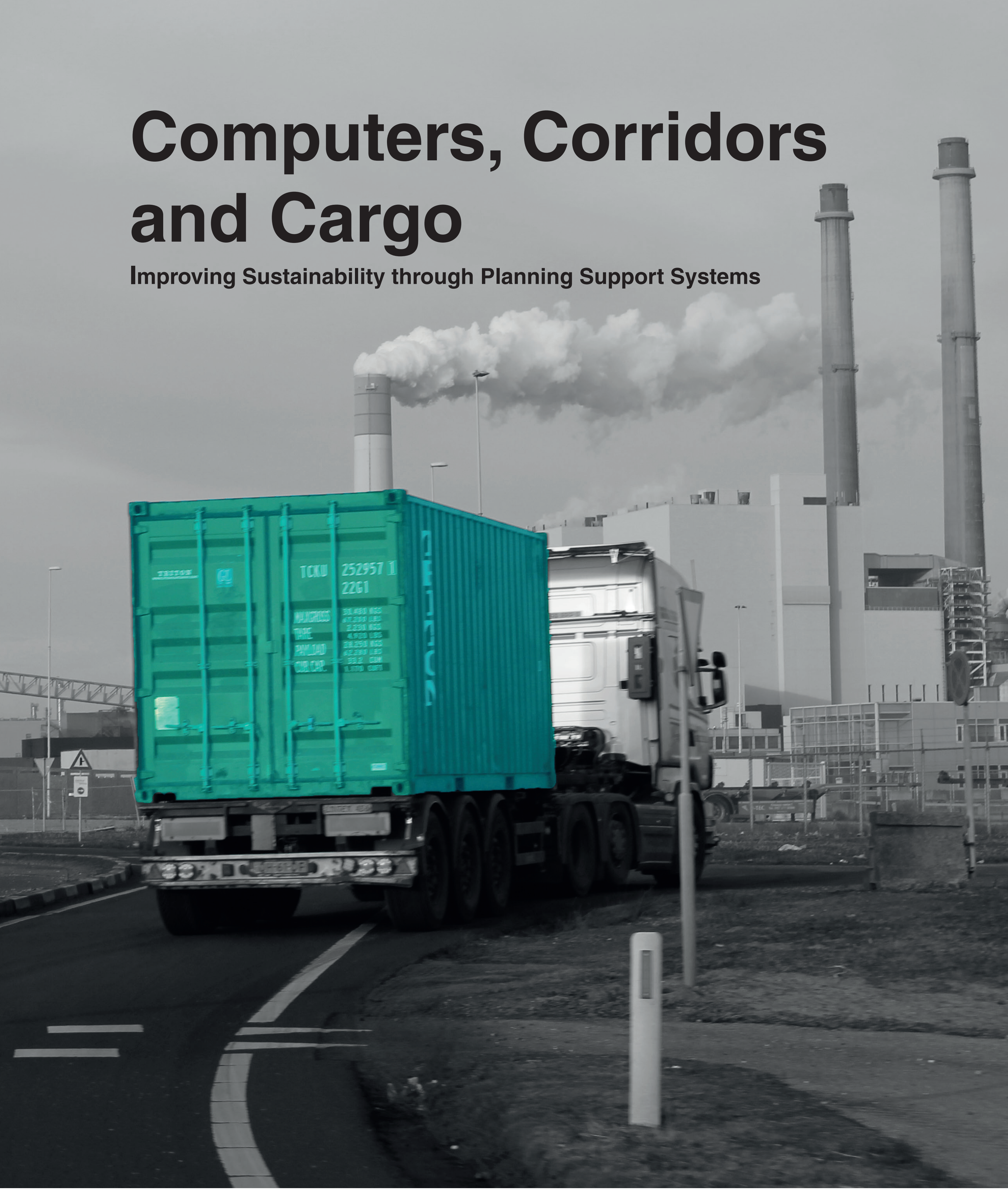
Computers, Corridors and Cargo

Improving Sustainability through Planning Support Systems



Marc van der Woude
Master Thesis
December 2019

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Computers, Corridors and Cargo

Improving Sustainability through Planning Support Systems

Date:	December 2019
Name:	Marc van der Woude BSc
Student Nr.	4246683
Supervisor:	Dr. P.A. Witte

Master Spatial Planning
Graduate School of Geosciences
Utrecht University

Utrecht University

Preface and acknowledgements

At the time of writing, the issue of sustainability is in the news more often than not. Recent governmental decisions about the issues of pollution of NOx, Co2 and many other pollutants led to a temporary halt in most construction works in the Netherlands to comply with European regulation This trend led to protests of people working in the sectors of agriculture, construction and transport This last category has been an issue of debate in the recent decades. Along with goals from climate accords, European Union and governmental goals, the need for enhancement of sustainability in the sector of freight transport arises. During my internship at the Dutch Ministry of Transport, this was one of the main drivers of change. The issue is not *if* we need to enhance the sustainability of sectors such as freight transport, just *how*.

This research will elaborate on the relation between sustainability and the use of ICT systems in a transport planning perspective, two issues which held my interest both my bachelor and master's in planning at Utrecht University. To research this issue, I have interviewed several Dutch planning experts working in or around the field of freight transport planning. During these interviews it was clear that sustainability improvements are of great importance to the context of transport planning.

In a thesis with collaboration between stakeholders as an important aspect, it seems logical to thank certain people for their help and involvement in the creation of this thesis. First of all, I would like to thank my supervisor from Utrecht University P.A. Witte for his support and feedback in the process. The inspiration and opportunities in the creation of this thesis have been essential. I would also like to thank everyone involved in the expert interviews which were conducted, by either being interviewed or in the communication processes of finding the right interviewees. Their time and effort were of great importance to this thesis. A complete list of interviewees can be found in appendix E. Lastly I would like to thank my friends, family and girlfriend for their feedback, thematic discussions and motivational comments in the various stages of writing this thesis, as it has helped to cope with the diverse stages in the process of writing this thesis.

Marc van der Woude
29 – 11- 2019

Abstract

From 1990 and onwards, the European union started a project in connecting the different states in a new way. This led to the creation of the Trans-European Networks, with one of these networks dedicated to a transport network with corridors. These Trans-European corridors consist of multimodal international networks with a dedicated corridor management team to enhance the corridors. One of the goals of the European Union in these corridors is the enhancement of sustainability; in 2050 a decrease of 60% of all emission by the freight transport on the corridor in relation to the levels from1990. The foremost actions to achieve these goals are the actions promoting both continuous flow and multimodal transport on the corridors. In this research the planning context of these freight transport corridors were divided in four layers: the layer of trade, the layer of economics, the layer of traffic management and the layer of network management. There is also a fifth vertical layer crossing the four horizontal layers. This is the layer of information flow and ICT use. This research is focussed on the enhancement of sustainability on the freight transport corridors in regard to the enhancement of the fifth layer of this model. As the scope of the research is to view this 'wicked problem' through the lens of transport planning, the research views the use of ICT systems in these four layers of the model from a planning support system perspective. Planning support systems is a broad term in research as it encompasses the ICT systems used by planners in the aiding of their daily activities. Another characteristic of planning support systems is the broad nature of the systems as they include functionalities of data gathering, analysis, design functions and other functions to support planners in their tasks. The planning support systems started to emerge from the 1980's onwards but while the systems themselves grew in capabilities and complexness; the use seemed to stagnate. This mismatch in the use of planning support systems can be explained trough the division in the knowledge, communication and context gap. By using the method of semi-guided interviews with planning professionals the use of ICT systems on the four layers was examined, as well as current trends in context of sustainability in the case study and insight in the collaboration of these planners. The used case study is that of the TEN-T Rhine Alpine corridor, connecting the region of Rotterdam via the Ruhr Area in Germany to the city of Genova in Italy. The case study has its focus on the Dutch part of this corridor. The current sustainability trends were summarized as bottlenecks in the enhancement of the corridor. This context can be interpreted as the 'context' part in the context gap of the planning support systems for planners from the case study. The knowledge gap was researched using topics about the personal experience and use of planning support systems for their daily activities. The communication gap was finally researched by analysing the communication in the corridor management. The knowledge gap in the mismatch of planning support systems seems to be present as most respondents note to have slight experience in the use of planning support systems, on a rudimentary level. The outsourcing of more difficult use of planning support systems is also common but increases risks of misinterpretation or misuse of the outcomes. The communication gap is also said to be present in this sector because the stark and competitive nature of the sector itself. There are several issues regarding the sharing of data and the collaboration in certain aspects of the daily activities on the corridor. On the planning level this is enhanced due to the stark modal division in governmental parties. The context gap is present in a less pronounced manner. There are multiple ICT packages made for planners in a transport network planning perspective. These packages are however often only made for a single or a small amount of purposes. Broad and interconnected planning support systems assisting planners and other stakeholders in most or all aspects of their daily activities are still slim. This is again due to the reserved and competitive nature of the long-term freight transport sector. There are several bottlenecks identified in multiple categories. The usage of multimodal transport is often seen as an efficient method of enhancing sustainability on the corridor. While there is energy and effort on the promotion of multimodal transport, the respondents note that

this is still very slim. This, as well as several bottlenecks on the corridor is very dependent on the collaboration of stakeholders and the sharing of data. It can thus be concluded that enhancements on the fifth layer of information and ICT in the model translates to eventual enhancements in the sustainability of the corridor.

Table of Contents

List of Figures and Tables

1

1. Introduction

1.1 Research Motive

1.1.1 Transport sustainability

The Dutch economy relies heavily on the transport and throughput of produced goods. Main ports like the ports of Rotterdam and Amsterdam and airport Schiphol account for a large percentage of the Dutch GDP. The port of Rotterdam alone will process 469 million tonnes of cargo each year. The added value in this port is producing about 45,6 million euro's, accounting for 6,2% of the national GDP (Rotterdam Port Authority, 2019).

It is needless to say that this large node has a profound effect on the Dutch transport networks, especially in the case of continental transport. The port of Rotterdam utilizes four main modes of transport to transfer goods to beyond national borders. These are road transport, rail transport, inland waterways and pipeline transport.

In recent times, there is an improving need for sustainability on this corridor from Rotterdam to Germany and beyond. In the goals of either the Dutch government as well as European goals, the need for the enhancement of sustainability is clear. There are several directions to achieve these goals. In this research the focus will be on the current trend of data and ICT systems to help improve the sustainability of the transport and the corridor as whole (Banning & de Klein, 2016; Black & Van Geenhuizen, 2006; I. Harris, Wang, & Wang, 2015).

1.1.2 Network Creation

There are different initiatives to facilitate the continental freight transport in the Netherlands. On the smallest scale there are several municipal and provincial actions and plans. These actions are often in cooperation with the national government in several themed action-based programs. There are also international initiatives. The TEN-T project is one of the most influential examples of international network creation (Europäische Kommission, 2011).

The TEN-T (Trans European Network of Transport) is a European Union initiated programme based on ten international corridors. These corridors link important nodes within the European Union. the goal is described as follows:

'The ultimate objective of TEN-T is to close gaps, remove bottlenecks and eliminate technical barriers that exist between the transport networks of EU Member States, strengthening the social, economic and territorial cohesion of the Union and contributing to the creation of a single European transport area.' *Source: European Commission, 2019*

The goals of this European transport network is to enhance seamless transport along the network along with various network goals such as the enhancement of sustainability, where in 2050 the pollution has to be reduced with 60% from 1990 levels (European Union, 2013). The creation of the corridors started from 1990 under Article 75 under the Treaty of Rome as an action programme in the area of infrastructure to enhance the transport market. The original aim was a two-year programme, but this was extended for two extra years before being reworked to integrated European corridor networks in the areas of transport, telecommunications and energy structures. The networks were indicative, and no obligations arose from the creation. There were however several issues with funding as the TEN-T network did not have proper financial resources. In 2011 the European funding agency CEF, Connecting Europe Facility, was founded (Butcher, 2012). The TEN-T core network is depicted below in figure 1.

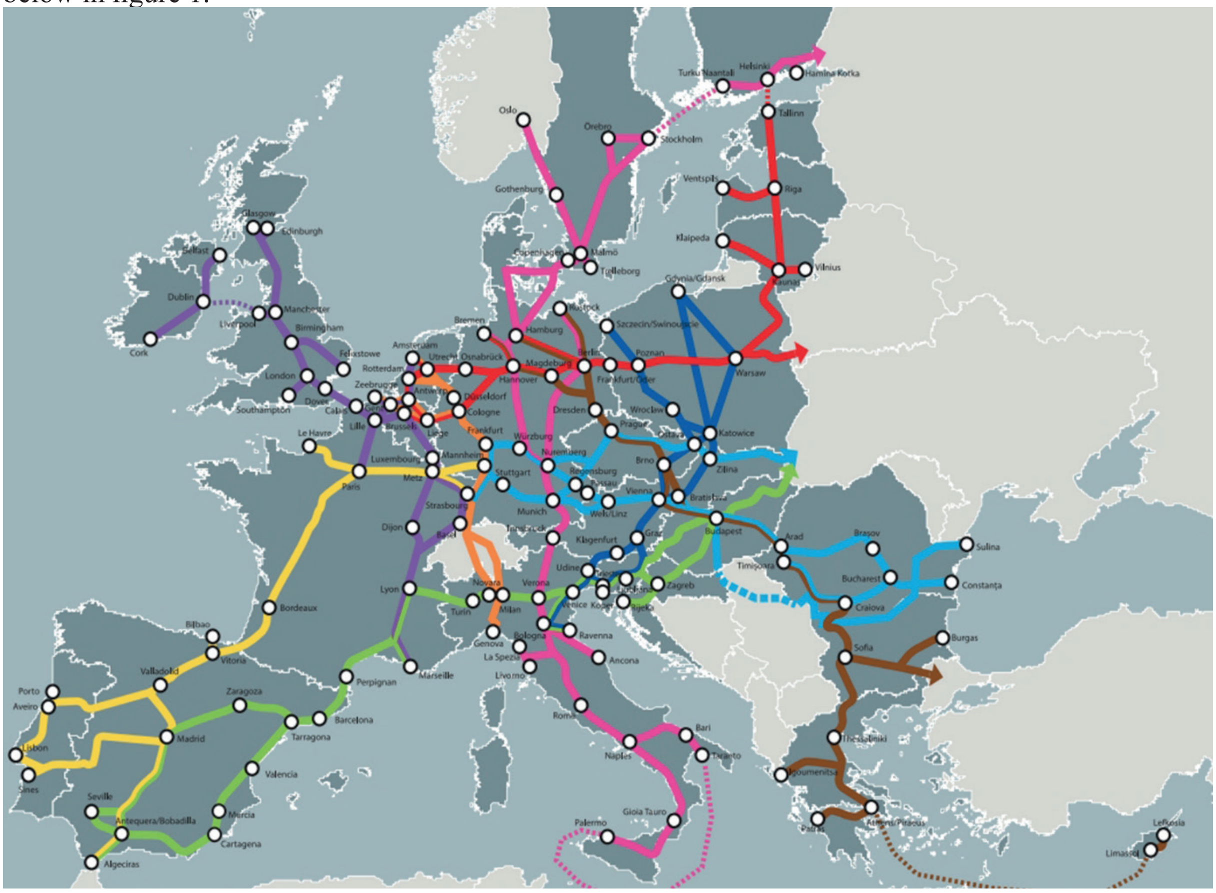

Figure 1: The TEN-T networks *Source: TEN-TEC, 2019*

The focus of this research will be on this network, in particular the TEN-T Rhine-Alpine Corridor, stretching from the Dutch coast through the Ruhr area in Germany to the Italian coast around Genova. This corridor is depicted in detail in figure 2.

1.1.3 Resilience

The need for an overall corridor perspective was demonstrated during the incident at the small town of Rastatt in Germany. During construction works on a tunnel underneath four railway tracks on the EGCTS corridor Rhine-Alpine, the frozen ground was unable to support the weight and collapsed. This was catastrophic incident for the freight transport sector as this railway connection supported up to 200 trains each day. Alternative routes in Germany faced difficulties in capacity and diversions to the French railway network faced legal and procedural issues. The railway diversions only had the capacity to take over about 85 freight trains each day. This meant a shift to road transport, straining the local road network and providing a challenge in the allocation of assets. The closure of the corridor eventually took about 10 weeks and cost an estimate of about 10 million euro every day. This stressed the importance of collaboration on this corridor and the implications of disturbance on the network

(Interregional Alliance for the Rhine Alpine Corridor EGTC, 2017).

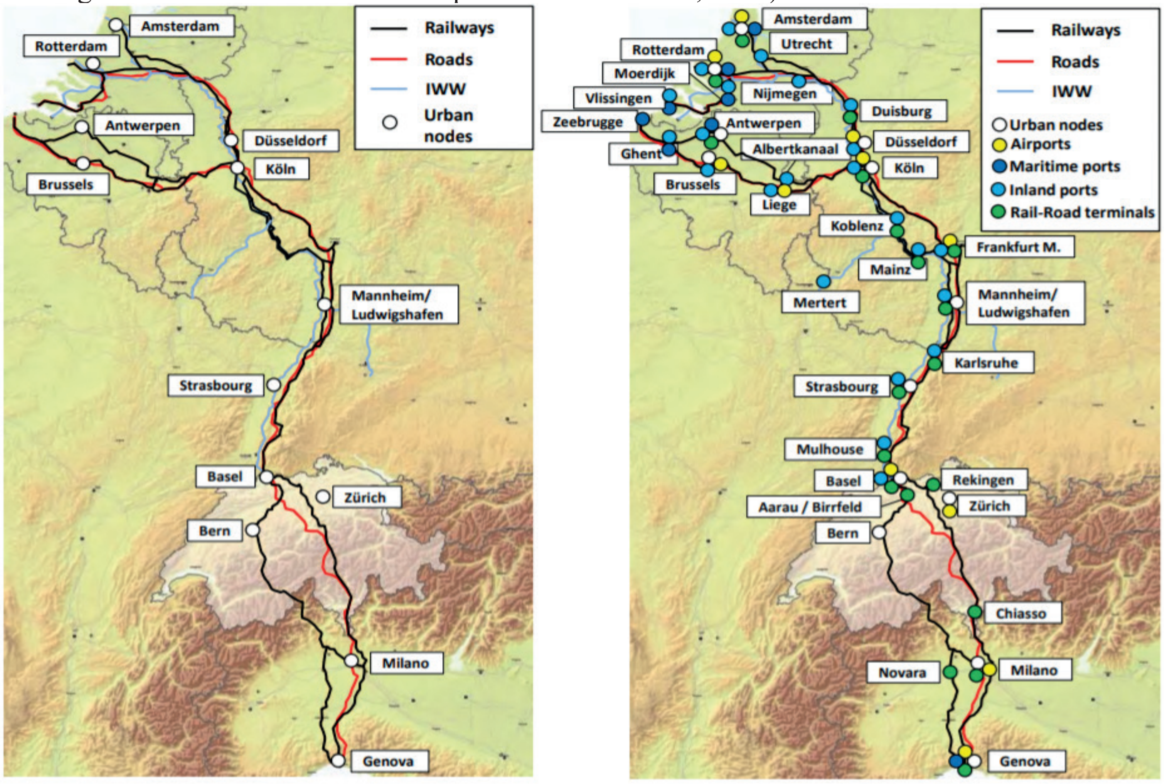

Figure 2: TEN-T Rhine-Alpine Corridor *Source: European Commission, 2014*

The TEN-T corridors themselves consist of multiple modes of transport and multiple routes within the corridor. Each corridor has its own governing body in cooperation with multiple governments to improve the transport on the corridor network. The TEN-T projects and actions are cooperating with actions and programs on the level of the national government and these actions are in turn cooperating with provinces and municipal experts. This is an iterative process, communication and actions are both top-down and bottom-up (Ministerie van Infrastructuur en Milieu, 2017).

1.1.4 Data in Corridors

The corridors and corridor management has next to the several actions regarding flow and sustainability also initiated several actions regarding the flow of ICT and information (de Boer, Rooijmans, & de Waal, 2016). The use of ICT systems in the aspect of planning for transport corridors is said to be essential for daily activities and might facilitate and accelerate certain innovations (de Boer et al., 2016).

Planning practitioners and supportive systems have a somewhat troubled relationship. The so-called planning support systems are said to have an implementation gap between the supply and demand. In the last decades, the systems have got more functionality, more capabilities, more user friendliness and they grew in number and availability. however, it seems the use of these supportive systems for planning practitioners has stagnated in the last 10 to 15 years. This research will focus on this apparent mismatch in availability and contextual use of planning support systems in a Dutch freight transport planning context.

1.2 Research objectives

The scope of this thesis is to research the implementation gap of planning support systems in freight transport planning and the effect this has on corridor sustainability. To research this the Dutch context of the TEN-T Rhine Alpine freight transport corridor was used. The scope is to view the use of ICT systems from a planning support system perspective. The research itself focusses on the planning perspective on the corridor, as it is not within the scope of this research to research the aspects of other actors in this context. It is also not within the scope to research political factors in the context, as it is only within the scope to research sustainability factors in the case of corridor freight transport planning. The subjects of Land Use-Transport integration and passenger- or urban freight transport are also out of the scope.

1.3 Research questions

The need for a more sustainable corridor inevitably leads to the need for action. There are several actions proposed in the European TEN-T white paper to improve the corridor. For this research the focus will be on innovation on the side of ICT systems. With the rise of ICT systems there was a general believe this would solve anything. Nowadays this believe is more grounded, as ICT systems are seen more as just a tool to support activities. The role of these tools in the activities in enhancing the sustainability of the corridor is the main theme of this research. This will be researched with the following main question:

In what ways can the sustainability of freight transport benefit from planning support systems?

This main question was broken down in three sub questions, which together provide the answer to the main question.

What are the current sustainability bottlenecks in the Rhine-Alpine corridor from a Dutch planning perspective?

How are planning support systems used in Dutch freight transport network planning and to what extent is this an accustomed practice?

How can the corridor sustainability benefit from collaboration between planners and stakeholders in the supply chain and to what extent are planning support systems used in this process?

1.4 Relevance

The relevance of this research is twofold. There is a separation between the societal and academic relevance. First the societal relevance is discussed.

The societal relevance of this research is mostly present in the sustainability part of this research.

Society has large benefits by the improvements of sustainability, be it in freight transport or any other pollution generating aspect of society. However not discussed in this thesis, the reducing of pollution generated by the corridor has a direct effect on the areas surrounding the corridor, enhancing liveability for the inhabitants. As the total freight transport in Europe is still increasing, it is of great relevance to guide this to a more sustainable sector. The societal relevance for the enhancement of the factors of ICT and planning support systems in this research can all be traced to the integral enhancement of the corridor and sustainability aspects of the corridor. Better planning support systems can thus accelerate innovations. Planners can also gain better insight on the network and actions can be more targeted, in the effort to create a better environment in Europe.

The academic relevance is mostly present in the connection of research on planning support systems in the aspect of transport planning, with practical findings. The relevance also arises due to the innovative nature of the academic debate about planning support systems. Research in this sector is heavily connected to the time it was done and, in this sector, research is prone to ageing. With this research the aim is to further develop the academic body of literature about the use of planning support systems. It is mentioned by several authors that the research on planning support systems is increasing nowadays. The current body of academic literature encompasses a lot of aspects regarding planning support systems. More present trends in this research is literature about the use of planning support systems in the context with stakeholder participation, land use transport integration or the added value of planning support systems. Research on the relation between freight transport, planning and planning support systems seems to be less present. This research will attempt to gain insight in this subject and will hopefully serve as inspiration for more research on the topic in different contexts an viewpoints.

1.5 Outline

First of all, the theoretical framework is presented in an effort to provide academic support in chapter 2. This will start with an overview of the definitions regarding supply chains and freight transport corridors. Thereafter the focus will be more on sustainability in this sector. The role of ICT will then be discussed starting with a quick historical overview. This part will conclude with the ICT use in a planning context. The debate on the definition of planning support systems is the following part of the theoretical framework. This will be followed with insights on both planning support systems in research and practice. The connection with freight transport will be explained thereafter, ending with the chapter conclusions.

Chapter 3 will encompass the methodologies used in an effort to answer the research questions. This will start with an introduction and with the context of the presented case study. The qualitative research strategy and topic list will be explained thereafter. The following part of the chapter will include the respondents and respondent selection. The use of Grounded theory for this research is presented next, followed by the elaboration on analysis. The reliability and validity of the research are explained before closing with the chapter conclusion. In chapter 4 the results will be presented. This will start off with the results regarding the aspect of sustainability in freight transport. This will be divided in four layers of the four-layer model as presented in the theoretical framework. Thereafter the results on the use of planning support systems will be discussed. These are also divided into four layers. The third part of the chapter encompasses the collaboration between actors and the chapter conclusions close this chapter. Chapter 5 is the conclusion of this research and will start with an overview of the main- and sub questions. The conclusions of the three sub questions will follow in 5.2, 5.3 and 5.4. This is followed by a conclusion regarding the main question. The discussion is followed thereafter. Chapter 5 will conclude with recommendations, further research and reflections.

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MAX.GROSS 34.000 kg 74.960 lb
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2. Theoretical Perspective

In the introduction and relevance, the need for more sustainable corridors became apparent. Together with the rise in the use of ICT systems in the sector of transport planning and an increasing need for collaboration using a corridor perspective the need for innovation on the European freight corridors is clear. The next chapter will pose as the theoretical base for this research. The chapter will encompass theories on the corridor perspective, sustainability in freight transport, planning support system theory and will conclude with theory about the interconnected nature of the sector.
First, the corridor perspective will be discussed. This will be followed by the corridor in the perspective of sustainability. The ICT revolution is presented thereafter, followed by the ICT use in planning. This is then followed by the definition of planning support systems. The insights of research and practical aspects of planning support systems will be discussed thereafter, concluding with the connection with freight transport and a chapter conclusion.

2.1: The Corridor Perspective

The first part of this theoretical framework is the elaboration on the corridor perspective and definition. To start this off the total supply chain and the role of transport in this will be explained.

2.1.1. Supply chains

Supply chains are, in contrast to their name, not systems with a definitive starting and ending point. The supply chains are interdependent networks of companies, factories, transport, stores, forwarders and other actors. Supply chains are more broad than individual firms or products. Within this supply chain there is the term of logistics. Logistics are an element of the supply chain containing all activities related to the flows in the supply chain. While this may encompass transport, logistics also includes service flow, information flow as well as inventory management. There are four phases of the integration of logistics services in the supply chain as mentioned by McKinnon in Brewer (2001). The first one is about the integration of outbound distribution. The second phase is the integration of both outbound and inbound distribution. The third phase is when logistics services are integrated in other activities like production, purchasing and marketing. The fourth phase is when the logistical activities are optimized across the entire supply chain. Within the factor of logistics there is the concept of transport. This is mostly broader than logistics as it also includes passenger transport. For this research we will however look at the freight transport in the logistics. This transport can be visualised as a transport chain, seen in figure 3. This shows the various modes of transport in the different stages of the total transport (de Jong & Ben-Akiva, 2010).

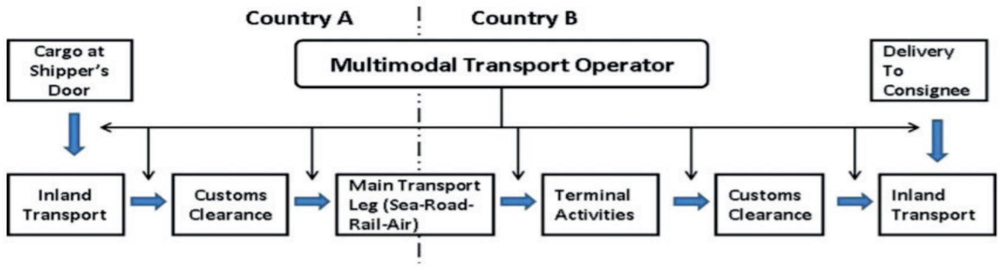

Figure 3. Multimodal transport chain *source I. Harris, Wang, & Wang (2015)*

2.1.2. Actors in the transport chain

In the sector of freight transport there are in contrast to the sector of passenger transport often multiple actors involved in the choice of transport mode and route. This mode and route choice are first of all influenced by the sender and receiver for the general route and demand for the transport services. Third- or fourth-party logistics providers are sometimes used to manage the shipping on the transport chain. Third party logistics are carrier firms whose product is the transport itself. Fourth party logistics are companies managing the collaboration between third parties, for instance during multimodal transport (de Jong & Ben-Akiva, 2010). The shipping firm is generally the most common decision maker about the product transport (Mason, Lalwani, & Boughton, 2007).

To conceptualise the total transport along a network of nodes and links, the concept of a transport corridor is used. This is a pre-assigned network of nodes and links connecting major hubs (Rodrigue, Comtois, & Slack, 2013). Most (for this research: freight) transport is transported over, but not limited to this corridor. Corridors are generally not bound to countries as they naturally arise. They do however pose difficulties in their management as it calls for cross-country cooperation. The corridor perspective is visualised in figure Figure 4.

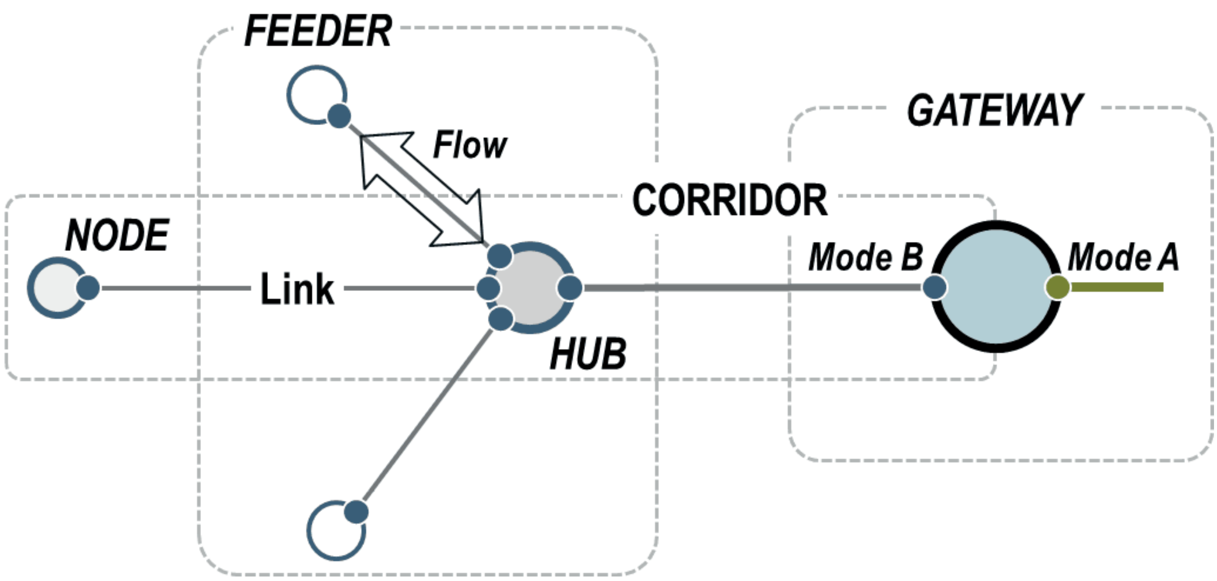

Figure 4: Corridor Visualisation *Source: Rodrigue, Comtois, & Slack, 2013*

2.1.3. TEN-T networks

The European Union drafted several goals for the transportation of freight along countries and has made use of the corridor perspective. From 1990 and onwards, the Trans European Network of Transport or in short TEN-T networks were founded. They consist of a core network of corridors along the European main hubs and links. Geographical areas are not exclusive to one corridor either as some of these corridors overlap to follow the naturally aspirated flow of goods. The corridors all share common goals and have their own corridor management (Panagakos & Psaraftis, 2016).

2.1.4 Bottlenecks

Within this international freight corridor management there are several challenges and goals. As seen in the introduction, this research will focus on the issues regarding sustainability. Sustainability challenges can be categorised using the bottleneck framework as described research by Witte, Wiegmans, van Oort, & Spit (2012). This categorises bottlenecks using four categories and eight aspects. The first infrastructural aspect contains the physical and organisational infrastructural bottlenecks. The spatial aspect includes the functional and morphological bottlenecks. The governance is separated in political and institutional impediments and the economical includes market and financial bottlenecks. This contrasts with the popular view of only congestion and waiting times at nodes being bottlenecks.

2.1.5. Collaboration

As mentioned by Mason et al., the current supply chain is mostly driven by customers (Mason et al., 2007, p. 187). The current supply chain actors and managers are more and more faced with trends as ICT innovation and trends as multimodality. Current supply chain managers are faced with more and more pressure for efficiency and other innovations, where according to Mason, Lalwani, & Boughton (2007)

'a new mind-set and openness to collaboration with supply chain partners, complimentors and even competitors is required.'

This collaboration used to be at a minimal level as the competition between shippers for transport is fierce and there is a severe focus on the total cost in the sector. Due to this, most activities unable to in some way reduce the total cost of transport were eliminated, such as collaboration with other shippers and governmental parties. In recent times however, it is recognized that with collaboration in some parts of the transport chain, activities might be more efficient and reduce the total cost. Mason, Lalwani, & Boughton (2007) state:

'Collaboration in transport management is (...) proposed to overcome some of the inherent inefficiencies which are invariably in the transportation process to provide superior, order winning performance'.

2.2 Sustainability in Transport and Transport Planning

As mentioned in the introduction the enhancement of sustainability and resilience on the network is an important issue. Multimodality in this perspective is an often-cited way to improve both of these factors. There are several factors of the enhancement of sustainability of transport. For this research, the focus will be on international freight transport (I. Harris et al., 2015, p. 88; Prajogo & Olhager, 2012). The geographical boundaries of the research are the TEN-T Rhine Alpine corridor on the Dutch perspective. As mentioned before, the incentive to improve sustainability is an important matter which is not only in EU legislation but also an important goal of the creation of the corridor itself (Europäische Kommission, 2011).

The Kyoto Protocol in 1997 had a clear aim: the reduction of worldwide greenhouse gas emissions by 5.2% of the levels of 1990. Transport was noted to be one of the important sectors in the achievement of this goal. Within the sector of transport there is a clear distinction between several modes of transport by pollutants. The major contributor on transport pollution is that of road freight transport (Chapman, 2007).

The fuel efficiency and efficiency of the moving assets of the freight transport sector has improved in the recent years, contributing to less polluting assets. This is however accompanied by a rise in the transport itself, leading to the freight transport itself being even more pollutant. To achieve a sustainable sector of freight transport however, solely technical innovations will not be sufficient. More fundamental changes in the transport itself, economy and behaviour are needed to achieve the necessary goals regarding sustainability .

The enhancement of sustainability can be accomplished by multiple actions on multiple levels of cooperation, change and difficulty. One of the corridor aims is that transport should be a continuous flow to make transport more efficient (I. Harris et al., 2015, p. 89). This efficiency of the corridor network is important as the construction of new additions to the network the coming decades is predicted to be very slim. The most important factors of improving sustainability in freight transport is to either change, avoid or decarbonise the transport itself. In several academic and non-academic sources, it is said that the use of ICT systems has a profound impact on the sector of freight transport planning.

2.3 ICT in Planning

2.3.1. ICT Revolution

The 1970's, 80's and 90's were very interesting decades for both planning and ICT. Both saw a shift in paradigm and grew closer. The ICT-revolution started when the first commercial systems were sold to the pubic; for instance, the rise of the first Macintosh or Commodore64. This ICT-revolution fuelled changes in countless fields. Music, games and other aspects of daily life became based on electronics and more and more were becoming digital. In science, the ICT revolution had a profound effect on science itself but also data sharing aspects of this technology had very important effects. A lot of scientist started using computers in all parts of their research: to collect data, to build models, to analyse findings and so on. The possibilities seemed endless.

2.3.2. ICT Revolution in Planning

In spatial planning, the rise of ICT did not go unnoticed either. Halfway the 1960's, the Canadian government found that there was a need for accurate and updated maps on the soil characteristics and ice coverage of the country. This led to the invention of the software package 'Canadian Geographic Information System', widely regarded as the first package of GIS/GeoICT software (Manning, 1990, p. 331). The use of ICT systems and computers rose both qualitatively and quantitatively, the possibilities seemed endless. It was during this time that there was the expectation of computers being able to do anything. If you just put the right data in, a solution would come out. Also, around this time multiple software packages became available and the bases were laid for some packages still in use like ERDAS-Imagine or ArcInfo (Klosterman, 1997).

The changes in the planning that time were ideal for the rise of planning support systems. These systems promised large benefits for both spatial planners and spatial planning scientists. In the 19080's, there was a large belief in the capability of ICT systems and computers. Scientists predicted that the effects of ICT on spatial planning would be large. Just as the car changed cities, the expectation was that ICT would have profound effects on cities (Cohen, Salomon, & Nijkamp, 2002, p. 32). However, 40 years later, his is however only partly true. While computers and computerized planning aids have seen a rise in number and complexity, there is no evidence of a revolution the size as the revolution from cars. The idea that a general ICT system will revolutionize cities has changed in the idea that big data and smart city software will revolutionize cities. In the lengthy realisation of those ideas however, the revolution lost its 'r'. The embodiment of smart city ideas is only just taking shape, 17 years later (Novais & Carneiro, 2016, p. 244).

2.3.3 Planning Paradigms

The planning paradigm in the 70's was also changing. In the beginning of the 1960's, the grand design or blueprint style of spatial planning gradually changed into the 'synoptic planning'. The paradigm of synoptic planning, part of the 'rational' planning paradigm together with blueprint planning had a stronger emphasis on quantitative analysis and public participation albeit in a minimal way (Khisty & Arslan, 2005).

Important factors for synoptic planning are the rise of use of the incremental approach, as specified by Lindblom in 'the science of 'muddling through'' (Lindblom, 1959). Participatory planning gained interest as well. The participation was however on a more informative level. Nevertheless, this synoptic approach of planning was a paradigm which fit the rise of computers very well. The prevailing idea in the time of Lindblom was to plan to reach a certain goal set beforehand. This in planning meant making great masterplans, often drawn by hand. Lindblom presented a very different theory by starting with a small action and evaluate and rethink the goal afterwards before starting a new action. This way, actions influence each other, and the process becomes incremental; hence incrementalism. This fit the rise in ICT as both the planning tasks as the systems became more complex. The ICT systems would help in evaluating and the planning of projects. The increasing use of citizen participation in planning processes fuelled the complexity as well. ICT systems provided help for this rising complexity (Tavasszy, 2008).

Some of the geo-based software caught on. Multiple systems with their bases in the 70's and 80's would benefit from the rise in ICT capabilities. This led to a steady rise in the capabilities of these geosystems, as well as the systems purely targeted at planners. In theory, this should make these systems high in demand by planning practitioners. The expectation would then be that the use of this 'smart' tool would rise in parallel (Exner, 2015).

There seems to be a mismatch in the supply and demand of a lot of these systems in spatial planning however, as the use of planning support systems stayed almost level, creating a gap between the supply and demand. Many however recognise the role of ICT in transport itself vital, with some even mentioning ICT systems as 'the nerve system of a multimodal transport chain' (I. Harris et al., 2015, p. 88; Prajogo & Olhager, 2012) .

2.4 Planning Support Systems definition

Planning support systems are defined in several ways by different authors of research on the subject. In general, it can be said that planning support systems are mostly based on geo-information technology and their common goal is to support planners and planning scientist in their daily goals by offering integrated support for multiple stages of their daily tasks, as well as support in the making of decisions.

The first notion of the term 'planning support systems' came, as described by Michael Batty (2007), from Harris (1989). Harris described the term being used by someone in the audience, making the exact origins of the term unclear. This unknown member of the audience used the term to describe:

"constellation of digital techniques (such as GIS) which were emerging to support the planning process"

Harris used the term to distinguish between the role of early Geographical support systems (GIS) in both management and planning. He argued that management needed routine support whereas planning required strategic support (Batty, 2007; B. Harris, 1989). This led to the clear distinction of the terms GIS, PSS and DSS. This was further explained by Ran & Nedovic-Budic, (2016) in figure 5.

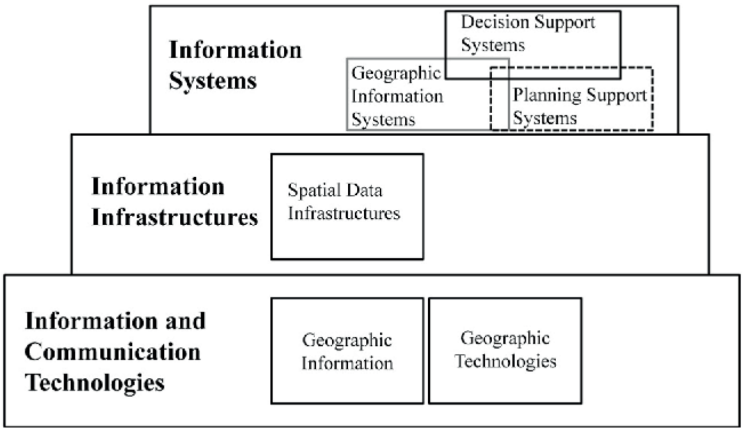

Figure 5: The place of PSS in the planning ICT. *Source: Ran & Nedovic-Budic, 2016.*

As seen in the figure, ICT is the main pillar of geographic software. This is specified to special data infrastructures and further to three distinct information systems. The Planning Support Systems are a combination of GIS (Geographical information systems, purely focussing on geographical/spatial data) and decision support systems (Geertman, 2006). This makes for the Planning Support Systems to have both a process and an information component. The process perspective is derived from the decision support system side. The information component is taken from the geographical information perspective.

Planning support systems often tackle various components of the decision-making process in planning by incorporating data retrieval, data analysis, decision components, design features and spatial information. Therefore, the packages tend to be hard to master as they are often complex. Another factor is that multiple PSS packages with different functions and user interfaces lack coherency.
Multiple years after this distinction by Harris (1989), Klostermann (1997, p51) had a different view on the definition of planning support systems, stating they are:

"an information framework that integrates the full range of current (and future) information technologies useful for planning"

Klostermann broadens the term by saying all current and future technologies useful for planning can be integrated in a system. Different from Harris, he argues that the technologies themselves are not necessarily a PSS system but become one once they are embedded in a coherent framework. However, later definitions also tended to include more specific descriptions on the role of 'geo' in the technologies of the planning support system. Geertman and Stillwell (2003, p5) incorporate this aspect as systems that:

`involve a wide diversity of geo-technology tools... that have been developed to support public or

private planning processes (or parts thereof) at any defined spatial scale and within any specific planning context"

Geertman and Stillwell here see planning support systems as a part of the planning task as well as being made specifically to support any planning task on any spatial scale. In later research by Pelzer, Geertman, Heijden, & Rouwette, (2014, p. 16) they broaden the definition:

'...geo-information technology-based instruments that incorporate a suite of components that collectively support some specific parts of a unique professional planning task'.

The difference in their definition compared to earlier definitions is that they specifically include the statement of a unique planning task. Where others are vague in how the systems are actually supporting a planning task, Pelzer, Geertman, Heijden, & Rouwette describe planning support systems only support specific parts of said task. Brail (2005) adds to the definitions by other authors that there is a strong time element involved in defining what PSS are:

``planning decision support systems have as their purpose either projection to some point in the future or estimation of impacts from some form of development."

This definition was later used to describe a sub-category of planning support systems (Klosterman & Pettit, 2005, p. 477). Within the body of planning support systems, there are multiple groups of systems. The main groups are either systems with analytical tasks or systems with design/presentation/communication tasks. For this research, the scope is not to categorize multiple systems. For this research the scope is to look at transport planning support systems. As the definition by Pelzer, Geertman, Heijden, & Rouwette, (2014, p. 16) suggests, all software dedicated to supporting transport planners in their daily activities and supporting all or a part of the planning task is here seen as a planning support system. The goal of this research is not to investigate the commonly cited WhatIf, URBANSIM or CommunityVIZ pss packages but rather to investigate the use of ICT in transport planning trough a planning support system perspective.

2.5 Planning support systems in research

2.5.1 Focusses of planning support systems

Together with a rise in the amount of planning support systems, there is also a rise in PSS research. There are roughly two different categories of research on these systems. The first one is a more case-study/instrument focussed approach to PSS studies. The argue here is that there is too much focus on the instrument itself while in essence neglecting the planning context (Pelzer, 2017, p. 85). There tends to be a focus on the characteristics side of the PSS. This focus tends to have its main concern on the capabilities of the instrument itself. This instrument focussed view rarely oversees the 'big picture' and often has issues with connecting the specific package with both planning science and practical situations. Moreover, it is argued that these 'PSS case studies' almost never systematically measure the claims about the package's performance (M. te Brömmelstroet, 2013). The instrument-focussed view is by nature very specific and fails to see the 'bigger picture' of the PSS debate and the surrounding context in practical situations.

The second is a more conceptual focus on the support systems and often combines findings with theories from spatial planning (Geertman, 2017). Here, the context of the specific planning task and the relation with the supply and demand side of planning support systems is the main focus. The place of these systems in the bigger context as well as the added value of systems in a planning context are important in this perspective. For this research, the focus will be on the latter.

2.5.2 Instrument Focus

The usefulness of the system itself, sticking to the trend of the case-study/instrument approach, can be measured with different concepts. The first concept in analysing the systems is to measure their performance. This performance is seen as the extent to which PSS have an influence on practice while it also describes the contents of the system, according to recent studies (Goodspeed, 2016; Haasnoot et al., 2014). This performance concept is not coherent enough to provide a systematic framework for research. The second concept is that of effectiveness. This concept measures both contents and effects on practice. The distinction between the effectiveness of the instrument and the effect of this on practice is however blurry, rendering this concept less useful. The focus on instruments is still a substantial debate in science however, with multiple views and research papers on both the concept of performance as that of effectiveness. This is however beyond the scope of this research.

2.5.3 Application Focus

On the other hand, there is the application focus of planning support systems. Instead of focussing on the performance or effectiveness of the instrument itself, a wider approach is used in this focus. Here the relation between the instrument and her relevant planning context is of importance. In this view, an important issue often addressed is the research on the added value of the support systems (Pelzer et al., 2014, p. 16). While most case studies do cover this briefly, the added value of PSS as a concept is a newer terrain of the debate.

Lastly, the planning support systems can be compared by looking at their usefulness according to the task/fit tree (Goodhue & Thompson, 1995). In short, it regards if the system can do what is needed, thus incorporating criteria from planning practice by incorporating demand. This is shown in figure 6 by Goodhue & Thompson (1995).

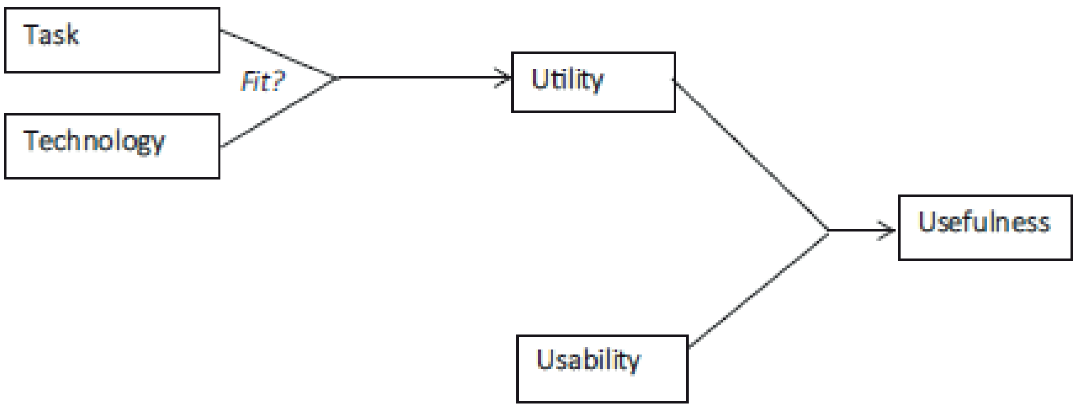

Figure 6: The Task/Fit Tree *Source: Goodhue & Thompson, 1995.*

Most recent research on planning support systems tends to incorporate both the application focus and the instrument focus. The important issue is to have a clear distinction between the terms added value, usability and usefulness. The argue is that in the instrument focus, there is a too extensive focus on the usability part of this tree. This focus is mostly on the instrumental aspects like the user interface and controls. This focus is however said to overshoot her goal, as illustrated by M te Brömmelstroet (2017):

"Much of the research on PSS implementation focuses on understanding and improving the user-friendliness of the instruments. Although this is an important topic to address, it is crucial to realize that user-friendly PSS are a means rather than a goal. Research should expand—even principally shift its focus—on the actual goal: improving the quality of planning practice"

The task/fit tree does not automatically translate to research on planning support systems. The context of planning was therefore added to the tree in figure 7:

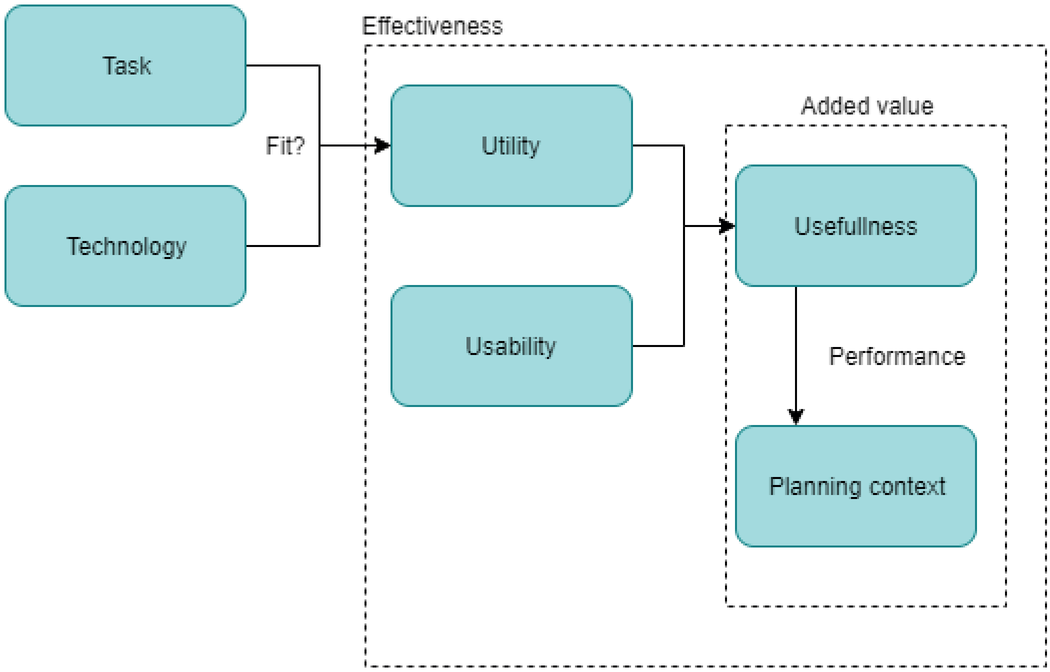

Figure 7: Task/fit tree with added value and effectiveness

The difference arises between usability, usefulness, performance, effectiveness and added value. It is important to note the focus on usability. In practice this gets interpreted as it being the easiness of operation and a fair learning curve. As noted by Brömmelstroet (2013) however, this is not the complete picture. The usability can also stand for an expert on the system operating the software for you. In this case, transparency and communication are deciding factors for this usability. The performance is influenced by the effect the tool has on the context or the quality of the instrument (Pelzer, 2017, p. 87). Added value is a bit broader than this by incorporating the tool as well. The broadest definition is effectiveness, looking at the relation between aspects of the tool on the planning context altogether (Pelzer, 2017). It is mentioned by Silva (2017) that there is a relation between the usability and the usefulness in the way that the usability can be seen as the product developers perception while the usefulness encompasses the practitioners perception of the planning support system (Silva, 2017, p. 68).

2.6 Planning support systems in practice

2.6.1 Implementation gap

In planning practice, there tends to be a mismatch in the supply and demand of the systems. While in recent decades there was indeed a rise in the amount of planning support systems and a rise in the capability of those systems as well, there is hardly a rise in the implementation of these PSS packages (Geertman, 2017). The implementation gap in spatial planning is very profound. There is a significant mismatch in the produced software packages and the use of these systems for planners in the planning practice. The last 20 years have seen these planning support systems become more diverse, more intelligent and less expensive then decades before. Software packages have become more user-friendly, less data-hungry and more all-round by combining both data collection, spatial research and design features in one package. Despite these advancements in this field, there use has not skyrocketed. Moreover, the use of these systems seems to have stagnated since the early 2000's.

This has led to the rise in research on the so-called ‘mismatch’ of planning support systems and her intended users.

This implementation mismatch in PSS is threefold. It consists of a knowledge gap, communication gap and a context gap. The knowledge gap is due to the contents of the systems, the communication gap is a mismatch in the communication between the planners and the context gap covers de difficulties of the planning context, as depicted in figure 8.

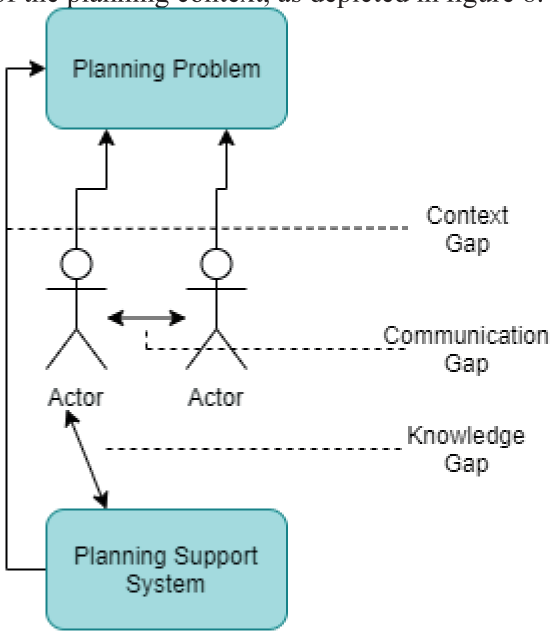

Figure 8: The implementation gap

2.6.2 Knowledge gap

This ‘mismatch’ in the use of planning support systems can be viewed from different perspectives in the entire process. The first one is the gap in the personal knowledge of planners, the knowledge gap as mentioned in the research by Cohen e.a., (2002). The knowledge gap is the term for the limited knowledge of the planning practitioner of ICT and geo-information technologies. One of the reasons for this is the limited knowledge of this ICT-world and a limited knowledge of the situational aspects. The knowledge of ICT and geo-systems of the planner is composed of different sources. These sources may include personal interest, previous education, the necessity to use certain systems, daily practices and the possibility to outsource more difficult ICT tasks.

This knowledge differs between each planner, and the communication between planners only makes the processes more difficult. The software packages tend to be very technocratic while they are often operated or used through outsourcing by planners with a more social mindset and skillset. The problem with the planning support systems has partly to do with the intended customers: the planning researchers but mostly planning practitioners. These practitioners are often rather hesitant to invest in these software packages. Without prior knowledge of the use of these complex pieces of software, investments in education on this is are also strongly recommended. The systems can of course be used trough outsourcing to professionals on the systems. This rises other challenges in for instance proper communication with the users of the software (Silva, 2017).

The keyword of this gap is the word ‘complexity’. The complexity can be seen on both sides of the gap. First, the systems themselves are complex pieces of software. There tends to be a steep learning curve for every package on the market. Unfortunately, the supply of different packages is too great to implement sufficient teaching in planning education. There are difficulties in the education on planning support systems due to their complex and broad nature. The different systems also face the problem of having user interfaces and functionality of every package differ from one another. The software is this complex as most manufacturers of PSS have the tendency to incorporate every aspect a planning practitioner might need for their research in their software. Because of this, most software packages include features for data collection, statistical features, analysis features and design features. This diversity can make the software hard to comprehend and provides a steep learning curve. Planning practitioners often choose a PSS for their projects on an ad-hoc basis. Regularly, there is little to no time to invest in a learning process. This will often lead to a underuse of the software (M. te Brömmelstroet, 2012, p. 98). This problem has risen in the past decades as more and more planning support systems were developed. This made investing time to learn a specific piece of software less tempting over time. The problem of a mismatch created by the lack of proper education will however not be solved by outsourcing the use of the systems to professionals. If the demand side of the planning support system question has little to no knowledge of the underlying principals, the communication and thus the result might suffer. This is also known as the 'communication gap'.

2.6.3 Communication gap

The second gap is the mismatch in communication. The communication between planners but also between the planners and other involved actors has proved to be a challenge to say the least. As planners sometimes lack professional education in the sector of planning support systems, their communication might suffer (Vonk & Geertman, 2008). Different terms and interpretations hinder efficient communication and raises the risk underusing the full range of functionality in the software. With other involved actors in the planning process, the risk of misinterpretation of results arises. This is as the risk of misinterpretation increases with every actor. There is also something to 'gain' from this: the mostly limited knowledge of other actors in the process allow experts in planning support systems to 'steer' the results to a desired outcome. This is a significant issue, but due to the size and complexity of this issue this will only partly be addressed in this research, as it is not within the scope.

2.6.4 Context gap

The complexity of the planning context is the other side of the implementation gap of planning support software. The current planning system is mostly designed to incorporate a variety of people and ideas. In planning processes, a lot of actors are involved with all different interests, disciplines and degrees of involvement. The planning process itself can even be viewed as a system (Exner, 2015). Whereas planning problems used to be less complex, the problems planners face today are best described as 'wicked problems' (Rittel & Webber, 1973). Wicked problems are planning situations where there is not a right question and no right answers, or as said by Brömmelstroet:

"[planning] involves actions ...regarding issues no one fully comprehends, in an attempt to guide events and processes that very likely will not unfold in time"(M. T. Brömmelstroet & Schrijnen, 2010, p. 3).

The best solution sometimes is to just 'muddle through' (Lindblom, 1959), a claim which in part fuelled the rise of planning support systems and is still relevant today. Wicked problems have a few characteristics, depicted below:

1) They do not have a definitive formulation.
2) They do not have a "stopping rule." In other words, these problems lack an inherent logic that signals when they are solved.
3) Their solutions are not true or false, only good or bad.
4) There is no way to test the solution to a wicked problem.
5) They cannot be studied through trial and error. Their solutions are irreversible so, as Rittel and

Webber put it, “every trial counts.”
6) There is no end to the number of solutions or approaches to a wicked problem.
7) All wicked problems are essentially unique.
8) Wicked problems can always be described as the symptom of other problems.
9) The way a wicked problem is described determines its possible solutions.

It is sometimes said that most planning problems nowadays are inherently wicked; and for some problems this is indeed the case (Rittel & Webber, 1973). This implies that for problems that are wicked, planning support systems will always have some sort of implementation gap in the form of a context gap, as it is simply not possible to have a planning support system for the exact problem.
Another factor of complexity is the complexity of human behaviour. In certain areas of ICT, the use of models to recreate and simplify reality is an easy and straightforward task, for instance in certain areas of transport visualisation. However, when incorporating land-use, transport and other factors in PSS for planners, a problem arises. The human behaviour is simply too irregular and too complex to model. This makes for mediocre models at best. Another problem is that land-use and transport influence one another by maintaining a supply-demand relationship. Wrongly made assumptions about the use of land and incorrect supply/demand figures reflect in the proposals for infrastructure. There is a substantial concept in planning research dedicated to this problem, the Land Use and Transport Integration discussion. As land use is not within the scope of this research, this trend is not further explained. This mismatch in context is simply not entirely avoidable, and models trying to limit the amount of errors in the assumption of human behaviour will need an enormous or even impossible amount of data. This makes this mismatch in the use of planning support systems tricky to overcome.
The complexity of systems rose to a level where novice users are able generate an outcome. However, due to the complex nature of the tools often only experts can generate relevant results. The amount of actors overtime went from a small focussed group to complex structures of participation involving planners, politicians, citizens and other actors. Those involved all have different views, skillsets, influence and (political) agendas. The problems they face also changed from simpler issues to ‘wicked’ problems without beginnings or endings, as mentioned before. Lastly, the learning curve arose as the diversity in user interfaces rose over time and making universal education on the matter more complex (M. te Brömmelstroet, 2017).

2.7 Planning Support Systems in Freight Transport

2.7.1. Assumptions in Freight Transport

The several planning support systems do not only differ in their abilities and context, they also differ in their supporting niche of spatial planning. For example, the planning support systems used in social housing planning differ from the systems in use in the transport planning practice. This research will focus on the latter. In the body of academic literature there is a trend of planning support systems literature connected to transport. This is however mostly literature about the structural accessibility layer in the trend of land use and transport integration focussing on behavioural modelling in urban transport (Silva, Patatas, & Amante, 2017). The planning support system literature about freight transport planning however seems to be slim.

There are multiple assumptions about the planning support systems used for transport planning. The foremost is that the implementation gap is mostly present in ‘regular’ spatial planning. In transport planning, this gap is said to be significantly smaller, as the systems are more grounded than for instance planning support systems in the land use – transport integration research (Geertman, 2017). Planning support systems differ from other planning software in the way that they are very loosely structured. The focus of the package also tends to be more technical instead of the social component (M. T. Brömmelstroet & Schrijnen, 2010). While this is the case for some research, there are other factors for a mismatch in the use of planning support systems in transport planning. As mentioned earlier, this research will focus on freight transport planning. While the aforementioned factors might indeed differ the systems in transport planning from other systems used in planning, the implementation gap is very much present in transport planning reality. The uncertainty is however present on a deeper level. An important aspect of transport planning is supply/demand data. This in itself is a precise matter, but the underlying assumptions might be less precise. They for example, must assume where people live and will live in the future, what goods are needed now and in the future and the most-used routes now and in the future. The underlying assumptions for supply/demand data can be imprecise, making the base of transport planning uncertain and imprecise as well. Box described this with the quote, ‘‘all models are wrong, but some are useful” (Box, 1979, p. 202).

2.7.2. Dutch Transport Planning

Another aspect of the mismatch between planning support systems and transport planning is the planners themselves. Some of them are transport experts with knowledge of planning support systems and (digital) transport modelling. Within the hierarchy of planning in the Dutch system, other actors involved in the practical side of transport planning are often not planning professionals. There is a substantial number of actors involved in this aspect of planning. Especially in the higher levels of the governance of projects, the planners tend to know less and less of the factual modelling, ICT and planning support system work. Another issue here is the cooperation between actors. The current practice of freight transport requires multiple actors with varying degrees of knowledge about planning support systems.

The current range of literature about transport PSS is heavily focussed on the planning of personal transport. This literature also shows that some of the planning support systems for transport planning also tend to have a focus on the transport of people. The current situation is so that there are a few TPSS focussed solely on freight transport. These packages tend to be developed by the users or user agencies like the Dutch Rijkswaterstaat. Most transport PSS suitable for freight transport planning are bigger software packages which also can be used for this purpose. The company-based software packages are mostly used only within that institution itself, where only the end product is shared. This secrecy has led to multiple systems for the same task, based on entirely different working methods, base data and outcomes. For complex planning tasks in this field of expertise, more open-use and task-focussed systems are a possible answer. Planning tasks such as the calculation of the added value

of multimodality are from a TPSS point of view very data intensive, precise and complex.
One of the possible issues of the aforementioned technocratic view on the planning support systems and models and the lack of connection between systems. The research done by Tavasszy bridges this gap by proposing a structure to help understand the complicated nature of ICT systems in freight transport planning. This model is presented in figure 9.

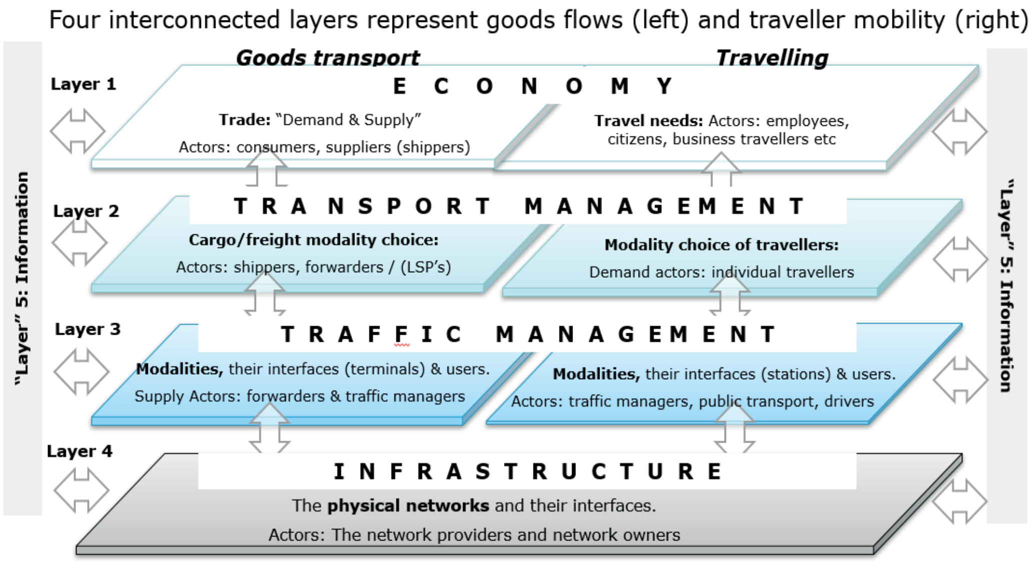

Figure 9: Integrated Logistics Conceptual Model by Hazelhorst, an adaption on Tavasszy (2008). Source: Hazelhorst (2019)

This model uses different layers to project the transport practice. For the sake of this research only the 'goods transport' side of the model is used. This presents the freight transport sector in the categories 'demand & supply', 'cargo/freight modality choice', 'modalities/ interfaces and users' and the physical networks. The fifth presented layer is the most interesting for this research. This is the layer used to include the aspect of ICT systems and their connections with practice. As shown, this 'information' layer intersects all other layers. This is due to the interconnected nature of the information and ICT systems providing this information to the respective practitioners on their layer (Tavasszy, 2008). In the same research, it is also explained how the models and ICT systems in the sector of freight transport changed in paradigm from the 60's. It is shown how the paradigms started with narrow research on single topics in the 70's and how the rise in ICT systems also influenced the modelling research. The models became more advanced as well as broader and more connected (Tavasszy, 2008).

This fifth layer is also where the planning support systems can be categorized. They would fall under the information systems for the layer of infrastructure as they support the planners with information and decision support in their daily activities. The systems for the layer of transport management or the layer of shipping (cargo) differ from the used information or ICT systems used in the other layers but due to the connected nature of information in the sector of transport, they are still connected. The current view on planning support systems is focussing on the systems connected to their corresponding layer. However, the interconnectedness of the systems and sharing of information, systems and data is also of great importance to the overall performance of the supply chains. (I. Harris et al., 2015)

2.9 Chapter Conclusions

This chapter presented the trends from academic literature most important for this research. This started with the distinction between supply chains, transport chains and the role of logistics. The connected supply chain network encompasses logistics and transport. The freight transport corridor was then defined as a core network of nodes and links. This is also the case of the TEN-T core networks. Collaboration between actors on these corridors is increasing overtime to improve efficiency. The corridors face several issues and goals, of which the improvement of sustainability is profound. The improvement of ICT is one of the goals to achieve this. ICT use in planning rose from the 1980's, along with changing paradigms in planning, While the ICT systems grew in capabilities and complexity, the use seemed to stagnate for the so called planning support systems. These systems are defined to provide support for planning processes on various stages and with various capabilities. The concept of planning support is present in research on two levels, with an instrumental focus or a more applicational focus. The application focus is more practical by providing a more embedded view by incorporating the context such as the focus on added value. On the practical side of planning support systems there seems to be a mismatch, also called the implementation gap. This consists of the knowledge gap, the communication gap and the context gap. In the aspect of freight transport, it is said that the use of planning support systems is more grounded. This is however not the full story is the implementation gap is still present in this sector. The interconnected nature of the freight transport sector leads to the use of a more broad definition of planning support systems for this research by using the four-layer model by Hazelhorst or Tavasszy to analyse the use of planning support systems in the context of the enhancement of corridor sustainability.

Following these findings from the theoretical framework, the focus will shift to the methods used to research the implementation gap in the case of the Dutch TEN-T Rhine-Alpine context. The next chapter will elaborate on the chosen research method and methods of analysis. Results and a conclusion will follow thereafter.

3

3. Methodology

In the theoretical framework, it became apparent that there are several gaps in the use of planning support system in freight transport planning and that the enhancement of these systems allow for a more sustainable corridor. Therefore, it is a logical step to incorporate a planning context and empirical study in the form of a case study on the topic.

For this research, the research direction is explained first. Thereafter, the selected methods are clarified. This will be shown visually in a conceptual model. Thereafter the chosen case study will be explained. Following this the research methods are explained in depth along with an explanation of the use of grounded theory in this research. After this the analysis will be discussed. The reliability and validity of the research design are discussed then, ending this chapter with chapter conclusions.

3.1 Direction

For research on the link between ICT, planning support systems and corridor sustainability the decision was made to have a qualitative based research design. Qualitative research is a better fit in the context of the chosen case study for this research. Quantitative research is generally narrower and relies heavily on the testing of hypotheses and the researchers influence on the outcome is more substantial than in using qualitative research. It was chosen to u a qualitative research method as the nature of this research is more explorative than statistical nature. In this perspective, it was chosen to perform the research using a deductive research design. A broad perspective was chosen following the theoretical background. Due to the deductive nature of the research a semi-guided interviewingtechnique was chosen to gather the most relevant data about the different sub questions.

As mentioned, the aim is to answer the main question and sub questions by using a semi-guided interviewing structure with several planning experts working in or around the field of freight transport These planners consisted of both experts and non-experts of PSS and would follow the four layers from the four layer model on the layers of the supply chain, following the data.

The method of a semi-structured interview was used to gather relevant data. This was used due to the interconnectedness and broad scope of the subject. To gain a full perspective, the guidance of the interviews was reduced to a topical level. Thereafter, the interviews were transcribed and concepts were formulated using the method of grounded theory. The scope of this analysis is to review the assumptions made about the use of planning support systems and the link with sustainability. The details of the research are explained in a conceptual model below, in figure 10. The details of the research are explained in the following subchapter, as is the use of theory.

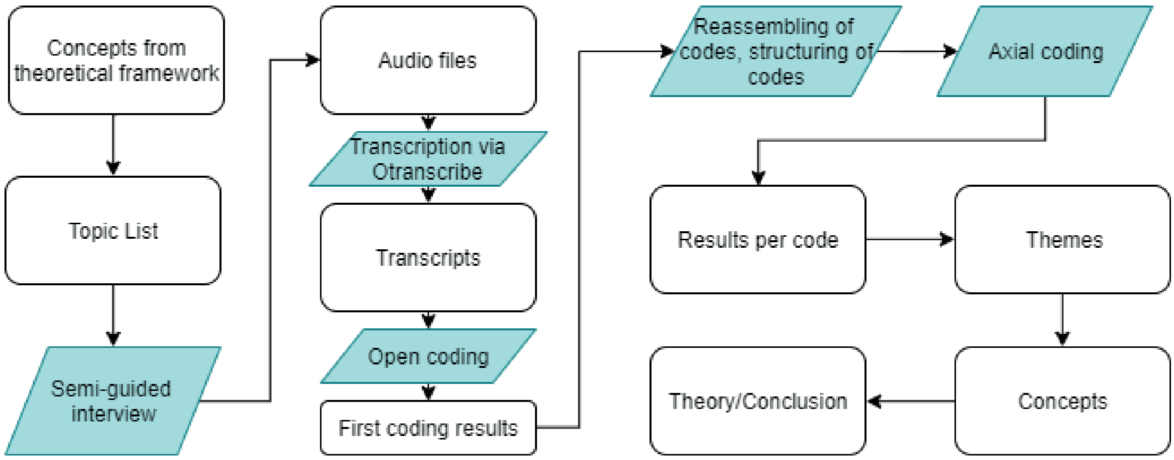

Figure 10: Conceptual Model

3.2 Case Study Context

To answer the main question and side questions, this research is based on a case study. As mentioned before, the research is focussed on the TEN-T freight corridor 'Rhine-Alpine' in the Netherlands starting at the port of Rotterdam and continuing to the German Ruhr area, while eventually ending at the Italian city of Genova (European Commission, 2014). Due to the scope of the research, it was chosen to focus on the Dutch setting. To gain a better insight in this case, several respondents were interviewed on multiple levels of both the Dutch government and non-governmental parties. As mentioned before it was chosen to interview respondents with planning and advisory roles. This case study was chosen as it is a good benchmark of an international transport corridor. This corridor is still in the process of development, which makes the case study interesting for a connection with planning. On the other hand can the corridor be seen as a wicked problem; which is inherently never finished as only the issues change. The current main issues and points of improvement are the issues of sustainability and the enhancements of the efficiency and flow on the network. This case study was also chosen as it is a substantial research area with widespread effects on the surrounding areas, the fore- and hinterlands and the countries overlapping (Europäische Kommission, 2011).

3.3 Qualitative research strategy

There are multiple important points deriving from the theoretical framework. The focus on technical approach mixed with the various research papers with an instrumental approach does not seem to match the interconnected nature of the practice of international freight transport. The aim of this research is to provide a wide view on the sector of transport and her relation with the use of ICT systems and planning support systems. An approach to research using quantitative would not fit this goal as it is not sufficiently broad to explore the multiple relations and dependencies. This would also insufficiently or inaccurately describe the human factor in an otherwise technical practice. Quantitative approach would also require a set structure and hypotheses beforehand. This would have as drawback that certain insights would be overlooked. As mentioned by Bryman (2012) the reason this method for research is derived from the nature of the topic itself. The choice was made to perform a qualitative collection of data for this topic. In line with the interconnected and broad nature of the topic, the decision was made to perform separate interviews with respondents from a multitude of employers from various standpoints on the topic. A focus group discussion would have been the other option. It was feared however that the respondents would omit certain answers and aspects of the topic in favour of consensus in the group or a part of the group. The semi-structured interviews provided a more in-depth approach to the topic and also enhanced the richness of the data by providing ample space for their interpretations and views (Scheepers, Tobi, & Boeije, 2016).

3.4 Topic list

Following the concepts from the theoretical framework of this research, several topics can be listed as relevant to the topic. With a deductive approach, certain concepts and topics were used to guide the interview. Two general themes were used. The first of those being about sustainability in their daily practice and the second the use of ICT and Planning Support Systems. This general structure was also used in coding. The first sub question in the research is structured into the topic list by incorporating the topic of sustainability and the sustainability in the context. The second sub question was translated to the topic list by adding the topics of ICT and planning support systems in their context to the list. Another topic was added with question on the personal experiences and skill with planning support systems. The third sub question was used by incorporating the topics of sustainability in relation to data, cooperation and ICT. The topic list can be found in appendix A and B. The interviews were afterwards transcribed using the software OTranscribe as it presented the opportunity to slow down the audio. The 18 transcripts were then imported into NVIVO and analysed using a grounded theory approach.

3.5 Respondents and respondent selection

Several planning professionals were interviewed for this research. For this, the four-layer model was used to sort the multiple respondents afterwards. The respondents represent all four layers of the connected transport model. As the subject of this research was that of the role of these systems in the practices of planners, only respondents with positions in planning or consulting were approached. This means that this model and distribution of respondents should be carefully interpreted as the respondents in the field of trade are thus planners with views on and activities in the trade perspective of international freight transport planning. The only exception for this is one respondent with a position at a planning support software supplier. While their daily activities involve consulting and in-depth knowledge about the use and benefits of this software, it is strictly speaking not a position in planning. Due to the theme of the research, the interview was held nonetheless. While it is interesting to interview also the experts from each of the four layers, it was not within the scope of this research as the research is aimed towards planners and the influence on their ICT systems.

The case selection started by approaching several planners involved in a governmental program on the enhancement of the TEN-T Rhine-Alpine corridor. While this is an obvious place to gather data, the research has a broader aim. Using the snowball method to come into contact with other planners in the field, about 30 planning professionals and their workplaces were approached. The first four interviews were conducted in the month of July 2019 with five respondents working in different fields at Rijkswaterstaat. Thereafter, a few slight changes were made to the topic list and the interviewing resumed in September 2019. A total of 18 interviews were conducted, of which the last was an interview with two planning professionals working in the same team. There were several case selection criteria. The first was to interview only respondents working as planners. The second criteria were that the respondents had to be connected to the international TEN-T Rhine-Alpine corridor, there were no criteria in what modality or field. The third criteria were to not interview planners working in the same field on the same issues as this will only increase the number of interviews held and not the quality of the results. It was also chosen to have as much respondents as possible from different institutions. The final criteria were to interview at least one planner per layer of the aforementioned four-layer model.

3.6. Grounded Theory

This research has made use of the popular method of grounded theory as founded by Strauss and Glaser in 1967. At the time it was the first book providing an in-depth step by step approach to research and analysis in the qualitative field However, Glaser and Strauss disagreed about the details of this method afterwards. They went their own directions soon after. This has led to the distinction between Strausian and Glaserist directions of grounded theory. In the nineties this was supplemented by the views of Charmaz & Belgrave (2015). The views by Glaser and Charmaz are much broader than the more institutionalized approach by Corbin & Strauss (1990). The approach of Strauss and Corbin was chosen to perform this research. This is due to the more institutional nature of the research and research field. This also due to the analysed transcripts. Strausian grounded theory methods are better suited to more formal texts and documents such as the collected data for this research. The methods by Glaser and Charmaz are better suited for more varying types of data, as '…everything is data' (Heath & Cowley, 2004).

After the selection phase and interviewing/ transcribing phase the Strausian grounded theory analysis started. As mentioned in the research, the first step is to use open coding on all transcripts. This was done on the eighteen transcripts for this research. The open coding consisted of a line by line coding without predetermined codes. As mentioned in the research, a constant comparison approach was chosen when coding in this open coding phase. After the first quarter of transcripts, a pattern of codes became apparent. The coding remained open however and new codes were being added until the final transcript. This resulted in a total of 38 unstructured codes. Memos were added during this open coding phase to keep track of emerging patterns and concepts. The memos were used to store any thoughts and ideas about the data and about the comparison of data. This was beneficial in the way that it minimized preoccupation and minimizing assumptions regarding the data. This is an important aspect when dealing with this approach of research as it helps in finding clear concepts and theory.

3.7 Analysis

Thereafter, the emerged codes were categorized and classified using memos and emerging structures from the open coding phase. This resulted in a coding tree consisting of 24 codes. Using this coding tree as a guide the transcripts were coded again for the phase of axial coding. The coding tree for this axial coding can be found in appendix C and D. This was done in a separate session with empty transcripts to eliminate the chance of assumptions based on the codes from the open coding phase. The transcripts were coded again using the codes as mentioned. This is also called the selective coding phase.

After finishing this second coding phase the analysis started. The analysis was performed by creating concepts from the coding results. These concepts are then used to create an overall theory. In this final code reviewing phase is one of the distinctive methods of the Strausian grounded theory approach. In contrast with the other approaches to this method there is a hierarchy to be found in the codes. It is argued that most concepts arising from the data revolve around a central theme (Corbin & Strauss, 1990). For this research it resulted in the distinction between the concepts of ICT and sustainability grouped in four layers. While the coding phases were approached with an open perspective and measures were in place to minimize the assumptions prior to coding, an aforementioned pattern emerged. In the phase of structuring and classifying codes, the general outline of the four-layer model emerged as the leading theory to structure the views of the planners. This provided a clear distinction of the results of both sustainability and ICT/ planning support systems by their user groups.

3.8 Reliability and validity

To perform relevant and correct research, the aspects of reliability and validity are important. In the case of quantitative research methods this is a factor which is easier to manage as mathematical calculations can provide information on this. The aspects of reliability and validity of research performed using quantitative methods are somewhat more difficult to substantiate. the academic debate on this topic is also substantial. The use of these two terms to validate research is a factor of debate. With the topics of reliability and validity being somewhat vague for qualitative research, these terms might lose their credibility. This has led some researchers to be more negative about using these terms, or as Wolcott states:

"Whatever validity is, I apparently 'have' or 'get' or 'satisfy' or 'demonstrate' or 'establish' it. . ." (Wolcott, 1990, p. 121).

To cope with reliability and validity for this research however, several aspects of verification were used to secure this. Verification is used as a way to improve the correctness of the research by working incrementally ensuring the reliability and validity. This has also to do with the incremental nature of the qualitative methods and grounded theory approach as you move back and forth between steps of the research. This also leads to avoiding the mistakes before they are made. The incremental approach promotes constant checking and leads to either the conformation or need to remove or change parts of the process (Morse, Barrett, Mayan, Olson, & Spiers, 2002).

The first factor of the verification process is the methodological coherence. This is to ensure the questions and the data, theoretical framework and research methods match. This is also an iterative process and both the questions and research design have changed during the process. It has led to the end result where this is more in line with each other. The second aspect of the process is to select an appropriate sample size to perform the analysis on. This is dissipated in this research by using the grounded theory procedure of conducting research until theoretical saturation occurs. This happened in the four categories when the eighteenth interview was performed. The process of finding respondents and conducting interviews was therefore halted. The third factor is to keep the iterative process during the various stages of data collection and data analysing. This ensures the avoidance of mistakes during the process instead of an ex-post review, when mistakes can no longer be corrected. The fourth aspect is to involve the theory in every step of the data collection and data analysing. This enhances the iterative process and also enhances the relevance of the data to the theory and questions to better connect the results to the theory. This was done using the technique of memo writing during the various analysis stages of grounded theory. The last aspect is to move between the micro and macro scale of the data and research. This assures that the data is relevant in its context and establishes the boundaries and scope of this research. It also makes for a more relevant conclusion and the research will be more relevant for further research (Morse et al., 2002).

3.9 Chapter conclusion

This chapter explained the theory and motivations behind the research on the topic of sustainability and planning support systems to answer the main question and sub questions. Following the theory from the theoretical framework and using the basis of the case study on the TEN-T corridor, a qualitative research approach was proposed. Using a semi-guided topic list, 18 interviews were conducted and the results were analysed using the method of Strausian grounded theory. The reliability and validity were discussed afterwards using the method of verification.

The following chapter will elaborate on the results of the aforementioned semi-guided interviews with planners affiliated with the corridor. This was done using inspiration from the coding structure presented in the coding tree for the layer of axial coding. The connection of these results with the broader context of freight transport planning, corridors, sustainability and planning support systems will follow thereafter in the conclusion.

4

4.Results

Following the methods of this research, the fourth chapter will present the results. The results are separated in three categories. The first of these are the results on the concept of sustainability trends. These will be structured according to the four-layer results. The second part of the results chapter focusses on the aspect of planning support systems. The chapter concludes with results on the collaboration between actors. This loosely follows the coding tree from the axial coding tree following the methods chapter. This chapter will close with a chapter conclusion.

4.1: Sustainability results

The first results to be discussed are the general trends and outcomes in the questions themed to sustainability. The first results will be from the commercial perspective on transport. Thereafter, the transport itself is discussed. This is followed by the economics perspective and closed off with the perspective on the sustainability of the network

4.1.1 Commercial trends

The is the lack of sustainability as a commercial problem. The first commercial counterwork for sustainability is the emphasis on TCO/TCT. This may sound obvious, but this aspect hinders sustainability in multiple ways. One is that a lot of sustainability goals are unsuitable to connect to the commercial goals. If a certain innovation or action in favour of sustainability is costing money or effort, the chances of it being used are very slim. The commercial problem is also in the companies contracts. The first in this perspective is the nature of short contracts for the shippers. The major risk is that if they innovate, this is not paid off in the duration of the contract. Furthermore, if you cannot provide excellent service and value for money from the start you will be seen as a commodity and customers lose interest. This halts innovations massively, especially for smaller shippers. In short; if it doesn't earn money, they will not use the sustainable innovation. Another type of impediment of sustainability due to contracts is the use of leased or rented (reefer) container. In the interviews there was the mention of cooled (reefer) containers being leased under contract, in which there is no return flow. Because the leased container is demanded back in a set time in the contract, empty container flows are promoted. The results are visualised in following table 1.

Infrastructure	Physical	
	Organisational	
Spatial Structure	Functional	
	Morphological	
Governance Structure	Political	
	Institutional	
Economic structure	Market Conditions	- Focus on TCO - The lack of sustainability issues being market-driven - Contracts demanding empty return flows
	Financial	- Duration times of contracts too short to invest in innovation

Table 1: Sustainability Commercial Results

4.1.2 Transport

The results about the sustainability of the transport itself is grouped in three categories, as used by multiple interviewees. These include the shift in transport, the greening of current transport and the avoidance of transport.

The first results are based on the shift in transport modality to enhance sustainability. It was stated that multimodality is a very sustainable option for international freight transport as a lot more cargo can be transported by fewer assets, reducing transport. It is stated that for the one to about three TEU of one truck, will transport up to 90 TEU. Inland barges are able to transport up to 900 TEU even.

One of the major hindrances of multimodality in the case of water transport for the European and especially Dutch practice is the difference in width of shipping containers. While the 20 and 40 ft. units all seem to look similar in size, there is a size difference in European containers. The two sizes are the regular marine, the ISO container and the European 'Pallet Wide' container. The latter is about 22 centimetres wider than the 'regular' container to better fit the common Europallets. The basis of the pallet wide containers is sustainable because their capacity is better suited to common loads making the general load factor higher. This container size is however relatively new, which imposes problems for inland shipping barges. Their depreciation is relatively long, making most current inland barges decades old. They are simply not built for this type of container so either other containers are used, or a lot of space will be unused. By stowing load in pallet wide containers, shippers inherently force the use of the modality of road transport as they are able to transport. The road transport is able to easily shift to these new containers because their depreciation is much shorter. The width is also less problem as containers are not stacked side to side. Interviewees stated that only about two percent of all continental containers is being shipped by inland barge, making this a structural problem in the face of improving sustainability.

Interviewees also explained how smaller shippers are less willing to use the option of multimodality. There are fears about outsourcing a part or the entire transport to shippers of another modality. The first fear is damage or loss of the goods. It is a larger risk for them to outsource their transport than to use their own stock or trusted sources. The shippers fear their clients will lose trust in them. The second fear is losing the customer to the shipper of the other modality. They fear that the client will deem them obsolete and plan their own multimodal transport. One interviewee stated that it is best to not only try and persuade the shipper to become more multimodal but to also contact the cargo owners about the possibilities. A lot of cargo owners and road shippers tend to think that multimodality is difficult and expensive, while this is more often than not untrue.

The stark nature of the sector is also a problem for the use of multimodality. It was stated that it is difficult to switch to a multimodal approach when it concerns an occasional event. The problem is that the switch in transport mode is difficult enough to be used only in the case of a structural approach. A lot of shippers have too diverse freight and contracts to make structural use of a multimodal approach. This uncertainty is a major hindrance. This phenomenon of structural change only also touches the before-mentioned short term nature of contracts in the world of logistics. As said before, the shipper has to invest in the switch to other modalities and might not have the time to liquidate these investments. There are efforts to bundle the occasional goods suitable for transport by train or ship from different shippers, but these efforts are still very difficult and scarce.

The next hindrance for multimodality is the lead time. The lead time for inland shipping is for instance two days, whereas road freight can reach the desired destination in about one day. The nature of the goods also plays a role as some are deprivable goods bound to reach their destination quickly.
The final hindrance is the offered frequency of the connection. By bundling goods, the frequency often falls compared to road freight. This might not be a problem for certain bulk goods but some

goods with a time dependent nature are hindered from being transported in a multimodal and thus sustainable manner.

The second theme within the transport itself is the use of technologies to make the current transport and transportation assets greener.

Within this theme, the aspect of reducing pollution are small changes in the road transport to reduce pollution at minimal effort. The aspects range from making use of somewhat cleaner trucks to start stop systems for the use at traffic lights. Other noted aspects are more efficient tyre profiles, better tire pressure and improved aerodynamics. Most of these aspects are already common and used. They however provide the least profit in reducing pollution.

Most people associate the reducing of pollution with sustainable fuels. The most notable and most commonly stated by the interviewees are Liquid Natural Gas (LNG), biodiesels, hydrogen and electric transport. The issue however is some of these being gateway fuels; these seem sustainable but still pollute to a degree. With the LNG and hydrogen fuels the problem of their transport arises; these fuels are difficult to transport and transfer and most transport of these fuels to the fuel stations have to be done by truck, increasing overall transport. The problem is also that these issues are on the supply side. The demand side also has to match the transition to biofuels. The problem is that the transition to trucks and barges on hydrogen is a slow process. Even the switch to the fossil 'transition fuel' LNG is proving to be a relatively slow process.

Efforts are made to switch from the use of liquid- or gas-based fuels to electric transport. In recent times, this has proven to be successful for personal transportation. The issues arise in the aspect of long-haul transport. While it may in theory already be (semi-) possible to use electric trucks, it proves to be more of a work in progress. The issues lie for example in the amount of batteries needed in the truck. Trucks for international transport would have to use a lot of otherwise cargo space for the batteries. The electric drivetrain is also a lot heavier than a diesel one. One interviewee mentioned the use of 10 electric trucks in a large fleet of national and international trucks. The owner of the company mentioned that the use of these trucks is hindered mostly by her unreliability, as the heavy trucks would need heavy-duty drivetrains, management systems and charging infrastructure. This would frequently cause errors and faults as a single broken part might have a snowball effect in the rest of the truck. Due to the complex nature of the drivetrains, repairs are expensive and take substantially longer than its diesel counterparts. Another innovation which was mentioned was the E-highway by Scania. They consist of rails in the asphalt which can be used by trucks via pantographs on the trucks. This is however still in a very early phase with concerns about safety, durability and standardization. Most of the innovations on electric transport are focussed on road transport. There are however also projects on the electrification of inland shipping. The weight and needed power for the barges is however still a problem. The other issue with inland shipping and electrification is the need for a lot of batteries, increasing weight and thus decreasing load side and buoyancy. There are however plans for the 'portliner', an inland shipping barge powered by batteries inside standardized container formats. These can be easily switched in ports and be loaded. This also eliminates the problem of loading time for the barge itself. This is however still in a very early stage and far from being widely adopted.

The current problem in the electrification is the lack of a disruptor. In the case of the personal transport, the disruptor came in the form of Tesla. Tesla was a company from outside the industry, which revolutionized the mostly fossil-dominated market by changing the perspective. This disruptor is not yet present in the international road- and water freight transport. The difficulty also lies in the nature of these companies. It was mentioned during the interviews that within truck companies like DAF, their core business is the productions of diesel drivetrains. They are more focussed on the engines than the rest of the trucks. It is hard for such a company to switch to the production of trucks on alternative fuels or electricity.

The main driver or obstacle for change in the sector if international transport is the cost. One of the most important aspects is the Total Cost of Ownership. It was calculated by one of the interviewed that the gap between an electric and a diesel truck is still about 25 percent of total cost. This is a major obstacle as this is a sector where margins of 1 to 2 percent of TCO are the deciding factor between profit or loss.

The final theme within the sustainable transport results are the avoidance of transport. This is already partly covered by the shift from road transport to other modalities, which can be seen as a form of bundling load to use less transportation assets. The bundling of loads also applies to smaller scales such as the scale of one truck or container. The increase in mean load of the transport assets means the same can be transported using less assets. The practice of load bundling is already present and there are several initiatives to enhance this. The smaller shippers mostly have trouble doing so as they tend to be less innovative and stick more to the 'business as usual'. Interviewees mentioned several governmental and non-governmental organisations promoting this.

Another option to improve sustainability is to lower the empty return flows. As mentioned before, due to contracts and the lack of proper communication and supporting data there is still the problem of empty return flows for assets like containers, trucks, barges and (less so) trains. The matching of return flows with send flows is however still a difficult situation to change, as it relies heavily on communication and collaboration between rival companies.

The final aspect of transport avoidance within the theme transport is the most obvious and commonly addressed: the route optimisation. The reason that this is easily addressed is the fact that every kilometre less driven is a direct economic impulse, especially on structural routes. This is also what most interviewees noted as being the most data-driven in the transport theme. The results are visualised in following table.

Infrastructure	Physical	- Width of shipping containers - Size issues with electric drivetrains - Reliability issues with electric drivetrains - Lack of a disruptor in the sector
	Organisational	- Lead times along the network - Frequency of multimodal connections
Spatial Structure	Functional	- Issue of transporting green fuels to fuel stations
	Morphological	
Governance Structure	Political	
	Institutional	- Starkness of the sector in contrast to multimodality - Smaller shippers are less open to innovations and tend to stick to 'business as usual' - No matching of empty return flows
Economic structure	Market Conditions	- Fears of outsourcing transport for multimodality by smaller shippers
	Financial	

Table 2: Sustainability Transport Results

4.1.3 Economics

The modern public is more and more getting used to ordering something online and receiving tomorrow; or even the same day. This is a problem which also touches international freight transport

as it hinders efficient planning and promotes half-empty transport. Large companies like amazon even have the funds to arrange company stock like trucks and freight planes. This might be less efficient and more expensive but for them it is about offering a distinctive, or 'luxury' service.
Another economic aspect is the trend of local production. While the production nowadays often takes place far from the buyer, this may change in the future as transport can become increasingly hard and expensive. Some interviewees noted the invention of the 3d-printer. This enables people to print objects themselves, saving transport. Some noted this as a major trend to reduce transport: the local production of otherwise specific products.
The innovation in products themselves is also a notable economic aspect of sustainability in the sector of transport. One interviewee noted that a large freight airline presented their workflow as being very sustainable by matching certain flows with return flows; in this case the otherwise empty cargo plane would be empty for the second route from south Africa but would land in Kenia to load flowers destined for the Netherlands. While this seems like a sustainable solution in the short term, the interviewee noted that while flowers normally spoil within 2 to 3 days, there are inventions keeping flowers fresh for up to 14 days. These types of innovations could be of great importance to the paradigm changes in the transport sector, as they change the nature of the flows.
The results are visualised in following table.

Infrastructure	Physical	
	Organisational	
Spatial Structure	Functional	- Specialized products often have to be transported
	Morphological	
Governance Structure	Political	
	Institutional	
Economic structure	Market Conditions	- Ordering online for same day or tomorrow delivery
	Financial	-

Table 3: Sustainability Economics Results

4.1.4 Network

The final theme within the sustainability results is the sustainability from a network perspective. The first aspect of improvement of sustainability is the reducing of delays on the network. The delays on the network vary in sources, such as incidents, crowded roads, rail or waterways, weather conditions, strikes, certain events or waiting times at bottlenecks like bridges, locks or The reducing of delays or jams on the network have a large short-term effect on pollution on the network. This reducing is mostly initiated from governmental parties. The second aspect is the more market-initiated theme of night-time transport. The shift of most continental freight transport to the nighttime has widespread effects on the network as there is a better balance between personal and freight use of the network. This does not only count for road transport but also for rail transport as freight trains will have to wait for passenger trains to go by. This is already being done but could be a lot more commonly used.

Another incentive to make the network more sustainable is the prohibition of certain vehicles in certain areas. For instance, some cities are already banning diesel powered vehicles of a certain age in the city due to pollution concerns. One interviewee noted the use of the EURO truck qualification. Due to the prohibition of trucks below EURO6 qualification of trucks, the road transport as generated by the port of Rotterdam is relatively clean. There is more effort and there can be more gained in for example the urban distribution and construction logistics than from the continental freight transport. These types of prohibiting measures will make the network more sustainable by forcing shippers to choose assets with a certain maximum pollution.

The next opportunity for a more sustainable network is to better accommodate the before mentioned modal shift. To accommodate this, more transhipment points can be created on the network. When there is no way to transfer the goods from one modality to the other, multimodality is hard to achieve. More points also mean less waiting times at the points themselves, making the transition possibly easier and cheaper. The networks also benefit from these transhipment points in the perspective of resilience. Multiple respondents noted that in the future, climate is said to play a more pronounced role in transport. When transport over a certain modality is impeded by environmental difficulties, more points to shift cargo onto other modalities minimize the disruption. It is still difficult to for instance shift all rail cargo from a certain route to road cargo, but more multimodal options reduce the amplitude.

Interviewees also noted that for the case of the Netherlands, new infrastructure developments will be very slim, focussing on renovation and refurbishment instead. It was noted that in these cases it is imperative to take into account what dimensions and characteristics the assets of not only the present but also the future need. For example, the current locks were built for ships with dimensions consistent with the common transport of dry bulk loads of the 60's. When refurbishing those locks, they tend to be made up to date with the dimensions of the container barges of the present. The incentive is to look at smarter solutions like a small transhipment terminal or solutions for the charging of batteries of the (possibly) electric barges of tomorrow. This requires a comprehensive and multimodal view of the network. In governmental institutions it was noted that the work is still too sectoral to achieve greater sustainability through these network changes. It seems that collaboration on the network is key. The international aspect of the freight transport also proves to be a drawback for sustainability, as the pollution is hard to assign to a specific country, as can be the case for air transport and deep-sea. The results are visualised in following table.

Infrastructure	Physical	- Delays on the network - Not enough nighttime transport for long distance freight - Dimensions of assets like locks and bridges
	Organisational	
Spatial Structure	Functional	- Not enough use of multimodality in terms of (climate) resilience
	Morphological	- Not banning polluting assets on national or corridor scale from certain areas
Governance Structure	Political	
	Institutional	
Economic structure	Market Conditions	
	Financial	

Table 4: Sustainability Network Results

This part of the research elaborated on the results in the aspect of sustainability as noted by the interviewees. The results were presented divided in the four-layer model. To further conceptualise the results, they were divided in the eight categories of bottlenecks as provided in the research by Witte et al. (2012). The results are present in all eight categories of bottlenecks. The next part of this chapter will present the results on the use of planning support systems.

4.2 Planning Support System Results

The results on the planning support systems are divided in four parts, following the four-layer model. The first results are elaborating on the use of support systems in the aspect of trade. Thereafter, the results of the category of economic services is presented. The transportation management results will follow before closing with the results on the use of planning support systems on the network and planning level of the four-layer model.

4.2.1 Trade

The first results for the theme of trade within the results for the use of planning support systems is the use of ICT systems in the perspective of the shippers.

The first result is that the systems used are under heavy operational pressure. These systems have to be reliable and easy to use as there are time and operational pressures inflicted. It was noted by the interviewees that the most commonly used systems are the warehouse management systems (WMS) and transport management systems (TMS). It is said that almost all commercial shippers use some sort of TMS system. However, there are no structures on which the systems have to be based, nor are there standardisation requirements. Efforts are made to standardize elements of these systems, but there is no required standard as of yet. This has led to the creation of a plethora of systems which work roughly the same way but are hard to connect. The translation between systems makes it harder for data to be shared as this takes time and effort. Another disadvantage of the plethora of systems and users is that when using the same systems, different people might fill the systems in in a slightly different manner. In this case, the translation is even harder.

Different users also require different systems in their daily activities. While some larger shippers require larger and more interconnected systems, smaller shippers might suffice with a small GIS based system. This also leads to various capabilities and different insights in the transport. It is also harder to implement changes to the systems as they are updated at set dates. These updates might introduce new functionalities but make day to day need for updates harder.

Interviewees noted that it is not within the role of the government to interfere with practices regarding ICT systems for shippers. There is however still a role for this government by promoting the sharing of data and the interconnectedness of the systems. This is something otherwise less likely to be done by the shippers themselves. Several parties are now involved in the interconnectedness and standardization of the systems. This should enhance communication, and eventually help in a more efficient transport, while also enhancing sustainability. The gaps between smaller and larger shipping companies is also reduced.

The main driver for the changes in the ICT systems used however is still the aspect of profit. These systems should be made for gainsharing with the companies involved; as they profit of more connected and more effective systems. The main obstacles in connected ICT systems are money and privacy. When a certain action in either the sharing of data, use of big data or any other new action on their system is not in some way positively effecting their profit, the chances of it happening are slim. However, when a certain action on or change to their system is improving profit, it is said that companies are quick to incorporate such functionality. The second obstacle is their privacy. To stay competitive in a fierce market of shippers, data is said to be worth more than gold. This is why it is still onerous for companies to share data with one another. It is noted that only if there is a very clear insight in who can see what data sharing commences. Factors like authorizing people in a system or signing a small legal contract about this data might prevent companies from sharing data.

A more used aspect of the sharing of data is that between companies and governmental parties. Governmental parties are already sharing a plethora of high-quality open data. Interviewees indicated that there is a rise in the sharing of real-time data to some of these systems. This can improve functionalities by for instance use data on disturbances or delays on the network.

4.2.2 Economic services

The use of ICT and planning support systems is less present in the economic theme. The need for transport-oriented ICT systems and models is more indirect and less pronounced than in the other themes. Interviewees noted that the focus in this theme is more oriented towards long-term economic models and the use of historic data. The goals of using ICT systems are less geo-oriented as they mainly help to predict the consumer demand and other economic trends. In the construction and placement of companies however, certain services and models are used. The connections between companies and links to international transport corridors in multiple modalities are of importance to the placement of industrial and commercial sites. Interviewees noted that they mostly use results of models in the communication process.

4.2.3 Transportation Management

The first use as mentioned by the respondents is the real-time managing of the network. This requires real-time data to be used as basis of interventions or changes in the network. These actions are in place to enhance the resistance on the network. This real time info can for example be used to send inspectors to an incident as fast as possible to assess the possible damage of a part of the network, in order to open this part and improve traffic flow. Another example is the use of data to warn drivers of delays on communicative matrix boards on the sides of highways. These systems make use of counting points, sensors and traffic cameras to acquire to-the-second or to-the-minute data. This is what most people associate with big data as this produces a very large but detailed set of data. These actions do not only promote flow but also enhance sustainability on the network.

Another function of this data is to give insight in the current waiting times and lead times in the hubs of the network. This also requires the real time sensor data but could be used in the near future for a better flow of traffic, thus enhancing sustainability. Interviewees also mentioned that within this theme, another type of ICT system is being used to enhance traffic flow by using real time data to gain insight and predict the near future. This is by gaining insight in the current and expected states of assets like bridges and locks. By careful nudging, a certain asset can adjust their speed and/or route to reduce waiting times. This again also enhances sustainability.

The use of historic data is also an aspect of the use of ICT systems in this theme. Here, historic data of up to one, or in few cases several years is used. The data used is often real-time data in enormous, detailed archives used to create averages and prognoses of bottlenecks and also to measure the performance of the network. Whereas the long-term theme of network and planning uses traffic models to gain insight, this is often not detailed enough for this theme. The users in this theme demand more precise and grounded data to exactly see what the source of the delay was on what time, and what they can expect tomorrow on that time.

4.2.4 Network and Planning

In the network and planning theme about ICT and PSS, interviewees mentioned a multitude of projects and models either they, their direct colleagues or other partners were involved in. It is not in the scope of this paper to discuss all those different projects. Of the four themes in this subchapter, the most emphasis is laid on the network and planning as this is the source of the apparent mismatch in

Planning Support Systems A more conceptual approach was chosen for these results. These results are presented in three subthemes: Mismatch, Logistics/transport/planning and Collaboration.

To start the results of the mismatch in the use of ICT systems and PSS on transportation, the first interviewee noted that these systems are being used to most of their potential. This respondent noted this from a network management perspective and noted besides that the software itself lacks in quality. He stated that the larger and more data-rich traffic modelling datasets should be used as the basis for long-term models and support systems. This result is interesting as most other interviewees noted that there seems to be some sort of mismatch, but this is due to the diverse and interconnected nature of these systems. Another interviewee noted that indeed there is a large pool of available software and the quality seems to vary. It was noted that the use also lacks, with interviewees noting that the use of ICT and PSS seem to lag behind and stay in the past, whereas the systems are evolving.

The problem of this however is said not to be the lack of knowledge and interest from the planners and other intended user, but the problem seems to be more fundamental. One interviewee in the supply side of both planning support systems as trade based TMS systems noted that this is a problem in the planners demand. They had constructed a model beginning with economic demand and changes in production. Thereafter, this was calculated to the forecasted transport issue. This was then converted in loads to be transported over the network. The interviewee noted this model was how planning support systems and models should be initiated and built. However, he noted that this is not properly used as the model was quick to be reduced to a national level. Then, only the forecasted bottlenecks were eventually visualised, misusing the richness of the model and the data. The source of the transport is noted not to be properly used in the models and systems. This apparent mismatch is present in such a way that communication, bureaucracy and institutionalism hinder proper use of models by misusing this interconnectedness and broad perspective. Interviewees on the supply side of the systems also indicate it is very hard to sell new functionality and better models and software as the demand side is very much focussed on what they are using in their day to day activities. They note this is a major halt for innovation.

The results of the theme network and planning continue with the mentioned relation between logistics, regional planning and infrastructure. In the conversations with multiple experts, the image grew that in the coming years the expansion of the network would be very slim in the case of the Netherlands due to multiple restraints. This means most of the focus of the transport planners are focussed on a smarter network, nudging and increasing efficiency. This is also beneficial for the aspect of sustainability of international freight transport. They note that within the producing and receiving factories and companies, the departments of import of bulk and crude products differ very much from the exporting departments. The worlds of logistics and transport also are two self-contained worlds. The better connection between the departments of logistics, transport and regional planning would improve the communication and use of data. It is mentioned that substantial efficiency can be gained my improving this. For example, the larger bugs in the network (the smaller bugs are mostly solved by the traffic managers) can thus be analysed and solved by the planners. The bottom line of the mismatch in planning support systems, ICT and models for transport planners is that it is more about people than about data or transport. It seems the communication and collaboration is key. It was also said that every functional improvement in the current sector of transport is relying on the collaboration between people and the sharing of data.

The mismatch in the use of these systems is present partly due to the sector being very separated. From a governmental perspective, most teams working on improving transport are organised in separate modalities, separate ICT companies or teams and different teams with different responsibilities. For instance, a municipal planner concerned with international freight transport from the port of Rotterdam will have a very different perspective and position than the person concerned with the supply of stores along the Lijnbaan in the centre.

Interviewees also stated that there is indeed an interest in the use of ICT, big data and PSS in current practices but there is a very large emphasis on the hardware and systems themselves. Two factors are regularly overlooked. The first is the prevailing thought that if you put data in a system, it will just output results, overlooking the underlying assumptions and the systems shortcomings. The output from systems is not a result in itself; the interpreters make the results. The second overlooked factor is that of the demand. Respondents stated that sometimes there are innovations and outcomes of systems overlooking the market demand. In that case the results are less relevant as they were only produced for the sake of producing results. This was for example the case with recent innovations on the platooning of trucks. While pilots were being held and there was sufficient energy present from a governmental sight, the market demand did not seem to complement market demands.

The last result is that most interviewees seemed to use or create models, ICT systems and planning systems in their daily activities. However, most interviewees also said that while they see a lot of future in these systems, they are unable or only partially able to create these systems and models and they outsource this to external experts. This raises the question of validity, as the collaboration between the planner and the expert is of great importance as even slightly different underlying assumptions or even the colours used in the outputs might be of effect in the further communication. It seems that that also in this case, the communication is key.

The use of ICT and planning support systems as noted by the interviewees was presented using four different viewpoints. The next part of the results chapter will elaborate on the collaboration between actors.

4.3: Collaboration between actors

The collaboration between actors working in the sector of freight transport is an aspect noted by multiple interviewees. The interconnected nature of the sector is not only present in the sharing of data but also in the collaboration between people. Interviewees noted that in this sector the focus on the collaboration between people might be as important as the technical details of the transport and supply chain itself.

This collaboration in the supply chain starts within the companies themselves. It was stated that the collaboration between certain departments within the companies themselves are not good enough. For instance, the collaboration between inbound and outbound products in factories are not matched and collaboration is low. On other parts of the supply chain the communication processes also hamper, such as collaboration between companies or between shippers in the corridor. Interviewees noted that the collaboration also hampers due to supply chain managers in companies not being reprimanded for inadequate collaboration. In the use of transport models and ICT systems this collaboration is however very much present, as a lot of the more complex tasks are outsourced to other companies and professionals. To provide valid and justified results, the communication has to be clear, something that the interviewees noted to be in order.

The collaboration between governmental parties and other stakeholders in the corridor is troubled sometimes. It was noted that there are several issues regarding collaboration with actors on the corridor, which may lead to unwanted solutions. Interviewees noted that sometimes there is a lot of effort and energy created concerning certain innovations while the market, in this case the actors operating on the network, are not demanding these innovations. One of these innovations was noted, in which case there had been a pilot project. After learning the disinterest from the market, the energy and efforts were reduced. There is also the risk of leaving something for the market to pick up or elaborate on while the market actually demands the role of corridor management from the government, or the market is more in need of active collaboration with governmental parties.

The governmental parties like the Ministry of Transport as well as Rijkswaterstaat become increasingly concerned with the collaboration in the supply and demand processes happening in the freight corridor. It was noted that this is traditionally not the role of the government. What they are ‘supposed’ to do is let the market handle the different challenges in the transport and on the corridor. However, it is noted that in that case most companies try to become more efficient themselves but due to multiple factors the overall situation might not improve. This is also the result of the fragmentation in the sector. There is the need for governmental parties to act as supply chain or corridor management to improve this collaboration and uniform innovations across the sector. This is justified by a very important goal in the public interest: sustainability. Several governmental projects are in place to enhance both the collaboration and thus the environmental factors of the corridor.

Within the government itself there is a stark division in modalities. It was noted by interviewees that the collaboration between the different modalities is at best impractical. To this day the current governmental divisions aiming to improve transport and infrastructure are mostly divided in separate modalities. Even the guidelines of the European TEN-T corridor network are divided into separate modal categories. To improve multimodality on the corridor, interviewees note that this current division is a major bottleneck. This is partly due to concerns about the other modalities or departments overturning their plans. It is of major importance to improve this collaboration on the corridor, or as some interviewees noted to improve the human factor in freight transport instead of focussing on technical advancements to enhance the corridor.

4.4 Chapter results

The fourth chapter presented the results of the 18 interviews held with planning professionals working in and around the TEN-T freight corridor in the Dutch perspective. The results started with identifying the current bottlenecks on the sustainability of the corridor as noted by the interviewees. Thereafter the different mismatches in the use of ICT and planning support systems were discussed. The results chapter concluded with the results on the collaboration between actors. These results will be linked to the findings in the following chapter. In this concluding chapter the main questions will be answered and the findings from this chapter will be put in a broad perspective.

5

5. Conclusion

The concluding chapter of this thesis starts with the three sub questions of the research. Thereafter the main question will be answered. A discussion on the topic in a wider context will follow. The chapter will conclude with recommendations, further research and reflection.

In the introduction the need for a better corridor development and sustainability was cited. The sustainability of the freight transport is enhanced partly due to the rise in ICT technologies, data sharing and collaboration between stakeholders in this aspect. These trends were examined in this research. This cause has led to the use of the following main question for this research:

In what ways can the sustainability of freight transport benefit from planning support systems?

This main question was broken down in three sub questions, which together provide the answer to the main question by providing an overall view of sustainability, collaboration, ICT use and planning support systems. The sub questions of this thesis are depicted below.

What are the current sustainability bottlenecks in the Rhine-Alpine corridor from a Dutch planning perspective?

How are planning support systems used in Dutch freight transport network planning and to what extent is this an accustomed practice?

How can the corridor sustainability benefit from collaboration between planners and stakeholders in the supply chain and to what extent are planning support systems used in this process?

In the following three parts of the concluding chapter the sub questions will be discussed and answered by using views from both the theoretical framework as well as the results chapter. Thereafter the main question will be answered. Following the conclusions on the main and sub questions a few recommendations are presented and the chapter will conclude with reflection and further research directions.

5.1: *What are the current sustainability bottlenecks in the Rhine-Alpine corridor from a Dutch planning perspective?*

The first sub question aims to research the current sustainability bottlenecks in freight transport. The sustainability of this sector is a much-debated topic in recent times. In the case of the TEN-T Rhine-Alpine corridor, there are several actions regarding the improvement of sustainability on the corridor. In this first sub question of this research the emphasis is on the current sustainability trends for the TEN-T corridor from the Dutch perspective. The planning problem of the bottlenecks in the enhancement of the corridor sustainability shares characteristics of a wicked problem as described by Rittel & Webber (1973). While a lot of current planning tasks nowadays can be seen as 'wicked problems', the issue of sustainability in freight transport does indeed seem to have no stopping point, no one good solution and the solutions are never true or false, only good or bad.

The results vary from different longer-term measures to small adaptations to the current transport to make the freight transport more sustainable. The different sustainability results were categorised according to the division in four layers which seem to overlap with the transport model as constructed by Tavasszy (2008). Within these four categories, the results were categorized as bottlenecks of the enhancement of sustainability using the structure by Witte et al. (2012). They are depicted in table 5 below.

Infrastructure	Physical	- Delays on the network - Not enough nighttime transport for long distance freight - Dimensions of assets like locks and bridges - Width of shipping containers - Size issues with electric drivetrains - Reliability issues with electric drivetrains - Lack of a disruptor in the sector
	Organisational	- Lead times along the network - Frequency of multimodal connections
Spatial Structure	Functional	- Not enough use of multimodality in terms of (climate) resilience - Specialized products often have to be transported - Issue of transporting green fuels to fuel stations
	Morphological	- Not banning polluting assets on national or corridor scale from certain areas
Governance Structure	Political	
	Institutional	- Starkness of the sector in contrast to multimodality - Smaller shippers are less open to innovations and tend to stick to 'business as usual' - No matching of empty return flows
Economic structure	Market Conditions	- Focus on TCO - The lack of sustainability issues being market-driven - Contracts demanding empty return flows - Ordering online for same day or tomorrow delivery - Fears of outsourcing transport for multimodality by smaller shippers
	Financial	- Duration times of contracts too short to invest in innovation

Table 5: Sustainability Bottlenecks

These bottlenecks were noted by the interviewees and were said to be the most dominant bottlenecks on the network. The identified bottlenecks are occurrent on various parts of the supply chain. These bottlenecks are however identified as problems with relation to sustainability and data and is thus not a complete list of bottlenecks on the corridor. The responsibility in coping with these bottlenecks are partly the concern of governments, partly that of the corridor management and partly that of other actors in the supply chain such as third or fourth- party logistic service providers.

It seems from the results as well as the theoretical framework that the use of multimodality is one of the key aspects of a more sustainable long distance freight transport along the corridor (I. Harris et al., 2015). This is supported by visionary and goal-setting reports from the European Union. Along with the use of multimodality to change and avoid transport, the aspects of both innovations to avoid transport and actions on the network to promote a continuous flow are important. Focus on the involvement of smaller shippers in innovation processes and the reducing of institutional barriers like contracts or collaboration issues is also key to a sustainable network.

5.2 *How are planning support systems used in Dutch freight transport network planning and to what extent is this an accustomed practice?*

For this sub question the respondents discussed the various planning support systems they use or come into contact with through their work with certain partners or cases. The respondents were mostly planning professionals with broad knowledge in transport planning. They discussed various ICT systems they know ore use in their daily activities. Instead of concluding only on the basis of the instrument approach, the choice was made to analyse the planning support systems in their contextual use of freight transport planning on the Dutch TEN-T corridor. As mentioned in research this application focus and focus on the added value and effectiveness of planning support systems provides better insight in the relation between the context and use of the systems (M. te Brömmelstroet, 2013; Pelzer, 2017). There are multiple explanations for the term 'planning support systems' and this influences the scope of these systems. As in the sector of freight transport planning systems and actors are very connected, the scope of planning support systems is broad, as mentioned by several authors on the topic. The definitions mostly encompass a sort of ICT system based on Geo-technology and capable of supporting (a part of) a professional planning task (Brail, 2006; B. Harris, 1989; Klosterman, 1997; Pelzer et al., 2014).

This definition has as outcome that the planning support systems in this research are not limited to systems made solely for the support of long-term planning projects, but the scope is more elaborate. To clarify this the results about planning support systems were divided into the four layer division (Tavasszy, 2008). mentioned in their research. The scope of planning support systems here are all ICT systems capable of producing data, are geo-based and which are used to either enable, change or influence freight transport on the corridor network are defined as a planning support system. To conclude that both transport management systems of shippers as well as real-time ICT solutions to intervene with the current traffic situation or freight transport models to predict the need for changes in the network on a long term are considered to be planning support systems in this research has to do with the interconnected nature of the supply chain which underlies all freight transport.

As mentioned by most respondents in the research, the systems are not fully used when seen as self-contained systems. They argued that the sharing of data and collaboration of the systems and their users make the systems useful for use in freight transport planning. There seems to be a mismatch in the use of planning support systems according to the current academic debate about this topic. This mismatch is divided in several gaps. The gaps mentioned are the knowledge gap, communication gap and the context gap. These gaps are different in the divided planning support system level in the four-layer structure.

The first planning support system category is that of the trade use. In this category the use of TMS systems and route planning is the most dominant. The knowledge gap in this sector is very specific. As this sector of commercial transport and shippers is mostly revolved around lowering the total cost of ownership and lowering total transport cost, the users of the TMS systems are mostly very familiar with their functions as optimal use of this system reduces cost. There are however two exceptions to this. First, the problem arises of larger and smaller companies. Whereas larger companies seem more familiar with the systems, the smaller companies are less able to use those. The second problem is that of new functions. It is hard for the manufacturers of the software to implement new functions and technologies as most users are not experts on the systems but use these out of habit. Changing this is said to be difficult. This has led to the manufacturers providing more and more education and support on their systems. The communication gap is more pronounced as it covers data sharing. The sharing of data in this sector still proves to be difficult as there are several issues regarding standardisation, trust and use. The last gap is the context gap. This is less present in this sector as most systems are made specifically for their goal in assisting the shipping companies in their daily activities regarding transport.

The second sector is that of the economic factor. Due to the ICT systems being very broad and often the lack of an underlying Geo-base, these ICT systems are not seen as planning support systems. They are therefore omitted from the conclusion and this sub question. The communication gap is however present still. The data from these systems and economic models are relevant to incorporate in other systems used by planners. This is however done on an irregular basis and the planning support systems could benefit from a better integration and data sharing.

The third category is the transportation management perspective. This is a category relying heavily on the use of ICT systems to monitor the network and provide small changes on the network on a short term. This can vary from sending road engineers to coping with bottlenecks or problems in the short term. The first cap is the knowledge gap, which is less present in this category. Most respondents replied that they have experience with the systems and other planners also noted that there does not seem to be a mismatch in this category. There seems to be a communication gap, however. The sharing of data and knowledge to other actors operating in the supply chain seems to be difficult, as this is not common practice in the sector. The nature of the data also plays a role in this conclusion as it is often very detailed and big. The context gap in this sector is less present as most ICT systems for this sector are already tailor-made for their purpose. There is also a rise in the sharing of data by providing information on lead times or bottlenecks. For instance, there are several examples of apps providing information on the opening times of locks and bridges to promote flow on the network.

The last category is the perspective from long-term transport planners. This can also be seen as the 'classic' planning support system category. In this category the focus is on more complete ICT packages providing support for various actions in the planning cycle. This can range from design functions to modelling, decision support, citizen participation elements to GIS applications. The first gap here is the knowledge gap in the users of these systems. As mentioned in the results this gap is indeed present in this category. Most planners had some knowledge or reacted they would, after some struggle, be able to produce some results with planning support systems. They also responded that this is rarely the case in their daily activities as they mostly outsource the work on more complex systems to experts. This makes the communication gap all the more important. The risk here is that in every step of communication improves the risk of misinterpretation. The communication between expert and planner and planners between themselves interpret the results or communicate the demands slightly wrong. The respondents note this is indeed sometimes the case. The last gap is the gap in context of the mentioned tools for the planners. This gap is present as the systems are inherently very broad and complex. Most systems benefit from having a lot of base data and would benefit from data out of the other categories as well. The problem of data sharing arises here as the systems are very dependent on base data to serve the complex planning context.

It can be concluded that freight transport is only an element of the total supply chain and this can be translated to the use of planning support systems also. Systems used by planners to help with their daily practice are only an element of the total ICT base underlying and connecting the different parts of the supply chain. The argue is that the ICT systems used in the different parts of the supply chain are functioning better because of their connection and can thus all be seen as a planning support system; they function on an iterative base and thus all contribute to the planning challenges. It seems that the interconnected systems as a whole function more like a planning support system: a geo-based system providing different elements of the planners daily activities.

5.3: *How can the corridor sustainability benefit from collaboration between planners and stakeholders in the supply chain and to what extent are planning support systems used in this process?*

As mentioned in the results above, there are several actions regarding the sustainability on the corridor and the collaboration of stakeholders. The communication gap, which is present in the use of planning support systems is a phenomenon present in the entire corridor. The freight transport corridor has an interconnected nature and the collaboration between stakeholders in information, sharing of data and collaboration on certain aspects may seem logical. The respondents noted however that this is not the case as the collaboration is still an issue. The technological collaboration, which is part of the fifth layer of the four-layer model, is still in early stages. While the ideas, processes and goals of data sharing might not sound very difficult, interviewees note that this is still hampering. The sharing of data between stakeholders is dependent on three variables; the technological standard, the juridical/ operational standard and the standard of trust. The current technological issues are relevant to the fragmentation in the sector as there are several issues in standardisation and quality of data. The juridical and operational standard is present as this provides the sharing party with more work like setting up contracts or authorising parties. As this is often work without a direct monetary reward, this is often an obstacle. The standard of trust is present as data is often very competition sensitive. As said, data is the new gold and most actors treat it with care.

The collaboration between actors is also still an issue. Governmental parties are participating with actors on the supply chain as they take the role of supply chain or corridor management in the pursuit of the public interest. This public interest is to enhance the sustainability on the corridor. They are putting effort and energy on this in the network improvements themselves but also in enhancing the collaboration between stakeholders as well as the sharing of data between stakeholders. The governmental parties collaborating in processes in the market is important to meet market demands. The current trend of multimodality is heavily dependent on collaboration on both technical and non-technical level to take shape. This is the case first of all because of the data-heavy process this implies. Several systems of shippers are then to be connected, posing difficulties in the communication between systems of the shippers and the third- or fourth party logistics provider if they are involved. The communication between the companies and governmental parties in the multimodal transport chain is important as well. It is important for the process of multimodal transport itself but also in the creation of new multimodal options and in the dissemination of ideas and information. It seems then that '*a new mind-set and openness to collaboration with supply chain partners, complimentors and even competitors is required'*, as stated in 2007 by Mason et al. is still the issue of today. While there is effort and energy on this topic, enhancements are still required.

5.4 In what ways can the sustainability of freight transport benefit from planning support systems?

Improving the sustainability of freight transport is dependent on a lot of factors. Using the four-layer model the division in freight transport actors was made. Enhancements on the fifth traversing layer of information and ICT can be concluded to promote the sustainability. The role of planning support systems in this aspect is to support in the various tasks planners face concerning the network. Several issues on the corridor are actually market issues and it was noted that these can be left to the market as this is not within the scope of governmental parties. There are goals about the network in the public interest however, the most notable being the sustainability of the corridor or network. The planning support systems should be able to support planners in achieving this. However, there is a mismatch in the use of planning support systems. This implementation gap is threefold. The first gap in this apparent mismatch is the context gap. This relates to the system not being entirely suitable for the context it is used in. The current bottlenecks in the enhancement of sustainability on the TEN-T corridor can be seen as this context. As they are fragmented over all categories of the bottleneck framework as proposed by Witte et al. (2012), it can be concluded that a single planning support system should encompass all categories and thus be very broad. The second gap is the knowledge gap. This knowledge gap here consists of the freight transport planners having limited knowledge on the use of planning support systems. It can be concluded from the research on the TEN-T case that this is indeed the case as most planners note that they would only be able to handle simple systems and they would only be able to handle certain actions in geo-ICT and planning support systems. The final gap is the communication gap. In the TEN-T case it was noted that outsourcing of the ICT work is not uncommon. This raises the need for good communication to prevent misunderstandings. This communication between actors is of great value. The other aspect of the communication gap is the obstacle of sharing data between actors. In the TEN-T case this is not a common practice still, and there are several barriers for this. There is however a lot of energy and effort on this. It can be concluded that the enhancements made to reduce this implementation gap of planning support systems or the use of other related ICT systems leads to the innovations in the sector being accelerated. Furthermore, it seems that while the use of planning support systems may sound technical, the focus is on human behaviour as well. This 'human factor' on the use of planning support systems may be the key to enhance sustainability.

5.5 Discussion

The field of freight transport planning is a highly specialized field of planning where the use of ICT systems to support multiple parts of a professional planning task is not uncommon. When researching the use of planning support systems in this sector, it is inevitable to gain insight in the broader use of ICT systems and stakeholder collaboration. In this sector, the collaboration between stakeholders is present in both the use of ICT systems and planning support systems and in the enhancement of sustainability. In this case it is not enough to only consider planning support systems such as the often quoted 'URBANSIM' or similar packages. Especially in this interconnected sector it is of importance to see other ICT systems used by planners as planning support systems, as they support their daily activities. Trough the enhancement of collaboration between planners and other stakeholders in the corridor management, the freight transport planners can promote the use of ICT systems and the use of data sharing. This has a positive effect on the sustainability of the corridor overall trough several actions these planners are promoting together with the stakeholders. The use of all-round planning support systems providing planners with support in aspects of the planning tasks is still not straightforward for freight transport planners. On one hand it is stated that these large systems are the future of sustainable transport and that trough the use of a single system based on various base data sets systems are capable of performing multiple tasks for the planners. Such a single planning support system is said to be everything the planner in the trade, economic, traffic management or long-term planning aspect of the corridor needs. On the other hand, this may be a utopian future as the current planning support systems used by planners in the freight transport planning are highly specialized and fragmented. It seems that collaboration with several parties with different tasks on the level of data sharing is important to gather base data for the planning support systems. The cross-linking of ICT systems used by planners and other stakeholders can instead of a single planning support system create a network of data sharing and collaboration. The collaboration on a non-technical level has also proven to be important in this aspect. This aforementioned communication gap is very important in the mismatch of use of planning support systems in the case of this research. The knowledge gap of planners but also other actors is another important aspect. Especially with the outsourcing of more difficult ICT and planning support system tasks to ICT professionals it is of great importance to have proper communication and understanding of the results to prevent unforeseen consequences of the results. The final context gap of planning support systems is important as systems have to be more tailor-made to meet the demanding requirements on the systems. The enhancement of each of these three gaps in the mismatch of planning support system use are beneficial for the fifth layer of the four-layer model. The enhancement of this information flow is very beneficial for the activities on the corridor and thus for the sustainability on the corridor, as current bottlenecks can be enhanced by this trend.

5.6 Recommendations, Further Research and Reflections

The recommendations for practice in this research follow the findings from the theoretical framework, results and conclusion. It must be noted that the recommendations are often nothing new; they follow the interviews with planning professionals. While this may be the case, the sector of freight transport is sometimes difficult to innovate. Theoretically speaking some solutions are not hard; hence they are hard to implement in practice. The first recommendation for practice is a broader view of the sector. Multiple interviewees noted that there is still a harsh division between modalities and that broader insight will enhance the sector as a whole. The second recommendation follows this in recommending more collaboration between actors. This may seem simple, there are already efforts on this but still more collaboration between actors on the corridor is required for better innovation. This also counts for the collaboration between the producers and end users of results with planning support systems as this reduces misinterpretations. The third recommendation in line with the results on planning support systems is the technocratic focus on ICT systems. Interviewees noted that it seems as if everyone is trying to invent the wheel. A focus on the connection of systems and the reducing of hindrances on these connections is required. This will eventually enhance collaboration but also the capabilities and richness of data in this. The last recommendation is to enhance the managing role of several governmental and non-governmental parties, as well as the recommendation for the (smaller) companies on the corridor to be more open to this corridor management; one company is not able to solve a wicked problem such as corridor sustainability. For this research a certain case and certain methods were chosen to answer the main question. The first recommendation for further research is as always to change the chosen case study for different cases. In this research there is a severe focus on the case, which in this research is European. Different geographical but also contextual cases are very interesting to research on their use of planning support systems in different transport contexts. The second recommendation for further research is the methodological change. For this research the emphasis was laid on semi-guided interviews with professionals in the sector, but different methods within either qualitative or quantitative research might be used to gain insight on the topic. There are also several opportunities regarding the scope. For example, the issue of passenger transport of aspects of urban freight transport are highly debated and interesting aspects for research in this sector. They can provide a more complete overview on the usage of the network and the network management. Furthermore, the more technical aspect of planning support systems, case studies such as this one and modelbuilding can provide a range of different views on the matter. Reflecting on this research, there are several notable aspects. The first reflective aspect is the aspect of the theoretical research. The theoretical framework in this thesis is focussed on several aspects concerning planning support systems, corridors and sustainability. Different viewpoints can be used to enhance the insights in the theoretical framework. A broader perspective also including for example urban traffic or personal traffic can be used in this retrospect. The second is the reflection on the used methods for this research. While the expert interviews for this research provided substantive results for this thesis, other research can benefit from the use of different methods or combining methods. In the used methods the response could also be improved and the interviewing of non-planner actors is also an aspect. As mentioned before, this research focussed heavily on one case in Dutch transport planning. Not all results and conclusions are therefore valid for the management of corridors, improvements of sustainability or the use of planning support systems in other cases worldwide.

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References Artwork:

Front page	M van der Woude, 2016
Introduction	I.D.E de Vries, 2019
Theoretical Framework	M van der Woude, 2016
Methods	I.D.E. de Vries, 2019
Results	I.D.E. de Vries, 2019
Conclusion	M van der Woude, 2016

APPENDIX A. TOPIC LIST (ORIGINAL/DUTCH)

Introductie van scriptie en onderzoek

Dagelijkse werkzaamheden respondent

Aspect van duurzaamheid in dagelijkse werkzaamheden

Relatie tussen werkzaamheden, duurzaamheid en internationaal transport

Duurzaamheidsdoelen/bottlenecks

Rol van data in deze duurzaamheidsdoelen

Uitleg definitie planning support systemen

Het gebruik van planning support systemen in dagelijkse werkzaamheden

Eigen ervaring met ICT en planning support systems

Zijn er barrières die dit belemmeren?

Hoe heeft het gebruik van deze systemen toegevoegde waarde?

Hoe ziet u de toekomst van het duurzame goederentransport?

APPENDIX B. TOPIC LIST (TRANSLATED/ENGLISH)

Introduction of the research and thesis

Daily activities of the interviewee

Aspect of sustainability in the daily activities of the interviewee

Relations between daily activities, sustainability and international freight transport

Sustainability Goals/bottlenecks

Role of data in sustainability goals

Definition of planning support software

Use of planning support systems in respondents daily activities

Experience with planning ICT and planning support systems

Hindrances in the use of planning ICT and planning support systems

Perceived added value of planning support systems

Perceived future of sustainable corridor transport

Appendix C. NVIVO Code Tree Axial Coding (ORIGINEEL/NEDERLANDS)

1. Planning Support Systemen
- **1.1 Perspectief Verlader**
  - **1.1.1 Belemmeringen**
  - **1.1.2 Samenwerking**
  - **1.1.3 Gebruik**
- **1.2 Perspectief Economie**
  - **1.2.1 Belemmeringen**
  - **1.2.2 Samenwerking**
  - **1.2.3 Gebruik**
- **1.3 Perspectief Verkeersmanagement**
  - **1.3.1 Belemmeringen**
  - **1.3.2 Samenwerking**
  - **1.3.3 Gebruik**
- **1.4 Perspectief planoloog**
  - **1.4.1 Belemmeringen**
  - **1.4.2 Samenwerking**
  - **1.4.3 Gebruik**
- **1.5 Persoonlijke ervaring**
- **1.6 Toegevoegde Waarde**

2. Duurzaamheid
- **2.1 Verduurzaming Toekomst**
  - **2.1.1 Transport**
    - **2.1.1.1 Veranderen**
    - **2.1.1.2 Vergroenen**
    - **2.1.1.3 Vermijden**
  - **2.1.2 Netwerk**
    - **2.1.2.1 Efficientie**
    - **2.1.2.2 Samenwerking**
- **2.2 Huidige Staat Verduurzaming**
  - **2.2.1 Belemmeringen Verduurzaming**
  - **2.2.2 Schaal Bedrijven**
  - **2.2.3 Samenwerking**
- **2.3 Persoonlijke Toekomstvisie**

3. Aanleiding Onderzoek (NIET GEBRUIKT)

Appendix D. NVIVO Code Tree Axial Coding (TRANSLATED/ENGLISH)

1. Planning Support Systems
- **1.1 Shipper perspective**
  - **1.1.1 Hindrance**
  - **1.1.2 Collaboration**
  - **1.1.3 Use**
- **1.2 Perspectief Economie**
  - **1.2.1 Hindrance**
  - **1.2.2 Collaboration**
  - **1.2.3 Use**
- **1.3 Perspectief Verkeersmanagement**
  - **1.3.1 Hindrance**
  - **1.3.2 Collaboration**
  - **1.3.3 Use**
- **1.4 Perspectief planoloog**
  - **1.4.1 Hindrance**
  - **1.4.2 Collaboration**
  - **1.4.3 Use**
- **1.5 Personal Experience**
- **1.6 Added Value**

2. Sustainability
- **2.1 Future Sustainability**
  - **2.1.1 Transport**
    - **2.1.1.1 Change**
    - **2.1.1.2 Greening**
    - **2.1.1.3 Avoid**
  - **2.1.2 Network**
    - **2.1.2.1 Efficiency**
    - **2.1.2.2 Collaboration**
- **2.2 Current state of Sustainability**
  - **2.2.1 Sustainability hindrances**
  - **2.2.2 Scale of Companies**
  - **2.2.3 Collaboration**
- **2.3 Personal vision of the future of freight transport**

3. Cause of research and action (Unused)

APPENDIX E. Interview Respondents

List of interviewees by name and organisation, in random order.

Name	Organisation
Jan Helmer	Rijkswaterstaat
Leon Koster	Rijkswaterstaat
Tom van der Schelde	Rijkswaterstaat
Margriet Bakker	Rijkswaterstaat
Marco van Steekelenburg	Provincie Zuid Holland Energy Innovation Board Zuid Holland
Joost Roeterdink	Provincie Gelderland
Wim Willink	Waterschap Rijn en IJssel
Ton Neumann	Provincie Limburg Programma Topcorridors
Antoon van de Ven	Provincie Brabant
Joop Verdoorn	Port of Rotterdam
Michiel Haarman	Neutraal Logistiek Informatie Platform Connekt Topsector Logistiek
Roy van den Berg	Smart Port
Aad van den Engel	Panteia
Twan van Lankveld	Midpoint Brabant Smart Logistics
Werner van Dinter	DocksNLD Gemeente Montferland
Gerard Eikelenboom	Verkeersonderneming Rotterdam
Joris Cornelissen	Programma Topcorridors Rijkswaterstaat
Willem-Otto Hazelhorst	Rijkswaterstaat
Robin Huizenga	PTV group NLD