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A route to success? Effects of the Betuwe-route examined

By

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Acknowledgments

After 4 months of research, I am proud to present to you the results of studying the master Urban, Port and Transport Economics in the form of this thesis. I would like to use this part of the thesis to express my gratitude to the people that helped me to achieve this.

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Abstract

In this thesis, the effects of the Betuweroute are investigated. The goal is to find out what the effects of the Betuweroute on transportation and society in the Netherlands are. Current research on the project is mainly focused on evaluating the expectations formulated when planning the Betuweroute and on the costs involved in building and maintaining the route. This research tries to add a more broad evaluation by also looking at the effect on amount of freight transported by rail, rail passengers, passenger train punctuality, road traffic intensity and emissions generated by transportation. To test this, various t-test and regressions are performed on data gathered from multiple sources. The most prominent results are a significant positive effect on amount of freight transported by rail of 5.5 million gross tonnes, the fact that there are less trains on the mixed tracks because of the Betuweroute and the effect of a reduction in emissions ranging from 20,937 tonnes of CO_2 to 50,445 tonnes of CO_2. Effects on amount of rail passengers, passenger train punctuality and traffic intensity could not be found in the regressions. These results lead to the conclusion that the Betuweroute has some positive effects. Regarding the project as a failure therefore seems not right, especially because there are some mitigating circumstances for not meeting the original expectations.

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1. Introduction

In the world of freight transport, modal shift has been a big item in the recent years. Countries want to replace truck transport with rail and barge transport, to reduce pollution and congestion. The European Union has set targets regarding this matter and to reach these targets changes will have to be made. Large infrastructure projects and policy changes are being developed in order to make the future of European transportation more sustainable.
A large infrastructure project that is already completed is the Betuweroute. To increase freight transport via rail, the Dutch government has invested a large sum of money into this dedicated rail connection from the port of Rotterdam towards Germany. The project had a total cost of 3.9 billion euro (measured at the 1995 price level) and took 6 years to construct (Koninklijk Nederlands Vervoer, 2014).

The Dutch government expected the project to result in a large flow of goods being transported via the new infrastructure. During the planning and decision making regarding the Betuweroute there were expectations and goals formulated. These were mainly about the usage of the route in the future. According to Kennisinstituut voor Mobiliteitsbeleid (2017) there have been four estimations of the net tonnage transported over the route. The first one was estimated at 30 million net tons in 2015 by a special committee that was appointed to investigate the desirability of the project. This was estimated in 1995. After this, some other estimations have been made of 37, 33 and 40 million net tons to be transported in 2015.
For this amount to be reached, the government would introduce some policies to discourage road transportation and make rail more attractive. The biggest policies were a discount for rail freight companies using the Betuweroute, a kilometre based charge for trucks, extra infrastructure investment in Germany, called the third railway, and liberalizing the market. The discount and liberalization of the market has been realized, but important measures like the kilometre based charge and the third railway to connect the Betuweroute to Germany have not yet been introduced (Kennisinstituut voor Mobiliteitsbeleid, 2017)

The project has received a lot of criticism, especially because of the large costs associated with the construction of the route. From research conducted by the Kennisinstituut voor Mobiliteitsbeleid (2017) it has become clear that the targets set were not reached with only 20.9 million net-tons transported via the Betuweroute in 2015. It has also not been possible to operate the Betuweroute without making a loss, making it necessary for the government to incur extra costs (Algemene Rekenkamer, 2016).

Looking at these facts, one could conclude the project is a failure. However, the route may also have benefits that have not been noticed yet. Research on the achievements of the Betuweroute has only looked at financial results and utilisation so far. However, the project might also have had a positive effect on passenger transport, road congestion and emissions in the Netherlands for example. Furthermore, measuring the success of the project according to the targets set in 1995 is possibly not the best way.
This thesis aims to investigate the benefits in a more broad way than the current research has done so far. This way it will be better possible to determine the success or failure of the project, which in turn can help decision makers to better consider new projects to improve rail freight transport.

The research in this thesis will be a quantitative analysis based on data gathered from multiple sources. To explain the results found with this analysis, findings from literature and an interview with ProRail will be used.

Structure of the paper

To structure the research into the Betuweroute, it needs to be specified what will be researched. The starting point in this will be the central question.

Based on this central question a set of sub-questions have been formulated, to address parts of the central question separately.

The central question for this research will be:

What are the effects of the Betuwe-route on transportation in the Netherlands?

According to the central question, the benefits for Dutch society will be examined in this research. This includes benefits for the government, companies and civilians in the Netherlands. As this is a large area to investigate, sub-questions will help to research the central question step by step.

Q1: *What is the effect of the Betuwe-route on rail freight transport in millions of gross tonnes in the Netherlands?*

Q2: What are the effects of the Betuwe-route on the situation of passenger trains on the multi-purpose tracks and on highways that follow the same route?

Q3: What is the effect of the Betuwe-route on the emissions in tonnes of CO_2 of total transport in the Netherlands?

These sub-questions can be addressed in a set of hypotheses that translate the question into a testable matter. These hypotheses will be formulated in the methodology section of this paper.

The second part of the paper will be the theoretical framework. In this part the relevant literature regarding the subject will be reviewed to get some insights into the driving forces behind rail freight transportation and what benefits improved rail infrastructure has. Also included is a part about the problems associated with correctly valuating large infrastructure projects.

After this theoretical framework there is a section dedicated to the data used in the research. It describes how the data was gathered, what adjustments have been done to the data and gives some descriptive statistics on each variable included in the dataset.

Then the methodology followed in the research is presented, for every sub-question the hypotheses associated with it are given with a description of the tests that will be performed to reject or not reject the hypotheses.

In the results, the outcomes of these statistical tests will be given, along with an analysis these results.

Finally, a conclusion and discussion are included in the thesis. Here conclusions will be drawn based on the results shown before. The discussion will be used to try to explain the outcomes of the research and to show the limitations that need to be considered.

2. Theoretical framework

2.1 Rail freight transport overview

In this section the characteristics of the rail freight transport market are discussed. First a general overview of the market is given, also with some determinants that determine how much freight is transported via rail. After this the Dutch rail freight market is discussed, as knowledge of this market is the most relevant when looking into the Betuweroute. Finally, the government initiatives regarding rail transportation and specifically the goals the Dutch government set for the Betuweroute.

2.1.1 Recent developments in rail freight transport

In the past, rail freight transport has been mainly the business of state enterprises. These enterprises had a monopoly on the national railways of a country. After the 1950s, rail freight transportation started to decline. The railways faced fierce competition from road and barge transportation. To make rail transportation more efficient, the European Union promoted the liberalization of the rail transportation sector. Competition of other railway companies should motivate the large state-owned railway companies to improve their operations. This resulted in the introduction of a European policy in 2007 that fully liberalized the rail freight market in all EU member countries (European Commission, 2018).

For passenger transportation, countries can choose to publicly tender a rail connection or just give the right to operate to a company without a tender. There have been plans to change this and to fully open the market, but many countries still oppose this (NRC, 2015).

In the Netherlands the first steps to liberalization were already taken in 1995. To allow for the rail liberalization, some adjustments had to be made. In the Netherlands constructing and maintaining the rail infrastructure was taken care of by the state-owned railway company. To be able to allow multiple companies on the rail infrastructure, the railway company had to be split into a company that operates the trains and a rail infrastructure company. In 1995 the railway company was split into NS, to operate trains, and ProRail, to manage the infrastructure. (NOS, 2012). In the rail freight market the liberalization has resulted in quite a few companies competing on the Dutch market for rail freight transportation.

2.1.2. Determinants for rail freight transport

In Europe and the Netherlands in particular, the share of rail in the total freight transport is low. Especially when compared to the share of rail in the United States. Curious is that in the 1950s rail had a similar share in both the US and Europe. In both areas the share of rail started to decline initially, but in the US the decline was turned around while the share in Europe kept declining (Vassallo & Fagan, 2007). In 2000, only 8% of total freight was transported via rail in the European Union, while the share was 38% in the United States. Comparing the situations in Europe and the United States can be used to identify some of the factors that determine the amount of rail freight transportation in an area.

The paper by Vassallo & Fagan (2007) mentions several reasons for rail transport being more successful in the United States. A part of these reasons are geographical. The United States has three times the land mass of the European Union. These long distances are in favour of rail transport over road transport. Despite being three times larger, the United States have just one-ninth of the coast line of the European Union. This makes the US less suitable for coastal shipping and more suitable for rail transport. The U.S. also have a different mix of commodities that is shipped, these commodities are more suitable for rail transport compared to the commodities shipped in the European Union.

In the paper, there are also some differences mentioned regarding the public policies. Different policies like a higher tax on fuel and higher road taxes in the European Union compared to the U.S. should serve to make rail freight more attractive in the European Union. Another difference is that the rail freight industry was structured different in the U.S. In the U.S. the railway companies have been private for a long time, while in Europe the railway companies were state-owned. Recently a lot of European countries have also privatized their railway companies, but the market is still less liberalized than is the case in the U.S.

To quantify the effect of both the geographical differences as well as the policy differences, Vassallo & Fagan (2007) made a calculation of how the rail freight share in the U.S. would change if it would have the same characteristics as the European Union. From this calculation they concluded that 83% of the higher share of rail in the U.S. was caused by the geographical factors mentioned. This indicates that 17% can be explained by the differences in policy mentioned in the paper. So by implementing the right policies, the European Union can increase the share of rail transport significantly.

Bennathan, Fraser, & Thompson (1992) observe a strong relation between the demand rail freight transportation and GDP. The elasticity between the two seems to be close to unity. According to this research, another important factor in demand for rail freight transportation is the distance over which freight is transported.

2.1.3. Initiatives to improve share of rail

The European Union has been trying to promote rail freight transportation for a long time. In 2001 the European Union launched the Marco Polo program, to promote all initiatives that try to shift transportation from road to rail (Merk & Notteboom, 2015).
In addition to this, to further reduce emissions and congestions from freight transportation, the European Union has formulated targets to increase the share of non-road transport in total transportation, changing the so called modal split. This target was published in the EU white paper on transportation of 2011.

It says:
"30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors. To meet this goal will also require appropriate infrastructure to be developed."
(European Union, 2011)
So, the EU member states need to use non-road transport, which includes rail freight transport, to transport 30% of current road freight. This is in addition to the existing non-road transport in 2011. To achieve this goal, the EU member states are encouraged to undertake steps that will enable this shift to non-road transportation. This will include investment in rail infrastructure. Of the 30 priority infrastructure projects of the EU, 18 are railway projects and 3 are mixed rail/road projects (Innovation and Networks executive agency, 2011). This indicates rail transportation is seen by the European Union as an important means to reach the target. Other initiatives include the European Union Agency for Railways that has the goal to promote railway use and integrate the railways of all EU member states into an EU railway network (European Union Agency For Railways, 2018).

2.2. Benefits of rail freight transportation

Both the European commission and the Dutch government are trying to replace road freight transportation with rail freight transportation. Both are convinced that this shift will have large

benefits for society. In this sector the literature regarding these benefits will be discussed to find out whether these benefits exist and how large these benefits are.
From literature it is clear that there are a few main benefits of a shift towards rail transportation.

2.2.1. Reducing externalities

Research from Forkenbrock (1998) looks at three possible categories of benefits regarding replacing road transportation with rail transportation. These categories are: accidents, emissions and noise. As negative factors will partly be compensated in the price of the transportation by taxes, the research compares the external costs for all categories for both modes of transportation.

Accidents

In the research, the cost to society of accidents were accumulated and the compensation paid by the particular mode was subtracted from this to get the external costs. This resulted in much higher external costs caused by accidents per ton-mile for truck transportation compared to rail transportation ($0.0059 for truck and $0.0017 for rail). This means a shift from truck to rail transportation would reduce costs of accidents for society.

Emissions

Externalities from emissions are divided into air pollution and greenhouse gas emissions by Forkenbrock (1998). Both for air pollution per ton-mile ($0.0008 for truck and $0.0002 for rail) as well as greenhouse gas emissions per ton-mile ($0.0015 for truck and $0.0002 for rail) the emissions from truck transport were higher than those of rail transport. A shift from truck to rail transportation would lower the externalities of emissions for society. However, this is not always the case as research from Bryan, Weisbrod, & Martland (2007) states that rail will not be more fuel efficient when transporting goods over short distances.

Noise

Finally, the externality of noise was investigated. After looking at multiple sources from literature and own calculations, Forkenbrock (1998) concluded that the external costs of noise were similar for both modes of transportation. So moving freight from road to rail will not result in a reduction in noise.
In addition to the three externalities mentioned by Forkenbrock (1998) there is another externality involved in a shift from road to rail freight transportation.

Congestion

Reducing congestion is often mentioned in literature as a positive effect of a shift from road to rail like in Janic & Vleugel (2012). However, they do not quantify this benefit. It is mainly based on the intuition that more rail transportation means less trucks on the road, and this will in turn cause less congestion. To evaluate the change in congestion caused by the Betuweroute, it will be needed to quantify this effect.

2.2.2. Reduced emissions

Before, the externality of emissions has been discussed. However, with sustainability and the environment getting more and more attention, it is hard to estimate costs associated with these emissions. Because of this, it is also good to estimate emissions in grams of CO_2 per tonne/km for both road and rail transportation.

Emissions for electricity powered rail transportation range from 14 to 19 grams of CO_2 per tonne/km. The general figure for rail, which includes diesel fuelled trains, is estimated to be 22 grams per tonne/km (ECTA, 2011). As trains on the Betuweroute are fully powered by electricity, both 14 and 19 grams per tonne/km will be used as lower and upper bound estimation of the reduction in emissions.

For road transport, emissions are estimated to be 62 grams of CO_2 per tonne/km, this is based on an average load factor of 80% of the maximum vehicle payload and driving empty 25% of total kilometres (ECTA, 2011).

2.2.3. Improved passenger transportation

In Europe, passenger transport usually receives priority over freight transportation (Lindfeldt, n.d.). This is the same in the Netherlands. The Netherlands originally only had mixed railways. The railway infrastructure was used for both passenger transportation and freight transportation. With the introduction of the Betuweroute, which is dedicated freight rail infrastructure, rail freight traffic can shift from the mixed railway to the dedicated railway. This might open up more space and time for passenger trains to operate. A result could be more frequent passenger train services and improved punctuality for the passenger trains.

Literature does not provide us with clear insights at this point. Pyrgidis & Christogiannis (2012) do state in their research that mixed railways have seen total volume transported decrease, while total volume transported on dedicated railways has flourished.

According to Wijewera & Charles (2013), who researched what determined rail passenger transportation in Australia, the most important determinants were the costs of a train ticket, population and the total kilometres of rail network available. Other less significant factors were price of fuel, amount of rail accidents and per capita income.

2.2.4. Economic benefits

In the last decade the countries in the East of Europe have been by far the fastest growing members of the European Union. A lot of companies from West-Europe have opened factories in these countries to produce goods for the Western European market (Labaye et al., 2013). Considerable investments have been made into these countries over the last years. Poland for example is second in Europe when it comes to foreign direct investment, after the UK and before Germany (Valentina Romei, 2017). To profit from the developments in the East of Europe, the Netherlands will need to be able to provide cheap and efficient freight transportation. As barge transportation is not feasible for most of these countries, rail is a good way to transport freight over the long distances between the Netherlands and Eastern Europe. An increase in freight transportation towards the East of Europe will benefit the throughput volumes in the Port of Rotterdam and generate more economic activity in the Netherlands. Over distances of more than 200 kilometres, rail freight transportation is really competitive when looking at price (Slobbe, 2015). Right now, Hamburg has the advantage of better rail connections to Central and Eastern Europe, but with better rail connections the port of Rotterdam can become more competitive in this area. Dedicated rail freight corridors are mentioned as an efficient way of transporting freight from a port by Merk & Notteboom (2015). An example is given of the Alameda corridor, which connects Downtown Los Angeles to the ports of Los Angeles and Long Beach. This corridor was very successful in providing an efficient way of freight transportation in the area.

2.3. Rail freight networks

In this section, the way rail networks are set-up will be discussed. First some literature on optimal rail network design will explain more on what is needed for an efficient rail network. After this, the existence of so-called rail corridors will be discussed. Finally, the rail networks of both entire Europe and more specifically the Netherlands will be described. This will provide some further insight about the possible value of the Betuweroute as a part of some of these rail corridors.

2.3.1 Optimal rail networks

In a paper by Jeong, Lee & Bookbinder (2007) the hub-and-spoke network type is discussed. In this rail network there are two different types of rail locations. The spoke is a location that generally does not handle transhipment of goods. Cargo is transported from the spoke to a hub. At this hub it is possible to consolidate the cargo and tranship it to other hubs. These hubs will eventually distribute the cargo to other spoke locations.

The advantage of this is that it is possible to consolidate cargo from different spokes at the hub, allowing for fuller train cars sent to other destinations. The larger volumes between different hub locations also have the advantage that they allow for trains with more capacity to operate between the hubs, allowing economies of scale to arise.

The paper on intermodal freight hub locations by Racunica & Wynter (2005) is also about this hub and spoke network for rail freight. In addition to the consolidation and economies of scale advantages mentioned earlier, they see additional advantages in the fact that shuttle train services can operate between hubs. This will increase frequency of freight trains between hub locations, which will allow for a more reliable service, more time slots to choose for customers and decrease terminal times as it will not be needed to reconfigure trains.

For an efficient hub and spoke network to be possible, Racunica & Wynter (2005) underline the benefits and importance of dedicated or semi-dedicated freight rail infrastructure. Dedicated rail freight infrastructure will allow freight trains to increase their speed and will open up new time slots to operate freight trains on, as on the mixed net freight trains are often restricted to operating at night or when there are no passenger trains on the track.

2.3.2 Freight transportation corridors

Both the Dutch national government as well as the European Union uses the term freight corridor to indicate a much used freight transportation route. The corridors connect major ports to large demand regions. The purpose is to transport the goods efficiently and environmental friendly.

2.3.3. Rail network in Europe

The European rail freight network consists of a net of railway tracks, grouped in 11 rail freight corridors. These corridors are part of the Trans European Network-Transport (TEN-T).

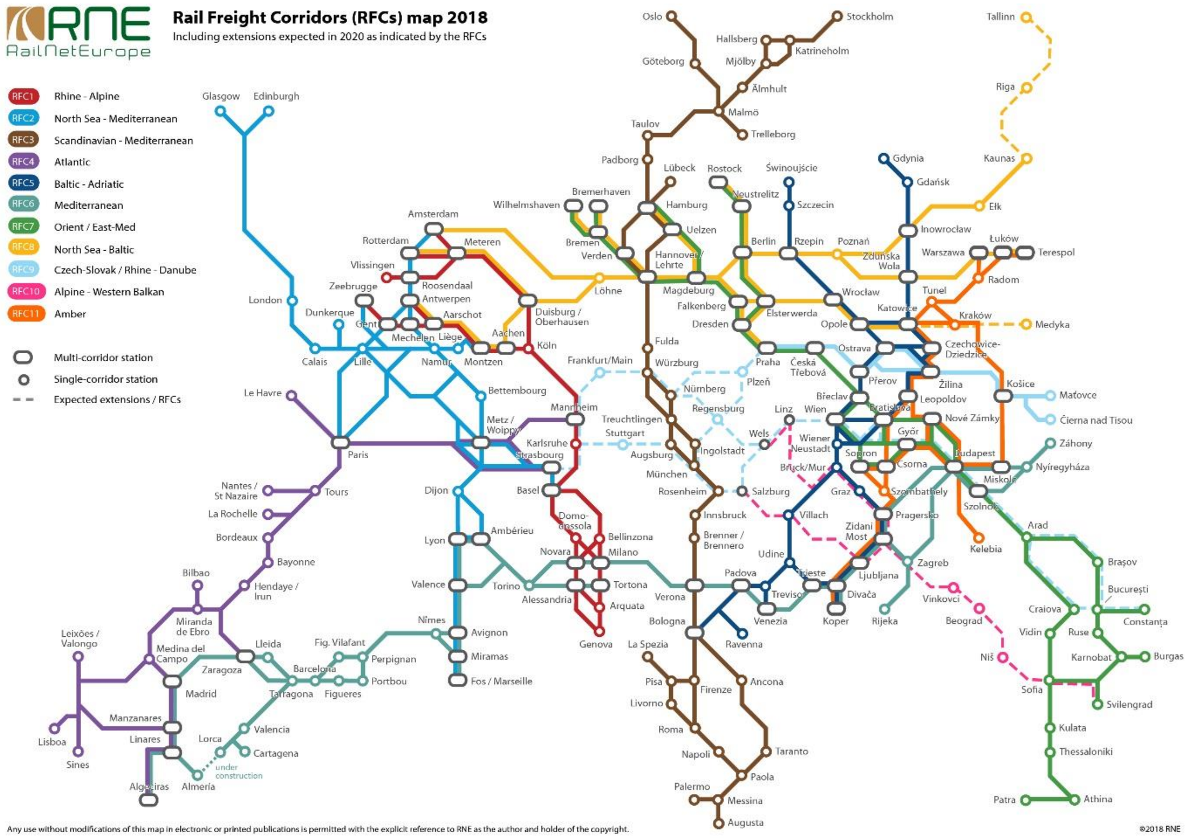

Figure 1: Map of European rail freight corridors.Source: (Rail Net Europe, 2018)

It can be seen in the map that Europe has an extensive rail network. Through the connected lines, a large variety of European destinations can be reached with freight trains. From the dotted lines it can be seen that some major additions to the network are expected. These additions will make transportation from Western Europe to Eastern Europe more appealing, the port of Rotterdam is directly connected to the Rhine-Alpine, North Sea-Mediterranean and North Sea-Baltic. Of which the Rhine-Alpine is one of the busiest rail freight lines of Europe (Port of Rotterdam, 2017).

According to a paper written by Jeong et al. (2007). The European rail network has a series of hubs used for transhipment and consolidation of goods. Some of these hubs are Mannheim, Munich and Milan. The hub of Mannheim allows for consolidation of cargo from the Dutch and Belgian seaports that is transported towards the Mediterranean and also allows for distribution of cargo from the Mediterranean to different locations in North-West Europe. The hub of Milan allows for consolidation and transhipment of cargo that needs to be transported across the Mediterranean or towards North-West Europe. The hub of Munich serves as a hub for cargo consolidation between the ports of Hamburg and Bremen and the Mediterranean. As can be seen in figure 1, the most additions to the rail network are planned near Mannheim and Munich. This will provide the Mannheim and Munich hubs with a faster rail connection to Central and Eastern Europe.

2.4. Situation in the Netherlands

2.4.1. Competition in Dutch rail freight transportation

Multiple companies operate freight trains on the Dutch railways, including DB Cargo, RTB Cargo, KombiRail and RheinCargo (Koninklijk Nederlands Vervoer, 2018). Of these companies DB Cargo has by far the largest share of the Dutch rail freight market, approximately 50 percent of total cargo transported (Europe Economics, 2015). Although this is large, the researchers did not find excessive market power for DB Cargo, as multiple companies have entered the market and are able to compete.

2.4.2. Rail transport in the Netherlands

The share of rail transport in the Netherlands is small, even compared to the average European share. Only 2.2% of goods are transported via rail in 2016 (Compendium voor de Leefomgeving, 2018). Reasons for this small share are mainly the crowded rail network of the densely populated Netherlands and the fierce competition of barge transportation (CBS, 2016) due to the extensive inland waterway network present. The option of barge transportation is not available in many other countries. The short distances in the Netherlands also provide an advantage for road transportation, as road transport is cheaper than rail transport over short distances (Bryan et al., 2007).

The Dutch government tries to promote rail transport nonetheless, as it is seen as a way to reduce congestion on its highways and reduce the greenhouse gas emissions produced by its transportation sector (Government of the Netherlands, 2017).

2.4.3. Stimulation of rail transport in the Netherlands

In addition to the steps taken by the EU to promote rail transport, the Netherlands also have some own initiatives regarding this matter. One of them is the Betuweroute, the project this thesis is about. Another measure is the modal split requirements that have been given to the terminals at the Maasvlakte 2 part of the port of Rotterdam. The terminal operators that operate these terminals have been given modal split requirements that oblige them to transport a certain part of their throughput to the hinterland using intermodal transport (Port of Rotterdam, 2018b). The port of Rotterdam is key in increasing rail transport as it handles most goods transported through the Netherlands. The port has taken some other initiatives as well. These include the Rail Incubator, which promotes starting railway companies, and Bayrolo, a collaboration with the Bavarian authorities to promote rail links from the port of Rotterdam to Bavaria (Port of Rotterdam, 2018a).

2.4.4. Rail network in the Netherlands

There are three major rail corridors in the Netherlands, each of them brings cargo from west to east and vice versa. As most freight from the Netherlands is transported over the Rhine-Alpine corridor. These three rail corridors can be roughly characterized as the Northern (IJsselroute and Twente-Line), Central (Betuweroute) and Southern (Brabantroute) rail corridors.
These rail corridors can be seen on figure 2 (ProRail, 2017) on the next page. When looking at the yearly tonnage transported on every corridor, the Betuweroute is by far the most used freight transportation railway. Second is the Brabantroute. This implies that the Betuweroute already has developed into the most important rail freight transport infrastructure in the Netherlands.
When looking at the different rail freight connections in the Netherlands, the Betuweroute has some major advantages over the other two routes.

1. The Betuweroute is directly connected to the busy Rhine-Alpine European freight corridor. It is the shortest route to Duisburg/Oberhausen and from there onward towards Mannheim, which was mentioned before as an important rail freight hub in Europe.
2. The dedicated freight rail infrastructure of the Betuweroute is very beneficiary to European rail networks according to Racunica & Wynter (2005). It allows for faster and more frequent rail shuttle services.
3. As it is not a part of the mixed rail network of the Netherlands, it will have less problems with the capacity of the Dutch railways, which is nearing its maximum capacity according to National Railways director Roger van Boxtel (OVPro, 2017). This is in line with the report NMCA of the Dutch ministry of Infrastructure and Environment (2017). This report states that on several Dutch rail routes, the limits of capacity will be reached in 2030.

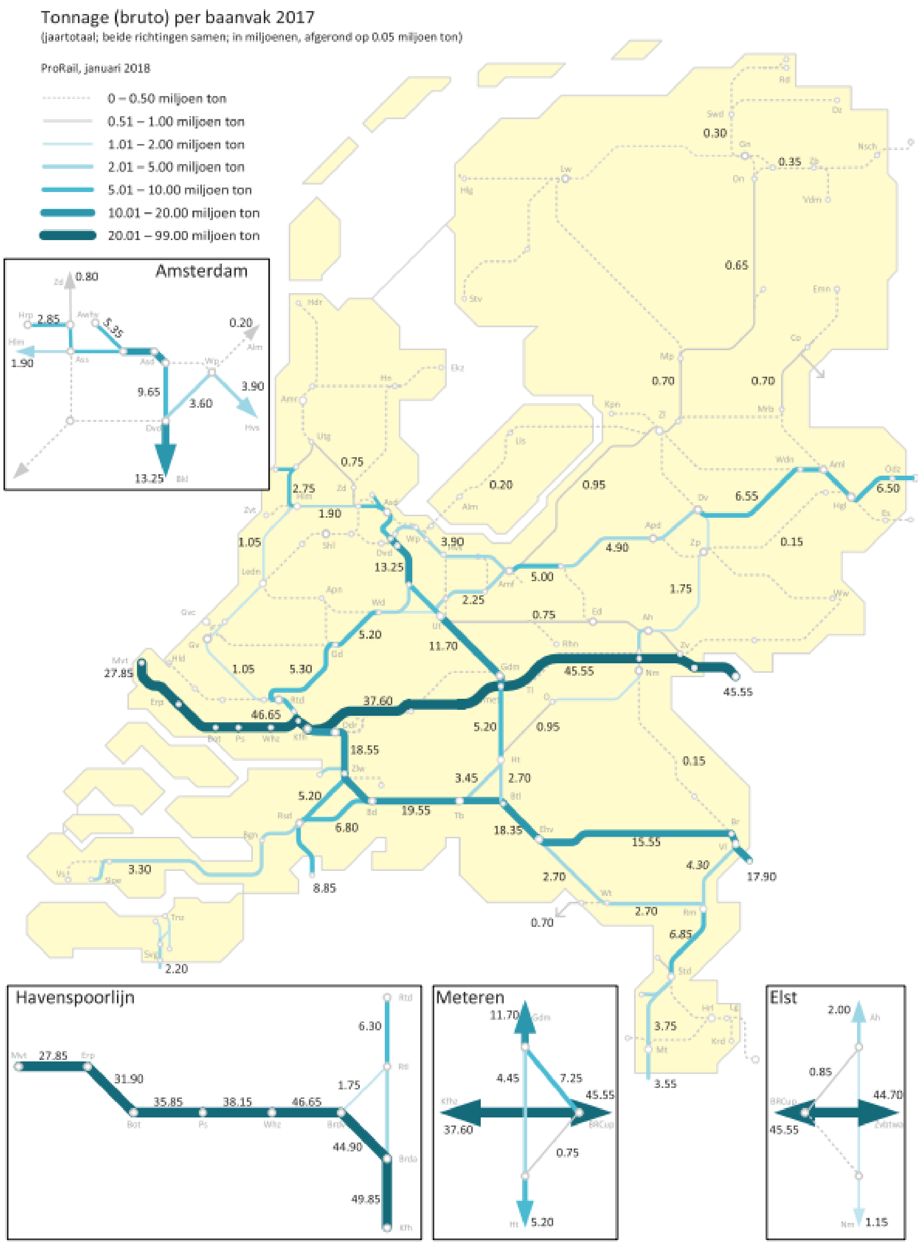

Figure 2: Rail used for freight transportation in the Netherlands.Source: (ProRail, 2017)

2.5. Valuation problems

History has proven infrastructure projects to be very risky investments. Many projects have been characterized by large cost-overruns and benefit shortfalls (Flyvbjerg, 2007a).

The first question in this matter is why the costs and benefits of infrastructure projects are often wrongly estimated. According to Flyvbjerg (2007) there are three factors that can explain the wrong estimations of both costs and benefits. First mentioned is the technical explanation.

Forecasting techniques are imperfect, and the future is hard to predict. The people that do the forecasting might also be inexperienced, so they will be more prone to errors. It is argued that this technical explanation is the least important of the three, as with the improvement of forecasting techniques the error should become smaller over time. This is however not observed in data on infrastructure projects.

Second is the psychological explanation. Planners and project promoters can be in the grip of so called planning fallacy, making decisions out of delusional optimism instead of a rational weighting of benefits and costs. Although this bias would better fit the data, it is also unlikely to be the main cause of the wrong estimations made. If this was the case, planners would learn from it and errors should decrease, the same as with the technical errors.

Third is the political-economic explanation. According to this explanation planners and promoters intentionally overstate benefits and understate costs. The reason for this is that a project with a very positive outlook is most likely to gain approval and funding, benefiting the people involved in the project. This looks like the most valid explanation for the structural cost overruns and benefit shortfalls.

2.5.1. Cost overruns

Figures about cost overruns in the Netherlands can be obtained from research done by Cantarelli, Molin, van Wee & Flyvbjerg (2012). They have investigated all large infrastructure projects between 1980 and 2012 in the Netherlands. The average cost overrun for rail, road and bridges and tunnels are given separately. The average cost overrun for rail was 10.6%. For road this was 18.6% and for bridges and tunnels it was 21.7%. The cost overrun for all these projects combined was on average 16.5%.

Flyvbjerg (2007b) uses a dataset that includes infrastructure projects from all around the world. The average cost overrun for rail was 44.7%. The other figures were 33.8% for bridges and tunnels and 20.4% for road. Average over all projects investigated in the paper was 27.6%. Compared to the world-wide research it stands out that the Netherlands is performing relatively well when it comes to cost management of infrastructure projects, especially in the rail infrastructure segment. This might be explained by the fact that the Dutch rail infrastructure projects were mainly constructing heavy rail, while the projects in the worldwide research were mainly light rail infrastructure projects, which are often more prone to big cost overruns.

2.5.2. Benefit shortfall

In Cantarelli et al. (2012) the average benefit shortfall of the projects is also calculated. This indicates by how much the demand forecasting was wrong. For rail the demand forecasts were on average -51.4% off. This means that the demand for rail transport was on average less than half of what was forecasted. Forecasting for road infrastructure was off 9.5% on average, so demand for the new road infrastructure was on average 9.5% higher than forecasted.
For the benefit shortfall in the Netherlands specifically, no literature can be found. This means the possible benefit shortfall of the Betuweroute will have to be compared to the average of the worldwide research. On a lot of large projects, like the Channel tunnel between England and France and the Danish Great Belt rail tunnel, operating still need to be subsidized to be able to attract customers to the service. Because of this the investment in these projects have proved to be non-viable.

2.5.3 Derived demand

When talking about the benefits of infrastructure investments, understanding demand for infrastructure is important. In transportation, demand for transportation is often described as derived demand. This means that demand for transportation is generated because of economic activity, such as goods that have been produced and need to be transported to the store to be sold (Rodrigue, 2006). Transportation itself is not an economic goal. In this case, demand for rail freight transportation along the Betuweroute is mainly a result of goods being exported or imported to or from Germany. Constructing this infrastructure itself will not lead to a higher demand for transport. Economic activity determines the amount of goods transported, infrastructure only facilitates the need for transportation.

2.6. Conclusion

This part consists of an overview of the most important parts of the theoretical framework.
After 1950, rail has declined in the modal split of transportation. In each country within the European Union this mode of transportation was controlled by large state-owned enterprises. The railways faced fierce competition from road and barge transportation. The railway companies were privatized and the rail freight market was liberalized to make rail freight transportation more attractive. However, rail freight transportation is still used far less in the European Union compared to the United States. Because of this it is good to look at determinants of rail freight transportation. A large part of the difference between the US and EU can be explained by geographical reasons, but there is also a part determined by policy

differences. GDP and distance over which goods are transported are also good determinants for rail freight transportation. New initiatives to make rail freight transportation more attractive are large infrastructure projects concerning rail done by the European Union.

The reason governments are trying to promote rail freight are the benefits it has over road transportation.
One of the main benefits is reducing the negative externalities associated with road freight transportation. These externalities are accidents, emissions and congestion.
A benefit specific for the Betuweroute is the fact that it causes less freight trains to operate on the mixed tracks. This can open up space and capacity for more passenger trains. Another benefit is the possibility of reaching markets in Eastern Europe more efficient than with road freight transportation.

As rail freight is only viable over large distances, an extensive network is needed for good rail freight transportation. A hub-and-spoke network is an efficient way to structure rail freight transportation and this setup is used in European rail freight transportation. In Europe important freight routes are grouped in 11 so called corridors. Because of the hub-and-spoke networks a fast and efficient connection to major European hubs along these corridors is important to make full use of rail freight transportation.
In the Netherlands, there are 3 major corridors for freight transportation of which the Betuweroute is the largest in terms of tonnes transported. The other two are the Brabantroute and the IJsselroute/Twenteline.
The rail freight transportation sector in the Netherlands is completely liberalized. The biggest company in the sector is DB Cargo, which is responsible for approximately 50% of all rail freight transportation in the Netherlands. The share of rail in total freight transportation is small in the Netherlands, even compared to the rest of Europe.

It is not uncommon for large infrastructure projects to exceed costs budgets and have a benefit shortfall. This can be explained by the fact that forecasts are often more optimistic compared to reality. This has both psychological as well as political reasons. These valuation issues can lead to governments investing in projects that are not viable, because the information provided about this projects is not realistic.
Overall, rail freight transportation is heavily stimulated by both the European Union as well as the local Dutch government. The goal is to shift freight from road transportation to rail

transportation. In this development the Betuweroute can be an important and sustainable connection to large rail freight hubs in Germany and emerging markets in Eastern Europe.

3. Data

To be able to test the effects of the Betuweroute, a series of statistical tests will be performed. For these tests data will be needed. In this section the data required for each sub-question will be discussed.

3.1. Data test rail freight transportation

Data gathering

The variable that will be the key to test the effect of the Betuweroute on rail freight transportation is the total gross tons transported by rail*, short: tons by rail,* from 2000 to 2016. This data was found in an overview of the total gross tons of freight transported in the Netherlands given by Compendium voor de Leefomgeving (2018). The variable that will signal the effect of the *Betuweroute* is derived from the years in which the Betuweroute was used. This can be seen in data from ProRail. In 2007 the railway was officially complete, but only 500 trains used the railway. Because of this, 2008 will be seen as the first year in which the railway was first fully used.

The *recession years* are based on data from CBS about the GDP of the Netherlands. The years of 2008 and 2009 are seen as recession years in this thesis, as the value of GDP was lower than that of 2007 in these years, while in 2010 this value was higher than in 2007 again.

The *amount of congestion*, in millions of kilometres multiplied by minutes, from 2000 to 2016 is found in data provided by Rijkswaterstaat.

Diesel prices in the Netherlands from 2000 to 2016 can be found in data from CBS on daily fuel prices in the Netherlands. For each year the price on the first of January is used.

Export to EU for the years 2002 to 2016 is found in data from CBS on the export of the Netherlands to other countries in the European Union. The years 2000 and 2001 were missing from this dataset. This variable was chosen over GDP as an indicator of economic activity, because during the research it proved to be a better explanation on the economic factors that influence rail freight transportation in the Netherlands.

Unemployment in the Netherlands, as a percentage of the total labour force, is also found in data from CBS. In the rest of the thesis, the variable names will be shortened to the currently underlined parts.

Below the variables have been summarized in a table, followed by the source where the data was found.

Data	Source
Total gross tons transported by rail 2000-2016	(Compendium voor de Leefomgeving, 2018)
Betuwe route operating years	(ProRail, 2018)
Recession in the Netherlands	Own insights (Years in which GDP was lower than the highest value before)
Amount of congestion on Dutch highways 2000-2016	(Rijkswaterstaat, 2018)
Fuel price in the Netherlands 2000-2016 (Diesel)	(CBS, 2018c)
Export to EU 2000-2016	(CBS, 2018b)
Unemployment in % Netherlands 2000-2016	(CBS, 2018a)

Table 1: Data concerning rail freight transportation.

Data adjustments

Most data found for this section was ready to be used without transformations. There was one case of missing data, namely *export to EU* where the years 2000 and 2001 were missing. To still be able to use all 17 data points the values of *export to EU* for 2000 and 2001 are estimated based on the average growth rates of export to EU from 2002 to 2007. These years are chosen to base the estimation on, because the crisis of 2008 disrupted the normal growth patterns.

Descriptive statics

Variable	Observations	Mean	Std. Deviation	Minimum	Maximum
Tons by rail	*17*	*34.41*	*4.47*	*26*	*40*
Betuwe route	*17*	*0.53*	*0.52*	*0*	*1*
Recession	*17*	*0.12*	*0.33*	*0*	*1*
Congestion	*17*	*11.84*	*2.38*	*8.1*	*15.7*
Diesel prices	*17*	*1.08*	*0.22*	*0.79*	*1.44*
Export to EU	*17*	*248644.3*	*59598.06*	*148056*	*317031*
Unemployment	*17*	*440.65*	*125.35*	*252*	*660*

Table 2: Descriptive statistics concerning rail freight transportation

The descriptive statistics show some fluctuations in the variables over the 16 years used in this research. The variables *Betuweroute* and *Recession* are dummy variables.

3.2. Data tests rail passenger transportation and road transportation

Data gathering

In order to test the effect of the Betuweroute on rail passenger transportation and road passenger transportation additional variables are required.

For the amount of freight trains on multi-purpose tracks from 2000 to 2016 (*Trains mixed*) and freight trains on the Betuweroute from 2008 to 2016 (*Trains Betuweroute*), ProRail has been contacted. The data was provided by ProRail. The variable that will indicate passengers on the Dutch railway network will be total amount of *passenger railway kilometres* by the National Railways from 2000 to 2016, this was found in a dataset from CBS published by CLO (2017). The *punctuality* and *satisfaction* figures of the Dutch National Railways were found on the website Treinreiziger.nl (2018). The yearly congestion on the A15 highway (*Congestion A15)* from 2002 to 2016 is obtained from data in the 'file top 50' provided by the VID (2018). From this list the busiest locations on the A15 can be obtained. From each year the biggest congestion location between Rotterdam and Gorinchem is used as an indicator of congestion on the A15. As bottlenecks in congestion on highways shift sometimes the location is not always exactly the same. However, it still indicates the same congestion, so the congestion between Rozenburg and Ridderkerk at Vaanplein is used for 2002-2013 and after this congestion between Ridderkerk and Gorinchem is used as an indicator for congestion on the A15. The change can be explained by the fact that the capacity at Vaanplein was enhanced (Rijkswaterstaat, 2017). Initially the intention was to use daily vehicles on the A15 as indicator for traffic on the A15, but not enough data was available on this matter.

Additional data	Source
Amount of freight trains on multi-purpose tracks 2000-2016	ProRail (2018)
Amount of freight trains on Betuwe-route 2008-2016	ProRail (2018)
Total amount of passenger railway kilometres by National Railways 2000-2016	(Compendium voor de Leefomgeving, 2016)
Punctuality figures National Railways 2000-2016	(Treinreiziger.nl, 2017)
Satisfaction figures rail transportation 2000-2016	(Treinreiziger.nl, 2011)
Yearly traffic congestion on A15 2000-2016	(VID, 2018)

Table 3: data concerning rail passenger transportation and road transportation

Data adjustments

In the data there are some missing variables. In the amount of freight trains on multi-purpose tracks, there is one year (2001) missing from the data. In the congestion on the A15 figures there are 2 years (2000 and 2001) missing. As there are no ways to make a realistic estimation of this data. These years are left as missing data and will be omitted in statistical tests with these variables. In the punctuality figures, the years 2014-2016 are missing from the dataset as well. For these years only traveller's punctuality is known instead of the 3 minutes punctuality that is used in this thesis. To generate the missing variables the years where both traveller's punctuality and 3 minutes punctuality are known are used to assess the relationship between the two figures with a regression. Based on the regression coefficient, the missing variables are generated based on the value of traveller's punctuality in that year.

Descriptive statistics

Variable	Observations	Mean	Std. Deviation	Minimum	Maximum
Trains mixed	*16*	*25362.5*	*7124.59*	*16200*	*39350*
Trains Betuweroute	*10*	*16480*	*8432.35*	*200*	*25050*
Passenger railway kilometres	*17*	*15.87*	*1.35*	*13.85*	*18.10*
Punctuality	*17*	*85.49*	*2.68*	*79.9*	*89.6*
Satisfaction	*17*	*68.53*	*9.98*	*45*	*78*
Congestion A15	*17*	*11.84*	*2.38*	*8.1*	*15.7*

Table 4: Descriptive statistics rail passenger transportation and road transportation

3.3. Data emissions and distances transport modes

Data gathering

The data about emissions is gathered from a report written by ECTA (2011). In this report the average emissions for both road transportation and rail transportation are researched. For rail the emissions of fully electric trains will be used as trains on the Betuweroute run fully electric. The data about distances is gathered from a website called EcoTransit that calculates routes and distances for different modalities.

Additional data	Source
Emissions road transportation	(ECTA, 2011)
Emissions rail transportation	(ECTA, 2011)
Emissions barge transportation	(ECTA, 2011)
Distances Rotterdam Germany for each transport mode	(EcoTransIT, 2018)

Table 5: Data concerning CO2 emissions

Data transformation

There are no data transformations needed for the emissions data.

Descriptive statistics

Values are fixed at 62 grams of CO_2 per tonne-kilometre for road transportation and 19 grams of CO_2 per tonne-kilometre for rail transportation. Barge transportation has an estimated co_2 emission of 31. The distances from Rotterdam to Germany are: 176 km for rail, 184 km for road and 198 km for barge.

4. Methodology

4.1 Assumptions of OLS

There are six assumptions that have to be made when using OLS. To be sure the results of the statistical tests are reliable, it will have to be confirmed that all of those six assumptions hold.

These are the six assumptions:
Assumption 1: The regression model is linear in the coefficients and the error term.
This assumption holds for all regressions as the model that will be estimated has linear coefficients and a linear error term.
Assumption 2: The error term has a population mean of zero.
This can be seen in the scatterplots of the residuals, if these plots appear random the assumption holds.
Assumption 3: All independent variables are uncorrelated with the error term.
It can not be assumed that there are no factors that influence both the independent as well as the dependent variable when looking at causes for rail freight transport. Because of this, coefficients might be biased.
Assumption 4: Observations of the error term are uncorrelated with each other.
A scatterplot will be made with the residuals of each prediction for the year the prediction is for. This plot will be made for all regressions used. When this scatterplot is shaped randomly, the assumption seems to hold.
Assumption 5: The error term has a constant variance, there is no heteroscedasticity.
To check for this, the residuals and the fitted values will be plotted in a scatterplot for all regressions used. When these scatterplots have a random shape, the assumption holds.
Assumption 6: No independent variable is a perfect linear function of other variables.
The variation inflation factor will be used for testing for collinearity between the variables for all regressions. If the VIF/1 is close to 1, there is no collinearity. If it is close to 0, there much collinearity.

Based on the tests, the regressions will be changed to make sure the assumptions hold.

4.2. First tests

To test whether the hypotheses are useful to test a series of t-tests will be performed. This is done to test whether there is a significant difference in the means of the tested variables before and after the completion of the Betuweroute. With these tests a simple approach to testing the effects is taken.

4.3. Effect Betuweroute on rail freight transportation

The first question to be answered is the following:

Q1: What is the effect of the Betuweroute on rail freight transport in millions of gross tonnes in the Netherlands?

For answering this sub-question tests will be run to reject or confirm hypothesis 1.

H1: The Betuweroute has a positive effect on the total amount of gross tonnes of freight transported by rail in the Netherlands.

To determine whether the Betuweroute has an effect on the total amount of rail freight transported a regression will be performed. The dependent variable in this regression will be the total gross tons transported by rail in the Netherlands. The effect of the Betuweroute on this will be measured with a dummy variable that indicates whether the Betuweroute was already present in the year or not. The control variables will be the total export to the European Union from the Netherlands, the amount of congestion on the Dutch highways, the price of a litre of diesel fuel in the Netherlands and a dummy variable to compensate for the years of recession in the Netherlands.

4.4. Effect Betuweroute on rail passenger transportation and road transportation

Next, the second sub-question will have to be answered.

Q2: Did the introduction of the Betuweroute result in less congestion for passenger trains on the multi-purpose tracks and on highways that follow the same route?

This sub-question will be tested in parts. The first part is tested with hypothesis 2.

H2: The introduction of the Betuweroute resulted in a shift of freight trains from the multi-purpose track to the Betuweroute.

To test this hypothesis the results of the t-test from 4.2. can be used. Based on this test it can be determined whether the mixed tracks are less used by freight trains, leaving more space for passenger trains.

After this the third hypothesis will be tested, which is about the rising amount of rail passengers

H3: The Betuweroute allowed the National Railways to transport more passengers.

The dependent variable in this regression will be total amount of kilometres travelled by passengers transported by the National Railways. The number of trains on the Betuweroute will be used as an independent variable to test the effect of the Betuweroute on the amount of passengers transported by the National Railways. The control variables will be GDP of the Netherlands, amount of congestion on the highways, satisfaction rates of rail transportation, punctuality of the National Railways, unemployment and diesel prices.

The next hypothesis is about the quality of transportation by the National Railways. The following hypothesis will be tested.
H4: The introduction of the Betuweroute allowed the on-time percentages of the passenger trains to improve.
The regression to test this will include the dependent variable punctuality. The independent variables will be a dummy variable to signal the completion of the Betuweroute and the yearly rail passenger kilometres will be the control variable.

The last hypothesis concerning this sub-question is hypothesis 5.
H5: The Betuweroute has caused traffic growth on the A15 to slow down.

To be able to test this hypothesis figures about yearly congestion on the busiest part of the A15 highway will be used as representing the traffic intensity on the A15 highway. It has to be determined whether the introduction of the Betuweroute has reduced the amount of congestion on this highway. To test this, a regression will be performed with GDP, diesel price and congestion kilometres in the Netherlands as control variables.

4.5. Effect of Betuweroute on emissions

Finally, the last sub-question will have to be answered.
Q3: What is the effect of the Betuweroute on the CO_2 emissions of transport in the Netherlands?

To test this hypothesis 6 will either be confirmed or rejected.
H6: CO_2 emissions of transport have been reduced by the shift from road to rail because of the route.

To test hypothesis 6 the results from testing hypothesis 1 and 5 will be used. The answers to hypotheses 1 and 5 will be used to check how large the increase in rail transportation was because of the Betuweroute. After this it will be calculated which share of this shift would otherwise be transported by barge and which share by road. After this the emissions with and without Betuweroute will be calculated and compared, to see the actual increase or decrease in emissions.

5. Results and Analysis

In this section the results of performing the methodology of chapter 4 will be viewed. The results are given and analysed, to provide further insights about what the results mean for the paper.

5.1. First tests

Group 1 includes the observations before completion of the Betuweroute, group 2 includes the observations after completion of the Betuweroute.

Variable	Mean group 1	Mean group 2	T-score	P-value
Rail freight tonnes	31.875	36.667	-2.5583	0.109
Amount of freight trains on mixed tracks	29757.14	21944.44	2.5412	0.012
Amount of rail passengers	14.62262	16.96936	-7.7879	0.000
Train punctuality	83.925	87.4667	-3.3811	0.001
Congestion A15	93465	113298.3	-0.8179	0.214

Table 6: T-test results

The results show a significant higher mean for rail freight, amount of rail passengers and train punctuality after completion of the Betuweroute at the 95% confidence level. The results also show a significant lower amount of freight trains on mixed rail tracks at the 95% confidence level. The causes for this significant difference in means can be researched further with statistical regressions. Both tonnes of rail freight transported and traffic congestion on the A15 highway do not show significantly different means between the means of group 1 and 2.

5.2. Effect Betuweroute on rail freight transportation

The first thing that is researched is what effect the introduction of the Betuweroute had on the amount of freight transported by rail in the timeframe used in this thesis.

	Rail_transported	Rail_transported	Rail_transported
0b.Betuwe_route	0.000000	0.000000	0.000000
1.Betuwe_route	4.791667	-0.008215	5.518190
	(2.56)*	(0.00)	(4.74)**
ExporttoEU		0.000081	
		(3.27)**	
0b.Recession		0.000000	0.000000
1.Recession		-4.490400	-7.287082
		(3.10)*	(4.72)**
Unemployment		0.010737	0.022811
		(2.18)	(4.93)**
Congestion_km		0.675933	1.346273
		(2.62)*	(6.05)**
Diesel_prices		-7.084090	
		(1.35)	
_cons	31.875000	9.744736	6.354829
	(23.39)**	(2.38)*	(1.67)
R^2	0.30	0.95	0.89
N	17	17	17

* p<0.05; ** p<0.01

The regression that explains the most of the variation in tonnes transported by rail appears to be the following:

$$Tonnes\ transported\ by\ rail = Constant - 0.008215 * \ Betuwe\ route + 0.000081 * \ Export\ to\ EU - 4.490400 * \ Recession + 0.010737 * Unemployment + 0.675933 * \ Congestion\ kilometers - 7.084090 * \ Diesel\ price$$

However, to be able to use this regression to draw conclusions about the effects of the Betuwe route on rail transportation the assumptions for OLS regressions have to hold

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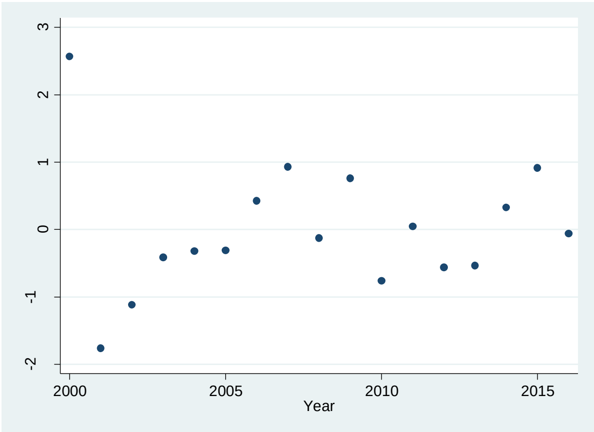


Figure 3:Scatterplot of residuals vs. years

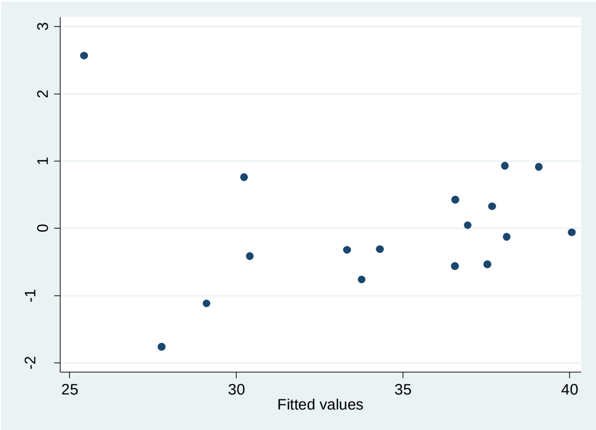


Figure 4: Scatterplot of residuals vs. fitted values

In both the left scatterplot (Residuals per year) and the right scatterplot (Residuals for each fitted value) the residuals seem to be distributed randomly, as there are no clear patterns visible. Based on this it seems that observations of the error term are not correlated with each other and that there is no problem with heteroscedasticity.

Variable	**VIF**	**1/VIF**
Betuweroute	9.46	0.105659
Export to EU	22.97	0.043434
Recession	2.46	0.407146
Unemployment	4.04	0.247346
Congestion kilometres	4.00	0.250088
Diesel prices	14.25	0.070169

Table 7: VIF values regression 1

When looking at the variation inflation factor it seems that there is collinearity between variables in this regression. Especially *export to EU* and *diesel prices* show strong collinearity with other variables in the regression. To solve this problem both variables will be removed from the regression. Now the new regression is the following:

$$Tonnes\ transported\ by\ rail = Constant + 5.518190 * \ Betuwe\ route - 7.287082 * \ Recession + 0.022811 * \ Unemployment + 1.346273 * \ Congestion\ kilometers$$

For this regression it is also checked if the assumption of OLS hold.

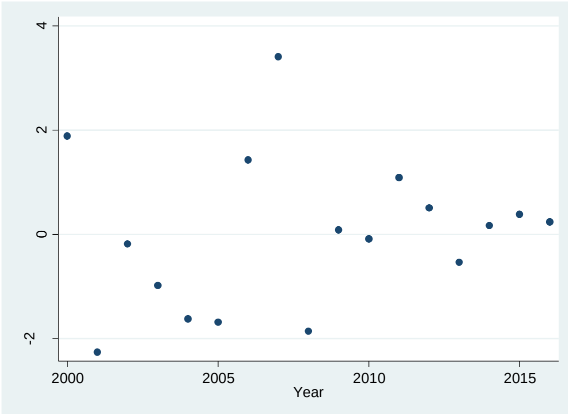


Figure 5: Scatterplots on residuals vs years

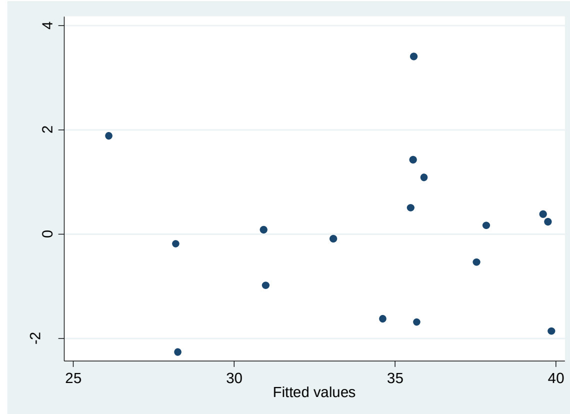


Figure 6: Scatterplot on residuals vs fitted values

In both the scatterplots the residuals appear to be randomly distributed, so the two assumptions tested by this hold again.

Variable	**VIF**	**1/VIF**
Betuweroute	2.01	0.497324
Recession	1.47	0.680044
Unemployment	1.89	0.529726
Congestion kilometres	1.57	0.637376

Table 8: VIF values regression 2

The variation inflation factor looks a lot better than the regression estimated before. Not one variable shows strong collinearity with the others.

Because of this, this regression is the most suitable to estimate the effect of the Betuweroute on the amount of freight transported by rail. In this regression, the dummy variable that indicates the presence of the Betuweroute has a positive effect on the amount of rail freight transported which is significant at the 95% confidence level. The coefficient is 5.518, this means that in the years were the Betuweroute was present the amount of tonnes of freight transported by rail was 5.518 million tonnes higher than the years without Betuweroute. The dummy for the years of recession has a negative effect, significant at the 95% confidence. The coefficient is -7.287 which means that in the years of recession the amount of tonnes of rail freight was 7.287 million tonnes lower than other years. Unemployment has a positive effect, significant at the 95%

confidence level. The coefficient is 0.023, so an increase of 1% in the percentage of people that are unemployed increases tonnes of rail freight by 0.023 million tonnes. Congestion kilometres has a positive effect, significant at the 95% confidence level. The coefficient of 1.346 indicates that an increase in the of 1 million in the amount of congestion kilometres times the minutes the congestion lasts increases the amount of rail freight tonnes by 1.346 million.

Based on these results, the hypothesis that the Betuweroute has a positive effect on the amount of rail freight transported in the Netherlands can not be rejected.

5.3. Effect Betuweroute on rail passenger transportation and road transportation

Trains on mixed tracks

First it is investigated whether the Betuweroute has led to less freight trains on mixed tracks on the route followed by the Betuweroute. To check this the results of the t-tests done in chapter 5.1 can be used.

Variable	Mean group 1	Mean group 2	T-score	P-value
Amount of freight trains on mixed tracks	29757.14	21944.44	2.5412	0.012

Table 9: T-test values trains mixed tracks vs trains Betuweroute

From these results it can be concluded that there are significantly less freight trains on the mixed tracks. The mean after introduction of the Betuweroute is lower than before, while the amount of freight trains in total was higher in this period. This can be seen in the graph below.

Figure 7: Total freight trains crossing the Dutch-German border

Based on this results the hypothesis that the Betuweroute has caused less trains on the mixed tracks can not be rejected.

Rail passengers

In the table below the results of a set of regression to examine the effect of the Betuweroute on the amount of rail passenger kilometres are presented. Again, four regression have been performed to check which variables to include in the optimal model.

	Rail_passengers	Rail_passengers	Rail_passengers	Rail_passengers
0b.Betuwe_route	0.000000	0.000000	0.000000	0.000000
1.Betuwe_route	2.346730	0.934358	-0.662156	0.511060
	(7.79)**	(2.29)*	(1.67)	(1.27)
GDP		0.000011	0.000021	0.000013
		(4.05)**	(6.82)**	(5.11)**
Unemployment			-0.004710	
			(3.69)**	
Traveler_satisfaction			0.081630	
			(3.52)**	
Punctuality			-0.249245	
			(2.98)*	
Congestion_km			-0.309310	-0.103970
			(5.04)**	(2.27)*
Diesel_prices			0.344792	
			(0.44)	
_cons	14.622625	8.919051	25.001232	9.222382
	(66.69)**	(6.30)**	(4.37)**	(7.37)**
R^2	0.80	0.91	0.98	0.93
N	17	17	17	17

* p<0.05; ** p<0.01

The most complete regression is the one below.

$$Rail\ passenger\ kilometers = Constant - 0.662156 * Betuweroute + 0.000021 * GDP - 0.004710 * Unemployment + 0.081630 * Traveler\ satisfaction - 0.249245 * Punctuality - 0.309310 * Congestion\ kilometers + 0.344792 * Diesel\ prices$$

Again, it will be checked whether the assumptions of OLS all hold in this regression.

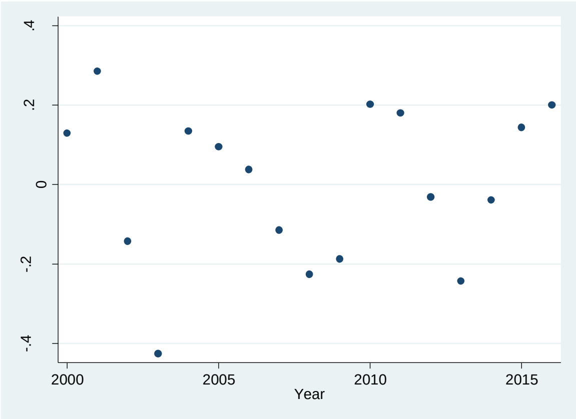


Figure 8: Scatterplot of residuals vs years

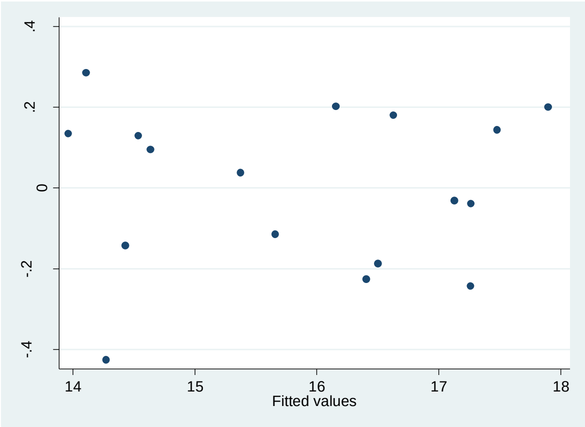


Figure 9:Scatterplot of residuals vs. fitted values

In both scatterplots there is no clear pattern in the residuals, so based on these plots the assumptions of no correlated observations of the error term and no heteroscedasticity hold.

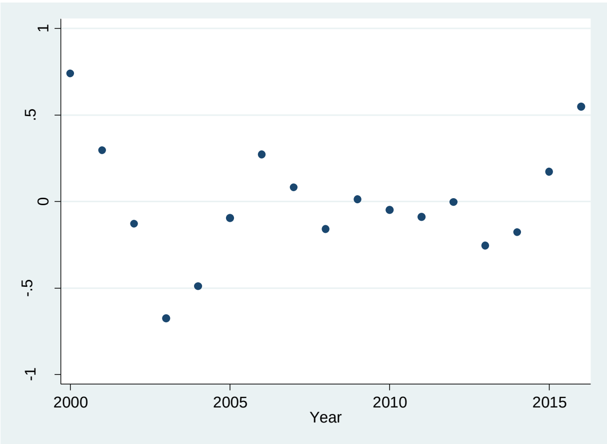
Variable	VIF	1/VIF
Betuweroute	9.59	0.104238
GDP	13.18	0.075855
Unemployment	5.90	0.169534
Traveler satisfaction	12.39	0.080713
Punctuality	10.31	0.097027
Congestion kilometres	4.91	0.203485
Diesel prices	7.01	0.142706

Table 10: VIF values regression 3

The variation inflation factor shows a lot of collinearity between the variables in this regression. Because of this a few variables will be dropped from the regression. These are traveler satisfaction, punctuality, unemployment and diesel prices. Based on the VIF scores GDP would be more sensible to drop than unemployment, but including GDP instead of unemployment makes the model more accurate.

After modifying the model it results in the following regression.

$$Rail\ passenger\ kilometers = Constant + 0.511060 * Betuweroute + 0.000013 * GDP -$$
$$-0.103970 * Congestion\ kilometers$$



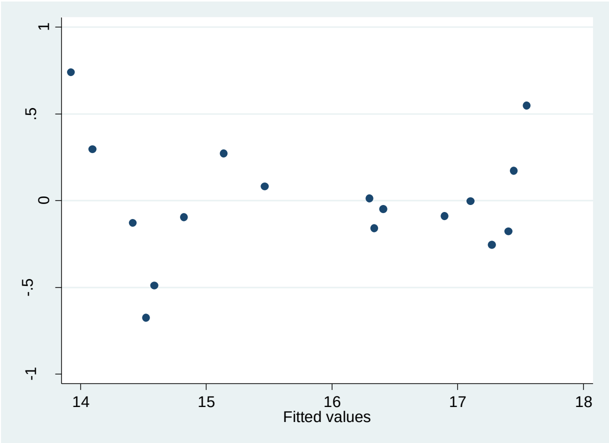


Figure 10: Scatterplot of residuals vs year

Figure 11: Scatterplot of residuals vs. fitted values

Now, the two scatterplots have changed, but the two assumptions still appear to hold.

Variable	VIF	1/VIF
Betuweroute	4.72	0.211828
GDP	4.20	0.237925
Congestion kilometres	1.30	0.771486

Table 11: VIF values regression 4

By dropping the variables from the regression the collinearity has decreased. There still is some collinearity between GDP and the dummy variable for the Betuweroute but it now is at an acceptable level.

Now the regression results can be interpreted. The dummy indicating the presence of the Betuweroute has a coefficient that is not significant at the 95% confidence level so an effect of the Betuweroute on amount of rail passenger kilometres can not be found. GDP has a positive effect on the amount of rail passenger kilometres that is significant at the 95% confidence level. The coefficient is 0.000013, which means that for an increase in GDP of 1 million euro rail passenger kilometres increase with 0.000013 million. This might seem like a small effect, but considering that GDP has increased by 254,580 million euro the effect is in fact considerate. Congestion has a negative effect on rail passenger kilometres. This effect is significant at the 95% confidence level. The coefficient is -0.104, so for an increase in congestion of 1 million kilometre-minutes rail passenger kilometres decrease by 0.104. The constant is significant at the 95% confidence level. A situation where all variables are 0 will not appear in reality, so interpreting the coefficient alone is not useful. It only has a use in combination with other variables.

The hypothesis that the Betuweroute has caused the National Railways to transport more passengers can be rejected based on these results.

Punctuality

Regarding the punctuality of passenger transport in the Netherlands the regression results in the following outcome.

	Punctuality	Punctuality	Punctuality
0b.Betuwe_route	0.000000	0.000000	0.000000
1.Betuwe_route	3.541667	1.230534	0.895913
	(3.89)**	(0.83)	(0.80)
Rail_passengers		0.984831	0.233567
		(1.53)	(0.23)
GDP			0.000012
			(0.69)
Trains_mixed			-0.000005
			(0.07)
_cons	83.925000	69.524182	74.763738
	(99.67)**	(7.21)**	(7.49)**
R^2	0.52	0.58	0.61
N	17	17	16

* $p<0.05$; ** $p<0.01$

Regardless of whether the assumptions of OLS hold, this regression does not provide explanation of the effects of the Betuweroute and other variables on punctuality because the coefficients are insignificant at the 95% confidence level. Further checks on the OLS assumptions are not needed.

The regression does not explain the variation in punctuality of the National Railways. As the t-test does give a significant higher mean after completion of the Betuweroute that can not be explained by different variables in the regression, it can still be possible that the Betuweroute has a positive effect on punctuality, but more data and control variables are needed.

The hypothesis that the Betuweroute allowed the on time percentages of the National Railways to improve is rejected based on these results.

Congestion

As shown in the t-test, there is no significant difference in congestion on the A15 highway before and after completion of the Betuweroute. The regression that was performed supported this and did not find a significant effect of any of the variables on congestion on the A15.

Considering this, the hypothesis that the Betuweroute slowed down the growth in traffic on the A15 highway is rejected.

5.4. Effect of Betuweroute on emissions

To test the effect of the Betuweroute on emissions first the emissions from freight transportation will be addressed.
As the regression of 4.2. shows a positive effect of the Betuweroute on tonnes of freight transported by rail. This results in less emissions, as this freight would have to be transported by road or barge otherwise.

As the regression coefficient is only an indicator of the size of the effect, a 95% confidence interval will be made to determine an upper bound and a lower bound for this value.

$$95\%\ confidence\ interval = 5.518 \pm 1.96 * 1.164$$

This results in the following confidence interval: {3.237; 7.799}

Which part of this shift would otherwise be transported via road transport or barge is calculated based on the total transportation figures of 2016 (CBS, 2018). In 2016 17.5% of total tonnes was transported from and to the Netherlands by barge, and 40.2% was transported by road. The other transported modes such as sea shipping and pipeline transportation are not viable options to replace rail transportation.
So by converting the percentages of road and rail to a combined 100% we can find the shares of road and barge in replacing rail transportation.

$$Road\ \% = \frac{40.2}{40.2 + 17.5} * 100 = 69.72\%$$

$$Rail\ \% = \frac{17.5}{17.5 + 40.2} * 100 = 30.28\%$$

Now these shares can be used to determine how large the increase in road and barge transportation would have been without the Betuweroute.

In the lower bound scenario:

$$Replaced\ by\ road\ transport = 3.237 * 0.6972 = 2.2568\ million\ tonnes$$

$$Replaced\ by\ barge = 3.237 * 0.3028 = 0.9802\ millions\ tonnes$$

In the upper bound scenario:

$$Replaced\ by\ road\ transport = \ 7.799 * 0.6972 = 5.4374\ million\ tonnes$$

$$Replaced\ by\ road = 7.799 * 0.3028 = 2.3615\ million\ tonnes$$

The distances for each modality are as stated in section 3.3.

The following equation will now be used to calculate the emissions.

$Transport\ in\ millions\ of\ tonnes * Distance\ in\ kilometers *$
$Emission\ of\ CO2\ in\ grams\ per\ tonne - kilometer = Emissions\ in\ grams\ of\ CO2$

So in the case of transportation by rail, emissions would be:

$$3.237 * 176 * 19 = 10824.528\ million\ grams\ of\ CO2$$

Which translates as 10,824.528 tonnes of CO2 emitted in the lower bound scenario.

$$7.799 * 176 * 19 = 26079.856\ million\ grams\ of\ CO2$$

Which translates as 26,079.856 tonnes of CO2 emitted in the upper bound scenario.

In the case of road and barge transportation:

$$2.2568 * 184 * 62 + 0.9802 * 198 * 31 = 31762.042\ million\ grams\ of\ CO2$$

So in the lower bound scenario rail saves 20,937.514 tonnes of CO2 in terms of emissions.

$$5.4374 * 184 * 62 + 2.3615 * 198 * 31 = 76524.7462\ million\ grams\ of\ CO2$$

In the upper bound scenario rail saves 50,444.8902 tonnes of CO2 in terms of emissions

6. Conclusion

The goal of this thesis has been to look into the effects of the Betuweroute on society. Both direct benefits like increased freight transportation via rail, as well as indirect benefits like an increase in passenger transportation have been researched. This gives a more broad evaluation of the effects compared to the reports already available on the Betuweroute. The central question of this research is the following: *"What are the effects of the Betuwe-route on transportation in the Netherlands?"*

As mentioned in the literature review, possible benefits of the Betuweroute include less congestion, less accidents, reduced emissions of CO2 and improved connections to emerging markets in Europe.

To answer the central question, three sub question were formulated and answered. The first sub-question is: *What are the effects of the Betuwe-route on rail freight transport in the Netherlands?*

The first tests show that the amount of freight transported via rail has not significantly increased after the introduction of the Betuweroute. However, based on the results of the regressions it is plausible that the Betuweroute in fact had a positive effect on the amount of rail freight transportation in the Netherlands. The effect is also quite large, 5.5 million gross tonnes on a total of 40 million gross tonnes. This would mean the Betuweroute has stimulated rail freight transportation in the Netherlands by allowing more freight to be transported by rail.

The second sub-question addresses a changed situation in passenger transportation: "*What is the effect of the Betuwe-route on the situation of passenger trains on the multi-purpose tracks and on highways that follow the same route?"*

The amount of freight trains on the mixed tracks has significantly decreased after introduction of the Betuweroute. This would mean that there is more capacity available for the passenger trains on the tracks. Rail passenger kilometres has also increased significantly in the same period. However, this increase can not be attributed to the introduction of the Betuweroute, as the effect of the Betuweroute on rail passenger kilometres is not significant. The mean train punctuality was also significantly higher after completion of the Betuweroute, but again the effect could not be attributed to the Betuweroute because of the lack of a significant coefficient. There was no significant effect on congestion on the highway observed. Altogether, the Betuweroute has resulted in less busy mixed railway track. Despite this, no significant effect on amount of rail passenger kilometres, punctuality percentages and highway congestion could be found.

The third and last sub-question is about the effect that the Betuweroute has on CO2 emissions. *What is the effect of the Betuwe-route on the emissions of transport in the Netherlands?*
As found in sub question 1, the Betuweroute had a positive effect on rail freight transportation. According to ECTA, rail is the mode of transportation with the least emissions, compared to road and barge. An estimation was made of the savings in emission made by transporting via rail instead of road or barge transportation. The savings in CO2 emissions range from 20,937 tonnes of CO2 to 50,445 tonnes of CO2.

With the answers to these sub-questions, the central question can be answered. Based on the results it can be concluded that the Betuweroute has had an impact on the rail transportation sector in the Netherlands. It had a positive effect on gross tonnes of freight transported by rail and reduced emissions of transportation. Another result was that the mixed tracks have become less crowded with freight trains, which resulted in more space for passenger transportation. However, based on the data there was no significant effect of the Betuweroute on the amount of passenger kilometres and punctuality.

Although some positive effects have been found, it is hard to label the Betuweroute as a success based on these results. Limitations in the research do not allow for making strong conclusions. In the discussion these limitations will be discussed. On the contrary, there are too much benefits to call the project a failure, especially because there are some explanations for not meeting the expectations formulated in 1995. These explanations are also included in the discussion.

7. Discussion

The final part of this thesis will be dedicated to discuss the research and its underlying approach. First, the limitations of this research will be discussed. After this, results and conclusions are further elaborated based on literature and an interview with a ProRail employee. Finally some future expectations on the Betuweroute and implications for future research are discussed.

7.1. Limitations

When gathering the data for the research some of the preferred variables for the regressions could not be found. Data about the amount of traffic on the A15 highway for instance could only be found for the years 2009-2016. Because of this, it was not possible to do a proper test on the possible reduction in road traffic caused by the Betuweroute. Another data problem was that there were some missing observations in the data, usually one or two years. Some could be estimated based on other variables, and for some one year had to be omitted from the regression. These missing observations make the results of the tests less accurate.

Another limitation is omitted variables bias. There were some factors that could probably influence the dependent variable but could not be included in the regression. One of these factors is the price of train tickets for passengers, which was not included because there was no data available. Some other variables had to be dropped from the regression due to collinearity issues with the variable that signalled the presence of the Betuweroute. This was the case with the variables GDP and Export to the EU. The fact that these variables were not included in the regression on total freight transported by rail might have caused an upward bias in the effect of the Betuweroute. This would mean the effect is less strong than was found in this research.

The last limitation is reverse causality, some results are probably signs of reverse causality. An example of this is the effect of the amount of congestion in the Netherlands on rail passenger kilometres. This effect is negative, the best possible explanation for this is that less people traveling by train causes less congestion, instead of the other way around.

7.2. Remarks on the performance of the Betuweroute

In the report of Kennisinstituut voor Mobiliteitsbeleid (2017) the conclusion was that the goal of 30 million net tons of volume transported over the route was not reached. Why can we not conclude that the Betuweroute is a failure?

To answer this question we first have to look at the expectations and the assumptions made when these expectations were formulated. The Betuweroute was planned to be introduced along with several other changes to reduce transport by road and promote transport by rail. Some of these changes have been implemented, but some others not. The kilometre based charge for road users and the rail freight track that was supposed to be constructed in Germany were not realized. Because of this, it would be unfair to judge the Betuweroute based on the expectations while the changes that were expected were not implemented.

The fact that the rail connection in Germany was not constructed is also an explanation for the stagnation in the amount of freight trains using the Betuweroute that is visible over the last few years. The track cannot be used to its full capacity until the planned railroad in Germany is finished. The amount of trains currently using the route is the maximum until the German railway will be finished, according to ProRail (2018). The original expectation of 30 million net tonnes of throughput is therefore currently impossible to realize.

Another disruptive factor was the economic crisis of 2008. The crisis caused the economic growth forecasts to be wrong as the economy did not grow like before. In 2015, the year for which the expectations were formulated, the economy and especially international trade was still suffering from the aftershocks of this crisis.

The developments in transportation are also influencing the net tonnes transported via the Betuweroute. The transition to more sustainable energy production causes the amount of coal transported from the Netherlands to Germany to decrease. Coal is used less as an energy source and smaller coal fuelled plants are closed in favour of larger more efficient plants. It is more efficient to supply these by barge. The share of containers in total goods transported by rail is rising. As wagons loaded with coal are relatively heavy compared to for instance container wagons, the numbers about net tonnes transported can be misleading.

7.3. Future expectations

As mentioned before, the construction of the German connection to the Betuweroute will allow for an increased capacity on the route. The construction of this project has begun in 2018, so it will eventually be finished, although a precise date is not yet known. As rail is the transportation mode with the least CO_2 emissions compared to road and rail transportation, this capacity will likely be used in the future when environmental laws will become increasingly important. From the interview with ProRail it was learned that future developments in safety systems can also be beneficial for the Betuweroute. The Betuweroute is equipped with the new safety system ERTMS, while this is not common in the rest of Europe. This means that trains using the Betuweroute and continue further in Europe need to be able to handle both ERTMS and the old safety systems. This makes it more expensive to operate on the route. As ERTMS will be implemented more in other European countries operating trains on the Betuweroute will become less expensive.

7.4. Recommendations for further research

Future research can be done when more data will be available on the subject, it will be particularly interesting to see if the volume will increase strongly when the connection to Germany will be ready. Further, instead of an analysis of the effects, an analysis on the costs of the Betuweroute can also be done. This way a complete cost benefit analysis can be made in the future.

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Appendix

Interview Ron Demmers

Date: 19-7-2018

Function: Program manager at ProRail

Mr. Demmers provided data on the yearly amount of trains using the Betuweroute and the mixed rail tracks between on the border crossing for the years 2000-2016. In addition to this, he was also willing to answer questions about the Betuweroute and trends in rail freight transportation. A summary of this interview is given in this part.

Q: What are the biggest trends on rail freight and rail passenger transportation in the recent years?

A: The type of goods transported by rail are changing. The amount of coal transported by rail is decreasing, because coal is being used less as a source of energy and smaller coal fired power plants being closed in favour of larger coal powered plants. These larger plants are often located along the Rhine, which makes barge transportation the most efficient way to supply them.

There is also heavy competition among rail freight companies, in the Netherlands there are 15 to 20 companies competing on this market. Because of this there is high uncertainty among these companies, as they can easily lose customers to a competitor.

Q: Do you think the expectations formulated by the commission Hermans in 1995 regarding the Betuweroute were realistic? And why do you think this?

A: Expectations and forecasts are always based on assumptions, regarding rail freight but also regarding the entire economy. Not knowing these assumptions it is hard to say whether expectation are realistic or not. It is probable that the expectations were based on a lot of capacity being available in Germany. This capacity is not there at the moment, because the German connection to the Betuweroute has not yet been built. Without this connection to Germany, it is not possible to operate more trains on the Betuweroute, because they will not be able to go into Germany. Also, net tonnes do not always tell the whole story, as a wagon loaded with coal is heavier than a wagon with container-goods.

In addition to this, forecasts are often based on wishful thinking. A Dutch report will be positive about the Dutch performance in the future. For instance the Port of Rotterdam will be positive about being better than Hamburg in the future, while a German report will be positive about the opposite.

Q: What are the advantages of transporting freight by rail?
A: It is a clean and environmentally friendly way of transporting goods. It is also the safest mode of freight transport. Containers on rail wagon can be decoupled and uses as temporary storage method. Regarding speed the average transportation time is between the average transportation time of road (which is faster) and barge (which is slower).

Q: Do you think the Betuweroute has made it possible for more passengers to use the train and has increased the punctuality figures of the National Railways?
A: I have conducted some research on mixed rail routes parallel to the Betuweroute, but there was no big change visible because of the Betuweroute. The increase in rail passengers and punctuality after completion of the Betuweroute has not been large. Around the year 2000 there were some bad years regarding punctuality, those were caused by cold winters and hot summers.

Q: Do you think rail freight transportation has to be done as much as possible on dedicated rail tracks, or is it possible to combine freight and passenger transportation on the same track?
A: Of course dedicated tracks can be used to plan rail freight transportation very well, but in the Netherlands there will most likely not be another dedicated track constructed, as there is very little space for this. Combining freight and passenger transportation can also work well, the key is to not stop freight trains. Stopped freight trains take up a lot of capacity where freight trains at full speed are not much slower than passenger trains when looking at average speed.

Q: Is the Dutch rail network almost at its maximum capacity?
A: The Dutch rail infrastructure is becoming more crowded. For instance the frequency of passenger trains between Amsterdam and Eindhoven will be one in every ten minutes. Also depends on average speeds of trains and amount of stops how close trains can be behind each other.

Q: What are the prospects for rail freight in the future?
A: With better rail connections, Dutch rail freight can compete with Hamburg for Southern Germany and Eastern Europe. These two markets have the largest potential for growth.

Opinion mr. Demmers

Betuweroute is a good addition to Dutch infrastructure and the Dutch transportation networks. Most criticism about the Betuweroute is about the large costs of the project, while most increases in costs were a result of changed demands for safety and nuisance. The project has just a small cost overrun, better than most other infrastructure works. Some decisions might not have been ideal, like the use of ERTMS safety systems and 25kV as power source for the trains. This means trains to Germany have to be able to drive with both ERTMS as well as the old safety system and with multiple voltages. This makes trains on the Betuweroute more expensive.