides a Level of customer orientation ≥ 100, which means the company ranks above its goals.

Table 9-2: Score on customer orientation for a rail freight operator

Attribute	Weight	Score	Level of customer orientation
Accessibility	4%	98.77	100.47
Information	7%	97.43	
Reliability	58%	101.05	
Celerity	5%	100.00	
Finding solutions	14%	100.00	
Customer understanding	12%	100.74	

Source: Author

9.2 Case study 2: Benchmark customer orientation of several service providers

9.2.1 Description of the case

The proposed methodology presented on Chapter 7 for benchmarking freight and logistics companies regarding customer orientation was validated with data from 6 logistics and freight companies from Switzerland, Germany and Austria on the frame of the research project "*Erarbeitung eines Index zur Messung der Kundenorientierung in der Logistikbranche"*. The companies provided specific data, so the indicator-based-system could be applied in each of those companies. Some companies provided a complete set of data and, therefore, a full customer orientation analysis was carried out; others only provided part of the data, thus, partial customer orientation analysis was conducted on those cases. Therefore, benchmark was only possible among those indicators which needed data was provided.

9.2.2 Application of the metrics

Indicator values are calculated following the same formulation of Chapter 9.1.2, but instead of defining a base value for each indicator, a mean value for each indicator has been calculated. This mean value is used to benchmark the indicators of each company. It is calculated as indicated in eq. 9.2. After calculating the mean value, it is converted into a symbolic value of 100. Companies that perform better than the mean value, get a punctuation higher than 100 on the indicator, and companies performing worse than the mean value get a punctuation inferior to 100.

$$Mean\,Value\,of\,I = \frac{\sum_{i=1}^{n} I_i}{n} \qquad (9.2)$$

Where n is the total number of benchmarked companies.

The case study results are summarized in Table 9-3. It presents a benchmark analysis of all 6 companies. Companies 1, 2 and 4 are rail freight operators; Company 3 is a logistics service provider; Company 5 is a road freight and logistics provider; and Company 6 is a post service company.

Table 9-3: Customer orientation benchmark of 6 freight and logistics companies

Indicator	Mean Value	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6
I 01	46.18%	108.27	126.32	90.23	90.23	99.25	85.71
I 02	99.64%	99.94	100.36	100.36	100.36	98.97	(-)
I 03	65.04%	145.74	(-)	153.75	(-)	0.51	(-)
I 04	79.62%	19.92	(-)	141.93	(-)	138.16	(-)
I 05	36.63%	219.54	273.01	0	7.46	0	(-)
I 06	90.31%	106.23	(-)	110.72	(-)	83.04	(-)
I 07	91.37%	92.29	109.45	109.45	101.26	87.56	(-)
I 08	98.56%	100.98	101.43	96.26	(-)	101.33	(-)
I 09	74.50%	90.05	54.91	134.23	120.81	(-)	(-)
I 10	96.13%	101.30	(-)	101.49	94.28	102.93	(-)
I 11	2024.37	395.18	(-)	0	(-)	0.05	4.77
I 12	9.23	-71.84	(-)	182.67	(-)	189.17	(-)
I 13	43.42%	76.69	(-)	87.21	92.13	143.96	(-)
I 14	2.84%	113.29	211.32	102.09	41.99	31.31	(-)
I 15	33.25	86.71	(-)	24.06	223.89	60.16	105.18
I 16	42.45%	82.54	235.60	44.98	101.63	0	135.26
I 17	8.04%	0.48	(-)	298.83	(-)	0.69	(-)

(-) Blank box due to absence of data to calculate the indicator value.

Source: Author

9.2.3Evaluation and rating

Since results are based upon incomplete data, full comparison among companies cannot be stated. Nevertheless, neglecting unknown data, some basic comparisons can be made:

- First, it could be stated that Companies 2 and 3 perform better than the others. Company 2 ranks in 7 indicators above the mean and also as with the higher values, while it only ranks on 1 indicator as the worst company. Company 3 ranks in 10 indicators above the mean value and ranks in 7 indicators as the best company, while it ranks in 4 indicators as the worst one.
- Second, Company 1 would be one level below in terms of customer orientation since it ranks above the mean value in 7 indicators, but it does it only in 1 indicator as the best company, and 4 times as the worst one.

- Third, Company 4 and 5 rank 5 times above indicator's mean value. Company 4 ranks in 2 indicators as the best company and 1 as the worst, but Company 5 ranks in 3 indicators as the best company and 7 times as the worst.
- Therefore, although the full analysis could not be conducted on each company, given the available data, the classification of the companies in terms of their customer orientation would be in the following order (from better to worst): Company 3, Company 2, Company 1, Company 4 and Company 5. Company 6 is not listed in order because only 4 of its indicators were evaluated.

There are several conclusions that can be made based on the benchmarking analysis results:

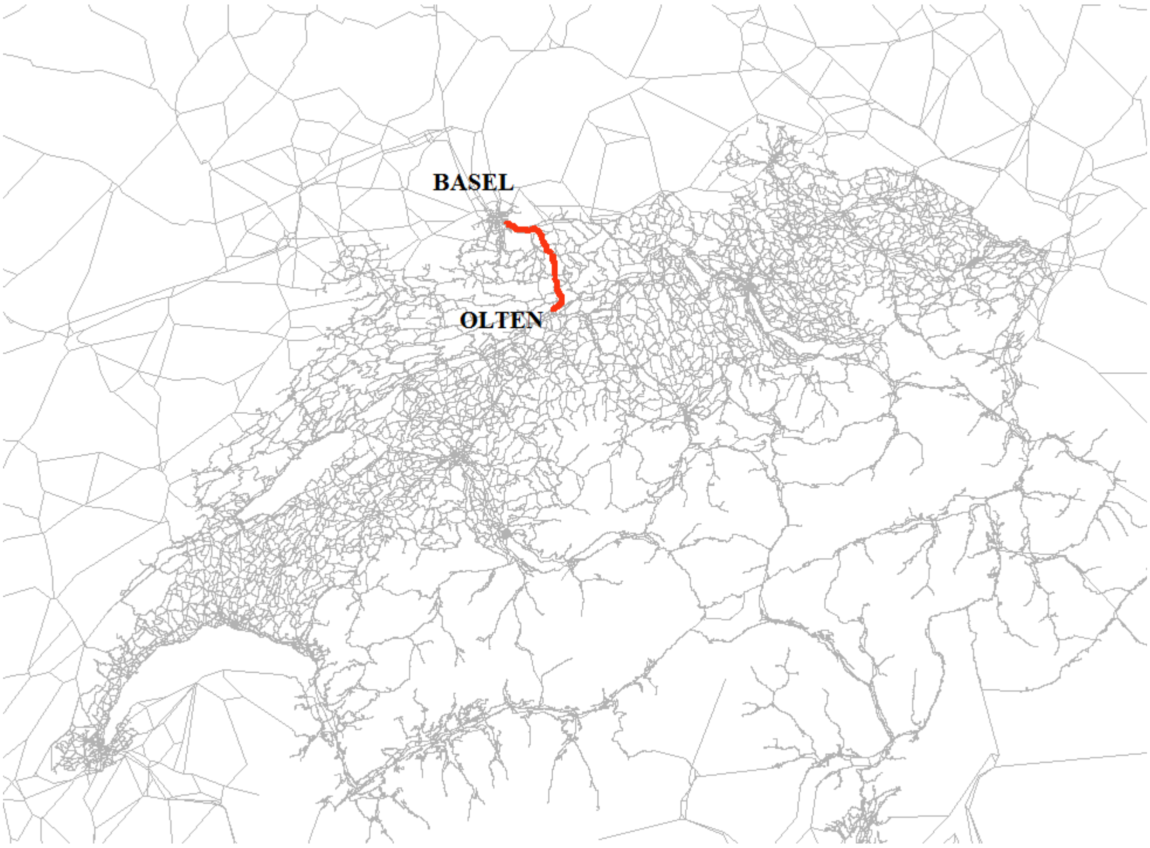
- The benchmarking analysis method proposed in this research is suitable for use as a basis for structuring cross-company benchmarking.
- Missing data or differing interpretations in the collected data make it difficult to compare companies.
- Despite a reduced data set, it was possible to make statements on possible approaches to improve customer orientation for different companies.
- These statements on improving customer orientation are descriptive, not explanatory.
- The benchmarking analysis interpretation and conclusions must be determined in collaboration with the specific companies because the companies have different sizes, different types of clients and different market strategies.
- Not for all the companies the level of customer orientation could be calculated due to missing data, however individual benchmarking indicators can be determined.

9.3 Case study 3: Level-of-Service evaluation of a link

9.3.1 Description of the location

This case study illustrates the application of the metrics developed in Chapter 8 to calculate LoS on links of a freight transport network. The link selected to illustrate the methodology is the road segment that connects the port of Basel and the interaction of the Swiss highways A1 and A2 in Olten. This is an important link on the Swiss road network because it connects the biggest trimodal terminal in Switzerland to a strategical area in central Switzerland where many logistics and consolidation centres are located. The relevance of this link for the freight and logistics sector makes it an interesting example. The link is mostly part of the highway network, meaning maximal speed of 120 km/h for vans and 90 km/h for trucks and trailer trucks. The vehicle height accepted is 4.5 meters.

Figure 9-1: Road link between Basel Port and A1-A2 Olten intersection



Source: Author

The data used to evaluate this link are:

- Road speeds, volumes and length of lanes from the Personenverkehrsmodell, ARE 2010.
- Road accidents related to freight from ASTRA 2013-2015.

9.3.2Application of the metrics

The metrics developed in chapter 8 are applied on this link. Each attribute is measured below using the indicators concerning links.

			Level of Service					
Attribute	**Indicator**	**Unit**	**A**	**B**	**C**	**D**	**E**	**F**
Travel time	$\bar{v}_{\vartheta}$	Km/h	>80	60-80	40-60	20-40	<20	SYSTEM BREAKDWN
Reliability	$\frac{\sigma_n(v)_L}{\bar{v}_{L,\vartheta}}$	-	<0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	
Safety and security	$\frac{\alpha \sum_i^n a + \beta \sum_j^m r}{V_L}$	$\frac{Accidents}{Mio.Veh-km}$	0-0.75	0.75-1.5	1.5-2.25	2.25-3	3-3.75	
Frequency	$\frac{FS}{day}$	Trains/day	221 - 600	40 - 220	12-39	3-11	0-2	
Accessibility	Opening hours	h/week	168	146-167	100-145	90-99	60-89	
	Hazardous goods	-	yes	yes	no	no	no	
	Perishable goods	-	yes	yes	yes	no	no	

9.3.2.1 Travel time

The mean speed on the link has been calculated using eq. 8.4 for each freight vehicle type using data from the Personenverkehrsmodell, ARE 2010. The model provides speed, length and volume for per mode of each single stretch of the road Swiss network. All vehicles circulate on the link with a mean speed > 80km/h. Therefore, LoS on travel time is A.

Table 9-4 Travel time evaluation of the Link Basel – Olten

Vehicle type	Mean Speed (v)	LoS
Van	90,43 km/h	A
Truck	80,13 km/h	A
Trailer Truck	80,51 km/h	A

Data: ARE 2010

9.3.2.2 Reliability

To evaluate reliability, it is needed to calculate average speed and standard deviation for each vehicle type. Reliability is the variance of speeds on one link over a time period. It could be calculated with GPS car data or with loop detectors data. Unfortunately, GPS data belongs to private companies and it was not possible to have access to it. Moreover, the loop detector data available in Switzerland is not suitable for this study since each loop detector stores data individually and produces a file per day. Meaning that if we want to study a year behaviour for a given link, it is needed to compute data from thousands of files, making this task unmanageable by the means of this study. Therefore, it is decided to get data from the Personenverkehrsmodell and use the following calculations to get an approximate indicator of reliability. The average speeds have been presented above. The standard deviations are calculated using eq. 8.8, where $\bar{v}$ are the mean speeds presented above; v_i are the speeds of every single stretch the model divides this link into and weighted by its length and volume; and n is the sum of all link model stretches' lengths and volumes ($\sum l_i \times V_i$). All data come from the Personenverkehrsmodell, ARE 2010. For all vehicle types, the reliability indicator is in this case between 0.1 and 0.2. Therefore, the LoS on reliability is B.

Table 9-5 Reliability evaluation of the Link Basel – Olten

Vehicle type	Mean Speed (v)	Standard deviation $(\sigma_n(v))$	$\frac{\sigma_n(v)}{v}$	LoS
Van	90,43 km/h	15,26 km/h	0,1687	B
Truck	80,13 km/h	11,89 km/h	0,1484	B
Trailer Truck	80,51 km/h	11,91 km/h	0,1479	B

Data: ARE 2010

9.3.2.3 Safety and Security

Safety and Security is calculated using eq. 8.14. Data about robberies of cargo have not been found and therefore calculations are only based on accident data. The accidents involving freight vehicles that occurred on the Basel - Olten link between 2010 and 2015 are found on the accidents dataset of ASTRA 2010-2015. These accidents have been normalized by the freight volume (in vehicle-km) on that link on 2010 (see Table 9-6). The calculation is based on data from the Personenverkehrsmodell, ARE 2010. From 2010 to 2015, the indicator values are below 0.75, thus the LoS is A.

Table 9-6 Volume freight (vehicle-km) on the Basel - Olten link

Direction	Van	Truck	Trailer Truck	All freight vehicles
From Olten to Basel	54,133,730	19,070,879	45,496,258	118,700,868
From Basel to Olten	49,665,525	19,376,045	44,694,653	113,736,224
Both directions	103,799,256	38,446,924	90,190,912	232,437,093

Data: ARE 2010

Table 9-7 Safety and security evaluation of the Basel – Olten link

Year	Accidents	Volume (vehicle-km)	Indicator	LoS
2010	79	232,437,093	0.3399	A
2011	63		0.2710	A
2012	39		0.1678	A
2013	45		0.1936	A
2014	48		0.2065	A
2015	50		0.2151	A

Data: ARE 2010 and ASTRA 2010-2015

9.3.2.4 Accessibility

Concerning accessibility, there are three indicators that need to be accounted: Opening hours, hazardous goods and perishable goods.

- Opening hours: On the Swiss road network there is a law called *night driving ban* that prohibits road freight transport between 10pm and 5 am (Art.9 Abs. 2 VRV). There is also another law called *Sunday driving ban*, which prohibits freight vehicle to circulate on Sundays, New Year, Good Friday, Easter Monday, Ascension, Pentecost day, 1st of August and Christmas day. This means that on average, road freight has access to the link during 100 hours per week (LoS C)
- Hazardous goods: the highway allows hazardous goods to be transported on the specialized vehicles and loading units. Therefore, this indicator is labelled as “yes” (LoS A or B).
- Perishable goods: There is no restriction on perishable goods on this road. Thus, this indicator is also labelled as “yes” (LoS A, B or C).

The most restrictive value indicates the actual LoS for the attribute. Therefore, LoS on accessibility is C.

Table 9-8 Accessibility evaluation of the Basel – Olten link

Indicator	Opening Hours	Hazardous goods	Perishable goods	Overall
LoS	C	A or B	A, B or C	C

9.3.3Evaluation and rating

The LoS of this link has been calculated using analysis results from Chapter 9.3.2, i.e., the LoS of each attribute. Furthermore, Frequency is qualified with LoS A, since Frequency on road is LoS A by definition (see chapter 8.3.3). Table 9-9 summarizes the LoS evaluation of the road link Basel –Olten. Weights and values come from Table 8-16 and Table 8-17 respectively. Since link LoS does not include any flexibility indicator, the result of the LoS calculation has been normalized by the sum of the weight of the attributes used on this case. Therefore, LoS for this road link is B.

Table 9-9 LoS evaluation of the link Basel - Olten

Attribute	Weight	LoS	Value
Accessibility	0.28	C	0.666
Travel time	0.19	A	1
Frequency	0.13	A	1
Flexibility			
Reliability	0.17	B	0.833
Safety and Security	0.16	A	1

$$Level\ of\ Service\ = a_1 \cdot Attribute_1 + a_2 \cdot Attribute_2 + \cdots + \ a_n \cdot Attribute_n = 0.870 > 0.833 \Rightarrow LoS\ B$$

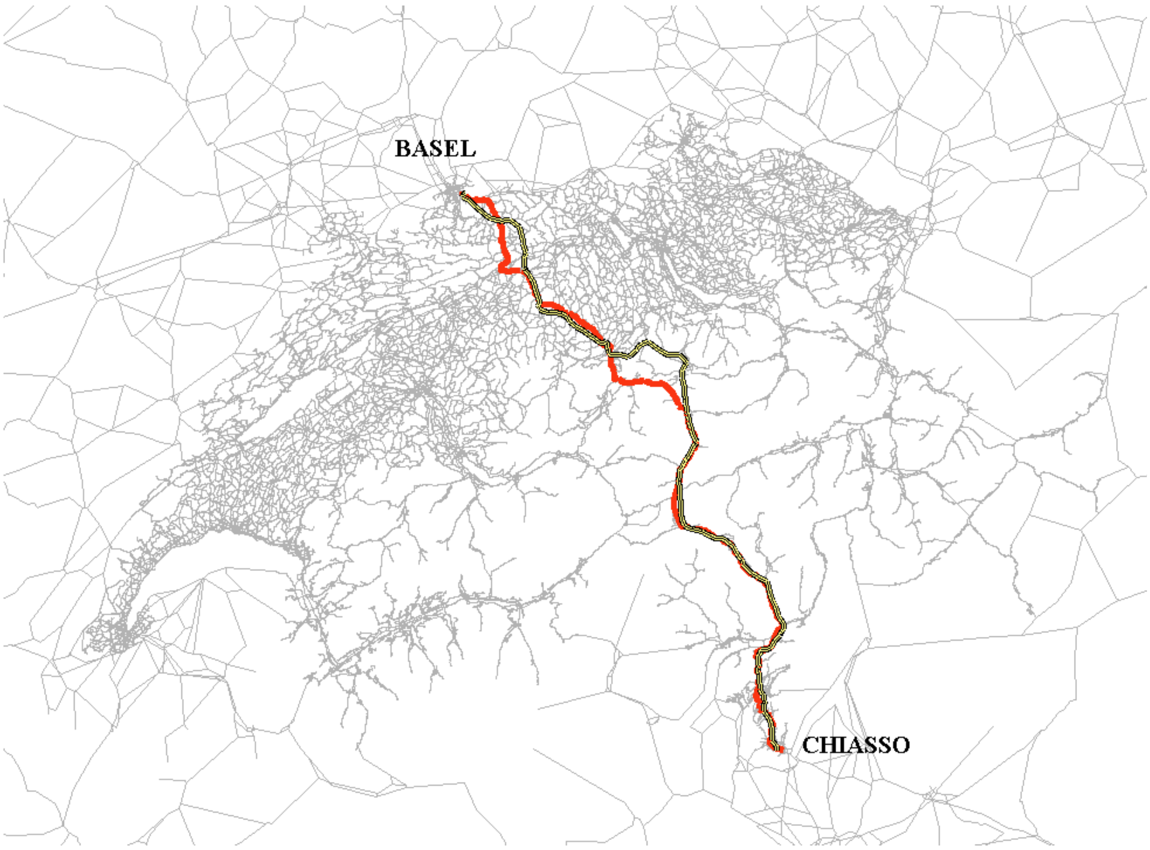
After analysing the road link between Basel Port and the intersection of highways A1 and A2 in Olten, the results show the link has a very good overall LoS for freight transportation. Therefore, it is understandable that freight operators chose this route for their services between Basel and central Switzerland. In fact, most of its attributes are qualified as excellent (Travel time, Frequency and Safety and Security), and Reliability is qualified as very good. The worst attribute's qualifications are on Accessibility due to freight transit temporal restrictions (*night driving ban* and *Sunday driving ban*), although it is still an acceptable quality qualification. In order to improve the LoS of this link, the freight transit temporal restrictions should be removed since they are mostly the unique challenge for freight transportation on it.

9.4 Case study 4: Level-of-Service evaluation of a corridor

9.4.1 Description of the location

The corridor Basel – Ticino is the Swiss part of one of the most important European freight corridors: the Rotterdam – Genova corridor. Freight and logistics services are provided both by rail and by road, including also their combinations, such as Ro-Ro transport or intermodal. It is the most important axe in Switzerland in terms of freight volumes, and it connects different strategical points of Switzerland with Italy on the south and France and Germany on the north. Furthermore, Switzerland has been allocating for years an important part of its budget to improve this corridor by enhancing tunnel heights to allow 4m high trains and constructing the biggest base tunnel of the world: the Gotthard tunnel. Investments and constructions continue with the aim to remove freight transport from the road and attract it to the rail freight network.

Figure 9-2: Corridor Basel Port - Chiasso Stazione Ferroviaria



Source: Author

The data used to evaluate this corridor are:

- Road speeds, volumes and length of lanes from the Personenverkehrsmodell, ARE 2010.
- Road accidents related to freight from ASTRA 2013-2015.
- Rail time tables from the Fahrplan SBB 2016 and the Trassenkatalog Fahrplan 2017.
- Rail accidents related to freight from UVEK 2013-2015.
- Rail volumes from SBB Open-Data-Zugzahlen.

9.4.2Application of the metrics

9.4.2.1 Travel time

On road, the mean speed on the corridor has been calculated using eq. 8.4 for each freight vehicle type using data from the Personenverkehrsmodell, ARE 2010. The model provides speed, length and volume for per mode of each single stretch of the road Swiss network. All vehicles circulate on the corridor with a mean speed > 80km/h. Therefore, LoS on travel time is A. On rail, the mean speed has been calculated using eq. 8.1 and 8.4 for an average trip using data from the Swiss rail timetables (SBB, 2016a). The mean speed calculation includes the time spent on stops for changing locomotives and changing staff. Since rail freight mean speed is between 40 and 60 km/h, travel time qualification for rail is LoS C.

Table 9-10 Travel time evaluation of the Corridor Basel – Chiasso

Vehicle type	Mean Speed (v)	LoS
Van	99.70 km/h	A
Truck	82.09 km/h	A
Trailer Truck	82.27 km/h	A
Freight train	43.95 km/h	C

Data: ARE 2010 and Fahrplan SBB 2016

9.4.2.2 Reliability

Due to the same reasons explained in 9.3.2.2, reliability is calculated as explained here. To evaluate reliability, it is needed to calculate average speed and standard deviation for each vehicle type. The average speeds have been presented above. For road, the standard deviations are calculated using eq. 8.8, where $\bar{v}$ are the mean speeds presented above; v_i are the speeds of every single stretch the model divides this corridor into and weighted by its length and volume; and n is the sum of all corridor model stretches' lengths and volumes ($\sum l_i \times V_i$). All data come from the Personenverkehrsmodell, ARE 2010. For all road vehicle types, the reliability indicator is in this case between 0.2 and 0.3. Therefore, the LoS on reliability is C for road. For rail, the standard deviations are calculated using eq.

8.8, where $\bar{v}$ are the mean speeds presented above; v_i are the speeds of every single slot, and n is the sum of all slots. Data comes from Fahrplan SBB 2016. The indicator ranks below 0.1, so it has LoS A.

Table 9-11 Reliability evaluation of the Link Basel – Olten

Vehicle type	Mean Speed (v)	Standard deviation ($\sigma_n(v)$)	$\frac{\sigma_n(v)}{v}$	LoS
Van	99.70 km/h	25.93 km/h	0.2601	C
Truck	82.09 km/h	22.73 km/h	0.2770	C
Trailer Truck	82.27 km/h	22.73 km/h	0.2763	C
Freight train	43.95 km/h	4.07 km/h	0.0925	A

Data: ARE 2010 and Fahrplan SBB 2016

9.4.2.3 Safety and security

Safety and Security is calculated using eq. 8.14. Data about theft of cargo has not been found and, therefore, calculations are only based on accident data. The accidents involving road freight vehicles that occurred on the Basel – Chiasso corridor between 2010 and 2015 are found on the accidents dataset of ASTRA 2010-2015. These accidents have been normalized by the freight volume on that corridor on 2010 (1015.53 million vehicle-km). The calculation is based on data from the Personenverkehrsmodell, ARE 2010. From 2010 to 2015, the indicators values are below 0.75, meaning LoS A.

Table 9-12 Safety and security evaluation for road on the Basel – Chiasso Corridor

Year	Accidents	Volume (vehicle-km)	Indicator	LoS
2010	382	1015.53 million	0.3761	A
2011	319		0.3141	A
2012	277		0.2728	A
2013	290		0.2856	A
2014	267		0.2629	A
2015	243		0.2393	A

Data: ARE 2010 and ASTRA 2010-2015

For rail, the accidents involving freight trains that occurred on the Basel – Chiasso corridor between 2013 and 2015 are found on the accidents dataset of UVEK 2013-2015. The accidents are normalized by the annual freight volume of those rail lines for each year. These data is found online on the SBB Open-Data-Zugzahlen. During this period (2013-2015), the indicator values are below 0.75. Therefore, Safety on rail is LoS A.

Table 9-13 Safety and security evaluation for rail on the Basel - Chiasso corridor

Year	Accidents	Volume (train-km)	Indicator	LoS
2013	3	6854530.33	0.4377	A
2014	3	7128590.95	0.4208	A
2015	2	7237291.29	0.2763	A

Data: UVEK 2013-2015 and SBB Open-Data-Zugzahlen

9.4.2.4 Accessibility

Concerning accessibility, there are three indicators that need to be accounted: Opening hours, hazardous goods and perishable goods.

- Opening hours: On the Swiss road network there is a law called *night driving ban* that prohibits road freight transport between 10pm and 5 am (Art.9 Abs. 2 VRV). There is also another law called *Sunday driving ban*, which prohibits freight vehicle to circulate on Sundays, New Year, Good Friday, Easter Monday, Ascension, Pentecost day, 1st of August and Christmas day. This means that on average, road freight has access to the corridor during 100 hours per week (LoS C). However, there is no restriction on access for rail freight. Therefore, rail has LoS A.
- Hazardous goods allowed on Switzerland by road, by train and on combined transport (ECE, 2015; SBB Cargo International, 2013). Therefore, this indicator is labelled as “yes” (LoS A or B) for both road and rail.
- Perishable goods: There is no restriction on perishable goods neither on road or rail. Thus, this indicator is also labelled as “yes” (LoS A, B or C) for both road and rail.

The most restrictive value indicates the actual LoS for the attribute. On road, accessibility indicators are LoS C, LoS A or B and LoS A, B or C. Therefore, accessibility on road is LoS C. Nevertheless, on rail, all three indicators belong to LoS A. Thus, accessibility on rail is LoS A.

Table 9-14 Accessibility evaluation of the Basel – Chiasso corridor

Indicator	Opening Hours	Hazardous goods	Perishable goods	Overall
Road LoS	C	A or B	A, B or C	C
Rail LoS	A	A or B	LoS A, B or C	A

9.4.2.5 Frequency

The frequency of freight trains in that corridor has been calculated using eq.8.17. Data used for this calculation such as rail freight volumes (annual train-km) are from the SBB Open-Data-Zugzahlen, and rail lines distances are from the Streckendaten of the Graphic

Timetables of SBB. All of them are between 40 – 220 trains per day. Therefore, rail frequency is LoS B. Furthermore, road freight frequency is always LoS A by definition.

Table 9-15 Frequency evaluation for rail of the Basel – Chiasso corridor

Year	Trains per day	LoS
2013	61.72	B
2014	64.39	B
2015	63.77	B
2016	49.94	B

Data: SBB Open-Data-Zugzahlen and Fahrplan SBB 2016

9.4.3Evaluation and rating

The LoS of this corridor has been calculated using analysis results from Chapter 9.3.2, i.e., the LoS of each attribute. Table 9-16 summarizes the LoS evaluation of the bimodal corridor Basel –Chiasso. Weights and values come from Table 8-16 and Table 8-17 respectively. Since corridor LoS does not include any flexibility indicator, the result of the LoS calculation has been normalized by the sum of the weight of the attributes used on this case. Therefore, LoS for this corridor is B for rail and for road.

Table 9-16 LoS evaluation of the corridor Basel - Chiasso

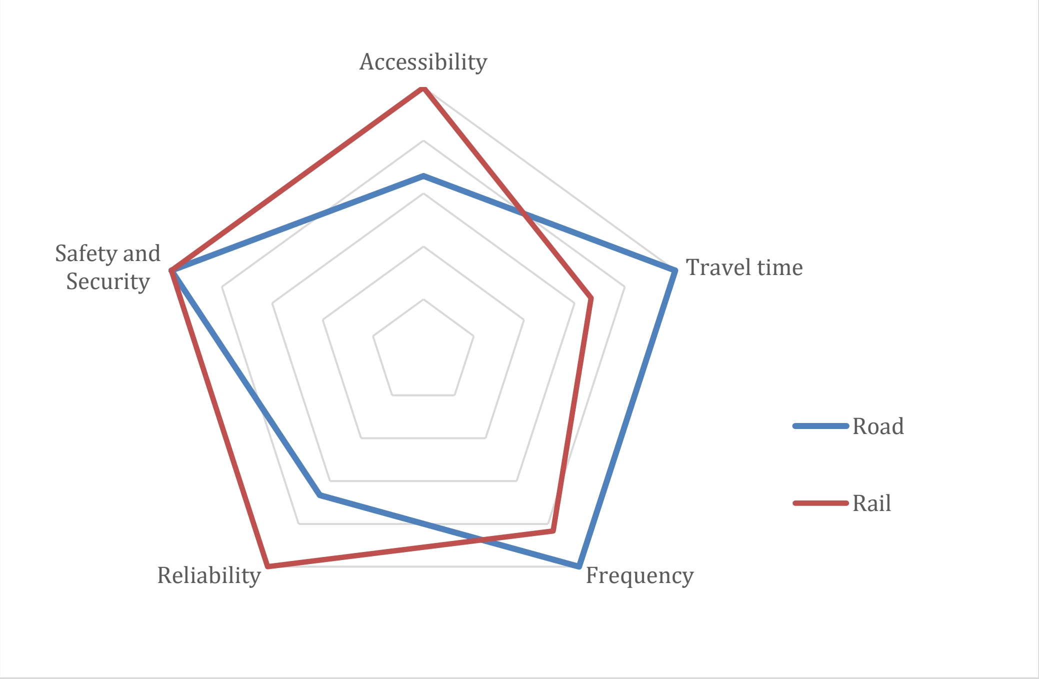
Attribute	Weight	LoS Road	Value	LoS Rail	Value
Accessibility	0.28	C	0.666	A	1
Travel time	0.19	A	1	C	0.666
Frequency	0.13	A	1	B	0.833
Flexibility					
Reliability	0.17	C	0. 666	A	1
Safety and Security	0.16	A	1	A	1

$$Road\ Level\ of\ Service\ = \sum_{i=1}^{n} a_i \cdot Attribute_i = 0.838 < 0.833 \Rightarrow LoS\ B$$

$$Rail\ Level\ of\ Service\ = \sum_{i=1}^{n} a_i \cdot Attribute_i = 0.908 > 0.833 \Rightarrow LoS\ B$$

The bimodal freight corridor that connects Basel Port and Chiasso Stazione Ferroviaria has been evaluated using the LoS for freight transportation. The corridor presents different service qualifications on the same attributes in road and rail. For instance, road freight transportation excels at travel time and frequency, whereas rail freight transportation does it in accessibility and reliability. On Travel time, road offers higher average speeds than for rail, and in terms of Frequency, road operators can travel into the network without pre-booking slots as opposite to rail operators. By contrast, rail operators can travel through the network 24/7 since there is no restriction on rail freight whereas road freight has some legal limitations due to Swiss legislation and are not allowed to travel at night, on Sundays and on special days. Furthermore, rail freight transportation is more reliable because the rail system works under schedule and as a result paths have higher probability to be respected as opposed to road freight, which has a higher level of stochasticity within its network, which implies that speeds and travel times are susceptible to be less reliable.

Figure 9-3: Comparison of LoS between Road and Rail modes for the Basel – Chiasso corridor



Source: Author

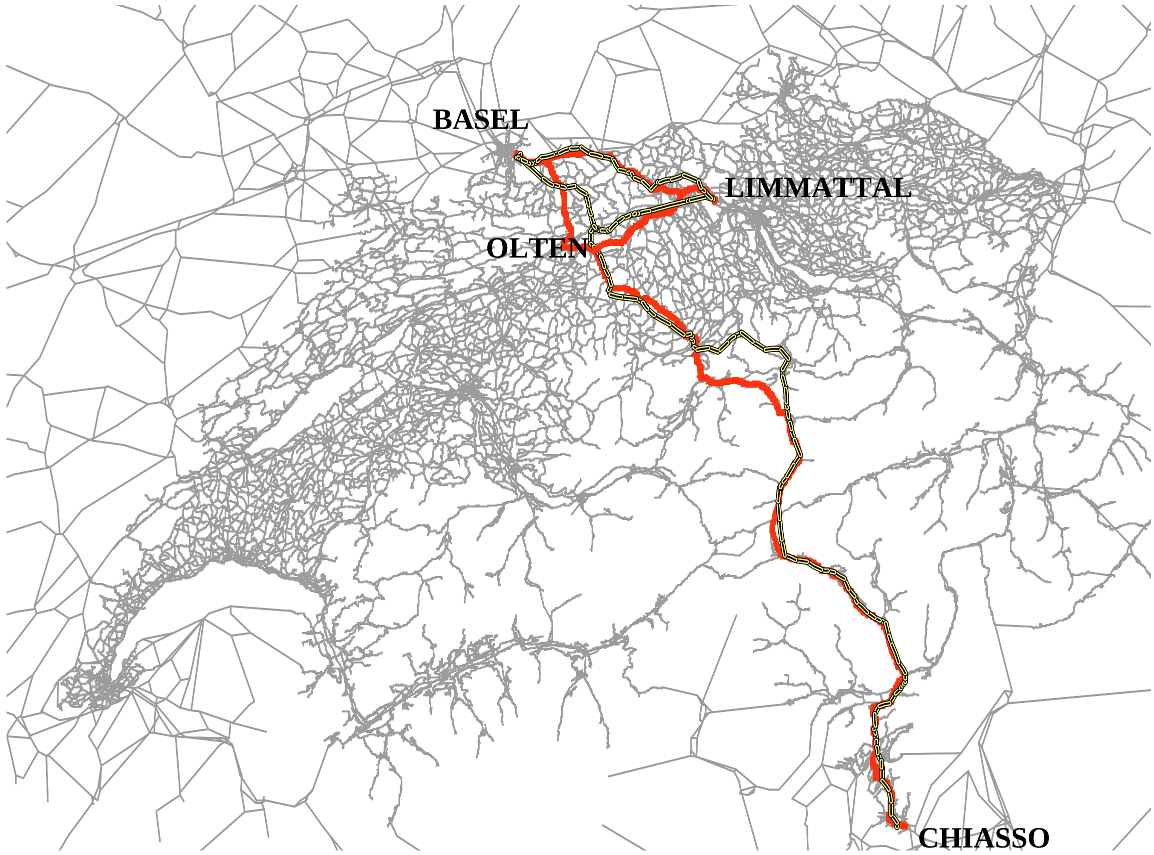
On overall, qualifications indicate that, in this corridor, freight transportation has a better LoS on rail than on road. Therefore, in general terms, shippers and operators should prefer to use rail than road for their shipments in this corrido. Nevertheless, small particularities of each shipment might have a stronger influence on the mode choice before the LoS, i.e. cost, exact origin and destination, size and type of good. For improving road freight transportation on the Basel – Chiasso corridor, two main challenges should be addressed: the temporal transit restrictions and the reliability. For the first one, restrictions should be removed to allow 24/7 freight transport. For the second, a possible solution could be to set up freight dedicated lanes. That would give them priority over passenger transportation and reduce the mixed traffic interaction, reducing therefore delays and even reducing accidents. For improving rail freight transport on the Basel – Chiasso corridor, travel time should be improved. A possible solution should be to increase freight trains speeds, which might require using better rolling stock, and reducing stop times for changing locomotives or personnel.

9.5 Case study 5: Level-of-Service evaluation of a network

9.5.1 Description of the location

The network selected for this test case is formed by the previously analysed corridor Basel – Chiasso, and two additional bimodal links (rail and road): Basel – Limmattal and Limmattal – Olten. Furthermore it includes the shunting yard of Limmattal as main freight terminal of the network. This network is selected due to its importance in Switzerland. It connects the main freight corridor (Basel – Chiasso) with one of the most important shunting yards of the country, the Limmattal shunting yard. Besides all the internal transhipments, Limmattal is usually also the terminal of most of the international maritime containers are consolidated and later distributed around Switzerland. In Figure 9-4, the network is sketched out of the GIS map used for the data analysis of case studies 3, 4 and 5. In red the road links and corridor, and in yellow and black, the rail links and corridor.

Figure 9-4: Freight network Basel - Olten - Limmattal - Chiasso



Source: Author

9.5.2 Application of the metrics

The quality evaluation of the corridor done on chapter 9.4 will be used at the end of the case study to calculate the overall LoS of the network. In this chapter, first the analysis of the two bimodal links, Basel – Limmattal and Limmattal – Olten are presented. After, the Limmattal shunting yard will be analysed.

9.5.3 Basel – Limmattal link and Limmattal – Olten link

9.5.3.1 Travel time

On road, the mean speeds on both links have been calculated using eq. 8.4 for each freight vehicle type using data from the Personenverkehrsmodell, ARE 2010. All vehicles circulate on both links with a mean speed above 80km/h. Therefore, LoS on travel time is A for both links. On rail, the mean speed has been calculated using eq. 8.4 for an average trip using data from the Fahrplan SBB 2016. This calculation does not include time spent on changing locomotives and changing personnel since this will be done in Limmattal RB. Since rail freight mean speed is between 60 and 80 km/h, travel time qualification for rail is LoS B.

Table 9-17 Travel time evaluation of the Link Basel – Limmattal

Vehicle type	Mean Speed (v)	LoS
Van	96.92 km/h	A
Truck	83.54 km/h	A
Trailer Truck	83.02 km/h	A
Freight train	63.98 km/h	B

Data: ARE 2010 and Fahrplan SBB 2016

Table 9-18 Travel time evaluation of the Link Limmattal – Olten

Vehicle type	Mean Speed (v)	LoS
Van	103.69 km/h	A
Truck	89.82 km/h	A
Trailer Truck	89.79 km/h	A
Freight train	62.24 km/h	B

Data: ARE 2010 and Fahrplan SBB 2016

9.5.3.2 Reliability

Due to the same reasons explained in 9.3.2.2, reliability is calculated as explained here. To evaluate reliability, it is needed to calculate average speed and standard deviation for each vehicle type. The average speeds have been presented above. For road, the standard deviations are calculated using eq. 8.8, where $\bar{v}$ are the mean speeds presented above; v_i are the speeds of every single stretch the model divides each link into and weighted by their length and volume; and n is the sum of all corridor model stretches' lengths and volumes ($\sum l_i \times V_i$). All data come from the Personenverkehrsmodell, ARE 2010. In the Basel – Limmattal link, for all road vehicle types, the reliability indicator is ranks between 0.1 and 0.2. Therefore, the LoS on reliability is B. In the Limmattal – Olten link, for all road vehicle types, the reliability indicator is ranks below 0.1. Therefore, the LoS on reliability is A. For rail, the standard deviations are calculated using eq. 8.8, where $\bar{v}$ are the mean speeds presented above; v_i are the speeds of every single slot, and n is the sum of all slots. Data comes from Fahrplan SBB 2016. In the Basel – Limmattal link, the indicator ranks between 0.1 and 0.2 resulting on a LoS B, while in the Limmattal – Olten link, the indicator ranks below 0.1 and, therefore, its reliability is LoS A.

Table 9-19 Reliability evaluation of the Link Basel – Limmattal

Vehicle type	Mean Speed (v)	Standard deviation ($\sigma_n(v)$)	$\frac{\sigma_n(v)}{v}$	LoS
Van	96.92 km/h	15.90 km/h	0.1641	B
Truck	83.54 km/h	11.20 km/h	0.1341	B
Trailer Truck	83.02 km/h	11.12 km/h	0.1340	B
Freight train	63.98 km/h	6.64 km/h	0.1038	B

Data: ARE 2010 and Fahrplan SBB 2016

Table 9-20 Reliability evaluation of the Link Limmattal – Olten

Vehicle type	Mean Speed (v)	Standard deviation ($\sigma_n(v)$)	$\frac{\sigma_n(v)}{v}$	LoS
Van	103.69 km/h	3.50 km/h	0.0338	A
Truck	89.82 km/h	2.07 km/h	0.0231	A
Trailer Truck	89.79 km/h	2.06 km/h	0.0230	A
Freight train	62.24 km/h	5.59 km/h	0.0899	A

Data: ARE 2010 and Fahrplan SBB 2016

9.5.3.3 Safety and security

Safety and Security is calculated using eq. 8.14. Data about robberies of cargo have not been found and, therefore, calculations are only based on accident data. The accidents involving road freight vehicles that occurred on both links between 2010 and 2015 are found on the accidents dataset of ASTRA 2010-2015. These accidents have been normalized by the freight volume on that corridor on 2010 (1069.26 million vehicle-km in the Basel – Limmattal link and 719.86 million vehicle-km in the Limmattal – Olten). The calculation is based on data from the Personenverkehrsmodell, ARE 2010. On all years, the indicator values belong to the LoS A since they are quite lower than 0.

Table 9-21 Safety and security evaluation for road on the Basel – Limmattal Link

Year	Accidents	Volume (vehicle-km)	Indicator	LoS
2010	32	1069.26 million	0.0299	A
2011	35		0.0327	A
2012	23		0.0215	A
2013	27		0.0252	A
2014	34		0.0318	A
2015	51		0.0477	A

Data: ARE 2010 and ASTRA 2010-2015

Table 9-22 Safety and security evaluation for road on the Limmattal – Olten Link

Year	Accidents	Volume (vehicle-km)	Indicator	LoS
2010	39	719.86 million	0.0542	A
2011	33		0.0458	A
2012	40		0.0556	A
2013	35		0.0486	A
2014	37		0.0514	A
2015	21		0.0292	A

Data: ARE 2010 and ASTRA 2010-2015

For rail, the accidents involving freight trains that occurred on both links between 2013 and 2015 are found on the accidents dataset of UVEK 2013-2015. The accidents are normalized by the annual freight volume of those rail lines for each year. These data is found online on the SBB Open-Data-Zugzahlen. During this period (2013-2015), there was none accidents on freight train on the Basel – Limmattal Link, and only one accident in 2014 on the Limmattal – Olten Link. Therefore, Safety and Security on rail is LoS A for the first link and it oscillated between A and C on the second.

Table 9-23 Safety and security evaluation for rail on the Basel – Limmattal Link

Year	Accidents	Volume (train-km)	Indicator	LoS
2013	0	2984987.78	0	A
2014	0	3002801.14	0	A
2015	0	3104680.9	0	A

Data: UVEK 2013-2015 and SBB Open-Data-Zugzahlen

Table 9-24 Safety and security evaluation for rail on the Limmattal – Olten Link

Year	Accidents	Volume (train-km)	Indicator	LoS
2013	0	1719100.60	0	A
2014	1	1730256.89	0.5779	C
2015	0	1747144.37	0	A

Data: UVEK 2013-2015 and SBB Open-Data-Zugzahlen

9.5.3.4 Accessibility

Concerning accessibility, there are three indicators that need to be accounted: Opening hours, hazardous goods and perishable goods.

- Opening hours: On the Swiss road network there is a law called *night driving ban* that prohibits road freight transport between 10pm and 5 am (Art.9 Abs. 2 VRV). There is also another law called *Sunday driving ban*, which prohibits freight vehicle to circulate on Sundays, New Year, Good Friday, Easter Monday, Ascension, Pentecost day, 1st of August and Christmas day. This means that on average, road freight has access to the corridor during 100 hours per week (LoS C). However, there is no restriction on access for rail freight. Therefore, rail has LoS A.
- Hazardous goods allowed on Switzerland by road, by train and on combined transport (ECE, 2015; SBB Cargo International, 2013). Therefore, this indicator is labelled as “yes” (LoS A or B) for both road and rail.
- Perishable goods: There is no restriction on perishable goods neither on road or rail. Thus, this indicator is also labelled as “yes” (LoS A, B or C) for both road and rail.

The most restrictive value indicates the actual LoS for the attribute. On road, accessibility indicators are LoS C, LoS A or B and LoS A, B or C. Therefore, accessibility on road is LoS C. Nevertheless, on rail, all three indicators belong to LoS A. Thus, accessibility on rail is LoS A.

Table 9-25 Accessibility evaluation both of the Basel – Limmattal and the Limmattal – Olten Links

Indicator	Opening Hours	Hazardous goods	Perishable goods	Overall
Road LoS	C	A or B	A, B or C	C
Rail LoS	A	A or B	LoS A, B or C	A

9.5.3.5 Frequency

The frequency of freight trains in that corridor has been calculated using eq.8.17. Data used for this calculation such as rail freight volumes (annual train-km) are from the SBB Open-Data-Zugzahlen, and rail lines distances are from the Streckendaten of the Graphic Timetables of SBB. All of them are between 40 – 220 trains per day. Therefore, rail frequency is LoS B. Furthermore, road freight frequency is always LoS A by definition.

Table 9-26 Frequency evaluation for rail of the Limmattal – Olten Link

Year	Trains per day	LoS
2013	79.29	B
2014	75.93	B
2015	80.58	B
2016	78.08	B

Data: SBB Open-Data-Zugzahlen and Fahrplan SBB 2016

Table 9-27 Frequency evaluation for rail of the Basel – Limmattal Link

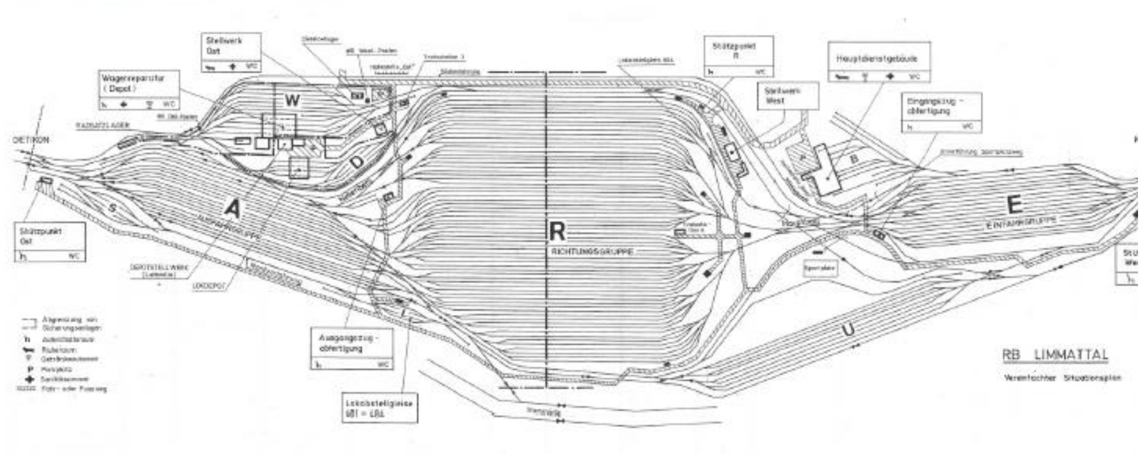
Year	Trains per day	LoS
2013	79.66	B
2014	80.14	B
2015	80.77	B
2016	83.56	B

Data: SBB Open-Data-Zugzahlen and Fahrplan SBB 2016

9.5.4Limmattal shunting yard

The analysis of the Limmattal shunting yard has been done using mostly data from an electronic interview on personnel of the Network development of SBB Cargo conducted on April 2017. Questions targeting the needed data were asked in order to apply the method developed by (Ballis, 2004) and included in this study.

Figure 9-5: Limmattal shunting yard



Source: (SBB, 2016a)

9.5.4.1 Dwell time

Question: How long does a wagon need to wait since it goes inside the station until it leaves?

Answer: A wagon entering a large marshalling yard leaves it about 2.5h to 3.0h later. In an RCP team it strongly depends on the production scheme. It can last from 20min up to several hours.

The waiting time is above 120 minutes but there is not “System Breakdown” since the terminal works normally. Therefore, the dwell time rate is LoS E.

9.5.4.2 Reliability

Question: Which percentage of trains are delayed on the shunting yard? How long is the delay?

Answer: On normal conditions 25% of the trains are usually delayed (+/- 3 mins). Average length depends what causes the delay.

A train is considered delayed by SBB Cargo when it is delayed +3 minutes. Nevertheless, the evaluation method considers that less than 10 minutes delay is still LoS A. Since more detailed data is missing, a safe estimation would be that about 20% of the delayed trains, so 5 %of the total amount of trains, could be delayed between 11 to 20 minutes. Therefore, the reliability of the terminal is LoS B.

9.5.4.3 Flexibility

Question: How long does it take between last wagon entering the shunting yard and the new consolidated train leaving the station?

Answer: In a large marshalling yard, it should not take more than 3 hours, since that is the maximum connection time. Although it can vary when the production scheme is adapted for client’s special needs.

The 3-hour interval indicates that the terminal’s flexibility is LoS C. Nevertheless, for some services the terminal can prioritize and offer better times. Therefore, depending on the service flexibility might be also LoS A or B.

9.5.4.4 Safety and security

Question: Which are the rates on loss of goods, loss loading units, loss of documents?

Answer: There was not a single case of loss of goods or loss of loading units in recent time. Information about loss of documents is not available.

It seems that safety and security is not a real problem in the terminal. Therefore, it has a LoS A.

9.5.4.5 Accessibility

To evaluate accessibility three indicators are needed: Opening hours, hazardous goods and perishable goods.

- The terminal is opened in average 17 hours per day (SBB, 2016b). Thus, this indicator is ranked as LoS C.
- Hazardous goods allowed on Switzerland by road, by train and on combined transport (ECE, 2015; SBB Cargo International, 2013). Therefore, this indicator is labelled as “yes” (LoS A or B) for both road and rail.

- Perishable goods: There is no restriction on perishable goods neither on road or rail. Thus, this indicator is also labelled as “yes” (LoS A, B or C) for both road and rail.

9.5.5Evaluation and rating

Both links present an overall LoS B either in road and rail. Both have very good or excellent conditions for freight transportation. The only handicap is the aforementioned road freight access restriction that reduces the amount of time per day road shipments can be carried out throughout the infrastructure. Table 9-28 and Table 9-29 present the summary of LoS qualifications of both links either in road and rail.

Table 9-28 LoS evaluation of the Basel – Limmattal Link

Attribute	Weight	LoS Road	Value	LoS Rail	Value
Accessibility	0.28	C	0.666	A	1
Travel time	0.19	A	1	B	0.833
Frequency	0.13	A	1	B	0.833
Flexibility					
Reliability	0.17	B	0.833	B	0.833
Safety and Security	0.16	A	1	A	1

$$Basel - Limmattal\ road\ Level\ of\ Service\ = \sum_{i=1}^{n} a_i \cdot Attribute_i = 0.869 > 0.833$$

$\Rightarrow LoS\ B$

$$Basel - Limmattal\ rail\ Level\ of\ Service\ = \sum_{i=1}^{n} a_i \cdot Attribute_i = 0.912 > 0.833$$

$\Rightarrow LoS\ B$

Table 9-29 LoS evaluation of the Limmattal – Olten Link

Attribute	Weight	LoS Road	Value	LoS Rail	Value
Accessibility	0.28	C	0.666	A	1
Travel time	0.19	A	1	B	0.833
Frequency	0.13	A	1	B	0.833
Flexibility					
Reliability	0.17	A	1	A	1
Safety and Security	0.16	A	1	A	1

$$Limmattal - Olten\ road\ Level\ of\ Service\ = \sum_{i=1}^{n} a_i \cdot Attribute_i = 0.899 > 0.833$$

$\Rightarrow LoS\ B$

$$Limmattal - Olten\ rail\ Level\ of\ Service\ = \sum_{i=1}^{n} a_i \cdot Attribute_i = 0.942 > 0.833$$

$\Rightarrow LoS\ B$

The method to evaluate quality of service in freight terminals has been applied on the Limmattal shunting yard. Results show there is room for improvement, such as in Dwell time (main challenging issue of the terminal), flexibility and accessibility, although terminal flexibility can be adapted to customer needs.

Table 9-30 LoS evaluation of the shunting yard Limmattal

Attribute	Weight	LoS	Value
Accessibility	0.28	C	0.666
Dwell time	0.19	E	0.25
Flexibility	0.07	C	0.666
Reliability	0.17	B	0.833
Safety and Security	0.16	A	1

$$Terminal\ Level\ of\ Service\ = \sum_{i=1}^{n} a_i \cdot Attribute_i = 0.669 > 0.666 \Rightarrow LoS\ C$$

The evaluation of each part of the network have been combined (values from Table 9-16, Table 9-28 and Table 9-29). Each qualification is weighed by the length of each infrastructure (l_j) and the total length of the network (L), which is the sum of all lengths. Thereby, the overall network LoS is calculated out of all the partial evaluations of its links and corridors. Results are presented below.

Table 9-31 LoS evaluation of the network Basel – Olten – Limmattal – Chiasso Link

Attribute	Road	Rail	Shunting yard
Accessibility	C	A	C
Travel time	A	C	E
Frequency	A	B	
Flexibility			C
Reliability	C	B	B
Safety and Security	B	B	A

$$Road\ Network\ Level\ of\ Service = \frac{1}{L}\sum_{i=1}^{n} a_i \cdot \sum_{j=1}^{m} l_j\ Attribute_{i,j} = 0.809 < 0.833$$

$\Rightarrow LoS\ C$

$$Rail\ Network\ Level\ of\ Service = \frac{1}{L}\sum_{i=1}^{n} a_i \cdot \sum_{j=1}^{m} l_j\ Attribute_{i,j} = 0.849 > 0.833$$

$\Rightarrow LoS\ B$

The quality of service of the freight network that connects Basel, Olten, Limmattal and Chiasso by road and rail has been evaluated using the evaluation method developed in Chapter 8. Comparing quality of service analysis results between the links and the corridor, different LoS for each attribute are found. This implies that quality of service is not homogenous along the network and that although an overall LoS is provided for each attribute on the network and for the network itself, it is important to keep also individual link and corridor analysis for a deeper understanding of the network. The aggregated values of the network analysis provide an overall qualification which is useful to understand how the network performs and to compare different networks, e.g. the road and the rail network, or the current network and a future scenario. Nevertheless, the analysis made on smaller scale (links and corridor) provide quality of service information for specific parts of the network. This is useful to understand the particularities of the network. It has potential implementation as, for instance, input on route choice and mode choice problems, or additional information on a multi-criteria analysis when deciding for infrastructure investment.

In overall, the rail freight network offers a better LoS than the road freight network. Nevertheless, the transshipment point evaluation affects the overall service and it should also be taken into consideration. The results show that the main challenge for the rail network is travel time, and dwell time for its terminal, while the main challenges for the road network are accessibility and reliability. In order to improve those challenges, rail freight operation should try to reduce time length during technical stops for personnel and locomotive changes. If that would be possible, the overall travel time would be improved since train speeds (without stops) are already on LoS higher than commercial speeds. For road, main issues are already described on the corridor analysis (see Chapter 0), and possible solutions could be to allow freight traffic 24/7 to improve accessibility and build dedicated freight lanes to improve reliability.

10 Concluding remarks and perspectives for further research

10.1 Summary of key results

At the beginning of this thesis some questions about quality of service on freight transportation were asked. In this chapter, those questions are answered as a summary of the developed work. Some issues are still unsolved because require further development and further research.

Which is the right approach to evaluate a transport chain? Does a transport chain consist of generic elements? Is possible to evaluate it holistically or is it better to evaluate each of the existing activities of the transport chain?

To answer these questions a hypothesis was formulated: *It is possible to divide a transport chain in standardized elements (transport modes and transshipment points)*. Definitions for generic elements of the transport chain have been provided in this thesis (see chapter 5.2 and chapter 5.3). These definitions are based on general aspects that englobe general characteristics of the transport chain elements. These definitions are useful to classify and evaluate the elements of the transport chain by groups and compare them among other elements of the same type. Thereby, standards can be stablished and objective evaluation of the elements and the transport chain can be executed under objective criteria.

A transport chain includes several transport and logistics processes (see Chapter 5.2). Even the most elementary transport chain is constituted by at least two logistic processes and one transport process. Each transport chain is defined by the processes that take place on it. As a result, the holistic evaluation of the transport chain is not possible as if it was a single unit. Therefore, the right approach to evaluate a transport chain is to use a method that allows evaluation of the different elements of the transport chain.

How to evaluate the quality of a transport chain? Which are the most suitable tools?

Two hypotheses were formulated in order to answer these questions. First, *it is possible to evaluate each part of the transport chain by measurable quality indicators*. The most common evaluation tools for transportation are designed as indicator-based metrics. These metrics allow a consistent evaluation under a given logic (see Chapter 2.3). This thesis presents a set of measurable quality indicators to evaluate quality on freight transportation.

Some of these indicators are selected from existing literature (see Table 6-4), while others have been developed ad hoc (see chapter 8.3.2). These indicators have been used successfully to evaluate a freight link (see chapter 9.3), a freight corridor (see chapter 9.4) and a freight network (see chapter 9.5).

Second, *Perceived Quality of Service is dependent on freight service performance and customer orientation*. According to the EN 13816 Perceived Quality is the quality customers think they receive. This quality involves the performance of the shipment and also the personal relation between customer and service provider, i.e., service provider's customer orientation. This thesis suggests a set of measurable indicators for evaluating the freight and logistics performance under the name of Level-of-Service for freight transportation and another set of measurable indicators for evaluating freight and logistics customer orientation under the name of Level of customer orientation.

How to grade and classify the quality of service in a transport chain? Is it possible to apply the concept of Level-of-Service to freight transport? At which parts of the transport chain the quality of service can be measured using this methodology?

These questions propitiated the formulation of two hypothesis. First, *it is possible to define a measurable index for freight transport customer orientation to evaluate the quality of service not dependent from freight transport performance*. Customer orientation can be measured independently from freight transport performance. In order to do it, measurements should be based on the customer – service provider relationship during the three phases of the service (acquisition, production and after-sales). The measurable index should be based on a rational metric from customer's perspective. It means that indicators should be easy to measure and transparent, and their relative importance should be weighed by customer's opinion.

Second, *it is possible to define a measurable LoS for each of the quality indicators of any part of the transport chain and they can be combined to evaluate a bigger section of the transport chain*. Using data analysis of current European freight performance, it is possible to define a measurable LoS for each of the quality indicators of any part of the transport chain. Furthermore, using shipper's inputs on their shipment priorities, it is possible to find relative importance of those indicators and, therefore, combine them to evaluate a section of the transport chain. These qualifications can be combined to evaluate bigger elements as it has been shown in the test cases on Chapter 9. For instance, the results of the evaluation of some links belonging to the same corridor can be combined to evaluate the whole corridor. Another example would be to combine the quality qualifications of corridors and links that form a network in order to determine the qualification for the whole network.

Are all types of goods homogeneous insofar as their quality standards?

To answer this question a hypothesis was formulated: *The LoS of a given shipment varies depending on the type of good transported*. The idea behind this hypothesis was that certain commodities have different needs than others. For instance, perishables need to be transported very fast because travel time plays against market life of the product. On the other hand, manufactured goods shippers mostly worry about damage or loss and on-time reliability due to the high value of their goods and their type of market (see Table 6-3). Therefore, it was intended to find different shipper's preferences on the survey designed to find the right weighing for the attributes on the LoS metric (see chapter 8.5.2). Unfortunately, the response rate was really low and there were not enough answers to conclude different preferences and, therefore, different LoS scales for different types of goods. Therefore, this question remains unanswered and the hypothesis unproven.

Is it possible to evaluate the overall quality of service of an entire intermodal freight shipment by using this methodology to evaluate the quality of each of its elements?

The following hypothesis was formulated at the beginning of the study: *It is possible to evaluate the quality of service of an entire intermodal freight shipment by evaluating individually all its single parts*. The methods developed in this thesis allow to evaluate the overall perceived quality for an entire intermodal freight shipment, analyzing both, the customer orientation of the service provider and the performance of the shipment. The customer orientation measurement method analyses each relevant aspect from the first to the last contact between the shipper and the service provider. Moreover, the Level-of-service for freight transportation evaluates every relevant quality aspect of the shipment. It is possible to evaluate the quality of service of each part of a shipment by analyzing the different elements of each part and then combining them by a system of weighing. This system of weighing is defined by shipper's preferences and by relative size of each part, e.g., normalized by the length of the element.

Until which level of the freight network can such a quality measurement approach be applied?

Two hypotheses were formulated to answer this question. First, *it is possible to evaluate the LoS of a corridor based upon the values of the LoS of all its links*. And second, *it is possible to evaluate the LoS of a full network based upon the values of the LoS of all its corridors in the infrastructure level and in the capacity level*. As shown in the test cases, it is possible to combine the LoS of smaller elements that belong to the same bigger system in order to calculate its LoS. This is done by a weighed combination of quality measurements. In the case of linear infrastructure, this weighing is done by length and volume. In the case of nodes, as freight terminals, the terminal limits the quality of service of the corridor or network. For instance, if the links of a corridor or a network have LoS A on travel time, but the terminal that links them cannot provide LoS A on that attribute, the overall LoS of that corridor or network cannot be LoS A, since there is an element that influences the overall LoS by reducing its qualification.

10.2 Concluding remarks

The methods developed in this thesis indicate that quality of service evaluation tools for freight transportation could potentially be implemented. They have been validated as possible approaches to objectively analyze infrastructure and freight and logistics service providers. Furthermore, the methods can also be used to benchmark service provider performances, either in customer orientation or in freight transportation and logistics. Since all elements are evaluated under the same parameters, the outcome of service logistics activities can be compared regardless of their company size, their location, the transport modes used, etc. The concept of quality of service for freight transportation has been deeply studied in this thesis. Some steps into a better understanding of this topic have been made. The scientific interest on this field seems to be increasing since the last decades, as the amount of papers published on freight transportation and how to optimize its performance reveal. Therefore, it is expected that the knowledge on this field will continue to expand for the following years.

Potential application of the methodologies developed in this thesis are now stated. Besides the evident application of the customer orientation measurement method, which is to evaluate the company performance in this aspect, the method could also be useful for defining service provider market strategies. The information that provides the method could be input data for defining new allocation of company assets in order to achieve better results in the future, by better adapting to customer demands or by capturing new customers. Since the freight market is a private to private market with few clients and few service providers, this tool could provide interesting competitive advantage over other competitors, and in the long run, better adapt the full market to customer needs. In so far to the Level-of-Service for freight transportation, its potential implementation into infrastructure planning could be considered. The method provides information about quality of service in freight performance. Public bodies could profit from this information when planning freight corridors, or when deciding in which transport mode infrastructure invest and how.

Some challenges need to be underlined. Since most of the data necessary to do freight transportation experiments belongs to private bodies, such as service providers or shippers, it is really important to have some contact with the industry when planning to do some freight transportation research. As an illustration of this concept two experiences are here juxtaposed. Two freight surveys were conducted during this thesis. Both hat the ultimate goal to collect shipper’s perspective on quality of service, so methods could be calibrated under their preferences. One survey (regarding customer orientation) was executed in the frame of a research project. One of the project partners contributed with an extensive database of potential respondents. Nevertheless, for the second survey only few contacts were available. Although the response rate was similar, the absolute number of respondents was much higher on the first survey and therefore more data was collected on that case.

Switzerland is a good location for testing freight transportation methods since some companies are willing to collaborate and share some data and some infrastructure data is public or easily accessible thanks to standard official channels of petition. It would be really profitable for freight research that more countries and freight companies could also adopt this policy of supporting research since they could also benefit from research outcomes.

10.3 Perspectives for further research

This thesis has presented some methods on how to measure Quality of Service for freight transportation. The results have shown that it is possible to develop rational methods that calculate perceived quality under objective parameters. These methods could be further developed by using more data. For instance, bigger surveys that could be answered by a higher number of shippers, and not only from few countries but for members of all European countries, in order to get a dipper understanding and better parametrization of the European freight market. Also, a higher number of respondent might allow to spot statistically significant differences between freight commodities and logistics networks. Furthermore, the research could also be extended for other transport modes such as the plane, the deep sea shipping and the pipelines. These modes would complete the description of the European freight transportation market.

Another optic that could be considered for future research would be to define different indicators and quality grades to distinguish between urban and non-urban freight transportation. The geography of those two scenarios should be taken into account since infrastructure, speeds, congestion scenarios, vehicle types, and packaging can be completely different. But also, for terminals, because loading, unloading and transhipment points can be completely different in terms of location, accessibility, size, equipment, opening hours, etc. Furthermore, the shipper is also different in terms of size and role, since in urban freight distribution many freight customers are end consumers or small shops, whereas in national and international freight transportation shippers are usually bigger companies such as industries, construction companies or big retailers. Therefore, there is potential for new indicators if these different scenarios could be studied.

Finally, another step for further research could be to study the links between freight quality evaluation and passenger transport evaluation. So far, research tends to study these topics separately although both systems interact constantly in reality. It could be interesting to find out if there are synergies that improve both systems in terms of quality of service or it is always a trade-off. On the one hand, congestion of one of the systems affects negatively the other one when sharing infrastructure. On the other hand, freight and passenger services share sometimes the same vehicle. For instance, in aviation, companies use their flights for passenger and cargo at the same time. Therefore, it would be interesting to connect freight quality evaluation and passenger quality evaluation, stablishing connections among the knowledge existent up to date and finding bridges between these two systems that share time and space.

Appendix

Table A-1: Workshop results, indicators for contact with clients

Prozessschritt	Beschreibung			Beurteilung				
1. Akquisephase	**Kriterium**	**Indikators Zahl**	**Indikatorgrösse**	**Beeinflussbarkeit**	**Nutzen**	**Messbarkeit**	**Datenquelle**	**Erfassungsaufwand**
1.1. Kundenkontakt								
Dienstleister spricht Kunden Aktiv an	**Kundenkontakte, die von der Dienstleister aktiv angegangen werden**	1	Anzahl der aktiv angegangenen Kundenkontakte	*hoch*	*hoch*	*quantitativ*	*SAP CRM*	*niedrig*
		2	Anzahl/Form der proaktiven Kundeninformationen	*hoch*	*hoch*	*quantitativ*	*SAP CRM*	*niedrig*
Dienstleister wird von Kunden kontaktiert	**Kundenkontakte, die, die Dienstleister von sich aus kontaktiert haben**	3	Anzahl der Kundenkontakte, die der Dienstleister kontaktiert haben	*mittel*	*mittel*	*quantitativ*	*SAP CRM*	*niedrig*
	Transparenz der Ansprechpartner bei Dienstleister	4	Reaktionszeit der Dienstleister (z.B. bei Emailanfrage oder Nicht-Erreichbarkeit)	*hoch*	*hoch*	*quantitativ*	*SAP CRM*	*niedrig*
		5	% der Kundenkontakte, die direkt den richtigen Ansprechpartner gefunden haben (Transparenz)	*hoch*	*mittel*	*quantitativ*	*extern, Kunden-befragung*	*mittel*
	Sicherstellung der Erreichbarkeit der relevanten Ansprechpartner bei Dienstleister		Ausweichkanäle: Vorliegen einer Vertretungsregelung / gezielte Weiterleitung and kompetente Person - Häufigkeit der Weitervermittlung	*hoch*	*hoch*	*qualitativ*	*extern, Kunden-befragung*	*mittel*
			Abwesenheitsnachrichten/Mailbox mit entsprechenden Hinweisen					
Generelle Kriterien technischer und persönlicher Art	**Funktionsfähigkeit der angebotenen Kommunikationskanäle**	6	Anzahl der möglichen Kommunikationskanäle	*hoch*	*hoch*	*quantitativ*	*intern*	*mittel*
			Funktionalität der angebotenen Kommunikationskanäle					
			Technische Verfügbarkeit der angebotenen Kommunikationskanäle					
	Charakteristiken der Ansprechpartner bei Dienstleister	7	Freundlichkeit	*mittel*	*mittel*	*quantitativ*	*extern, Kunden-befragung*	*mittel*
			Engagement	*hoch*	*hoch*	*quantitativ*	*extern, Kunden-befragung*	*mittel*
			Kompetenz / Innovativität	*hoch*	*hoch*	*quantitativ*	*extern, Kunden-befragung*	*mittel*

Source: Workshop Kundenorientierung, 2015

Table A-2: Workshop results, indicators for tender preparation

Prozessschritt	Beschreibung			Beurteilung				
1. Akquisephase	Kriterium	Indikators Zahl	Indikatorgrösse	Beeinflussbarkeit	Nutzen	Messbarkeit	Datenquelle	Erfassungsaufwand
1.2 Angebotserstellung								
Standardleistungen	**Verständnis für die Kundenwünsche**	8	Häufigkeit der Angebotsanpassungen					
	Schnelligkeit der Angebotserstellung		Dauer von Anfrage bis Angebotsabgabe					
Individualleistungen	**Verständnis und Erfassung der Kundenwünsche**	9	Intensität des Austausches zwischen Dienstleiter und Kunden	***hoch***	***hoch***	***qualitativ***	***extern, Kunden-befragung***	***hoch***
		10	Verständnis zukünftiger Anforderungen	***hoch***	***mittel***	***qualitativ***	***extern, Kunden-befragung***	***hoch***
	Vollständigkeit des Angebotes im Hinblick auf Kunden wünsche		Häufigkeit der Angebotsanpassungen					
	Schnelligkeit der Angebotserstellung	11	Dauer von der finalen Klärung der Kundenwünsche bis Angebotsabgabe	***mittel***	***hoch***	***quantitativ***	***SAP CRM***	***niedrig***
Generelle Kriterien technischer und persönlicher Art	**Zuverlässigkeit bzgl. Zeitzusagen zur Angebotserstellung**	12	Pünktlichkeit im Hinblick auf zugesagten Termin	***mittel***	***mittel***	***nicht messbar***	***nicht messbar***	***hoch***
	Verständlichkeit und Aussagekraft des Angebotes	13	Häufigkeit der Kundennachfragen (Verständnisfragen)	***mittel***	***hoch***	***nicht messbar***	***nicht messbar***	***hoch***

Source: Workshop Kundenorientierung, 2015

Table A-3: Workshop results, indicators for negotiation with clients

Prozessschritt	Beschreibung			Beurteilung				
1. Akquisephase	Kriterium	Indikators Zahl	Indikatorgrösse	Beeinflussbarkeit	Nutzen	Messbarkeit	Datenquelle	Erfassungsaufwand
1.3 Verhandlung								
Standardleistungen	**Preisspielräume**		% der Angebote, in denen Preisvorgaben umgangen wurden					
	Leistungsanpassungen		% der Angebote, in denen abweichend vom Standard Zusatzleistungen angeboten wurden					
Individualleistungen	**Preisspielräume**		% der Preisabschläge vom ursprünglichen Angebot					
	Leistungsanpassungen	14	Individualisierte Service-Vielfalt des Angebots	*mittel*	*hoch*	*qualitativ*	*extern, Kunden-befragung*	*hoch*
Generelle Kriterien technischer und persönlicher Art	**Beständigkeit des Angebots**		Anzahl der verhandlungsbedingten Änderungen und Anpassungen					
	Charakteristiken der Ansprechpartner bei Dienstleister		Argumentationsstärke / Überzeugungskraft	*hoch*	*hoch*	*qualitativ*	*extern, Kunden-befragung*	*hoch*
			Kompetenz	*hoch*	*hoch*	*qualitativ*	*extern, Kunden-befragung*	*hoch*
		15	Wettbewerbsverständnis / Marktverständnis	*hoch*	*hoch*	*qualitativ*	*extern, Kunden-befragung*	*hoch*

Source: Workshop Kundenorientierung, 2015

Table A-4: Workshop results, indicators for planning and disposition

Prozessschritt	Beschreibung			Beurteilung				
2. Prozessphase	**Kriterium**	**Indikators Zahl**	**Indikatorgrösse**	**Beeinflussbarkeit**	**Nutzen**	**Messbarkeit**	**Datenquelle**	**Erfassungsaufwand**
2.1 Planung & Disposition								
Anbindung / Einbeziehung des Kunden	**Technische Anbindung des Kunden**	16	% der Kunden die elektronisch angebunden sind	*hoch (ggf. aber aufwändig)*	*hoch (wenn Dienstleiter System anpasst., sonst tief)*	*schwierig*	*Anteil der nicht elektronischen Buchung + manuellen Buchungskorrekturen*	*gering*
	Pro-Aktive Klärung mit dem Kunden bei Unklarheiten	17	Anzahl der direkten Kundenklärungen	*hoch*	*hoch*	*schwierig*	*Zeitspanne zwischen originärer und geänderter Buchung (Problem: Änderung mit anderen Ursachen)*	*hoch*
	Transparenz und Sicherstellung der Erreichbarkeit der zuständigen Dienstleiter Personen durch Kunden	18	Anzahl Kundenreklamationen aufgrund fehlender Erreichbarkeit/unklarer Zuständigkeiten in dringenden Fällen	*hoch*	*hoch*	*einfach*	*Kundenzufriedenheits-analyse*	*gering*
	Pro-Aktive Information des Kunden bei Planungsänderungen	19	Anzahl der Änderungsinformationen	*hoch*	*hoch*	*in Clustern einfach - ggf. schwierige Einzelfällle*	*a) Datawarehouse b) Kunden-zufriedenheitsbefragun g*	*a) hoch b) gering*
	Dispositionsflexibilität bei kurzfristigen Zeit-, Ort, und/oder Mengenänderungen durch den Kunden	20	Anzahl der kundenbedingt kurzfristigen Anpassungen	*mittel*	*hoch*	*Ganzzug: einfach WLV schwierig*	*Ganzzug: wird erfasst WLV: keine Erfassung der nicht erfolgreichen Änderungen*	*Ganzzug: hoch WLV: hoch*

Source: Workshop Kundenorientierung, 2015

Table A-5: Workshop results, indicators for performance and invoicing

Prozessschritt	Beschreibung			Beurteilung				
2. Prozessphase	**Kriterium**	**Indikators Zahl**	**Indikatorgrösse**	**Beeinflussbarkeit**	**Nutzen**	**Messbarkeit**	**Datenquelle**	**Erfassungsaufwand**
2.2 Leistungserstellung								
Servicequalität der Leistungserstellung	**Servicezuverlässigkeit**	21	% der zugesagten Termine eingehalten	***hoch***	***hoch***	***Heute: schwierig, da Sendungs-pünktlichkeit nicht erfasst wird***	***Datawarehouse (in KYM abgebildet)***	***zukünftig: gering***
	Servicebeschaffenheit	22	% der Ware schadenfrei ausgeliefert	***hoch***	***hoch***	***schwierig (Sonsorik am Wagen erforderlich)***	***bisher keine***	***derzeit sehr hoch - mit Sensorik klein***
	Service-Lieferzeit		Durschnittliche Laufzeit der Sendung	***bereits im Angebot definiert***				
	Serviceflexibilität	23	% der kurzfristigen Änderungen and Gesamtsendungen	***hoch***	***hoch***	***schwierig Einzelfall-entscheidungen***	***SAP Reporting***	***sehr hoch***
Anbindung / Einbeziehung des Kunden	**Angebot Track & Trace (Passiv)**		Anzahl der kundenseitigen Abfragen	***in Frage 31 enthalten***				
	Pro-Aktive Kundeninfo bei Abweichungen in der Leistungserstellung		Anzahl der Pro-Aktiven Kundeninformationen	***in Frage 31 enthalten***				
2.3. Fakturierung								
Rechnungstellung	**Klarheit/Verständlichkeit der Rechnung**	24	Anzahl der Verständnisbedingten Rückfragen	***mittel***	***gering***	***einfach***	***Kundenzufriedenheit***	***gering***
	Übereinstimmung der Rechnung mit dem Angebot	25	Anzahl der Abweichungsbedingten Rückfragen	***mittel***	***hoch***	***einfach***	***Finanzsysteme / Kundenzufriedenheit***	***gering***

Source: Workshop Kundenorientierung, 2015

Table A-6: Workshop results, indicators for customer complain

Prozessschritt	Beschreibung			Beurteilung				
3. After-Sales-Phase	Kriterium	Indikators Zahl	Indikatorgrösse	Beeinflussbarkeit	Nutzen	Messbarkeit	Datenquelle	Erfassungsaufwand
3.1. Reklamation								
	Beschwerdeprozess		Zertifizierter Beschwerdeprozess	*hoch*	*mittel*	*einfach*	*Zertifikat*	*klein*
Reklamationszugang und -dauer	Reklamationskanäle		Anzahl der Möglichkeiten, eine Reklamation zu kommunizieren	*hoch*	*niedrig*	*einfach*	*Homepage*	*klein*
	Einfachheit, eine Beschwerde zu platzieren	26	Einfachheit, eine Beschwerde zu platzieren	*hoch*	*hoch*	*quantitativ*	*extern, Kunden-befragung*	*mittel*
	Sicherstellung der Erreichbarkeit der relevanten Ansprechpartner bei Dienstleister	27	Öffnungszeit der Kontaktanäle	*hoch*	*mittel*	*quantitativ*	*Homepage*	*klein*
		28	Responsequote / Servicequote	*hoch*	*hoch / mittel*	*einfach, wird gemessen*	*intern*	*automatisch*
			Ausweichkanäle: Vorliegen einer Vertretungsregelung / gezielte Weiterleitung and kompetente Person - Häufigkeit der Weitervermittlung		*niedrig*			
			Abwesenheitsnachrichten/Mailbox mit entsprechenden Hinweisen		*niedrig*			
		29	Zeitraum der Reklamationsbearbeitung	*mittel*	*mittel*	*einfach Ticketsystem Eröffnung und Abschluss*	*intern*	*automatisch*
			Kommunikation des erwarteten Bearbeitungszeitraums		*mittel*	*ja / nein Entscheid*		
Generelle Kriterien technischer und persönlicher Art	Zuverlässigkeit bzgl. Zeitzusagen zur Lösungsfindung	30	Pünktlichkeit im Hinblick auf zugesagten Termin		*mittel*			
	Nachvollziehbarkeit und Akzeptanz der vorschgeschlagenen Lösung	31	Häufigkeit der Kundennachfragen (Verständnisfragen) Qualität der Antwort	*mittel*	*hoch*	*qualitativ, subjektiv (Resultat des Bescheids verzerrt)*	*extern, Kunden-befragung oder intern quantitativ (Reklamationstickets)*	*hoch / gering*
Kulanz	Kulanzverhalten im Reklamaitionsfall		% Kulanzgewährung nach Kulanzanfragen (nach negativer Beschwerdebescheid)	*mittel*	*mittel*	*einfach*	*intern*	*gering*

Source: Workshop Kundenorientierung, 2015

Table A-7: Workshop results, indicators for customer follow-up

Prozessschritt	Beschreibung			Beurteilung				
3. After-Sales-Phase	**Kriterium**	**Indikators Zahl**	**Indikatorgrösse**	**Beeinflussbarkeit**	**Nutzen**	**Messbarkeit**	**Datenquelle**	**Erfassungsaufwand**
3.2. Nachfassen beim Kunden								
Bei erfolgreichem Angebot	**Nachfassen nach Abschluss der Leistungserstellung (und Fakturierung) auch ohne speziellen Anlass**	32	Anzahl der AfterSales Kontakte nach Abschluss des Auftrages	***hoch***	***hoch Begeisterung***	***mittel, qualitativ***	***intern, CRM***	***mittel***
Bei erfolglosem Angebot	**Nachfassen nach Absage des Kunden auf das Angebot**	33	Anzahl der AfterSales Kontakte (Telefon) nach erfolglosem Angebot	***hoch***	***hoch***	***mittel, qualitativ***	***intern, CRM***	***mittel***
3.3. Kundenpflege								
Bestandskunden	**Turnusmässige Ansprache von Bestandskunden**	34	Frequenz der Kundenbesuche	***hoch***	***hoch***	***mittel***	***intern, CRM***	***mittel***
Potenzielle Neukunden	**Turnusmässige Ansprache von potenziellen Neukunden**		Anzahl von Feedbacks potenzieller Neukunden					
CSR - Kundenfeedbacks	**Systematische Aufbereitung der Kundenfeedbacks (Aktualität der Kundendatenqualität)**	35	Aktualität und Aussagekraft einer CRM Datenbasis (z.B. Anteil Zustellungsfehler bei Kundenmailings)	***mittel***	***mittel***	***einfach***	***intern***	***klein, automatisiert***

Source: Workshop Kundenorientierung, 2015

Bibliography

AARA-MPS. (2011). *Rail Freight Service Review*. TC-1004219. Transport Canada.

Albacete-Sáez, C. A., Mar Fuentes-Fuentes, M., & Javier Lloréns-Montes, F. (2007). Service quality measurement in rural accommodation. *Annals of Tourism Research*, *34*(1), 45–65. https://doi.org/10.1016/j.annals.2006.06.010

Arvis, J.-F., Saslavsky, D., Ojala, L., Shepherd, B., Busch, C., & Raj, A. (2014). *Connecting to Compete 2014 : Trade Logistics in the Global Economy--The Logistics Performance Index and Its Indicators*. Washington, DC: World Bank.

Ballis, A. (2004). Introducing level-of-service standards for intermodal freight terminals. *Transportation Research Record*, *1873*, 79–88. https://doi.org/10.3141/1873-10

Bertram, D. (2008). *Likert Scales are the meaning of life CPSC 681 – Topic Report*.

Binnenschiffahrts-Verlag Gmbh. (2006). *Wasserstrassenkarte Europa*.

Bischofberger, N. (1997). *Zur Leistungsfähigkeit in Verkehrssystemen*. ETH. https://doi.org/10.3929/ETHZ-A-001794273

Bolis, S., & Maggi, R. (2003). Logistics Strategy and Transport Service Choices: An Adaptive Stated Preference Experiment. *Growth and Change*, *34*(4), 490–504. https://doi.org/10.1046/j.0017-4815.2003.00232.x

Bortz, J., & Döring, N. (2006). *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler*. *Text*. https://doi.org/10.1007/978-3-540-33306-7

Bouffioux, C., Beuthe, M., & Pauwels, T. (2006). La qualité des services de transport de marchandises : Une analyse agrégée des ordres de préférence déclarés. *Les Cahiers Scientifiques Du Transport*, (50), 135–158.

Brolsma, J. U., & Roelse, K. (2011). *Waterway Guidelines 2011*. (Directorate-General for Public Works and Water, Ed.). Rijkswaterstaat, Centre for Transport and Navigation.

Bruhn, M. (2009). Das Konzept der kundenorientierten Unternehmensführung. In H. H. Hinterhuber & K. Matzler (Eds.), *Kundenorientierte Unternehmensführung: Kundenorientierung - Kundenzufriedenheit - Kundenbindung* (pp. 33–68). Wiesbaden: Gabler. https://doi.org/10.1007/978-3-8349-8051-9_2

Brüls, H., & Wyer, D. (2016). Pharmaceutical Cargo Theft in Europe, A realistic view of the current trends, challenges, and financial impacts. *FreightWatch International*, 8.

Carsten Schmitz. (2015). LimeSurvey: An Open Source survey tool. Hamburg: LimeSurvey Project.

CEN. (2002). *Transportation - Logistics and services - Public passenger transport - Service quality definition, targeting and measurement*. EN 13816. European Committee of Standardization.

CER. (2013). *Rail Freight Status Report 2013, Rail freight after a decade of EU rail policy*. Community of European Railway and Infrastructure Companies.

Clements, M. E. (2004). Local telephone quality-of-service: A framework and empirical evidence. *Telecommunications Policy*, *28*(5–6), 413–426. https://doi.org/10.1016/j.telpol.2004.02.001

Daehre, K.-H. (2012). *Zukunft der Verkehrsinfrastrukturfinanzierung*.

Danielis, R., Marcucci, E., & Rotaris, L. (2005). Logistics managers' stated preferences for freight service attributes. *Transportation Research Part E: Logistics and Transportation Review*, *41*(3), 201–215. https://doi.org/10.1016/j.tre.2004.04.003

de Jong, G., & Ben-Akiva, M. (2007). A micro-simulation model of shipment size and transport chain choice. *Transportation Research Part B: Methodological*, *41*(9), 950–

965. https://doi.org/10.1016/j.trb.2007.05.002

DG Transport. (1999). *Design and Organizational Aspects of Combined Transport Terminals. Deliverable 11. IMPULSE Research Project: Interoperable Modular Pilot Plants Underlying Logistic System in Europe*. Brussels.

Dorbritz, R., & Scherer, M. (2011). Multimodale Verkehrsqualitätsstufen für den Strassenverkehr.

EC. (2016). Eurostat Database. *European Commission; Online Statistical Database*.

ECE. (2015). *European Agreement Concerning the International Carriage of Dangerous Goods by Road* (Vol. 1). New York and Geneva: Economic Commission for Europe, Committee on Inland Transport.

European Commission. (2014). *EU transport in figures Statistical pocketbook*. *EU transport in figures*. Luxembourg. https://doi.org/10.2832/63317

European Court of Auditors. (2016). *Rail freight transport in the EU: still not on the right track*. Luxembourg.

FDOT. (2002). *2002 Quality / Level of Service Handbook*.

Feo-Valero, M., García-Menéndez, L., & Saz-Salazar, S. del. (2016). Rail freight transport and demand requirements: an analysis of attribute cut-offs through a stated preference experiment. *Transportation*, *43*(1), 101–122. https://doi.org/10.1007/s11116-014-9566-x

FGSV. (1997). *Empfehlungen für Wirtschaftlichkeitsuntersuchungen von Straßen – Wikipedia*. (Forschungsgesellschaft für Straßen- und Verkehrswesen, Ed.). Bergisch Gladbach.

FGSV. (2001). *HBS : Handbuch für die Bemessung von Strassenverkehrsanlagen* (Ausg. 2001). Köln: Forschungsgesellschaft für Strassen- und Verkehrswesen.

Frank, J. P. (2013, January 1). *Methodik zur Effizienzbeurteilung der Kapazitätsnutzung und -entwicklung von Bahnnetzen*. *Schriftenreihe / Institut für Verkehrsplanung und Transportsysteme*. IVT, ETH Zurich. https://doi.org/10.3929/ETHZ-A-009989794

Fries, N. (2009). Market potential and value of sustainable freight transport chains. *Schriftenreihe / Institut Für Verkehrsplanung Und Transportsysteme*, *148*. https://doi.org/10.3929/ETHZ-A-006001850

Fries, N., Nash, A., Wichser, J., & Abay, G. (2008). Modal Split Functions for a Swiss National Freight Transport Model. In *AET Papers Repository*. Association for European Transport.

Ghaus Younossi. (2009). *Le transport combiné de fret : La construction d'un système de transport*. (Editions Celse, Ed.).

Giannakis, D., Jamasb, T., & Pollitt, M. (2005). Benchmarking and incentive regulation of quality of service: An application to the UK electricity distribution networks. *Energy Policy*, *33*(17), 2256–2271. https://doi.org/10.1016/j.enpol.2004.04.021

Gorse, C., Johnston, D., & Pritchard, M. (n.d.). *A Dictionary of Construction, Surveying and Civil Engineering*.

Gray, R. (2007). Behavioural approaches to freight transport modal choice. *Transport Reviews*, *2*(2), 161–184. https://doi.org/10.1080/01441648208716491

Growitsch, C., Jamasb, T., & Pollitt, M. (2009). Quality of service, efficiency and scale in network industries: an analysis of European electricity distribution. *Applied Economics*, *41*(20), 2555–2570. https://doi.org/10.1080/00036840701262872

Highway Research Board. (1965). *Highway Capacity Manual 1965*. (National Academy of Sciences & National Research Council, Eds.). Washington D.C.: Special Report 87.

Homburg, C., & Rudolph, B. (2001). Customer satisfaction in industrial markets:

Dimensional and multiple role issues. *Journal of Business Research*, *52*(1), 15–33. https://doi.org/10.1016/S0148-2963(99)00101-0

Instituto di Recerche Economiche, & Rapp Trans AG. (2005). *Bewertung von Qualitätsmerkmalen im Güterverkehr*. Zürich/Lugano.

Islam, D. M. Z., & Zunder, T. H. (2014). The necessity for a new quality standard for freight transport and logistics in Europe. *European Transport Research Review*, *6*(4), 397–410. https://doi.org/10.1007/s12544-014-0141-5

Johansson, R. (2003). Case Study Methodology. *Methodologies in Housing Research International Conference, Stockholm, Sweeden, 2003*, *1*(September), 22–24. https://doi.org/10.1016/S0148-2963(00)00195-8

Juran, J. M., & Godfrey, A. B. (1998). *Juran's Quality Handbook*. *McGrawHill*. https://doi.org/10.1108/09684879310045286

Kernohan, D. (2006). *Integrating Europe's Transport System | Centre for European Policy Studies*.

Knieps, G. (2006). The different role of mandatory access in German regulation of railroads and telecommunications. *Journal of Competition Law and Economics*, *2*(1), 149–158. https://doi.org/10.1093/joclec/nhl004

Konings, R., Kreutzberger, E., & Maras, V. (2013). Major considerations in developing a hub-and-spoke network to improve the cost performance of container barge transport in the hinterland: The case of the port of rotterdam. *Journal of Transport Geography*, *29*, 63–73. https://doi.org/10.1016/j.jtrangeo.2012.12.015

Kroes, E. P., Sheldon, R. J., & Sheldont, R. J. (1988). Stated Preference Methods: An Introduction. *Journal of Transport Economics and Policy*, *22*(1), 11–25.

Leerkamp, B., Dahmen, B., Janßen, T., & Vollmer, R. (2013). *Datenanforderungen an die Weiterentwicklung kleinräumiger Verkehrsnachfragemodelle des Wirtschaftsverkehrs -Praxisleitfaden*. Wuppertal and Aachen.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*. https://doi.org/2731047

Lin, W. B. (2007). An empirical of service quality model from the viewpoint of management. *Expert Systems with Applications*, *32*(2), 364–375. https://doi.org/10.1016/j.eswa.2005.11.033

Lu, Y., Zhang, L., & Wang, B. (2009). A multidimensional and hierarchical model of mobile service quality. *Electronic Commerce Research and Applications*, *8*(5), 228–240. https://doi.org/10.1016/j.elerap.2009.04.002

Macharis, C., & Bontekoning, Y. M. (2004). Opportunities for OR in intermodal freight transport research: A review. In *European Journal of Operational Research* (Vol. 153, pp. 400–416). https://doi.org/10.1016/S0377-2217(03)00161-9

Martínez-Caro, L., & Martínez-García, J. (2007). Measuring perceived service quality in urgent transport service. *Journal of Retailing and Consumer Services*, *14*(1), 60–72. https://doi.org/10.1016/j.jretconser.2006.04.001

Martínez Caro, L., & Martínez García, J. A. (2008). Developing a multidimensional and hierarchical service quality model for the travel agency industry. *Tourism Management*, *29*(4), 706–720. https://doi.org/10.1016/j.tourman.2007.07.014

Martínez de Osés, X., & Castells, M. (2006). *Análisis de los buques en el Short Sea Shipping Español (Mean particulars of ships operating on Spanish Short Sea Shipping routes)*.

McGinnis, M. A. (1979). Shipper Attitudes Toward Freight Transportation Choice: A Factor Analytic Study. *International Journal of Physical Distribution & Materials*

Management, *10*(1), 25–34.
Mendoza, G., & Macoun, P. (1999). *Guidelines for Applying Multi-Criteria Analysis to the Assessment of Criteria and Indicators*. *Management*. Bogor, Indonesia: CIFOR. https://doi.org/10.1016/j.ecolind.2006.11.006
Mest, L. (2011). *Typologische Ordnung von Logistikstrategien und -strukturen für die Güterwirtschaftsverkehrsmodellierung* (Logistik, Verkehr und Umwelt). Verlag Praxiswissen, Dortmund.
Meyburg, A. H. (1979). The applicability of behavioral modelling to the analysis of goods movements. In *Behavioural Travel Modelling* (pp. 624–635). Groom Helm.
Muchiri, P. N., Pintelon, L., Martin, H., & De Meyer, A.-M. (2010). Empirical analysis of maintenance performance measurement in Belgian industries. *International Journal of Production Research*, *48*(20), 5905–5924. https://doi.org/10.1080/00207540903160766
Nielsen, O. A., & Burgess, A. (2008). the European Transtools Transport Model. *Transportation*, 1–18.
Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y
Orth, H., Carrasco, N., Schwertner, M., & Weidmann, U. (2013). Calibration of a Public Transport Performance Measurement System for Switzerland. *Transportation Research Record: Journal of the Transportation Research Board*, *2351*(2351), 104–114. https://doi.org/10.3141/2351-12
Orth, H., Weidmann, U., & Dorbritz, R. (2012). Development of Measurement System for Public Transport Performance. *Transportation Research Record: Journal of the Transportation Research Board*, *2274*, 135–143. https://doi.org/10.3141/2274-15
Paixão, A. C., & Marlow, P. B. (2002). Strengths and weaknesses of short sea shipping. *Marine Policy*, *26*(3), 167–178. https://doi.org/10.1016/S0308-597X(01)00047-1
Parasuraman, Zeithaml, V. A., & Berry, L. L. (1988). SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing*, *64*(1), 12–40. https://doi.org/10.1016/S0148-2963(99)00084-3
Patterson, Z., Ewing, G., & Haider, M. (2007). Shipper Preferences Suggest Strong Mistrust of Rail: Results from Stated Preference Carrier Choice Survey for Quebec City—Windsor Corridor in Canada. *Transportation Research Record: Journal of the Transportation Research Board*, *2008*(2008), 67–74. https://doi.org/10.3141/2008-09
Pršić, M., Carević, D., & Brčić, D. (2011). Determining Inland Waterway Parameters with Application to the Sava River. *PROMET - Traffic&Transportation*, *23*(2), 147–154. https://doi.org/10.7307/ptt.v23i2.142
Rich, J., Holmblad, P. M., & Hansen, C. O. (2009). A weighted logit freight mode-choice model. *Transportation Research Part E: Logistics and Transportation Review*, *45*(6), 1006–1019. https://doi.org/10.1016/j.tre.2009.02.001
Rich, J., Kveiborg, O., & Hansen, C. O. (2011). On structural inelasticity of modal substitution in freight transport. *Journal of Transport Geography*, *19*(1), 134–146. https://doi.org/10.1016/j.jtrangeo.2009.09.012
Roberts, P. O., & Wang, K. (1979). *Predicting Freight Transport Level of Service Attributes* (Vol. 79). Massachusetts Institute of Technology, Center for Transportation Studies.
Ruesch, M., Abel, H., Karrer, R., Poersch, R., Fiedler, R., Reynaud, C., … Siciliano, G. (2005). *Integrated Services in the Intermodal Chain (ISIC), Final Report Task D:*

"Improving Quality of Intermodal Terminals." Zürich.
Ruijgrok, C. J., & Tavasszy, L. a. (2007). The Development of International Freight Transport in Europe as a Result of Developments in International Trade and Logistics. *Canada's Asia-Pacific Gateway and Corridor Research Consortium, Vancouver, BC, May*.
Saaty, T. L. (1988). What is the Analytic Hierarchy Process? In *Mathematical Models for Decision Support* (pp. 109–121). https://doi.org/10.1007/978-3-642-83555-1_5
Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, *48*(1), 9–26. https://doi.org/10.1016/0377-2217(90)90057-I
Sandberg, P., Spalding, T., Schweizer, C., & Associates, C. R. (2004). Mobility 2030: Meeting the challenges to sustainability. *The World Business Council for Sustainable Development (WBCSD)*.
Sapsford, R., & Jupp, V. (2006). *Data Collection and Analysis* (2nd ed.). London: SAGE Publications Ltd. https://doi.org/10.4135/9781849208802
SBB. (2016a). SBB Graphic Timetables. Retrieved from http://www.fahrplanfelder.ch/en/archives/graphic-timetables.html
SBB. (2016b). SBB Open Data. Retrieved from https://data.sbb.ch/pages/einstieg/
SBB Cargo International. (2013). *Guideline for hazardous goods transport*. Olten.
Schnell, R., Hill, P. B., & Esser, E. (2008). *Methoden der empirischen Sozialforschung*. *Grundbegriffe der Soziologie* (Vol. 5. Auflage). https://doi.org/10.1515/9783111369150
Shepard, R. N. (1972). A taxonomy of some principal types of data and of multidimensional methods for their analysis. *Multidimensional Scaling: Theory and Application in Behavioral Sciences*, *1*, 21--47.
Stölze, W., Hofmann, E., & Lampe, K. (2014). *Logistikmarkstudie 2014 - Das umfassende Nachschlagewerk für Logistik und Supply Chain Management*. GS1 Schweiz.
Thurstone, L. L. (1927). A law of comparative judgment. *Psychological Review*, *34*(4), 273–286. https://doi.org/10.1037/h0070288
TRB. (2000). *Highway capacity manual*. *Environmental Protection*. Transportation Research Board. https://doi.org/10.1061/(ASCE)HY.1943-7900.0000746.
UIC. (2004). *CODE 406 Capacity*. Paris: International Union of Railways.
UNECE. (2000). *Glossary of Terms on Statistical Data Editing*. Geneva.
UNECE. (2001). *Terminology on combined transport*. (European Conference of Ministers of Transport, Ed.). New York and Geneva: Economic Commission for Europe and United Nations.
UNECE. (2008). NST 2007. Retrieved from https://www.unece.org/trans/main/wp6/transstatwp6nst.html
Vellay, C., & De Joung, G. (2003). *Analyse conjointe SP/RP du choix du mode de transport de marchandise dans la Région Nord-Pas-de-Calais*. Santa Monica, CA: RAND.
Wang, Y., Bilegan, I. C., Crainic, T. G., & Artiba, A. (2014). Performance indicators for planning intermodal barge transportation systems. In *Transportation Research Procedia* (Vol. 3, pp. 621–630). https://doi.org/10.1016/j.trpro.2014.10.041
Weber, J. (2007). The Geography of Transportation Systems, edited by Jean-Paul Rodrigue, Claude Comtois, and Brian Slack. *Journal of Regional Science*, *47*(3), 642–644. https://doi.org/10.1111/j.1467-9787.2007.00523_8.x
Weidmann, U., Frank, P., Fumasoli, T., & Moll, S. (2012). *Optimale Netznutzung und Wirksamkeit der Instrumente zu deren Lenkung*. *Schriftenreihe* (Vol. 158). Zürich:

Institut für Verkehrsplanung und Transportsysteme, ETH Zürich.

Weidmann, U., Kirsch, U., Puffe, E., Jacobs, D., Pestalozzi, C., & Conrad, V. (2014). *Verkehrsqualität und Leistungsfähigkeit von Anlagen des leichten Zweirad- und des Fussgängerverkehrs. Quality of traffic conditions and capacity of cycling and walking facilities = Qualité du trafic et capacité des infrastructures des deux-roues légers et. Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK, Bundesamt für Strassen* (Vol. 1444). Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK, Bundesamt für Strassen.

Weidmann, U., Orth, H., Dorbritz, R., Schwertner, M., & Carrasco, N. (2014). Verkehrsqualität und Leistungsfähigkeit des strassengebundenen öV. *Eidgenössisches Departement Für Umwelt, Verkehr, Energie Und Kommunikation UVEK, Bundesamt Für Strassen, 1443*.

Wichser, J. (2010). *System- und Netzplanung Band 1.3 Grundlagen der System- und Netzplanung, Logistik und Güterverkehr*. (Vorlesungsskript, Ed.). Zürich: Institut für Verkehrsplanung und Transportsysteme, ETH Zürich.

Wiegmans, B. W. (2005). Evaluation of Potentially Successful Barge Innovations. *Transport Reviews*, *25*(5), 573–589. https://doi.org/10.1080/01441640500092208

Xiao, F., Ligteringen, H., Van Gulijk, C., & Ale, B. (2015). Comparison study on AIS data of ship traffic behavior. *Ocean Engineering*, *95*, 84–93. https://doi.org/10.1016/j.oceaneng.2014.11.020