Freight Value of Time

An Exploratory Study for Modelling Freight

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Preface

The idea of exploring Value of Time in my Master of Science Thesis was a combined result of my own personal interests in economy, modelling and multimodal transportation, and the first introduction to the topic of Freight Value of Time made by my examiner Professor Sebastiaan Meijer, whom I would like to thank for this and all his guidance throughout the project.

I would also like to extend my sincere gratitude to Licentiate Behzad Kordnejad who has been my daily supervisor and has offered me many hours of valuable guidance.

Furthermore, I would like to extend a thank you, to the freight actors who participated in the survey and the authors of all the publications on which this report is based. This study would not have been possible without your previous work.

Last but not least, I would also like to thank my family and friends for being the victims of my theoretical discussions and in general for being supportive.
Abstract
The main purpose of this project was to examine the reliability of Value of Time for freight applications by comparing the functionality of the Freight Value of Time modelling concept, with the functionality of the freight market.

The research questions of this report are:

How can the Freight Value of Time concept fulfil the requirements that decision makers in international freight have on the reliability of the modelling outcome?

What are the differences between the multimodal and the unimodal applications of Value of Time in terms of validity?

Within the scope of this study; modelling in the field of freight, logistics and supply chain management are presented with focus on Value of Time models. An overview of common freight models is initially presented as a starting point for literature reviews on trends and characteristics of the freight market, and on Freight Value of Time. These two literature reviews constitute the main methods of information retrieval on which the later analyses are based. The trends and characteristics of the freight market section provided the general requirements and a context for modelling freight, which was used for analysing and discussing Freight Value of Time.

Additionally, a survey was performed in order to provide some insight into the requirements that analysts and decision makers have. The survey results were presented in the form of six examples of Swedish decision makers in freight. However, the survey results were deemed unsuitable for general conclusions due to a low response rate (6 out of 60).

The analysis chapter of the report is divided into three parts; a general analysis section, a validity test of Freight Value of Time and a conceptual feasibility example. The general analysis focussed on issues with Freight Value of Time, the survey, freight market trends and multimodality.

In the general analysis Global production networks and supply chains were identified as major trends and were used as the main modelling context when analysing Value of Time as a modelling concept for freight. The rest of the general analyses focuses on how well the modelling concept Value of Time corresponds to the functionality of the market.

The validity test section showed that there are some possible issues with Freight Value of Time and that they can possibly be attributed to poor data availability and high aggregation levels.

Therefore, the feasibility example study was performed for a conceptual case where data that is often missing was available. The specific data was characterised as supply chain data, which could be available to external analysts if the companies decide to share it. The feasibility study thereby tested if it actually was the lack of data that is the main reason for models including Freight Value of Time to lack validity according to the validity test. Access to data was found to be an important factor when creating a freight model with Value of
Time, because by adding the supply chain data the performance of Freight Value of Time in the validity test was improved. However there were still potential issues with using Freight Value of Time concerning testing and verification in relation to the complexity of large scale freight models and the complexity of multimodal freight transport.

The main issues with Value of Time identified throughout the project were:

1. Discrete choice model selection
2. High aggregation levels due to lack of data
3. Explanatory variables
4. Identification of decision makers
5. Transport flow heterogeneity

A set of four recommendations for analysts were devised from the hypothesis of:

*Models using Freight Value of Time are not reliable enough to be used in practise.*

The recommendations to analysts interested in Freight Value of Time were:

- The specific model should be verified and validated before being used, which is probably best done for the specific application with a standardised verification and validation method such as the VV&A (used by Department of Defense in the USA).

- Freight Value of Time is best used for unimodal applications, but for multimodal applications it could be reliable enough if the model is properly adapted to the complexity of the reality which is modelled.

- The higher the complexity of a modelling scenario, the more data is needed. Therefore an analyst needs to make sure that this trade-off is kept at a level where the results fit the requirements of the application.

- Low aggregation levels benefits the accuracy of the model, but increase the amount of calculations. It is therefore good to be aware of the risk of calculation errors.

Summarised, the report concludes that Value of Time is sometimes the best method at hand but difficulties in gathering data can affect the accuracy negatively. Furthermore the complexity of multimodal freight transportation makes Value of Time less valid than for unimodal freight.
Sammanfattning
Svensk titel: Godstidsvärde
Svensk undertitel: En utforsknande studie för godstransportmodellering

Det huvudsakliga syftet med detta projekt var att utforska tillförlitligheten hos tidsvärdes-konceptet vid godstransporttillämpningar genom att jämföra hur tidsvärde fungerar i godsmodeller gentemot hur godstransportmarknaden fungerar.

Frågeställningarna i denna rapport är:

- Hur kan godstidsvärdes-konceptet (Freight Value of Time) uppfylla kraven som besluts fattare i internationella godstransporter har på tillförlitligheten hos modellingsresultatet?
- Vad är skillnaderna mellan validiteten hos de multimodala och unimodala tillämpningarna av tidsvärdes-konceptet?


Därutöver, genomfördes en enkätundersökning för att ge en inblick i de krav som analytiker och beslutsfattare ställer på godstransportmodeller. Resultaten från undersöknin presenteras som sex exempel på svenska beslutsfattare. Enkätresultaten bedömdes dock vara olämpliga för vidare analys och generaliseringar eftersom svarsfrekvensen enbart var 6 av 60.

Analyskapitlet i denna rapport är indelat i tre delavsnitt; ett generellt analysavsnitt, ett validitetstestavsnitt och ett konceptuellt genomförbarhetsexempel. De generella analyserna fokuserar på problembilden för godstidsvärdes-konceptet, enkätundersökningen, godsmarknadstrender och multimodalitet.

I det generella analysavsnittet identifierades globala produktionsnätverk och distributionskedjor som viktiga trender med påverkan på godstransportmarknaden. Dessa trender användes sedan för att analysera hur väl tidsvärdes-konceptet kan spegla funktionaliteten på godstransportmarknaden.

Validitetstestavsnittet påvisade att det kan finnas vissa problem med godstidsvärdes-konceptet och att dessa möjligtvis beror på bristfällig datatillgänglighet och höga aggregationsnivåer.
Därför utfördes en genomförbarhetsstudie för ett konceptuellt exempelfall där datatillgängligheten var mycket god genom att data från distributionskedjorna har gjorts tillgängliga för externa analytiker. Därigenom testade genomförbarhetsstudien om det verkliga var bristfällig datatillgänglighet som var huvudorsaken till att godstidsvärdes-konceptet hade bristande validitet enligt validitetstestet. Resultatet var att datatillgången föreföll vara en viktig omständighet när godstidsvärdesmodeller ska utformas. Det fanns dock fortfarande potentiella nackdelar med användandet av godstidsvärdes-konceptet rörande testning och verifiering av modellen, detta på grund av komplexiteten hos storskaliga tillämpningar och komplexiteten förknippat med multimodala transporter.

De främsta problemen med godstidsvärde ansågs vara:

1. Valet av modell för att beskriva diskreta val
2. Hög aggregeringsnivå på grund av brist på tillgänglig data
3. Förklaringsvariabler
4. Identifiering av beslutsfattarna
5. Heterogena transportflöden

En uppsättning av rekommendationer till godstransportanalytiker utformades baserat på projektet hypotes som var:

*Modeller med godstidsvärde är inte tillförlitliga nog för att användas i praktiken.*

Rekommendationerna är:

- Den specifika modellen ska valideras och verifieras innan den används, vilket bör utföras för den specifika tillämpningen med en standardiserad metod för validering och verifiering såsom VV&A-metoden (som används av USA:s försvarsdepartement).

- Godsvärdes-konceptet är bäst lämpat för unimodala tillämpningar, men för multimodala tillämpningar kan det vara tillräckligt tillförlitligt om modellen är korrekt anpassad till komplexiteten i den verklighet som ska modelleras.

- Desto högre komplexitet ett modelleringsscenario innebär, desto mer data behövs. Därför behöver analytiker se till att en avvägning görs mellan komplexitet och datatillgänglighet på en nivå som överensstämmer med den efterfrågade noggrannheten.

- Låga aggregeringsnivåer gynnar modellens träffsäkerhet, men innebär en ökad mängd beräkningar. Därför är det bra att vara medveten om den ökade risken för beräkningsfel.

Sammanfattat är slutsatserna i rapporten att godstidsvärdes-konceptet ibland är den bästa tillgängliga metoden, men att svårigheter med att inhämta data påverkar träffsäkerheten hos modellerna negativt. Därutöver ansågs komplexiteten hos multimodala tillämpningar innebära att godstidsvärdes-konceptet har lägre giltighet än för unimodala tillämpningar.
# Table of Contents

Preface ......................................................................................................................................... i  
Abstract ..................................................................................................................................... iii  
Sammanfattning ......................................................................................................................... v  
Definitions................................................................................................................................... ix  

1. Introduction ........................................................................................................................ 1  
   1.1. Background.................................................................................................................. 1  
   1.2. Problem Description .................................................................................................... 2  
   1.3. Purpose and Research Questions ................................................................................. 4  
   1.4. Hypothesis ................................................................................................................... 4  
   1.5. Limitations ................................................................................................................... 4  
   1.6. Disposition ................................................................................................................... 5  

2. Overview of Freight Models .............................................................................................. 7  
   2.1. The Definition of a Model ........................................................................................... 7  
   2.2. Assessment and Selection of Models ........................................................................... 8  
   2.3. Modelling Perspectives in Freight and Supply Chains .............................................. 11  
   2.4. Transport Forecasting Methods ................................................................................. 13  
   2.5. Dynamic Models ........................................................................................................ 15  

3. Methodology and Methods ............................................................................................... 17  
   3.1. Methodology .............................................................................................................. 17  
   3.2. Methodological Justification ..................................................................................... 18  
   3.3. Information Retrieval Methods ................................................................................. 18  
   3.4. Analysis Methods ...................................................................................................... 20  
   3.5. Conclusion Method .................................................................................................... 20  

4. Trends and Characteristics of the Freight Market ............................................................ 21  
   4.1. The Historical Background of the Transport Modes ................................................. 21  
   4.2. Supply Chains ............................................................................................................ 25  
   4.3. Globalisation of Supply Chains ................................................................................. 28  
   4.4. Other Trends and Characteristics ............................................................................. 30  

5. Literature Review of Freight Value of Time .................................................................... 35  
   5.1. Definition of Value of Time ....................................................................................... 35  
   5.2. Models with Value of Time ....................................................................................... 35  
   5.3. Calculating Freight Value of Time ............................................................................ 38
**Definitions**

Some parts of the transportation and freight terminology are ambiguous, but of great importance for the general comprehension of this report. The definitions of these keywords are therefore presented here as they have been intended in this report.

<table>
<thead>
<tr>
<th><strong>Keyword</strong></th>
<th><strong>Definition</strong></th>
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<tbody>
<tr>
<td>Aggregation</td>
<td>When data from several groups or observations, are combined to create one single group from the initial groups or observations.</td>
</tr>
<tr>
<td>Global Commodity Chain/</td>
<td>Discourses or concepts that describe how supply chains are functioning and/or behaving when they become globalised. See chapter 4.3</td>
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<tr>
<td>Global Value Chain/</td>
<td></td>
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<tr>
<td>Global Production Network</td>
<td></td>
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<tr>
<td>Logistics</td>
<td>The management of product and material flows from point of origin to point of consumption.</td>
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<tr>
<td>Model</td>
<td>A representation of reality that to some extent behaves similarly.</td>
</tr>
<tr>
<td>Multimodal</td>
<td>Using more than one mode or mean of transportation.</td>
</tr>
<tr>
<td>Operational decision</td>
<td>Short term decision on how to carry out the day to day operation; e.g. route choice.</td>
</tr>
<tr>
<td>Strategic decision</td>
<td>Long term decision for determining the overall direction of an enterprise (usually 1-5+ years horizon); e.g. markets to operate on or type of services to offer.</td>
</tr>
<tr>
<td>Supply chain</td>
<td>All aspects of an enterprise such transportation, people, activities, resources and information connected together as a system.</td>
</tr>
<tr>
<td>Supply chain management</td>
<td>The management of the supply chain with the objective of improving the system performance.</td>
</tr>
<tr>
<td>Tactical decision</td>
<td>Medium term decision for determining what actions to take in order achieve the strategic goals of the enterprise (usually 6-12 month horizon); e.g. how to market the company's services, budgeting or allocation of company resources between projects.</td>
</tr>
<tr>
<td>Unimodal</td>
<td>Using only one mode or mean of transportation.</td>
</tr>
<tr>
<td>Value of Time</td>
<td>The concept where time (often transport time) is assigned a monetary value.</td>
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1. Introduction
Freight Value of Time is the topic of this report. The introduction chapter will therefore first presents a short background on modelling, freight and passenger transport, and Value of Time. Thereafter problem description, purpose, research questions, hypothesis, limitations and disposition are presented.

1.1. Background
Freight Value of Time can be of interest to readers of various backgrounds. Thus, a bit of background can be useful to put this modelling concept into context. The background presented in this section explains what a model is, how it relates to freight and introduces Value of Time.

1.1.1. What is Modelling?
In most business operations there is a certain methodology in use. The farmers have their methods of fertilising in order to get the largest return of a piece of land; the chefs have their methods of preparing a sauce without lumps and so on. However, there is a difference between the farmer’s objective of maximising the return of the land and the chef trying to make a lump free sauce. The chef’s sauce can be either lump free or not. The farmer on the other hand is attempting to maximize his return, likely using as little resources (money) and time as possible. It is therefore in this example easier to determine when the chef has succeeded than when the farmer has succeeded since the optimum return of the land is unknown. Furthermore, the benefit of the farmer’s effort is difficult to measure. The farmer is thus likely to compare with the outcome for others using a specific fertiliser and method. Consequently creating a prognosis for the different alternatives before choosing fertiliser.

Similarly to the farmer, various decision makers in the field of logistics have different alternatives to choose from. There are also a variety of methods at hand for making the choice between these alternatives. Often just as the farmer made a prognosis with his comparative method, the decision maker trying to choose between different logistics alternatives use comparative methods. However, since the various alternatives are very different in terms of their characteristics, benefits and deficits, it is useful to be able to translate the characteristics into a common member. Often the non-monetary factors or characteristics are translated into monetary terms. In logistics it is relatively easy to calculate the cost of the actual transport itself (e.g. the cost of the vehicle, the cost of the fuel and the cost of the labour). However other factors also inflict a cost. For instance a delay or the transport time the customer has to wait for the delivery. It is the valuation of such factors that complicates the decision making process. Particularly since, not only do you need to determine the transport time and the risk of a delay but also how these translate into a monetary cost. This is where different models i.e. the methods are used. A model is a simplified representation of reality used to create an understanding of reality (Ortuzar & Willumsen, 2011). Consequently the ability to model transportation and make reliable forecasts is a vital part of infrastructure planning, operational planning and policy development, since these are areas where it is costly to try something out without knowing how it will work.
Modelling in transportation as previously described is performed by a participating actor, but could also be performed by an external actor. These types of models, which aim at representing decisions at the individual level, are called disaggregate models. Moreover, modelling can also be performed on a larger scale in order to determine what decisions all actors as a whole will make in for instance a specific region, business sector or country. These types of models that aggregate data on behaviours of a population are called aggregate models. Disaggregate models are often more difficult to use for the analyst and require a higher detail of data, and are thus often not possible to use. They have therefore not been as common as aggregate models. (Ortuzar & Willumsen, 2011)

1.1.2. Freight and Passenger Transport

Transportation as a field of study can be divided into two main types; passenger transport and freight transport. The annual growth rate for the period 2000-2010 was 0.9% for both freight and passenger transport in EU27 area (Eurostat, 2012). Although the growth rate is similar in freight and passenger transport, more research has been devoted to developing models to passenger transport than to freight transport. Therefore there are many reliable models for modelling the choices that the travellers make in passenger transportation, but not as much in freight modelling (Lundberg, 2006). In freight modelling there has however been several models and methods developed quite recently that claim to be able to produce forecasts of the choices that freight customers make. (Tavasszy & Jong, 2013)

1.1.3. Freight Value of Time

Transport time is often referred to as being one of the most important cost factors in freight transport. Price is however often considered even more important (Lundberg, 2006). It is therefore from a theoretical standpoint interesting to know how decision makers make the decisions on trade-off between time and price. One concept that is commonly used in passenger transports is Value of Travel Time Savings. This is when the time saved is translated into money by using a translation rate called Value of Time or the Opportunity Cost of time, i.e. the cost of reducing transport time.

Numerous researchers have reviewed how the corresponding concept for freight, called Freight Value of Time (sometimes referred to as FVOT), ought to be determined and how it can be useful in evaluations and forecasts. For instance by using the Freight Value of Time to monetize the time savings of an infrastructure project in a Cost-Benefit analysis, choices can be made by authorities on what alternatives that are most beneficial (Feo-Valero, et al., 2011). The view on how to use Freight Value of Time when modelling is however rather fragmentised (Bates, 2012; Feo-Valero, et al., 2011; Kreutzberger, 2008).

1.2. Problem Description

In infrastructure and transport planning there is a need of knowing what the effects of an investment or decision will be (Bates, 2012). Which is what simulations and models are used for; it is therefore important that the models that are being used are reliable. The complexity of logistics chains and difficulties gathering statistics means that it is difficult both to create
the models and to test them against reality (Ortuzar & Willumsen, 2011). It is therefore important that also the reliability and thereby the validity of Value of Time which is relatively new and unexplored as a modelling concept needs is researched. There is however a rather extensive amount research available on the topic by now.

The main reason for conducting more research on whether Value of Time is a relevant concept for modelling freight could be that the opinions and research on Value of Time is rather fragmentised. Value of Time is referred to as a single method, model or concept in some literature, even though many variations exist:

- The valuations of time in freight vary for the same mode and goods. (Kreutzberger, 2008)
- It seems to be difficult to know what factors that influences freight decisions since there are many different opinions on which factors that are important. (Feo-Valero, et al., 2011; Kreutzberger, 2008; Lundberg, 2006)
- Reliability and variability are often also considered important factors that influence freight decisions (Feo-Valero, et al., 2011; Vierth, 2010). These factors are however not independent from each other or time (Bates, 2012). This complicates the discrete choice modelling.
- The correct selection of discrete choice model (the main category of models that utilise Value of Time) is influenced by relationships between decision makers (Bates, 2012), which in turn is difficult to identify (Feo-Valero, et al., 2011).

These unclarities show that to know the reliability of a model containing Value of Time is not very straightforward. The five reports referred to in the list, have all tried to clarify how either the concept of Value of Time functions or how decisions are made. The methods have mostly revolved around theoretical knowledge about the models themselves, stated preference questionnaires or quantitative testing.

Another way of bringing clarity to the reliability of the Value of time concept could be to look at what is being modelled and compare it to how it is modelled. In other words, there is also research on trends, characteristics and the functionality of the freight market. This research could be compared to the functionality of the models to see if the models are able to represent the freight market in a desirable way.

Furthermore, logistics (of which freight transport is a part) is becoming increasingly complex due to that multimodal transport and international transports are becoming more common (Rentzhog, 2014). Since this is a part of the reality, it also becomes interesting to know how well the Value of Time concept copes with these complexities. Multimodality is especially interesting since Freight Value of Time has been more common for unimodal applications and is said to be reliable for unimodal road transports (Feo-Valero, et al., 2011).
1.3. Purpose and Research Questions

The main purpose of this report is to examine the reliability of Value of Time for freight applications by comparing the functionality of the freight models using Value of Time with the functionality of the freight market.

The report therefore reviews the Freight Value of Time concept concerning how it can be used, how it is used and how it fits into the existing field of modelling. Furthermore, existing research about the freight market is reviewed concerning what major trends that exist and which the general characteristics are. Thereby, the reliability of the Freight Value of Time in different contexts can be better understood.

The academic contribution of this report is therefore the combining of existing knowledge in order to clarify the reliability of Value of Time as a modelling concept for freight.

The main research question, presented below is thus formulated with the objective of understanding the Freight Value of Time and its inner mechanics. It is also formulated to include the complexity of international freight.

*How can the Freight Value of Time concept fulfil the requirements that decision makers in international freight have on the reliability of the modelling outcome?*

To further the understanding of the differences between unimodal freight transport modelling and multimodal freight transport modelling; a second research question is introduced:

*What are the differences between the multimodal and the unimodal applications of Value of Time in terms of validity?*

1.4. Hypothesis

In addition to the research questions which focus on reviewing Value of Time, a hypothesis was introduced. The purpose of the hypothesis was to explore how future analyses using Value of Time ought to be like. Hence the following hypothesis:

*Models using Freight Value of Time are not reliable enough to be used in practise.*

1.5. Limitations

*No practical testing* – This report reviews Freight Value of Time as a modelling concept. The focus is on the theoretical suitability based on what functionality that can be expected to be needed by decision makers in reality and how the freight market functions. This delimitation is motivated by the lack of data and availability/access to models, as well as the overall goal of examining Freight Value of Time as a concept. In other words, evaluating separate models using the concept is not likely to produce general conclusions about the concept, but about the specific models chosen.

*Geographical coverage* – This report investigates an international occurrence, i.e. multimodal freight. However, because there are many variations in how freight and logistics is organised
around the world; it would not be possible to describe all of them in this report. Sweden has therefore been chosen as the main example due to good information availability and being a country which highly relies on trade (consequently being involved in international freight).

1.6. Disposition
After this first introduction chapter the disposition of the report is as follows:

2. Overview of Freight Models – The world of freight transport modelling is introduced.
3. Methodology and Methods – Explaining how the work behind this project relates to the purpose and research question of this.
4. Trends and Characteristics of the Freight Market – A literature study on freight, logistics and economic trends which was performed to find out the main trends of freight market and to put freight modelling into context concerning the world the models represent.
5. Literature Review of Freight Value of Time – Reviews different aspects of Value of Time and explaining how it relates to freight modelling.
7. Analysis – Analyses on chapters 4, 5 and 6, followed by analyses on multimodal freight modelling using Value of Time. The chapter is concluded with a feasibility study on Freight Value of Time with good data availability.
8. Discussion – Discussion about the analysis findings and the methods used in this project.
9. Conclusions – The research questions are followed up on and the hypothesis is used to devise a set of recommendations for freight analysts interested in Freight Value of Time.
10. Recommendations for Future Research – Based on lessons learnt and observations made throughout the project, a set of suggestions or recommendations for future research are presented.
2. Overview of Freight Models

The purpose of this chapter is to give an introduction to the world of transportation modelling and freight transportation modelling in particular. This is of importance because Value of Time is a part of a large modelling context and understanding Value of Time is not possible without a basic knowledge of transport modelling. Even though it is likely that the reader possesses this knowledge, also transportation modelling in general consists of many different viewpoints and opinions. Therefore this chapter can also be seen as a delimitation of how freight modelling will be viewed in this report.

The aim of this chapter is however not to present all available freight models, but to give an overview of common models and aspects of modelling. The first part of this chapter treats the basic definition of a model. A few ways of selecting and assessing models are then presented. This is of importance for the analysis chapter in this report, as well as to show that there are ways in which a model can be better or worse.

Thereafter the main perspectives of modelling in transportation (i.e. what models can be used for) are presented. Then, this chapter briefly introduces the four-step model, the discrete choice model and the activity based models. This is because the four-step model constitutes one of the most common methods for transportation forecasting. Discrete choice models are the possible component of the four step model which is most related to the concept of value of time (the topic of this report). Activity based models are introduced due to them criticising how transport is traditionally modelled. Finally the dynamic model is introduced to show that there is yet another dimension of modelling.

2.1. The Definition of a Model

A model is specific to a certain problem and are used to answer questions such as “what happens if we…” or “how should we do to achieve…”. Furthermore, a model can be either physical (e.g. building blocks or a miniature version) or abstract. The models used in freight modelling and transport modelling are usually the latter. Also the abstract model comes in many forms, e.g. a mental image or mathematical models. Abstract freight models are commonly mathematical models aiming at reproducing the behaviour of the freight system. (Ortuzar & Willumsen, 2011)

If the objective is to find out “what happens if we…” the model would be manipulated to see what happens, which gives insights to what could happen in reality if the same action is taken. Manipulations of a model can certainly give important insights about the model, but to be able to draw conclusions about reality based on a model requires knowledge of how the model represents reality.

A mathematical model of how hydrogen atoms behave might give a good representation of reality. However, the same mathematical model is unlikely to give a good representation of how lorry drivers select routes. Consequently, a specific model is only valid under certain conditions and those conditions are important to be aware of (Ortuzar & Willumsen, 2011).
Additionally to knowing what the model represents, it is also important to know how detailed the representation is and if it actually includes the aspects in question. Otherwise having a too detailed model can mean extra work and time. After all, a model is generally supposed to be simpler than reality in order to make it more understandable or provide the possibility of manipulation. If the model on the other hand has a too low detail level it might not actually behave realistically. Furthermore, in addition to aggregation level the detail level of a model is also described by the granularity of the data. An example of a granularity commonly considered in transport modelling is the time scale, i.e. seconds, minutes, hours, days etc. (Ortuzar & Willumsen, 2011). Granularity could be described as the unit of the aggregation level, or perhaps better; the granularity of the data describes the lowest possible aggregation level.

2.2. Assessment and Selection of Models

This section presents a few methods of assessing the quality of a model and an example of what can be considered when selecting what model to use.

2.2.1. An Effective Model

It can be difficult to determine what a good model is and if a model is good. Because a model is a way of simplifying one definition of a good model can be that it is effective. Turnquist (2006) defined the following four criteria for an effective model:

1. “An effective model is focused on producing an output that someone wants and knows how to use.”
2. “An effective model includes the important variables that describe how the system works and represents their interactions clearly and correctly.”
3. “An effective model operates in a way that is verifiable and understandable.”
4. “An effective model is based on data that can be provided, so that it can be calibrated and tested.”

2.2.2. Verification, Validation and Accreditation Plan

Another way of determining what a “good” model is to have a clear standardised methodology of determining how good a model is. A verification, validation and accreditation plan (VV&A-plan) is such a standardised method. VV&A-plans is the method used by the United States of America’s Department of Defense. They let an independent organisation perform such a plan when a model or simulation is used for a new application; referred to as a Modelling and Simulation Application (or MSA). This means that not only is the model approved, but it is approved to be used for the specific application. One part of this formal and standardised assessment is the “acceptability assessment phase”, where all aspects of the model are assessed in order to both make sure that the model is “good” but also to make sure that all aspects of the model are known. The purpose of this is to make sure that no modelling or simulation decisions have to be made ad hoc. The practical part of the acceptability assessment is to create and measure indicators. (Balci, et al., 2000)
The main indicator categories in this assessment are:

1. “Quality of the product”
2. “Quality of the process used in creating the product”
3. “Quality of the MSA project management”
4. “Quality of the MSA documentation that describes the product, process, and MSA developer”

The indicators in these categories are tested by verification and validation. Verification is answering the question on whether it is being done right and validation is answering question whether the right thing is being done. There are more than 100 techniques for verification and validation, and the selection at the Department of Defense is done based on a set of guidelines. The reason for the acceptability assessment is to determine whether the model is going to be accredited; the main indicators used are (Balci, et al., 2000):

- MSA Requirements Credibility
- MSA Application Credibility
- MSA Experimentations Credibility
- MSA Project Management Quality
- MSA Cost
- MSA Risk

An accreditation report is produced based on these indicators, and the verification and validation process. In the report there are not only assessments and descriptive text; also figures such as Figure 1 are used to present the VV&A-plan. The report is then sent by the independent organisation to all parties involved, including the analysts at the Department of Defense. The report is accompanied with an accreditation recommendation; where the recommendation is given at a statistical confidence level. This is the risk of the recommendation to either accredit the VV&A-plan falsely or to falsely not accredit it. (Balci, et al., 2000)

The focus of the VV&A-plan is to be certain that certain levels of standards are fulfilled by any model or simulation in use. (Author’s remark)
2.2.3. Model Selection Criteria

The criteria of Turnquist (2006) and the VV&A-plan can be useful when choosing a model, however many different aspects should be considered. Ortuzar & Willumsen (2011) summarized a set of possible selection criteria for general transport modelling as a nine point list of aspects to consider:

1. **Precision and accuracy required** – Accuracy being how well it replicates the reality and precision being the size of the unit used.
2. **The decision-making context** – If it is a strategic, tactical or operational decision
3. **Level of detail required** – In terms of geography, unit of analysis, behavioural responses and the handling of time (Author’s remark: Ortuzar & Willumsen are referring to the level of aggregation).
4. **The availability of suitable data**
5. **State of the art** – All models leave out something. Therefore consider what has been left out when choosing model.
6. **Resources available for the study** – Money, data, time, skill etc.
7. **Data processing requirements** – More data generally means that more work and time is needed.
8. **Levels of training and skill of the analyst**
9. **Modelling perspective and scope** – L, D, P, S, CM and PR; see Figure 2.

This list presented by Ortuzar & Willumsen is for transport modelling in general.
2.3. Modelling Perspectives in Freight and Supply Chains

The six perspectives shown in Figure 2 were originally presented by Ortuzar and Willumsen (2010) as an idealised way of showing the perspectives of transport modelling in general. However, the perspectives are also related to freight modelling. Some of the perspectives are nonetheless closer to supply chain management, than transport modelling. This sub-chapter will therefore aim at clarifying what type of decisions that fit into each of the six perspectives.

2.3.1. Activity Location

In the Activity Location modelling discipline, the objective is to determine a suitable location for an activity. According to von Thünen’s model of agricultural land use; the price of land and the cost of transportation are the most important factors determining the economic development. Von Thünen found that land was the most expensive closest to the market where the product was sold and that the products were worth more as well (Thünen, 1826). This shows that the ability to transport the products produced influences the success of the business. Consequently availability of infrastructure and logistical systems influences the location of business activities. However, what is considered good infrastructure varies depending on the activity in mind. (Bowersox, et al., 2013)
2.3.2. Demand Models
Demand modelling is the core element of much transportation forecasting. Not only is it useful for getting to know what the vehicle flows look like, but also for what the trade flows will look like. (Tavasszy & Jong, 2013)

The demand model can produce part of the input (i.e. the demand) for the other modelling perspective. For instance knowing the demand for transport is useful when determining the location of a business and needed when determining the performance.

*Note: Demand modelling is described further in chapter 2.4*

2.3.3. Performance Models
These models are dependent on the transport supply and demand models to produce transport system performance outputs. Such outputs can be for instance Level of Service (LOS) or Level of Expenditure. (Ortuzar & Willumsen, 2011)

The performance models can also be applied to the cost minimisation process and the supply chain as a whole. (Bowersox, et al., 2013)

2.3.4. Transport Supply Action
Modelling transport supply actions (in Figure 2 referred to as simply “supply actions”) is when the actions that the suppliers of infrastructure and logistics services are modelled. The actions taken by the suppliers of transport services are dependent on their objectives. For instance a government supplying infrastructure might want to maximise welfare, whereas a private company is likely to want to maximise their profit. (Ortuzar & Willumsen, 2011)

2.3.5. Cost Minimisation
Cost minimisation is closely related to the supply chain management discourse, where the aim of reducing costs was one of the initial drivers for introducing supply chain management at many companies. (Lavassani, et al., 2008)

Later on integrating production, transport and storage became the next trend in supply chain management. This was followed by the supply chains expanding and becoming global. Thereafter outsourcing of manufacturing and distribution, as well as outsourcing the supply chain management itself were the main trends. (Lavassani, et al., 2008)

2.3.6. Production Models
The production models are used to model the production processes with the aim of improving them or improving the understanding of the production processes. Production models are also a part of the supply chain management because the production is considered to influence the logistics and both are parts of the supply chain. (Bowersox, et al., 2013)
2.4. Transport Forecasting Methods

The methods described in this sub-chapter are focused on determining demand, and thereby determining how much transports there will be (often within a specific geographical area). The four-step model is a type of demand model which can use discrete choice models as sub-models. Modal-split is for instance commonly calculated with discrete choice models. Finally the activity based models constitute an alternative to the four-step model which has become very common in transportation modelling (Ortuzar & Willumsen, 2011).

2.4.1. The Four-Step Models

The four-step model is very common in transport demand modelling and while the input data can be rather disaggregate; the output is presented at an aggregate level. It consists of four steps for making transport forecasts:

- Trip generation
- Trip distribution
- Modal split
- Route Assignment

In freight demand modelling the generation of freight trips can be calculated based on the product flows, macro-economic models, the growth-factor method, zonal multiple linear regression or aggregate approaches based on factors such as warehouse area. The distribution is often calculated with a gravity model or linear programming. For determining modal split it is most common to use discrete choice modelling, and especially Multinomial Logit. There are several methods for performing route assignment, the simplest being the shortest path method. Also various constraints can be added to the assignment, e.g. route capacity, hills or low bridges. (Ortuzar & Willumsen, 2011)

Route assignment can also be performed for multimodal freight by for instance using a multimodal route-tree (Friedrich, et al., 2003):

- Generation of direct route legs between all origins and destinations using unimodal information.
- Generation of route legs between transfer points using a unimodal search.
- Construction of route tree.
- Calculation of generalised costs for all routes including transfer costs.
- Distribution of demand onto routes.

2.4.2. Discrete Choice Model

Using discrete choice models as an approach for forecasting freight movements is a disaggregate alternative that can be used to model freight demand. It is possible to include factors concerning the transport service (tariffs, times etc.), the goods, the market and the shipping firm. When used in a disaggregate manner the discrete choice models produce the probability for one individual to choose an alternative from a finite set of alternatives.
However, discrete choice models are also a common way of aggregating data. Based on the probabilities produced, an estimate of how many out of population that would choose each alternative can be calculated.

*Note: Discrete choice modelling is described further in chapter 5.2*

### 2.4.3. Activity Based Models

In contrast to the four-step model, activity based modelling theory says that life consists of a series of activities that generates trips. An activity is defined by Ortuzar and Willumsen (2011) as “a continuous interaction with the physical environment, a service or a person, within the same socio-spatial environment”. The transport between the activities is represented by (Ortuzar & Willumsen, 2011):

- Stages: a movement with one single mode
- Trips: a sequence of stages that goes between two activities
- Tours: a sequence of trips where the start and the end is the same location

Activity based models for passenger transport is less conventional than the four-step model, and is even less conventional in freight modelling. However activity based methodologies over all are not new in the field of freight and logistics. *Activity based costing* is a financial assessment method used by many companies and is when each activity in the company is assigned a cost. The main challenges with the method are to identify the activities, related expenses and the drivers of expense. (Bowersox, et al., 2013)

The benefits of using activity based modelling in freight modelling is that it is a disaggregate approach that is able to take behavioural aspects into account that the four-step model misses out on due to aggregation. (Maes, et al., 2010)

One specific type of activity based models that are becoming increasingly popular are the agent based models. The agent based model looks at the activities of each actor and it is possible to take changes in how they interact into account. Several trends that influence the increasing interest for agent based models have been identified according to Maes et al. (2010). These are:

- Supply chains being managed by demand
- Logistics is getting more time sensitive and complex
- Just-in-Time (JIT)
- No single actor has knowledge of the whole supply chain

These trends leads to an interest in the details of the whole supply chain, and are thus modelled microscopically. By creating an understanding of the effects of decisions made by the individual decision makers it is possible to improve the quality of the forecasts (Maes, et al., 2010). However the identification of the different actors and their decisions is of importance for the outcome. (Maes, et al., 2010)
2.5. Dynamic Models

A dynamic model means that it changes over time (Powell, et al., 2005). This implies that the model adapts to different circumstances or the data available. When talking about dynamic decision making, typically one refers to sequential decisions which depend on each other. Therefore, since the theory of discrete choice models views decision making as discrete and not continuous; dynamic decision making needs extra consideration in order for the dependencies to be taken into account.

However, it is still uncommon to have dynamic freight models other than for route assignment or routing where vehicle routes are changed during operation (Rodrique, et al., 2009). It is possible to develop dynamic transport models according to Powell et al. (2005) who suggest that a dynamic transport model should focus on the allocation of resources. For instance the resources in a road freight operation would be the drivers, the vehicle and the goods. Each resource would also have different characteristics such as the destination of the goods, the home of the driver, when the drivers shift ends, etc. In the model a value function is used with the aim of maximising the long term profit of the resources. E.g. the driver wants to make as much money as possible. Time would be a factor included in the value function. (Powell, et al., 2005)

Even though, dynamic modelling is not very common in many cases; the dynamics does often exist in reality. Therefore these “dynamic relationships” are often simplified or perhaps estimated through non-dynamic methods. (Arcidiacono & Ellickson, 2011)

Note: Dynamic modelling in the context of discrete choice modelling is described further in chapter 5.2.3
3. Methodology and Methods

The overall methodology of this project has been to combine existing research from various fields and to analyse them jointly. This chapter will describe the methodological approach and the respective methods used in the different sections of the report.

3.1. Methodology

![Diagram](image)

Figure 3. The methodology of the report as a flow chart, displaying how the main chapters of this report are connected.
3.2. Methodological Justification

The project has been aiming at exploring and explaining Freight Value of Time, as well as describing the greater context of freight.

This report is therefore to be considered a qualitative research report where the main research question is of the type “how can...”. Therefore the main methods selected were also qualitative methods where information, findings and opinions were reviewed. This differs from a quantitative method where the question researched would have been “how much” or “how often”, and the methods applied would have been practical testing or experiments. (Nyberg & Tidström, 2012)

3.3. Information Retrieval Methods

The first step of this report was to put Value of Time into a greater modelling context by studying literature on transport modelling and freight transport modelling in general. This was done to create an overview of models available, and to highlight the complexity and width of the field.

Thereafter, since the aim of this report is to answer the qualitative research questions:

*How can the Freight Value of Time concept fulfil the requirements that decision makers in international freight have on the reliability of the modelling outcome?*

And

*What are the differences between the multimodal and the unimodal applications of Value of Time in terms of validity and effectiveness?*

It was reasonable to find out what Value of Time is. Therefore the first step was to perform a literature review to see what this concept is about and how it can be used. Because Value of Time as a method in freight is rather new, the availability of practical knowledge is limited. The focus of the literature review was thus on what researchers has found out about the method and how they define it. This gives an insight to what a potential analyst can find out about Freight Value of Time when interested in applying it in reality.

However, because the characteristics of freight in reality influences how well the model functions a separate literature review was performed on this topic, aiming at identifying trends and characteristics of the freight market. As a first step a conference on trends and inspiration about freight transports was attended, the conference Godsetdagen was held in Stockholm February 6th 2014. The conference was used as mean of finding sources for the literature review since the speakers referred the audience to where information could be retrieved.

These sources were studied together with additional research and statistics sources in order to identify what major global trends and characteristics that influence freight transport. This knowledge was thereafter used as background for determining what requirements a freight analyst is likely to have on their model since this is what they attempt to model. The literature reviews are altogether based on a little over 30 separate sources.
Additionally to the two literature studies a survey was sent out to 30 international and 30 Swedish actors on the freight market, with only six Swedish actors answering and none of the international.

The survey was performed since knowledge about how freight modelling is used by practitioners, as well as how and what they use modelling for, could be useful for determining what requirements the decision makers actually have. The survey consisted of 22 questions which aimed at determining:

- Type of companies and businesses.
- What the respondents function at the company was.
- What their operation was like in terms of modes and cargo.
- If and how they used models on strategic, tactical and operational levels respectively.
- If they were using time, reliability or variability based models.
- How difficult they found data retrieval for modelling purposes.

The questions were designed to measure the aspects that were of interest to this report, i.e. primarily how they are modelling today, and secondarily what do they want to model. Both with respect to what kind of company and business it is. Therefore a large share of the questions aims at characterising the companies.

The exact questions and survey form can be seen in Appendix A. Normally circa 40 respondents are needed to be able to draw high quality conclusions from the material. However, if the survey is performed as thorough interviews as few as 8 to 10 respondents can be sufficient (Nyberg & Tidström, 2012). Since the amount of respondents was below both of these limits; no generalised conclusions were drawn and no statistical testing performed. However, the survey was deemed suitable as an exploratory survey for exemplifying how a random Swedish actor in freight use modelling and make decisions. The survey results were therefore used as examples of decision making.

The recipients of the survey were selected by recommendation from others active in the field, based on their work or academic record. Most of the recipients were found on the internet through databases with contact information or through company websites. The survey was performed anonymously in the sense that it is not possible for the author of this report who also conducted the survey to know how answered the survey and who did not.

The survey was sent to the recipients three times. The first two times with a general email message and the last time with a personalised email containing the name of the recipient. The alteration of the last email was due to the importance of personal contact which has been highlighted by researchers that has performed similar surveys in the past (Lundberg, 2006).

The main contribution of the survey consequently became to exemplify the differences between how modelling is portrayed in research and how it can be viewed by freight actors in practice.
3.4. Analysis Methods

3.4.1. General Analysis

By identifying issues that are unique to freight as compared with Value of Time in passenger transport, possible shortcomings of Value of Time in freight were identified. Thereafter the survey was briefly analysed based on how the outcome compares to other research.

Thereafter the main trends were identified and analysed through the creation of a simple example that incorporated the trends identified. The insights on Value of Time were combined with the identified trends to analyse how Value of Time as a modelling concept copes with the trends and characteristics of the freight market. Because the second research question was related to difficulties with modelling multimodal freight with Value of time, the general analysis section finishes with an analysis of this.

3.4.2. Validity Test

In the chapter, Overview of Freight Models, a set of four criteria for an effective model were presented (Turnquist, 2006). These criteria were used as method of testing if using Value of Time for freight is a valid modelling concept.

3.4.3. Conceptual Feasibility Example

Based on the fulfilment of the criteria and the issues identified with adapting Value of Time to freight, a conceptual feasibility example was created to test if Value of Time would be feasible as a method for modelling freight if the main issues would be resolved.

The testing was performed on a conceptual desk modelling exercise. Where the modelling case was conceptually constructed based on the previous analyses and based on what data that is reasonable to assume to be available in an ideal case. Thereafter the modelling scenario was theoretically walked through and analysed simultaneously. The actual testing was performed using the same criteria as in chapter 7.2.

3.5. Conclusion Method

The methods, outcomes and findings of the analysis are discussed in the Discussion chapter, where a few conclusions are formed. The conclusions are stated in the Conclusion chapter.
4. Trends and Characteristics of the Freight Market
The global freight transport sector as well as many national and regional freight transport sectors are growing and continuously changing, both through smaller developments and through larger structural changes. This chapter will treat and try to identify these changes with the objective of identifying which of these changes that could be useful to include into freight models.

4.1. The Historical Background of the Transport Modes
The possibility to transport goods by combining different modes of transportation is not a new occurrence. It has been possible since when humans first tried to use animals, boats etc. to transport themselves. However since the emergence of ships, railways, motor vehicles for the roads and aircrafts did not occur directly at once, there have been periods where one mode has been the most preferred one. (Björk, et al., 2008)

4.1.1. On Water
The boat was the first vehicle/mode that made it possible to transport goods and passengers really long distances, except for perhaps walking or using animals. Because the boats and ships obviously were not able to transport goods and passengers on land, ports were built. Around these ports villages, towns and cities eventually formed. Nonetheless there was also a need for more modes at this time, such as using horses, manpower or smaller water vessels. Human settlements are therefore even today often found nearby large bodies of water or rivers (Björk, et al., 2008). Transportation on water has the benefit over most other modes that the infrastructure is already there. However, the water “infrastructure” that occurs naturally rarely form the most direct route. This issue was solved by constructing manmade waterways, i.e. channels. These inland waterways which include rivers, is often distinguished as a separate mode than deep sea transport/cargo/freight. Inland waterways are more restricted than deep sea (often seemingly unrestricted) regarding what vessels that are able to pass. This has led to that different vessels are used for transportation on inland waterways and on the deep sea. (Rodrigue, et al., 2009)

Nonetheless, there are also restrictions for the deep sea vessels. The port themselves pose a restrictions on what ships that are able to service the port. There are several factors that determine what ships are able to service a certain port. The most basic is probably the depth which determines how large ships that are possible to accommodate. Also length and width can determine if a ship is able to service the port. Furthermore, the transhipment facilities determine whether or not the specific ship and it goods is possible to handle. Some ports might for instance not handle bulk goods or tempered goods. The ships might also come across physical restriction during the transportation itself. For inland waterway transportation the size and depth of the channel or river is the obvious restriction, but also of deep sea transportation such restrictions exists. The Suez Channel and the Panama Channel are probably the two most famous “restrictions”. The size of these two time saving passages has
led to two standards in ship size. Namely Panamax and Suezmax, which denominates the maximum size of the ships which are able to pass the respective channel. These standards have consequently also become standards for ports. (Rodrigue, et al., 2009)

These are physical restrictions and equipment that determine whether or not it is possible handle a certain ship, there are however also other factors that might render a port as more or less preferable, i.e. the supporting infrastructure and availability of logistics solutions. (Rodrigue, et al., 2009)

In the last decades deep sea cargo has become very important for the intercontinental trade that has been increasing. The container ship traffic grew with 7 % during 2011, and has grown with an average of 8.9 % between 1980 and 2011. (Boeing, 2012)

![Figure 4. The historical development of different types of maritime cargo. (Boeing, 2012)](image)

During the last 30 years the containerization process where goods is transported in standardised units called containers has increased its market share substantially as seen in Figure 4. However, measured in tons, more goods is transported by both as tanker goods, bulk goods and non-containerised dry cargo.

4.1.2. On Rail

The next major invention was the steam engine or steam locomotive. Even though the railway itself might be seen as the important invention enabling long distance transportation of heavy goods, it was when it was motorised it became of major importance for longer distances. The pattern of where urban settlements were formed, previously seen with ports, was now repeated. Towns and villages grew around the stations along the railways. New major cities were often formed at railroad junctions. (Björk, et al., 2008)
When the railways were first introduced, they acted as both an important mean of passenger transport and freight transport. The trains were able to transport passengers long distances faster than both the horse and the ship. Nonetheless, railway and deep sea transportation were not absolute competitors. Two main factors for this was that ships where still the only way of travelling or transporting goods between continents and that railway became national ventures (Fröidh, et al., 2011). The first factor is easily comprehensible since there is not even today possible to travel on land intercontinentally. The second factor needs some background details as of how the railways emerged.

It commonly started out with either private railways that where constructed by companies that either saw the need for transporting their goods, by companies wanting to make money by transporting people or by national governments. At first the operations was very much unregulated with low transport flows. Accidents, higher speed, and more complex operation in the form of for instance signalling and shunting led the need of standardisation. At this time the different countries went for different regulations, signalling systems, rail gauges and later on also different electrical supply systems when the railway was electrified. These national standardisation efforts have led to a fragmentation in international standards. In large countries such as United States of America the railway was and is able to cover a larger area with the same train. On the other hand in especially Europe, where there are many different smaller nations this fragmentation complicates the possibilities of long distance cross-border railway transportation. (Fröidh, et al., 2011)

There is however an ongoing effort in Europe and the European Union to transition to a common standard through the ERTMS project. Not only is there a wide spread of rail standards across the globe, there is also a wide variation in how the railways are used and how they have developed. In the United States of America the railways are mostly used for freight. While in countries such as Japan and France where they early built high speed railways, the railways are also a common mean of long distance passenger transport. Some countries such as Sweden closed and demolished a lot of railway in the mid 1900’s because it was seen as abundant when the car and airplane became competitive for passenger transport, and the heavy goods vehicles for goods. Some major railway lines were kept due to their importance for transporting heavy goods and some for the combined goods and passenger transport. (Fröidh, et al., 2011)

The emergence of high speed rail transport has however since the 1950’s once again made railways attractive as a passenger transport. This transition has occurred at different time in different countries depending on national characteristics. It is often said that there is a certain distance where high speed train is most profitable, depending on travelling patterns and the size of the countries there has thus been a varying interest for building high speed railways. Additionally, the interest of rail freight has also changed over time. Recently a growing concern of the environmental effects of road transports (HGV) has led to an increased interest in railways for freight transportation. In many countries the growing interest in both freight and passenger transport at the same time on the railway has led to capacity issues which have given rail transport a bad reputation for not being reliable. (Fröidh, et al., 2011)
Albeit not being able to compete with intercontinental deep sea shipping, the railways successfully competed with the inland water ways. This led to many inland water ways losing their previous importance.

4.1.3. On the Road

Soon after the car was invented, the truck followed. Similarly as the car powered by fossil fuels became increasingly popular during the 20th century, the truck or lorry also became increasingly popular for transporting goods. Both the car and the truck had the advantage of being very flexible compared to both transport on water and rail. Although both had competed with horse transportation, the horse had still been vital for transportation to and from the port and station respectively. Thus a major advantage of the car and truck was the ability to offer door-to-door transportation both for short distances such as the horse but also for longer distances where the train had previously been the preferred choice. (Rodrigue, et al., 2009)

This meant that the horse in many countries went from a mean of transportation to a mean of recreation. It was also the start of the previously mentioned shift from rail transport to road transport. The flexibility of the car also led to the previous trend of aggregated settlements at important transport nodes to be discontinued. Instead many urban areas started to sprawl out and the average distance travelled per day increased. In these sprawled urban areas, goods transport by rail played a smaller part because road transport door-to-door was seen as a better alternative. (Rodrigue, et al., 2009)

4.1.4. In the Air

The invention of the airplane is often seen as an important step in long distance passenger transport. By shortening the travel time from days or weeks for intercontinental travels to hours, air travel was able to compete with passenger transport by sea to the extent where almost no passengers today travel by ship intercontinentally. The importance of aircrafts in freight transportation is not as obvious. Transportation of military equipment and resources belong to the earliest large scale freight transport operations.

Nonetheless, airfreight has been important for long time. One important function has been airmail, being able to send letters or small packages quickly between continents or countries. Although the importance of sending letters might have decreased since the internet emerged, the ability to send packages has become increasingly important and widespread. Due to the growth of internet shopping more and more packages are sent over long distances. Today it is estimated that 30% of the value of the goods transported globally is transported by air transport. (Jordahn, 2014)

Air transport has had an advantage over rail transport when it comes to the international transports even as the speed of trains has increased, by not having a fragmented regulation (Fröidh, et al., 2011). Air transport has functioned very well when it comes to international travel and transports. One reason can be that just as for transportation on water, no transportation infrastructure is needed between the nodes. Also when air transport first
emerged there was a time of larger international collaboration than when the railways were regulated (Fröidh, et al., 2011).

One trend in air cargo transport is that the goods are getting heavier. In 1992 the average weight of an international express delivery was 2.7 kg, compared to 6.2 kg in 2011. Another trend is that Asia is becoming an increasingly important market for air trade. Boeing (2012) estimates that 51.5 % of the world air trade was to or from Asia and that in 2031 the same Figure will have increased to 59.9 %. (Boeing, 2012)

4.1.5. Pipeline
Transportation through pipelines is a very important transport mode in many parts of the world used for transporting gas and liquids. In the USA 17% of the ton/km are by pipeline. Fresh water, sewage, gases and liquid fuels are the most common goods transported through pipelines. Even though it is an important transport mode the characteristics of pipelines are diametrically different from the other modes since it is continuous transportation and not vehicular. (Rodrigue, et al., 2009)

4.2. Supply Chains
Supply Chains can simplistically be seen as all aspects of an enterprise including transportation connected together as a system. The aim of this section of the report is to provide an introduction to the field of supply chains and supply chain management, and show how modelling within the field can differ from traditional transport modelling. This section does therefore not aim at describing everything related to supply chains and supply chain management, but to introduce the richness and some of the advantages of supply chain management. In order not to jeopardise describing supply chain management in a too strict manner, the focus will be on the possibilities of supply chain management for transportation. Thereby, potential contributions that supply chain management have given and can give to freight transport modelling are showcased.

4.2.1. Freight Transport and Logistics in Supply Chains
Traditionally the production industry related logistics were simpler than today. Raw materials or basic components were transported to the factory where the products were manufactured or assembled. Thereafter the products were transported to customers or retailers. Even earlier the only major transports needed were the delivery of the finished product since the production was located close by the raw materials, this was most common in pre-industrial times. (Rodrigue, et al., 2009)

A supply chain is a system consisting of companies, people, activities and resources aiming at producing, delivering and selling a product or service to a customer. Consequently the ability to transport resources and products becomes essential for the supply chain to function. Transport is often in supply chain management defined as the movement of the goods, while logistics is to manage the movements and positioning of inventory. The objective of logistics
is that the inventory ends up at the right place at the right time to the lowest cost, but logistics also include for instance packaging and storage. (Bowersox, et al., 2013)

With the emergence of large supply chains especially in combination with outsourcing of parts of the production a lot of semi-finished products need to be transported. Consequently there are more transports needed than if all the production is done by one company at one location. (Rodrigue, et al., 2009)

4.2.2. Supply Chain Management

Supply chain management can be described as a way of improving the performance of an enterprise. Supply chain management is a broad term that includes a wide range of aspects and possible components. A few examples of what supply chain management can be about are: communication, strategies, tactics, optimisation, organisation, downsizing, outsourcing, integration, simulation, Lean-manufacturing, Just-in-Time, financial planning etc. Consequently, supply chain management cannot be viewed as a single method, nor can supply chains be viewed as a single model of how an enterprise is organised. (Harrison, et al., 2004)

When using supply chain management in order to improve the performance of a supply chain; the focus is often on the total performance. In other words the overall goal is not to increase the performance of each subsystem, but improve the performance of the supply chain as a whole. However, this often means that the performance of the subsystems needs to be improved. For instance if Just-in-Time is introduced; it could include improvements to the transport system, production system, sales etc. (Rodrigue, et al., 2009)

The ideas of improving the overall performance of enterprises through supply chain management-like methods are not as new as the possibilities of realising these ideas. There are a wide range of methods for supply chain management. A distinction can be made between the strategic supply chain design methods and the tactical/operational supply chain execution methods. Within these two method families there are in turn several types of analyses or methods depending on the purpose. A few examples are:

Supply chain design:
- Manufacturing Strategy
- Supply Base Design
- Distribution Strategy
- Outsourcing
- New Product and Process Design

Supply chain execution:
- Inventory Management
- Managing Suppliers

4.2.3. An Overview of Supply Chain Models and Systems

In supply chain modelling, in contrast to transport modelling not only mathematical models are being used. A common model that is used in supply chain management consists of a line diagram where actors and actions in the supply chain are linked together. However, since supply chains integrates different logistical systems, firms, actors and productions together
and there are thus many different models used in the different integrated parts. (Bowersox, et al., 2013)

Information technology systems in supply chain management are referred to as “supply chain information systems” and can be divided into four functionality levels (Bowersox, et al., 2013):

- Strategic planning
- Decision analysis
- Management control
- Transaction systems

The transaction systems are not models per say since there is no manipulation. However, they produce data about orders, inventory, pricing etc. that can be used as input data for various models. The management control function is where the performance of the supply chain is measured. This is similar to what for transportation has previously been referred to as performance models. Common performance-measurements in supply chain management are cost, service and productivity. These models can be used to identify different constraints and unused resources. (Bowersox, et al., 2013)

The decision analysis includes vehicle routing, vehicle management, inventory levels, inventory management, resource allocation, network/facility location and vertical integration vs. outsourcing. It is at this level where different alternatives are compared and operational decisions are made. The strategic planning level is where decisions on the design of the supply chain are made. The reason for strategic planning in supply chains is to achieve competitive advantages. (Bowersox, et al., 2013)

One type of computer programs that are common in supply chain management are the Enterprise Resource Planning systems (ERP). The ERP system can monitor current and historical data from all different stages of the supply chain. ERP systems are used to monitor, and facilitate the business resources and business commitments in real-time. Since logistics is one of the resources integrated into the ERP systems, also logistics decisions are made and evaluated in real-time. This is closely related to the emergence of Just-in-Time and the “pull” business models. Namely, that instead of producing products and then selling them (“push” business model), the product is sold before it is produced. (Bowersox, et al., 2013)

The pull business models do not need the same forecasting efforts as when trying to anticipate future demand of a product, which is the case in a push business model. Another benefit is that the costs of storage are reduced and that there is no risk of not being able to sell the current inventory. However, the requirements on the supply chains efficiency and reliability increase. It is essential that the different parts of the supply chain are well integrated and functioning. For instance a production stop in supply chain using the pull business model will lead to a failure in delivering. (Bowersox, et al., 2013)
4.3. Globalisation of Supply Chains

A major structural change has occurred in the last decades concerning how transports relate to production, and this is often referred to as Global Production Networks (GPNs) or Global Value Chains (GVCs). GPN/GVC products are not made at one single factory location, but different parts or steps of the production process are made or take place at different locations specialised in that part or step. (Sakuda & Fleury, 2012)

These three discourses or concepts, all describe the phenomenon of supply chains being more and more globalised. It can be useful to know of them when modelling freight since these are also a kind of freight models, albeit non-mathematical.

4.3.1. Global Commodity Chains

The two concepts of Global Production Networks (GPNs) and Global Value Chains (GVCs) have their background in the concept of Global Commodity Chains (GCCs), and all three are describing different aspects of globalisation in trade. A commodity chain is a network with production, trade and services included; it covers the steps from raw material through the production steps, all the way to the delivery of the product. The representation of a commodity chain is commonly done by links and nodes. The links often being transfers or transactions, and the nodes is where value is added through production, services, etc. The global in GCC denotes that the commodity chain covers a geographically larger area by being international. (Rodrigue, et al., 2009)

4.3.2. Global Value Chains

The GVC on the other hand also explores four basic dimensions; input-output structure, geographical consideration, governance structure and institutional context. This addition of four dimensions, is how GVCs also include upgrading or in other words “how producers shift between different stages of the chain” (Sakuda & Fleury, 2012). By including the four basic dimensions, GVC receives a dynamic view with a focus on changes in the chain. Input-output allows for identification of what activities that is included in the chain and by taking governance structure into account it is possible to describe a variety of different production structures. Institutional context as a dimension allows for analysis on different detail levels. (Sakuda & Fleury, 2012)

Concerning the governance structure, five different types have been identified. The difference is in how business is coordinated. See Figure 5.
4.3.3. Global Production Networks

Unlike in GCCs and GVCs, Global Production Networks does not have a chain approach. GPN advocates criticise GCC and GVC for being limited in what configurations that are possible and that the focus is on the governance, meaning that other actors are not treated. GPNs instead have a multi-layered and multi-dimensional approach where also diagonal, horizontal and vertical relationships are allowed. (Sakuda & Fleury, 2012)

GNPs have a focus on (Sakuda & Fleury, 2012):

- “Emphasizes the relations and agency in heterogeneous networks”
- “Rejects artificial dualisms (global/local, structure/agency dichotomies)”
- “Conceptualizes networks as hybrid collectivises of human and non-human agents “

Even though GPNs are said to be better at representing decision making realistically than GVCs, some claim that GVCs are good enough at producing “a snapshot” of what they represent for the representation to be useful. Another critique of GVCs has been that flows are unidirectional; however this critique has been highly disputed by GVC promoters. Some promoting does however hold this as a main benefit of GPNs. (Sakuda & Fleury, 2012)

4.3.4. The Background to the Trend

Main drivers for this change are increased specialisation, improved information exchange and better availability of transport services. Information exchange has improved in the last decades due to the emergence of IT and it is now easier to find trading partners and transport
solutions than before. Furthermore transport has become cheaper, which makes it possible to have large Global Production Networks with many different locations and long transport distances. (Rodrigue, et al., 2009)

The specialisation means that different countries, regions and companies are better than others at a specific task, and that it therefore makes sense for them to specialise in this specific task and purchase the rest of the tasks from others specialised in other tasks. The basics for this are found in David Ricardo’s book *On the Principals of Political Economy and Taxation* from 1817, where he presented the idea of Comparative Advantage as a reason for specialisation. Summarised his idea was that countries should specialise in those activities that they have the largest advantage over their neighbouring countries. This way the economies will grow through export and international trade of the surpluses. (Ricardo, 1817)

Some however claim that David Ricardo’s concept is no longer relevant, with one argument being that western countries cannot compete with low-wage countries. These arguments can however also be seen as arguments for the concept of Comparative Advantage. Krugman (1998) argues that the arguments that the arguments on Ricardo’s concept being invalid are invalid since it is likely that when productivity improves in these low-wage countries, the wages will also increase. (Krugman, 1998)

This because the notion of Comparative Advantage itself is, that even though one might be better than others at producing everything it is still beneficial to specialise in what you are best at and trade the surplus for what you are not as good at producing. (Author’s reasoning)

How common specialisation and Production Networks really are, is probably difficult to gather exact statistics on due to complexity. However, some say that today 80% of the trade is within the production networks and that only 20% is between producer and consumer. Furthermore, some products are claimed to have more transport steps in the production process than there are parts in the finished product. (Rentzhog, 2014)

4.4. Other Trends and Characteristics

The supply chain and globalisation trends are large and general trends that influence many aspects of freight transportation. There are however also many other smaller, but still important trends and characteristics of the freight market. This section will therefore describe a few of them in order to present a wider picture of freight.

4.4.1. The Current Freight Characteristics and Trends of the Modes

The different modes have different characteristics and which that is most preferable depends partially on the distance as is shown in the traditional schematic distance-cost diagram in Figure 6.
This selection model is of course very simplistic and can be considered to only have time and cost as the only factors included in the decision model. In general freight on water is said to be the cheapest, followed by rail, road and air as shown in Figure 7.

In Figure 6 where the modes are shown to have theoretical optimum distances, the possibility of multimodal transport becomes evident. If transloading costs are low, it would be possible to perform a long distance transport faster than maritime and cheaper than road. (Author’s remark)
Consequently it becomes useful to have a basic understanding of the difference between transshipment and transloading. Transloading is the activity that is carried out at a transport hub when goods are moved from one vehicle/mode to another. Transshipment on the other hand depicts that the shipment is transported to an intermediate location before being shipped to the final location. (Rodrigue, et al., 2009)

4.4.2. The Actors and Activities in Freight and Logistics

Traditionally in the field of logistics the actors have been divided into different groups depending what function they have. Shippers are the ones that want to send something and thus generate a demand for transportation. The carriers are the ones that transport what the shipper wants to send and they thus constitute the transport service supply. These two actors are often seen as the two major actors in logistics. There are however other constellations of actors that participate in logistics. (Rodrigue, et al., 2009)

There could for instance be more than one carrier where the first leg of the transport is by one mode and the second leg is by another mode. This basic example where more than one mode is used is called multimodal transports. Another notion is intermodal transport; in this case the goods are transported in a standardised loading unit e.g. a container. Thus, transportation by pipeline is excluded from the notion. A third notion called combined transport includes maritime, rail and road transport, but has the condition that the longest leg of the journey has to be on either inland waterway, deep sea or rail. Therefore only a short part of the transportation, most commonly in the beginning or the end is allowed to be on road. (UN/EC, 2001)

Figure 8. Combined transport is done with mainly rail and/or maritime, with the last and shortest leg to the destination on road. Multimodal is when more than one mode is used. In Intermodal transport, standardised loading units are used.
In the case of any multimodal transportation there is a need of moving the transported goods between the modes. Consequently there is often the need for one more actor, i.e. a transshipment facility. Ports, freight terminals or shunting yards are examples of common transshipment locations. (UN/EC, 2001)

It is possible to be both owner and operator, and to combine for instance operator with being a forwarder (Bowersox, et al., 2013). However, multiple responsibilities at a company does not necessarily give any implications on how many decision makers there are. How decisions are made still varies.

Policy makers such as national governments, local governments, international organisations, unions etc. are also actors on the freight market that make important decisions influencing all other actors (Rodrigue, et al., 2009). Furthermore, the infrastructure owners are also making decisions influencing other actors (e.g. when to do maintenance or where to invest).

4.4.3. Transport Solutions Offered

Logistics services are increasingly being outsourced and are often being offered as package solution where the shipper contacts a forwarder that organises all of the transportation door to door. When such services are offered by the large forwarders that also are transport operators and transshipment facility operators, they are able to do much of the transportation themselves. Yet they do sub-contract transportation to other forwarders or operators. (Bowersox, et al., 2013)

4.4.4. Information Exchange and IT

Supply chain management, transport modelling, freight forwarding etc. as it functions today heavily relies on computers and IT. Not only are computers enabling more advanced forecasts and models, but they are also important for sharing information within companies and between companies. By enabling data gathering in real time and data sharing in real time, it is possible for various decision makers in logistics to make decisions they would not be able to make without this information sharing. It is also possible to relieve the decision makers of the decision making by automating logistics. Computers, advanced algorithms and information sharing make it possible to automatically sort for instance packages so that they end up on the optimum transport vehicle. (Bowersox, et al., 2013)

4.4.5. Taxes, Fees and Subsidies

Public policies are an important factor that influences the choices made in freight and logistics. For instance by implementing taxes on fossil fuels, transports tend to shift from road transport to water or rail transport. This is because road transport consumes fuel, and rail is possible to run on electricity. (Rodrigue, et al., 2009)

Similar results can be obtained by implementing a road taxes or fees for trucks. The LKW-maut in Germany is an example of road toll on heavy goods vehicles and has not only led to a modal-shift, but also to route changes avoiding the tolls. (Quoy & Walter, 2005)
4.4.6. Harmonisation

Policies are also important influences on how infrastructure develops. An example of policies aimed at influencing infrastructure development is the European Union’s attempts of harmonising European transport legislations and developments. The Lisbon Treaty for instance contains recognition of success of improving the interoperability and harmonisation of standards on the railway. This work is however not finished. (Soave, 2009)

This trend of harmonisation can also be seen in other fields such as port developments where the Panamax and Suezmax standards lead to harmonisation (Rodrigue, et al., 2009).
5. Literature Review of Freight Value of Time

5.1. Definition of Value of Time

Value of Time is the rate at which time is translated into monetary cost. It is used when determining demand. The demand can thereafter be used for various modelling purposes. Freight Value of Time is thus the rate which transport time for goods is translated into a monetary cost. In this chapter Freight Value of Time will be further described with respect to how it is calculated and used according to researchers.

An important note is that the willingness to pay for a reduction in time does not have to be the same as the willingness to accept an increase in transport time (Bates, 2012).

5.2. Models with Value of Time

Since Value of Time itself is not a single model but a concept that is included in various models, it is useful to be familiar with these models. This chapter will therefore introduce these models. Value of Time is one part of a utility function and discrete choice models are used to calculate probabilities of choosing alternatives with different utilities. (Ortuzar & Willumsen, 2011)

5.2.1. Utility Function Models

Bates (2012) identifies three types of utility models: Base, Mean-dispersion and Scheduling models. This is what often referred to as discrete choice modelling. In this discipline of modelling the decision makers are considered to be selecting an option from a set of alternatives. This methodology is common for determining modal split in passenger transport as well as determining the share of people that choose different transport alternatives.

The first step is to create the alternatives that the decision makers choose from. This is where the Base, Mean-dispersion and Scheduling models are used. They are different kinds of utility functions. The output of all three is a utility and there is a basic assumption that all decision makers attempt to maximise their utility.

The base model only takes a few factors into account such as time and cost (Bates, 2012):

\[ U_x = \beta_C \times C + \beta_T \times T \]  \hspace{1cm} [5.1]

\( U_x \) = The utility of alternative x  
\( \beta_C \) & \( \beta_T \) = The coefficients of cost (C) and time (T)  
C & T = The cost (C) and time (T) of alternative x

As equation 5.1 shows, coefficients are used in order to make cost and time comparable. These coefficients are the valuations of cost and time. Since only cost and time is included in this case the Value of Time can easily be extracted (Bates, 2012):
Equation 5.2 shows the relative valuation of time compared to cost, i.e. Value of Time.

The mean-dispersion models adds a dispersion part (i.e. standard deviation or variance) to the base model. The dispersion is a measure of the reliability of the alternatives.

The utility function for the mean-dispersion model using standard deviation is shown in equation 5.3. (Bates, 2012)

\[ U_x = \beta_C \times C + \beta_T \times T + \beta_R \times \sigma \]  

\[ \beta_R = \text{The coefficient of reliability} \]
\[ \sigma = \text{The standard deviation of transport time} \]

In mean-dispersion model using variance the \( \sigma \) would simply be replaced with \( \sigma^2 \).

Similarly to the calculation of Value of Time in the base model, the Value of Reliability can be calculated as shown in equation 5.4 (Bates, 2012).

\[ \text{Value of Reliability} = \frac{\beta_C}{\beta_R} \]  

Another concept that has emerged is Value of transport time variability (VTTV), which suggests that not only the value of reliability is useful, but also the variation of the transport time can be used when assessing benefits of projects (Vierth, 2010). Such utility functions would include both variance and standard deviation (Author’s remark).

The scheduling models distinguish between if the deviation is positive or negative. Therefore there is one coefficient for being early and one for being late; this is because in transportation the penalty for being late is often larger than for being early. It is also possible to combine the mean-dispersion model with the scheduling model, and thereby have both a \( \beta_R \) coefficient and late/early coefficients. However, Bates (2012) stated that “it is often difficult to find significant coefficients for both”.

The selection and design of the utility function is not always as straightforward as what is implied above. There are researchers that have tried to replicate the results of stated preference surveys and found that the traditional utility function can be improved by using logarithmic utilities. An example of a logarithmic mean-dispersion utility function with the scaling parameter \( \lambda \) is shown in equation 5.5. (Börjesson & Eliasson, 2012)

\[ U_x = \lambda \times \log(C + \beta_T \times T + \beta_R \times \sigma) \]  

There are several suggestions for how to modify the traditional utility function to give it a better representation of reality (Bates, 2012). This includes variable Value of Times depending on the size of the possible time savings or non-parametric utility functions which allows for a non-fixed relation between the factors (Börjesson & Eliasson, 2012). It is consequently clear that there are techniques available to improve the accuracy of the models.
5.2.2. Discrete Choice Models

The utility is calculated for all of the alternatives that the decision makers can choose from. Thereafter the objective is to calculate the probability that decision maker would select each of the utility alternatives.

For this calculation there are two main probability functions that are commonly used, namely Logit and Probit. Logit is the most common, probably due to its simplicity (Ortuzar & Willumsen, 2011). The standard Multinomial Logit function is shown in equation 5.6.

\[ P = \frac{\exp(U_1)}{\exp(U_1) + \exp(U_2)} \]  

This Logit probability function (equation 5.6) is used when calculating the probability for alternative 1 with the utility \( U_1 \) from a set of two alternatives with the utilities \( U_1 \) and \( U_2 \) respectively. Another common probability function is Multinomial Probit, which is more complex than Multinomial Logit (see equation 5.7) and therefore in general requires extensive computer calculations (Ortuzar & Willumsen, 2011).

\[ P = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \exp \left\{ \frac{-1}{2(1-\rho^2)} \left( \frac{x_1}{\sigma_1} \right)^2 - \frac{2\rho x_1 x_2}{\sigma_1 \sigma_2} + \frac{x_2^2}{\sigma_2^2} \right\} \, dx_1 dx_2 \]  

The main difference between Logit and Probit is that the coefficients are fixed in Logit, while Probit allows for variations. The ability to take these variations into account is useful when there are differences within the population that is modelled concerning how they value different alternatives. For instance a poor person tends to value costs higher than a rich person. (Ortuzar & Willumsen, 2011)

In addition to the standard Multinomial versions of Logit and Probit there are also Mixed Logit that is better at handling variations than Multinomial Logit and simpler than Multinomial Probit. According to Ortuzar and Willumsen (2011) Mixed Logit is ‘any model the probabilities of which can be expressed as an integral of Standard Logit probabilities over a distribution of the parameters such as’: (see equation 5.8).

\[ P_{iq} = \int L_{iq}(\theta) f(\theta) \, d\theta \]  

Where \( L_{iq}(\theta) \) is a Multinomial Logit probability, \( \theta \) a set of parameters and \( f(\theta) \) is the density function (Ortuzar & Willumsen, 2011). In other words, the density function \( f(\theta) \) is the function that determines how the different Logit functions are mixed (Hensher & Greene, 2001).

Consequently, when using Mixed Logit, the density function becomes important for the result. It is therefore important what assumptions that are made concerning the distribution (Hensher & Greene, 2001). Bates (2012) mentions normal and lognormal distribution, while Hensher and Greene (2001); also add the simpler triangular and uniform distributions to the
list of common distributions. They also stress the importance of choosing the appropriate
distribution and that there is often a need to add constraints to the distribution assumptions.
Furthermore, Mixed Logit requires that the data used is of higher quality than Multinomial
Logit (Hensher & Greene, 2001).

5.2.3. Dynamic Discrete Choice

When the modelled alternatives are dependent, it becomes difficult to create finite sets of
alternatives. This characterises dynamic modelling of choices in contrast to the regular case
problem which is static. Static discrete choice is often considered to be linear, but dynamic
discrete choice renders more complex functions. These functions can be solved by dynamic
programming which can become very complex, time consuming and difficult. There are
nonetheless methods to simplify the modelling of dynamic choices, which sadly also are
complex and might be difficult to use for the average analyst. There is however research
efforts focussing on verifying the validity of these methods and making them more accessible
for regular transport analysts. For simpler cases of dependent alternatives there is nested
Logit, which is a so called conditional choice probability estimator, i.e. an estimator of the
dynamic problem. (Arcidiacono & Ellickson, 2011)

Nested Logit is as the name implies when several Logit functions are nested, i.e. combined
together in a hierarchy. It is able to handle alternatives that are not independent, which
commonly occur in multimodal transports. In multimodal transport, subsequent mode choice
possibilities are dependent on the previous choices. A passenger transport related example is
when choosing between car, bus and tram. The tram and bus are not independent alternatives,
both are public transport and when making the mode choice two sequential decisions are
made as shown in the decision tree in Figure 9 (Bæres, 2012).

![Decision tree for a Nested Logit model for the choice between car, tram and bus.](image)

Dynamic discrete choice models are difficult both to use and verify, which has led to them
being rarely applied for freight. For instance using Probit for many alternatives leads to multi-
dimensional functions. (Tavasszy & Jong, 2013).

5.3. Calculating Freight Value of Time

There are two main methods of quantifying Freight Value of Time, namely the factor cost
approach and modelling the demand (Feo-Valero, et al., 2011)
5.3.1. Factor Cost

The factor cost approach is to measure the reduction in cost when the transit time is reduced. There are however variations as to what cost that are included, e.g. fixed costs are both included and excluded, depending on the time horizon. The factor cost approach is not able to give additional insights into other attributes such as reliability, flexibility and frequency. (Feo-Valero, et al., 2011)

5.3.2. Demand (for time) Modelling

Demand modelling on the other hand is able to give these additional insights. In demand modelling a distinction is made between disaggregate and aggregate models. In aggregate models the demand is represented by market shares, while in disaggregate models the choices made by the decision makers are observed. According to Winston (1983) disaggregate models could theoretically be more attractive because they are “more finely-tuned to the behavioural realities of freight transportation decision making”. However, due to the need for more extensive data collection aggregate models can be more useful. (Winston, 1983)

In disaggregate demand modelling a distinction is sometimes made on account of the kind of decision maker whose choices are being modelled. The first type of decision maker is the one in charge of the inventory and the second is the one in charge of the shipment. They are denominated as inventory models and behavioural models, respectively. If the decision maker is the one who is in charge of inventory, the freight decisions can be seen as a part of the production process. (Feo-Valero, et al., 2011)

There are also many other possible variations in classification of decisions within the disaggregate inventory models, for instance categorization of time horizons of decisions into short, medium and long term. (Feo-Valero, et al., 2011)

5.3.3. Transport Data Collection

The data gathering for the disaggregate demand models can be done by either revealed or stated preference. Revealed preference is when the data is based on the actions that are taken. It then shows how decision makers behave given the current supply. Stated preference on the other hand is based on statements from decision makers of what they would do in different hypothetical situations. The data from stated preference surveys will only be hypothetical and might have a lower accuracy, since it is not possible to know if the decision maker will behave the same way in reality. However, the benefit of stated preference over revealed preference is that it is easier to gather data on a wide range of scenarios and also to test different supply levels (Ortuzar & Willumsen, 2011). A combination of stated and revealed preference could increase the accuracy even further. However, difficulties in retrieving data on revealed preference makes stated preference a more common method than both revealed preference and combined methods. (Feo-Valero, et al., 2011)
5.4. Decision Making

In 1999 a survey was sent out by the Swedish National Railway Administration to decision makers at 413 freight hauling companies. The findings were that price, speed and influence on arrival/departure time; were the three attributes that were considered very or rather important by the highest share of decision makers (Nelldal, et al., 2000). This is similar to the attributes that are the most popular in the freight demand models, however in the survey the fourth most important factor was effects on environment. The fifth was to be perceived as environmental friendly (i.e. that others think that the company is environmental friendly) and sixth was energy consumption. Such environmentally related factors are seemingly uncommon in freight models (Author’s remark based on (Feo-Valero, et al., 2011)).

Decision making can however be influenced by different factors limiting the choices available. For instance the availability of a certain mode determines what alternatives which are possible. Winston (1983) states that choices; such as mode choice is influenced by many factors and that in production industry inventory related variables are important factors that influence the choices made.

It can also be of importance to distinguish between the different objectives of the decision makers. For instance shippers who outsource the transportation are perhaps only basing the Value of Time on what type of goods it is, but a shipper who carries out the transportation themselves would also include the vehicles and the staff needed. (Bates, 2012)

5.5. Modality

Freight Value of Time is most commonly used for road transports and not so much for deep-sea cargo, in-land waterways and air freight. Additionally, mode choice is often not seen as a transport attribute, this because they are using Freight Value of Time only for one mode and view mode choice as predetermined.

Deep-sea cargo is argued to have very long transit times, making transport time less important and thus implying that deep-sea cargo has a low Freight Value of Time (Feo-Valero, et al., 2011). This would however assume that Freight Value of Time is constant and that it does not change throughout the transport. If a delay happens early during a transport it is probably easier to compensate for it by either increasing the speed or rescheduling the services or transports that awaits the shipment when it reaches port. Furthermore, it is possible to argue that low or high Freight Value of Time is irrelevant since the decision is not made based on the Freight Value of Time but on cost that is calculated using Freight Value of Time. Therefore, since deep-sea freight generally takes longer time than other modes the final “cost of the time” might actually be high.

5.6. Units of Measurement

In addition to the currency a unit is needed for the shipment size. Common units are tons, pallets, shipment or TEU. An example of a unit for $FVOT_{rail}$ is shown in equation 5.9 and depicts the Freight Value of Time for a rail alternative.
Despite the unit being the same comparability between studies is complicated by Freight Value of Time varying for different modes, goods, origin, destination etc. (Feo-Valero, et al., 2011)

These variations present the possibility to divide freight Value of Time depending on the characteristics of the different shipments. For instance the different origins get a value which is added together with the value for the specific type of goods, the specific destination, the mode, and the way of dispatching and so on. The underlying idea is to get a more accurate Freight Value of Time.

5.7. The Importance of Time in Relation to Other Factors

Time and distance obviously are related given that if nothing else is changed but the distance the time elapsed will change accordingly. An increase in transport time and distance for a transport will generally if nothing else changes also lead to an increase in cost. This is because the cost of the vehicle and staff etc. increases when they are utilised for a longer time and distance. However, there are occasions when longer time and distance for a shipment is accepted. One such occasion is in case of bundling operations. Bundling is when shipments are co-organised into larger entities. When shipments are bundled together, the transport time and distance is typically increased due to detours, but the resources needed in terms of for instance vehicles or staff decreases. The increased complexity of the operations that this bundling procedure imposes does on the other hand increase the need for other resources. Such resources can be transhipment capabilities, and staff for planning and carrying out these transhipments. (Kreutzberger, 2008)

Even though longer time and distance is accepted when bundling, minimising distance and cost is an important mean of reducing costs. When offering a bundled transport service, the service provider offers a complete DTD service for one price. Hence, not only are flows or shipments bundled, but also the services. (Haralambides & Acciaro, 2010)

Bundling has also been used in a wide variety of other fields, e.g. when Microsoft bundled Windows with Internet Explorer. In this Microsoft example, Microsoft is able to offer the whole bundle by themselves. However, in logistics it is common to offer complete solutions by outsourcing part of the services that are included in the bundle to other companies. (Haralambides & Acciaro, 2010)

Time in freight transportation consists of several smaller components. The main one is the transport itself, which is called the on-vehicle time. Moreover also the on- and off-loading takes up time; hence there are also such time components. There is also the time when nothing is actually done with the goods, i.e. waiting time. Waiting time can occur for different reasons, e.g. when shipments bundled, due to capacity in handling or due to low departure frequency.
When shippers make transport decisions, alternatives are compared based on their performance. The performance is commonly either represented as door-to-door (hereon referred to as door-to-door) or for the main mode of transport. There are many ways of measuring the performance, such as cost, time, service frequency, departure time or arrival time. Also reliability (i.e. time, damage or loss), flexibility, restrictions in goods allowed and if partial loads are allowed are common performances that shippers take into account when making their choices. (Kreutzberger, 2008)

Price is by most research seen as the most important factor, especially for intermodal shipments. Despite the fact that time is a performance factor itself it is also a component of the price. In other words, the price of a transport service generally increases as time and distance increases. As to what performance factor is the second most important it seems to vary more. However, these factors have a common characteristic of generating costs for the shipper. An example of such a cost is the interests that the shipper has to pay for the goods while they are being transported; the total interest payments for the shipment are obviously dependant on the door-to-door time of the transport. Hence, time is an important performance factor which importance depends on interest rates and the value of the shipment. Many researchers have nonetheless concluded that reliability is a more important factor than transport time. (Kreutzberger, 2008)

Despite that most research on freight transport has found that time is an important factor, there is some researchers that have found that time “is not important at all” (Kreutzberger, 2008). This conclusion is however much less common. The findings are nonetheless reasonable since the monetary value determined in various reports vary. Kreutzberger (2008) made an overview of the Value of Time found in a range of reports. The values are presented per mode in Euros per hour and ton. In Table 1, the lowest and highest valuations for each mode from Kreutzberger’s overview are shown. Although Kreutzberger has divided the modes into different types of road, rail and water transport (size, goods, distance etc.), in Table 1 it is aggregated to road, rail and water in order to make it easily comparable, and also to highlight the fact that the valuations vary depending on how it is done and how it is presented.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>0.08</td>
<td>4.74</td>
</tr>
<tr>
<td>Rail</td>
<td>0.03</td>
<td>1.94</td>
</tr>
<tr>
<td>Water</td>
<td>0.005</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Because stated preference is used as a method for gathering data, the outcome is affected by the sample of respondents. Samples are often small due to a low willingness to respond, this gives a possibly unrepresentative result. Other sample related factors are the geographic selection and the choice of sectors to include.
Further there is also possible differences in what content that the respondents consider are included in Value of Time. Such content is interests, depreciating value of goods, goods perishing, market impacts for the shipper, market impacts for the transport operator and opportunity cost (Kreutzberger, 2008). Interest has been explained previously and goods perishing are simply that some goods that go bad during transport inflict a cost. Opportunity cost is the fact that the shipper instead of using the transport service could have used the money for other causes, for instance improving their business and this lost opportunity can be seen as a cost. Market impacts for the shipper or for the transport operator, illustrates the market mechanism where a shorter transport time opens up for getting a larger market share with the same amount of resources.

All the possible content mentioned above could be included in Value of Time, but it could also be included in other performance factors. Nonetheless, if this content is included the Value of Time becomes higher than otherwise. Whereas if waiting time when bundling shipments is considered not to be included in Value of Time by a respondent, the Value of Time would become lower than for those that include it. The exclusion can however be justified by considering waiting time to be a flexibility factor (if such a factor is used). (Kreutzberger, 2008)

Value of Time is also differently composed for the different actors. For instance, it is only the actor that has the actual loan that is interested in the interest, i.e. the shipper. This issue together with two other was similarly identified by Feo-Valero et al. (2011). They found that in demand modelling there are three different main issues (Feo-Valero, et al., 2011):

- **Identifying the decision-maker:** The forwarder often make the route choice and the customer (sender) the mode choice. However, the forwarder is often considered as the decision maker because if the customer is a small company they will not have the resources to organise their transports themselves. If the customer is seen as the decision maker, the companies included in the study are sometimes limited to companies above a certain size. Research has shown that the type of decision maker has influence on the final result in terms of freight Value of Time. (Feo-Valero, et al., 2011)

Even though both Feo-Valero et al. (2011) and Kreutzberger (2008) identifies the importance of knowing who that is modelled, they have different rationale. Feo-Valero et al. (2011) presses on the fact that the relationships between the actors vary between different logistics chains. Kreutzberger (2008) on the other hand identifies that the Value of Time is built up differently depending on what type of actor it is.

- **Transport flow heterogeneity:** Transport flows are heterogeneous in many ways, for instance in terms of mode, distance, origin, size and value of shipment (Tavasszy & Jong, 2013). Value of Time varies depending on these factors (Feo-Valero, et al., 2011). Using a mixed Logit model Zotti and Danielis showed that cost and transit time as well as reliability, and damages and losses were in their case study random variables (Zotti & Danielis, 2004; Zotti & Danielis, 2004). This means that cost and transit time should not be used as fixed parameters. Other research has shown that
above a certain distance Freight Value of Time decreases as the distance increases. (Feo-Valero, et al., 2011)

Also what Feo-Valero et al. (2011) called transport flow heterogeneity is mentioned by Kreutzberger (2008). Both reports find that Value of Time vary depending on mode, distance etc.

- **Explanatory variables**: Which variables that is included in a demand models varies, often depending on what data that is obtainable. There is however a few variables that are commonly included and accepted in the field of freight demand modelling. Transport cost and transit time are two that are almost always included. Additionally delivery time reliability, frequency and delivery conditions reliability are third, fourth and fifth most common, respectively. A 75 article review on variables for modal choice shows that the domain is made up by about 15 transport attributes, Feo-Valero et al. (2011) identifies delivery time reliability as the potentially most important transport attribute for mode choice. The ultimate selection of variables to include in a model is however often based on availability of data, quality of data and budget. (Feo-Valero, et al., 2011)

What Feo-Valero et al. (2011) refers to as explanatory variables is what Kreutzberger (2008) called performance factors, and also on this point are the two reports concurrent. However, Kreutzberger (2008) might be said to paint a somewhat more complex picture. They both name time and cost as two of the most important factors, and Kreutzberger (2008) also points out that there is interdependency between cost and time. This interdependency which also occurs for other factors complicates the process of determining Value of Time.

Since transport time often is both considered important and valued high for especially road transports costs are seemingly highly affected by the transport time. Thus, a reduction of transport time becomes an important mean for reducing overall costs (Kreutzberger, 2008). Additionally since the time of for instance deep sea freight is much longer it can still become a large cost.

Lundberg (2006) showed through a survey to 98 Swedish transport directors that decreasing the number of delays with 30 % is valued similarly to a 25 % reduction in travel time for low value goods (1000 SEK/ton). However for higher value goods (7500 SEK/ton) delays are valued twice as high. Consequently, this showed a correlation between high value and willingness to reduce delays. (Lundberg, 2006)
6. Survey: Six Examples of Modelling in Practice

Recently there has been an increasing amount of research carried out within the field of freight modelling and decision making. Most of this research is however either theoretical about how the models ought to be designed or on how decision makers value different factors when making decisions. A different aspect is how the current practice is today and how the current practice relates to the research. There has however been mentioned by some of these researchers that it is difficult to gather information from decision makers. This is partially because the decision maker is difficult to identify, but also because there seem to be an unwillingness to share what methods that are used.

Despite of this, a survey was performed within this project. There was a low response frequency as expected, with only six responses out of 60. Therefore there will be no general or statistical conclusions or drawn from this survey, but the responses will be examined one by one in order to produce a few examples of how modelling is used in practice. All of the examples come from Sweden and are therefore likely to tell more about freight modelling in Sweden than freight modelling in general. Google forms by Google Inc was used for creating the survey, which was sent out to decision makers in freight.

6.1. Introduction to the Dataset

The six different actors will hereon be referred to as actor 1 to 6. The six actors’ areas of business and the specific responder’s function at the company are shown in Table 2.

<table>
<thead>
<tr>
<th>Actor</th>
<th>The company's first area of business</th>
<th>The company's second area of business</th>
<th>The company's third area of business</th>
<th>The responder's function at the company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor 1</td>
<td>Freight forwarder</td>
<td>n/a</td>
<td>n/a</td>
<td>Operations Manager</td>
</tr>
<tr>
<td>Actor 2</td>
<td>Transshipment Facility Owner</td>
<td>n/a</td>
<td>n/a</td>
<td>Business developer</td>
</tr>
<tr>
<td>Actor 3</td>
<td>Freight forwarder</td>
<td>Transport Operator</td>
<td>n/a</td>
<td>CEO</td>
</tr>
<tr>
<td>Actor 4</td>
<td>Freight forwarder</td>
<td>Transport Operator</td>
<td>Transshipment Facility Owner</td>
<td>Intermodal terminal manager</td>
</tr>
<tr>
<td>Actor 5</td>
<td>Shipper</td>
<td>n/a</td>
<td>n/a</td>
<td>Project Manager</td>
</tr>
<tr>
<td>Actor 6</td>
<td>Freight forwarder</td>
<td>Transport Operator</td>
<td>n/a</td>
<td>CEO</td>
</tr>
</tbody>
</table>

In Table 3, it is shown what markets the actors are operating on and how many employees they have in order to give a hint about their geographical market coverage and size. Although company 1, 3, 4 and 6 all are forwarders, there are differences. The companies have different combinations of secondary and tertiary areas of business.
Table 3. What markets the actors operate in and company size (employees).

<table>
<thead>
<tr>
<th></th>
<th>In what markets is your company operating?</th>
<th>How many employees does your company have?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor 1</td>
<td>International</td>
<td>7</td>
</tr>
<tr>
<td>Actor 2</td>
<td>National/interregional, International</td>
<td>approx. 200</td>
</tr>
<tr>
<td>Actor 3</td>
<td>International</td>
<td>4</td>
</tr>
<tr>
<td>Actor 4</td>
<td>Local, Regional, National/interregional, International</td>
<td>Just the terminal 8 people</td>
</tr>
<tr>
<td>Actor 5</td>
<td>Local, Regional, National/interregional, International</td>
<td>n/a</td>
</tr>
<tr>
<td>Actor 6</td>
<td>National/interregional, International</td>
<td>650</td>
</tr>
</tbody>
</table>

For the six actors seven the goods that they handle have been divided into seven different types of goods. These are “bulk”, “containers”, “tempered goods”, “hazardous goods”, “small units” (i.e. parcels and packages), “trailers and swaps” and “project cargo” (special size cargo). The distribution of the different types of goods amongst the six actors is shown in Figure 10. Containers, tempered goods and hazardous goods are the three most common types. All three are used by a third or more of the six companies. It should be noted that all alternatives were given by the surveyor to the responders except for project cargo which was added by actor 3. In Table 4 it is shown what types of goods each of the actors use.

Figure 10. The number of respondents handling each of the different goods/classifications of goods.

* ‘Trailers and swaps’ and ‘Project cargo’ was added by two respondents. Trailers are HGV trailers with wheels transported on rail, and swaps or so called “Swap-bodies” is a type of container that has supporting legs for easy transshipment. Project cargo is goods with special attributes/dimensions used in projects such as construction projects.
Figure 11. The number of respondents using each mode. It was possible to select more than one mode. *Charter was added by one of the respondents and was not possible to select for the others. Charter does not depict which mode that was actually used, but implies that an entire vessel was chartered.

What modes the actors use or are involved with are shown in Figure 11 and in Table 4. Deep sea freight, HGV and Railway are used by four out of six of the actors. All but actor 2, are involved with more than one mode. However, actor 2 has a different role than the other actors due to being a business developer at a company that owns a railway transhipment facility.

Table 4. Which types of goods and modes that the actors are involved in.

<table>
<thead>
<tr>
<th>Types of goods transported</th>
<th>Actor 1</th>
<th>Actor 2</th>
<th>Actor 3</th>
<th>Actor 4</th>
<th>Actor 5</th>
<th>Actor 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Containers</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tempered goods</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hazardous goods</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Small units</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trailers and swaps</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project cargo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modes used</th>
<th>Actor 1</th>
<th>Actor 2</th>
<th>Actor 3</th>
<th>Actor 4</th>
<th>Actor 5</th>
<th>Actor 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep sea freight</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inland waterway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Heavy Goods Vehicles</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Goods Vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Railway</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air cargo airline</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Particularly notable from a dataset point of view is that although actors 1, 3, 4 and 6 all are freight forwarders, they use different mode constellations and also have some differences in what types of goods they handle. All the modes in Table 4 except for charter (added by actor 3) were predefined alternatives. Charter, not per say being a mode, will be interpreted as if the actor sometimes charters an entire vehicle, vessel, train or aircraft since these modes were the ones selected.

**6.2. Modelling**

The questions about how modelling is performed where divided into three categories; strategic, tactical and operational. Strategic decisions are long term decisions for determining the overall direction of the enterprise (usually 1-5+ years horizon); e.g. markets to operate on, type of services to offer etc. Tactical decisions are medium term decisions for determining what actions to take in order achieve the strategic goals of the enterprise (usually 6-12 month horizon); e.g. how to market the company's services, budgeting, allocation of company resources between projects etc. Operational decisions are short term decisions for determining how to carry out the day to day operation; e.g. route choice.

Table 5. Answers showing which actors that use models/simulation and on what decision level (strategic, tactical or operational).

<table>
<thead>
<tr>
<th>Does your company use computer models/simulation for …</th>
<th>…strategic decisions?</th>
<th>…tactical decisions?</th>
<th>…operational decisions?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor 1</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Actor 2</td>
<td>Yes</td>
<td>No</td>
<td>Our customers might</td>
</tr>
<tr>
<td>Actor 3</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Actor 4</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Actor 5</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Actor 6</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

As seen in Table 5, only actor 2 and actor 5 state that they use modelling at any of these levels. Actor 2’s answer on the operational level is reasonable to be disqualified since the company themselves do not use modelling for operational decisions, which was the question answered by the others. Since only actor 2 and 5 use modelling, they are the only that answered questions on how they model and that modelling has importance for them.

Actor two states, as a reply to the question “What programs or methods do you use?”:

- “We order simulations within projects sometimes and results can indirectly be used for strategic decisions”

On the same question, actor 5 states:

- “LogiX”
Thus, it is actually only actor 5 that perform modelling themselves. Furthermore, actor 2 states that demand modelling is of importance 2 on a scale from 1 to 10 for strategic decisions. Actor 5 on the other hand, who use modelling for tactical decisions state that demand modelling is of importance 10 on a scale from 1 to 10.

6.3. Mode Choice

Mode choice influences many sequential decisions and is one of the main applications for discrete choice models and Value of time.

Table 6. Answers on mode choice.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Is mode choice (e.g. lorry, inland water way, air freight...) strategic, tactical or operational for your company?</th>
<th>What methods do you use to make decisions on mode choice (what type of transports to use)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor 1</td>
<td>Operational</td>
<td>Based on customers’ requirements</td>
</tr>
<tr>
<td>Actor 2</td>
<td>Strategic</td>
<td>n/a, we aim to shift transports towards railway</td>
</tr>
<tr>
<td>Actor 3</td>
<td>Strategic, Tactical</td>
<td>Time vs price in combination with size/type of cargo</td>
</tr>
<tr>
<td>Actor 4</td>
<td>Strategic, Tactical, Operational</td>
<td>n/a</td>
</tr>
<tr>
<td>Actor 5</td>
<td>Strategic, Tactical</td>
<td>Transport time, price and reliability are factors to consider</td>
</tr>
<tr>
<td>Actor 6</td>
<td>Strategic, Tactical</td>
<td>Depending on the demands of the clients</td>
</tr>
</tbody>
</table>

In Table 6, the outcome of asking the actors on what level (strategic, tactical or operational) they consider mode choice to be. Actors 3, 5 and 6 state that it is strategic or operational, meaning that it is a medium to long term decision. Actor 1 being the only freight forwarder that have no other field of business, see mode choice as a purely operational decision and thus a short term decision, they have however seemingly made a long term decision to only offer air freight and deep sea freight. Actor 2 on the other hand sees mode choice as a purely strategic decision, which is confirmed by them being the only actor that is only involved with one single mode. In contrary to the others, Actor 4 considers mode choice to be all three; strategic, tactical, and operational.

In the second question in Table 6, four of the actors answer how they do chose between the modes. Actors 1 and 6 answered that the choice is made by the customer. Actor 4 whom similar to 1 and 6 is a freight forwarder, but also an operator name time vs price combined the size/type of cargo as factors included in their method. The weigh-off between time and price is a common method used in modelling as shown in the literature study.

These factors are also mentioned by actor 5, who also adds reliability being another common factor mentioned in the literature study. Moreover, actor 5 is the only actor that is a shipper and also the only actor that perform computer modelling/simulations by themselves.
6.4. Opinions on Time

None of the actors seem to be using time based computer models (i.e. Freight Value of Time). However four actors stated that they include transport time variability in their models/evaluations. Note that they probably mean in that it is included manually in their evaluations. Also all but actor 1 include reliability.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Is transport time variability included in your models/evaluations?</th>
<th>Is transport reliability included in your models/evaluations?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor 1</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Actor 2</td>
<td>Yes, in strategic models</td>
<td>Yes, in strategic models</td>
</tr>
<tr>
<td>Actor 3</td>
<td>Yes, manually</td>
<td>Yes</td>
</tr>
<tr>
<td>Actor 4</td>
<td>Yes, in operational models</td>
<td>Yes, in strategic models</td>
</tr>
<tr>
<td>Actor 5</td>
<td>n/a</td>
<td>Yes, in strategic models</td>
</tr>
<tr>
<td>Actor 6</td>
<td>Yes, in operational models</td>
<td>Yes, in strategic models</td>
</tr>
</tbody>
</table>

The actors were asked in what detail they model time (seconds, minutes, hours, days, weeks, months or years) for each of the three decision levels (operational, tactical or strategic). Actor 5 stated that they model their tactical decisions on an hourly or daily level. They also stated that on the operational level they make their decisions on the minute level. Also actor 2 stated that they make their decisions on the minute level. The rest of the actors stated that they “do not know” or “do not model time”.

6.5. Opinions on Data

Four out of the six actors answered the question on how difficult they found gathering data for models. As seen in Table 8, actor 1 as well as the two actors involved in modelling (2 and 5) stated that it was an eight or higher on a scale from one to ten. More notable might however be that the only actor that performs modelling by themselves also is the only actor that solely relies on experience when gathering data. Also three other actors use this method, but they also use stated preference and/or revealed preference. Revealed preference and experience was used by four of the five that answered, but stated preference was only used by two. Both revealed preference and experience is knowledge gathered within the company itself, and it is also historical data.
Table 8. Answers on gathering data.

<table>
<thead>
<tr>
<th>Actor</th>
<th>How difficult do you find gathering data for models? (1-10, where 10 is very difficult)</th>
<th>How do you gather data?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor 1</td>
<td>10</td>
<td>Revealed Preference (RP), Experience based (based on knowledge)</td>
</tr>
<tr>
<td>Actor 2</td>
<td>8</td>
<td>Stated Preference (SP), Revealed Preference (RP)</td>
</tr>
<tr>
<td>Actor 3</td>
<td>3</td>
<td>Stated Preference (SP), Revealed Preference (RP), Experience based (based on knowledge)</td>
</tr>
<tr>
<td>Actor 4</td>
<td>n/a</td>
<td>Revealed Preference (RP), Experience based (based on knowledge)</td>
</tr>
<tr>
<td>Actor 5</td>
<td>8</td>
<td>Experience based (based on knowledge)</td>
</tr>
<tr>
<td>Actor 6</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
7. Analysis
This chapter contains the analysis part of this report and consists of four analytic parts. The first part summarises the different aspects found in the literature study that could make Value of Time less suitable for freight applications than for passenger transport modelling. The first part also connects the most notable parts of the survey to the literature. The second part first states what the main trends that have been identified from the Trends and Characteristics of the Freight Market chapter. Thereafter it contains an example of when these trends can become difficult to handle in Value of Time based models and an analysis section on multimodal applications of Value of Time. The third part analyses the effectiveness of Value of Time as a general model by applying Turnquist’s four criteria for an effective model. This Method is used to its ability to be applied to a general concept in contrary with the Validity, Verification and Accreditation plan. Furthermore the third part introduces Supply Chain Modelling as a possible solution to the issues with Value of Time. Consequently, the fourth part is a conceptual feasibility example where the benefits of supply chain management are tested with a conceptual Value of Time model.

7.1. General Analysis

7.1.1. Adapting Value of Time to Freight
There are several reasons for expecting that Value of Time is less reliable when applied in freight models than in passenger transport applications:

- Less transparent due to confidentiality (Ortuzar & Willumsen, 2011)
- The decision on mode might be made based on customer requirements instead of based on transport attributes as shown in the survey (i.e. difficult to identify the true decision maker)
- Not as easy to gather data due to many different decision makers (Feo-Valero, et al., 2011)
- Too high aggregation level can lead to unrepresentative Value of Time estimates (Winston, 1983)
- The different modes have a different characteristics (Kreutzberger, 2008)
- Revealed Preference data is only available for internal use (Feo-Valero, et al., 2011)
- Value of time varies depending on various factors (Tavasszy & Jong, 2013) and it is therefore difficult to identify a finite number of alternatives for a discrete choice model. This leads to the need of more complex discrete choice models such as mixed Logit.
- Using mixed Logit requires proper identification of probability distribution.
- Alternatives composed of complex logistics chains can lead to interdependencies between alternatives. This would imply the need of nested Logit (Bates, 2012). However, nested Logit has a sequential build up (i.e. a tree structure) that is most suitable for short decision trees (Wen & Koppelman, 2001). The introduction of a more complex model could be useful, but when models get more complex they get very difficult to use and test (Wen & Koppelman, 2001).
7.1.2. The Survey

When analysing the survey presented earlier in this report two observations become extra notable; the low response frequency and that four of the six respondents do not use modelling at all. The first supports the claims of others that there is an unwillingness to share information in freight and logistics. The second should not be used for general conclusions due to the first. However it is possible to say that there are decision makers in freight that do not use modelling, i.e. not all decision makers model their decisions. Furthermore, all four of the non-modelling companies were freight forwarders (they also have other areas of business).

Customer requirements are mentioned as a factor that determines mode choice. Only one of the actors was a shipper, the rest therefore have a customer contracting them for their services. Time, price, cargo type and reliability are other factors mentioned as determining mode choice. In general the factors mentioned are in line with what has been found in the literature. However, that the shipper or customer would make the choice of mode (perhaps made arbitrary) does not seem to be considered in the Value of Time models. It would however imply that what Kreutzberger and Feo-Valero et al. mentioned about difficulties in identifying the real decision maker could be a valid concern. Also the GPN vs GVC discussion is largely focussed on difficulties in understanding and identifying decision makers.

Furthermore, not only did four out of the six decision makers not use modelling at all; but four out of five respondents on the question of data retrieval mentioned experience as a source of data for decisions. This together with three out of four finding data retrieval an 8 or above on a scale from 1 to 10 where 10 is the most difficult. These circumstances imply that lack of data actually is an issue in freight decision making.

7.1.3. Freight Trends

7.1.3.1. Freight Trend Identification

Three major trends in the freight market that could be interesting for a freight model to be able to cope with can be identified:

- Increased focus supply chain management
- Increased amount of transports within the supply chains
- Globalisation – transforming the supply chains into global production networks.

The implications of increased focus on managing the supply chains for freight are that the demands on efficiency and reliability increases. This is because more and more of the supply chains are pull-systems, where products are made after they are sold and need to be transported to the customer quickly and often delivered at a certain time.

The increased amount of transports within the supply chains can be traced to the underlying trend of outsourcing. When several steps of a production are performed at different locations or companies there is a need for transporting semi-finished goods.
Globalisation has been a general trend in trade for some time now and it has also influenced the supply chains. Not only are products being produced in one country and consumed in another, but one single finished product can have a supply chain where the production spans several countries.

### 7.1.3.2. Applying Value of Time Models in Global Production Networks

**Rudimentary example of issues of modelling freight with a lack of information:**

Taking the existence of Production Networks into account when trying to model the freight transports is likely to be essential when a majority of the transports are within these networks. The Production Networks also might change the picture a bit concerning how transport demand is created. Namely, if company A sends their semi-finished product to company B for some additional work before it is sent to company C who ordered the product from A, that transport between A and B is not included in the transports that are generated due to the demand for the finished product. Furthermore, the customer in this case was company A sending their semi-finished product to B for additional work, which would imply that the in this logistics chain there is push and pull logistics in the same Production Network. For someone who then wants to know how much freight transports that is going to or from his region when both company A and C is located in the region but B is not, looking at demand that Company C has for a deliveries from A will give one transport leg less and not show where the flows actually go.

The example above shows an issue with attempting to model complex logistics chains for an external analyst. This is however possible to model for an analyst who has the information and due to difficulties in obtaining this, it is likely to be an internal analyst. Consequently, similarities with supply chain management become evident. To be able to cope with this type of complexity where several decision makers are likely to exist and making decisions dynamically, a model able to cope with this would be needed for it to be representative of reality.

### 7.1.4. Modelling Multimodality

This part of the analysis is focused on identifying difficulties with multimodal freight modelling using Value of Time. Feo-Valero et al. (2011) found three main difficulties with modelling demand:

1. Identifying the decision maker
2. Transport flow heterogeneity
3. Explanatory variables

Because these three difficulties also were supported by other research (i.e. Kreutzberger 2008) they are likely to actually have an influence on the accuracy of a model and thus the validity. Therefore as a way of analysing multimodal modelling with Value of Time, the theoretical importance of these difficulties will be analysed.
When it comes to “identification of the decision maker” this is likely to be a larger issue than for unimodal freight due to how multimodal freight is organised. Multimodal freight is often the consequence of outsourcing or the reason for outsourcing, which leads to more decision makers. Multimodal freight also leads to more decisions due to adding transshipment; several transport modes and possibly several transport operators. The Value of Time is thus necessarily not consistent throughout the transport since it not only varies depending on mode (as shown by Kreutzberger among others), but also the different decision makers can have different ways of making decisions.

Multimodal transport also leads to an increased “transport flow heterogeneity”, naturally due to different transport modes being used. However, also due to that bundling of shipments becomes more common when transport is outsourced. Additionally having more companies or actors involved in a transport is also a type of transport flow heterogeneity. The heterogeneity could make it difficult to form discrete alternatives to calculate utilities for use in discrete choice models. The heterogeneity also leads to more sequential decisions when organising the shipments due to for instance the bundling.

“Explanatory variables” is perhaps a more general difficulty concerning modelling and discrete choice modelling in particular. The selection of explanatory variables might however be complicated by the addition of more transport activities such as transshipment. Explanatory variables do for instance both concern which variables to include when calculating the Value of Time and when using Value of Time; this because the interdependencies of variables affects how the model should be designed.

In addition to these three difficulties, multimodal freight adds more sequential decisions which are more difficult to model. The decision making therefore is likely to become dynamic due to dependencies between alternatives which commonly occur in multimodal transport as found in previous research (Tavasszy & Jong, 2013; Powell, et al., 2005).

7.2. Validity Test of Freight Value of Time

The validity test in this analysis is performed with Turnquist’s Effectiveness Criteria because it is a straightforward way of testing if Value of Time is an acceptable modelling concept. Since Turnquist’s Criteria is the simplest and most general assessment method presented in this report it can be viewed as a minimum level for a model. This can be motivated with that both the VV&A-plan and the model selection criteria by Ortuzar and Willumsen contain the same aspects but more thoroughly through more steps and criteria. Turnquist’s criteria were:

1. “An effective model is focused on producing an output that someone wants and knows how to use.”
2. “An effective model includes the important variables that describe how the system works and represents their interactions clearly and correctly.”
3. “An effective model operates in a way that is verifiable and understandable.”
4. “An effective model is based on data that can be provided, so that it can be calibrated and tested.”
7.2.1. Turnquist’s Effectiveness Criteria

In the inventory part a set of four criteria for an effective model was presented. The first criterion was that someone wants the output and knows how to use it (Turnquist, 2006). A reasonable assumption could be that no one uses a model unless they are interested in the outcome; however Turnquist presented an example which shows that many transport models are actually never used in reality. The example was from the development of a model that rendered great interest in the academic world but was never of interest of any practitioners. This actually seems to be the same case for the freight Value of Time concept, which is becoming a quite popular topic among researchers but it remains unconfirmed (to the author’s knowledge) whether it is in use in practice except for a few national models. Knowledge in how to use the output does however seem rather wide-spread, since many other models are able to use the output of a discrete choice model as input.

The second criterion was that the model should be including important variables that describe how the system works and that the model also represents the interaction of the variables clearly and correctly (Turnquist, 2006). Earlier in this report several accounts of different opinions on what variables to include into a model as well as on how to treat Value of Time in a discrete choice model. There is nonetheless a consensus on that certain variables (e.g. transport time, price and reliability) are important even though the relative importance is disputed. Whether models containing Value of Time are able to clearly and correctly represent the interactions is probably the most interesting part of all of the criteria. The level of aggregation might be one of the most important factors to take into account when determining if the representation is clear and correct. The Value of Time models in general are aggregated, but the level of aggregation varies. However, when the aggregation level is lowered the correctness might increase, but the clarity decrease. This is because a lower aggregation level in discrete choice theory leads to more complex models.

Consequently the third criterion of being verifiable and understandable becomes relevant since a complex model is more difficult to verify. Especially since on basic issue with the freight transport models in general is the lack of available data. Furthermore, the multinomial Logit is easy to understand, but aiming at fulfilling the second criterion more complex discrete choice models are likely to be needed which are more difficult to understand.

The fourth criterion of having data available to calibrate and test the model is also difficult to achieve due the difficulties in obtaining data.

The less aggregated supply chain models are perhaps more likely to be able to fulfil all of the criteria. Mainly, because they have got all the historical data they need for their supply chain. Such data means that they can verify, calibrate and test their model; thus fulfilling both requirement three and four. In a supply chain they also are aware of how the interactions work and it is then easier to make the model clearly and correctly describe the interactions. The first criterion can also be fulfilled because the output can be varied depending of what they look for.
7.2.2. Using Supply Chain Methods

Within the domain of supply chain management dynamic real time modelling is already in use. The ability to dynamically model decisions can prove useful in the future since there are several dynamic aspects of decision making in global freight, e.g. the dynamic relationships between decision makers and interdependencies between different transport alternatives.

Furthermore smaller units are used when modelling supply chains, i.e. product flows or container flows instead of vehicle flows. Thus, there is less aggregation and forecasts are possible to be more accurate. The outcomes are nonetheless only about the specific supply chain. If the forecast wanted is for a specific region or business branch it would require information on all supply chains in that region or business branch. A few possible issues when trying to replace freight models with supply chain models are:

- There will be a very large data flow to process due to the low aggregation level.
- Many supply chains are of global production network type, which would mean that only looking at the specific region or branch would require delimitating the large data flows.
- Supply chain modelling does not always have the same goals as freight transport modelling. The freight transport models used by national governments etc. aim at determining what choices the decision makers in the supply chains make under certain circumstances (e.g. changed policy or taxation) and the supply chain models want to optimise the individual supply chain.

7.3. Conceptual Feasibility Example

This example tests the feasibility of Value of Time based modelling concepts as a disaggregate approach. The testing is done as a desk modelling exercise, where the general concept of Value of Time with good data availability is tested theoretically. The purpose is to reveal potential difficulties and dangers that would exist. The purpose is not to determine the overall suitability of Value of Time.

7.3.1. Conditions of a Conceptual Modelling Case

The lack of available data has been mentioned as a reason for several modelling issues related to Freight Value of Time and freight modelling in general. Possible deficiencies related to lack of data includes the need for a high aggregation level, which was found as a reason for Freight Value of Time failing to fulfil Turnquist’s second criterion. Lack of data was also the reason for failing criteria three and four.

Therefore a theoretical feasibility test was performed for a conceptual modelling case where data is not an issue.

In this example a policy analyst at the transport authority in Sweden (Transportstyrelsen) wants to know how much Freight transport there will be on the roads, railways and inland waterways, respectively if they implement a kilometre tax for all the heavy goods vehicles (HGV) in the country. What effects will the implementation of a km-tax for HGVs have on
transports is perhaps the question the analyst wants to answer; i.e. they want to know the future modal split, the total demand for transport and translate this into demand for vehicle-kilometres.

Hereon an assumption is made concerning perfect information availability i.e. that the analyst has the following data available due to data being shared from the supply chains:

- Current product flows
- Design of current supply chains in the country
- How the supply chains are connected abroad

This data can be seen as an ideal circumstance data, since much of the data is already available for internal use. Furthermore the following transport data which is already available to analysts are also available:

- Vehicle flows on:
  - Major roads (Trafikverket, 2012)
  - Railways (Vierth, et al., 2012)
  - Inland waterways (Vierth, et al., 2012)

Hereby the issue of identification of the decision maker is also resolved since there is no need for this when all the supply chain data is available. The decision maker is revealed through the data.

Furthermore, it is assumed that the valuations of time used for decision making in the supply chains are unknown. This is because when the kilometre tax is implemented all we know is what choices the decision maker used to make, not how he will make them in the future for new alternatives. We do not actually know what the utility maximising process the analyst used actually was like. Therefore we want to estimate this process by using discrete choice modelling.

The model chosen is the four-step model due to it being a common modelling practice (Ortuzar & Willumsen, 2011). Value of Time is used in the third step (i.e. mode choice)

The main parts of the modelling effort related to Value of Time and discrete choice modelling are thus:

- Calculating coefficients for Value of Time
- Deciding on what other factors to include and calculate coefficients for them

Thereafter they calculate future demand and modal split.

7.3.2. Feasibility Testing

There were approximately 129 500 production, mining, transport, construction and trade companies in Sweden 2013 (SCB Företagsdatabasen, 2014). These areas of business were chosen based on the high importance of freight transport to the operation. Out of these 129 500 companies, 1650 have above 100 employees.
Therefore since most companies are rather small, the companies are assumed to only have one decision maker per company who makes all transport related decisions. This translates to a total of 129 500 freight decision makers in these fields of business in Sweden. Other fields of business are excluded because they rely less on freight.

By having only one decision maker per company, there will only be one valuation for the same conditions per company. If there are more than one person making decisions parallel to each other it would be possible that the Value of Time is not consistent.

When the modal split and current demand is calculated it can with the data available either be calculated individually for each firm per country (in Sweden) or with some sort of aggregation (e.g. firm type, per village). The individual case is chosen for feasibility test due to the interest in testing the effects of a low aggregation level.

**Calculation of future modal split and future demand individually per company:**

By answering the following three questions based on the data available, the current vehicle demand can be calculated.

- What is their demand per year for their products?
- How do they choose transportation alternative based on the characteristics of the goods (especially the value)?
- How do they organise the transports? Outsourcing or in-house? What is the loading factor per mode?

Now the first step of the four-step model can be performed.

1. **Trip generation:** the outcome of questions above is the trip generation part of the four-step model.

It would now be possible to calculate coefficients for Value of Time, Value of Reliability and Value of Variability. It would also be possible to calculate how many vehicles of each type they currently use, i.e. the current vehicle demand. For the future modal split and future vehicle demand it could be a case of just changing the cost function for the HGV-transport alternatives by adding the kilometre-tax to the cost part of the utility function.

However this is most likely not the case since also the company’s sales are likely to vary. Therefore forecasts about the company’s production have to be made. Furthermore if there are alternatives that are available, but have not previously been used; the cost function is not available for these alternatives. Thus, the data at hand needs to be supplemented with other data sources such as stated preference surveys (on e.g. mode choice, transport time preferences, physical criteria etc.). This would add an inaccuracy because of estimating the new alternatives.

If detailed information is needed on future vehicle flows; such as location and perhaps hourly flows (the example above would merely render a yearly total vehicle demand) more forecasting efforts are needed. It thus comes down to the first criterion of Turnquist; what does the policy analyst want? If the answer is
vehicle-kilometres per mode (could also be ton-km or ton-hours etc.), the next step would be (according to the four-step model):

2. *Trip distribution*: Calculate the distance (as the crow flies) each product travels.

3. *Modal split*: Modify the current modal split based on what effects the new cost-function (i.e. the tax) has. For this a discrete choice model incorporating Value of Time is used.

Thereafter by aggregating the product flows to vehicle flows; an average amount of vehicle-kilometres can be calculated. This result would be irrespective of the route length which changes when the modal split changes. Therefore the last step of the four-step model is needed:

4. *Route assignment*: Routes could with some effort be estimated and distances calculated.

Some modes are however not able to perform door to door transportation and would have to be supplemented with alternative modes. This adds a dynamic discrete choice aspect (e.g. nested Logit) due to the transport alternatives not being independent alternatives. Simple methods such as nested Logit might however not be sufficient if the logistic chains become complex and the more advanced methods are often unverified and very difficult to use. The complexity of the models needed was one of the reasons for avoiding a high aggregation level, but it does not seem to be completely avoidable because treating multimodality at a disaggregate level adds a different complexity through the dynamic aspect the decision making.

However, if we assume that this would have answered the question of how many vehicle-kilometres this company will demand per mode. Consequently, this needs to be repeated for the rest of the 129 500 companies. The complexity of this model is very high, when nested Logit needs to be performed for 129 500 decision makers. This would mean a lot of calculations.

To see if this conceptual example performs better than in chapter 7.2 a test against Turnquist’s criteria is presented:

"An effective model is focused on producing an output that someone wants and knows how to use." : OK, since vehicle kilometres is both the output and what was sought after. The output is possible to be used for evaluating the km-tax introduction.

"An effective model includes the important variables that describe how the system works and represents their interactions clearly and correctly." : OK, since the interactions are described on a supply chain level.
“An effective model operates in a way that is verifiable and understandable.”: Due to the high complexity (dynamic decision making) and large number of calculations (the sheer amount of companies), the results might not verifiable against the original data. It is after all a forecast and since no kilometre-tax is at place for the same conditions (e.g. Sweden and HGV) comparing against reality is difficult. However, it would be possible to compare against similar cases such as the German LKW-maut. Therefore this criterion can only be seen as partially fulfilled.

“An effective model is based on data that can be provided, so that it can be calibrated and tested.”: OK, due to the original assumption of the supply chain data being available.

When data is available as in this highly idealised conceptual example, Value of Time based models seems to perform better on Turnquist’s criteria. However due to the underlying complexity of what is modelled and the estimations that still needs to be made it is likely to be a very complex model. It is furthermore, probably difficult to perform this for 129 500 companies, due to the time required.

Hence the largest issue with a low-aggregation/good data-availability modelling case seem to be that it becomes a lot of data to handle. This occurrence is often referred to as “big data”. Big data is said to have three dimensions: volume, variety and velocity (Russum, 2011). In this conceptual case mainly volume and variety are present, velocity not so much due to no real time updating of the model. A dataset can however be considered to be big data even if only the volume is high. Even though big data does present technical risks and challenges, it is often seen as benefit by the big data discourse (Russum, 2011).

One main issue that could disqualify this conceptual modelling case from being realistic is that currently, this supply chain data is actually not shared.
8. Discussion

8.1. Analysis Findings

Several issues with using Value of Time for freight as compared with for passenger transport were found. However, these issues are possible to summarise with the following categories:

1. Discrete choice model selection
2. High aggregation levels due to lack of data
3. Explanatory variables
4. Identification of decision makers
5. Transport flow heterogeneity

The wary reader recognises number three to five as the difficulties identified by Feo-Valero et al. (2011). The first two, are additional issues that have been identified. The selection of discrete choice model; influences the result because the different models have different capabilities. For instance identifying the need for a nested Logit or another dynamic discrete choice model when there are sequential decisions is important since regular multinomial Logit is not able to handle dependent alternatives.

The outcome of the survey is mostly interesting for the reader in an exemplifying manner. Nonetheless, the survey itself implied that information is probably not shared very freely in the field of freight decision making. Since this also was the reason for the second difficulty identified above (i.e. lack of data), the connection between the low response frequency of the survey and the difficulties for gathering data (both mentioned in literature and the survey) becomes interesting. It was therefore also the starting point for the conceptual feasibility study.

The feasibility testing showed that it is possible to improve the effectiveness of a model, using the four-step model with discrete choice modelling and Value of Time. This testing is however not perfect and does not show whether or not it will be an accurate model. It does however further highlight the issue of data availability for freight analysts.

A large portion of this report was dedicated to trends and characteristics of the freight market, which in the analysis was summarised as three main trends:

- Increased focus on supply chain management
- Increased amount of transports within the supply chains
- Globalisation – transforming the supply chains into, e.g. Global Production Networks.

This summary of trends can be even further summarised as Global Value Chains or Global Production Networks. The importance of this trend is put into proportions by the estimate that 80% of the world trade is within these structures. It does however seem rather ironic that one of the main enablers for this trend (information exchange) also is the main obstacle when modelling the freight transportation that is an essential part of the Global Value Chains or Global Production Networks. Since these trading/production structures actually are supply
chains on a global market, it would probably be rather natural for an analyst to combine the fields of supply chain modelling and transport modelling when creating a freight model.

Supply chain management is however not one single technique, and supply chains not one single type of occurrence. Consequently it becomes important to characterise the supply chains and identify their components, which is what is done in the Global Commodity Chain, Global Value Chain and Global Production Network discourses. However, even here there are (at least) these three ways of looking at the globalised supply chains. Creating, testing and verifying freight models or supply chain models corresponding to the respective discourses are probably needed to be able to with confidence say which of these three discourses that is best used for describing this phenomenon.

Furthermore, multimodal freight seems to be more difficult to model accurately than unimodal freight, as shown in the analysis. Unimodal freight consists of less activities and decisions than multimodal freight, and is therefore easier to verify and understand (see Turnquist’s third criterion). Furthermore, because multimodal transportation leads to not all decisions being made at once in the beginning, the decisions develop over time. This was the definition of a dynamic model presented in chapter 2.5. Also the dynamic discrete choice models were said to be difficult to verify and also to use (Arcidiacono & Ellickson, 2011). Thus, the identification of decision maker as well as the selection of discrete choice model, the verification of the model and the usage of the model; become more difficult for multimodal freight transports than for unimodal.

Consequently a model aimed at representing the more complex multimodal case would in turn become more complex. It is thus probably inevitable that a certain model or modelling concept such as Value of Time is less valid in this more complex multimodal context. However it does not automatically disqualify Value of Time from being as valid for multimodal models as for unimodal models if it is properly adapted. Nonetheless, modelling multimodal freight will be more complex and the risk of creating an inaccurate model is likely to be higher.

8.2. Methods

This report has combined several in themselves extensive research fields in order to examine Value of Time as a modelling concept for freight transport. When reviewing a large research field such as freight transport models or particularly the trends of the freight market, inevitably some aspects are excluded. Not all minor trends have been analysed or identified in this report, but some major ones have. The contribution of this report is therefore not a definite verdict on Value of Time as a modelling concept, but having explored the concept and analysed it in a wider sense. By showcasing a few possible issues with the concept of Value of Time and freight modelling when representing a freight transport context described by the trends and characteristics of the freight market, this analysis was able to produce suggestions for further research (see chapter 10).

Furthermore, Value of Time is a concept that is utilised in many models and therefore many different views on how to incorporate into modelling exits. This report has attempted to show
various ways Value of Time can be used. The method of doing that was to first give an overview of the domain of freight modelling, and thereafter explain the domain of discrete choice modelling. To portray the variety of what demand models, discrete choice models and utility functions can be like; aimed at furthering that Value of Time in itself is far from a single model. Consequently, combined with the trends and characteristics of the freight market it becomes rather obvious that the model has to be adapted to what is modelled. This is also the idea behind the VV&A method used by the Department of Defense in the USA, which assesses modelling applications and not models.

Value of Time is as presented in the literature review not the only factor on which decisions in freight are based. It has however been the subject of a large portion of the research concerning these factors. Therefore this report has also been decided to devote a lot of focus to this factor, but also to introduce other factors such as the time related factors; reliability and variability. These three factors are performance related in contrast to many other factors that influence the decision, e.g. goods handled. It is the performance factors that are traditionally used in discrete choice modelling; the other factors are taken into account when creating the alternatives in the utility function. It might however seem remarkable that sometimes reliability and variability are excluded. Imagine that you order something from a company and that company subcontracts a second company to perform the transportation. If the goods is delayed this would probably affect your opinion about the first company. Therefore, based on reasoning reliability and variability ought to be interesting factors for decision makers. This reasoning is also supported by Lundberg (2006) who found that freight actors consider reducing delays as rather important and extra important for goods with high values. It would therefore seem reasonable to include these factors, but the question is probably: how do you reliably calculate the value of for instance loss of reputation due to delays? Likewise, “Value of Risk for Loss” could be an important factor and could be useful to include in future studies.

The initial aspiration of this report was to be able to draw valid conclusions from the survey section about the opinions and practises of freight actors concerning freight modelling. However, due to a low response frequency it was not possible. The low response frequency is mentioned as an issue by previous researchers as well. Even though the survey methodology applied in this report was not sufficient, it is possible to get responses from freight actors. This was proven by Lundberg (2006), who used a more personal strategy by performing interviews. Her research was however on how important different factors were considered to be, not on how they do their evaluations or perform their models before making decisions. By using a similar method as she did, it ought to be possible to gather knowledge on freight modelling practises as well.

The feasibility test for a “good availability of data” case in the analysis chapter gave further support to the notion of data availability being of great importance for the success of models using Value of Time. The testing was carried out by using Turnquist’s effectiveness criteria and showed that the model is more effective when more data is available. This is however not enough testing to actually know if a model will be reliable and adequate. Such knowledge about a model can be extracted from more detailed model assessment efforts such as the VV&A method. The effectiveness criteria were nonetheless able to give an overview of the
models validity. Consequently the effectiveness testing was able to render insights into Freight Value of Time which can be useful for future research as well as modelling applications. Validation of a model should however be carried out for the specific modelling application since the validity depends on the proper selection of identification of decision maker, aggregation level, utility function, discrete choice model and probability distributions; which are not universal.
9. Conclusions

Value of Time for Freight in practice is seemingly limited in its reliability due to issues with obtaining data. When enough data is obtained the complexity could provide difficulties in using discrete choice modelling accurately due to that the complexity of the models increase.

The main issues identified with Freight Value of Time are:

1. Discrete choice model selection
2. High aggregation levels due to lack of data
3. Explanatory variables
4. Identification of decision makers
5. Transport flow heterogeneity

Following up on the research questions:

How can the Freight Value of Time concept fulfil the requirements that decision makers in international freight have on the reliability of the modelling outcome?

Freight Value of Time has limitations in reliability that depends on how complex the system modelled is, and how complex the discrete choice model that is used is. The discrete choice model and utility function should correspond to the complexity of the system modelled, and the detail and reliability of the output needed.

However, since data availability often is a constraining factor when designing the model, Freight Value of Time models become difficult to design to provide a certain reliability level.

To take inspiration from supply chain management, and model the product flows instead of the vehicles would be helpful because detailed data on decisions is existing. However, since this data is not shared today it is still not possible. Furthermore, for large applications it becomes a very large amount of data to process as seen in the Conceptual Feasibility Example. If the supply chain data is at hand it would nonetheless provide the possibility to choose aggregation level based on the purpose of the modelling, rather than that choice being made based on data availability.

What are the differences between the multimodal and the unimodal applications of Value of Time in terms of validity?

Multimodal models become more complex due to the increased amount of activities, the increased amount of decision makers and the likely introduction of the dynamic decision making. Consequently the models become more complex and this complexity makes it more difficult to design an accurate model. The validity of the model in terms of how proper the representation of reality is will probably be lower than for a unimodal model unless the modelling application is adapted to the multimodal case. It is therefore important to validate and verify the model for the specific application case.
The hypothesis of this project was:

*Models using Freight Value of Time are not reliable enough to be used in practise.*

There are several reasons for confirming the hypothesis, such as decision making in reality can be dynamic, difficult to obtain data and decision making is not discrete. However, the models can in some cases be the best alternative available and applications in simple transport systems such as unimodal systems do not have all the drawbacks of applications to more complex systems. The hypothesis can neither be rejected because it is too difficult to verify Freight Value of Time models against reality. Therefore the following recommendations to analysts, interested in Freight Value of Time are made:

The specific model should be verified and validated before being used, which is probably best done for the specific application with a standardised verification and validation method such as the VV&A (used by Department of Defense in the USA).

Freight Value of Time is best used for unimodal applications, but for multimodal applications it could be reliable enough if the model is properly adapted to the complexity of the reality which is modelled.

The higher the complexity of a modelling scenario, the more data is needed. Therefore an analyst needs to make sure that this trade-off is kept at a level where the results fit the requirements of the application.

Low aggregation levels benefits the accuracy of the model, but increase the amount of calculations. It is therefore good to be aware of the risk of calculation errors.
10. **Recommendations for Future Research**

The exploratory methodology of this report opens up for further research on several aspects of freight modelling. Based on lessons learnt during this project the following recommendations and suggestions could be considered for future research on freight, freight modelling and Value of Time.

Instead of the survey, perform extensive interviews with decision makers figuring out what the freight modelling practice actually is like today. The personal contact is more likely to yield replies.

Perform quantitative testing of freight models using Value of Time if reliable data can be attained. It would be interesting from a testing point of view to compare the outcomes of different discrete choice models and utility functions for multimodal freight cases.

 Practically examine supply chain models in order to see how time and valuations of time are handled. This can probably give useful insights that can be adapted and used in transport models.

Additionally, attempting to incorporate theories from the Global Value Chains or Global Production Network discourses, with the existing modelling concepts can possibly provide new useful modelling perspectives for freight.

It would be useful to know how indirect costs (e.g. the risk of loss of reputation) affect the valuations of Value of Reliability and Value of Variability. Research into this topic could further the knowledge of how important these factors are in comparison with Value of Time.
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Appendix A: Survey
The survey is presented as it was seen by the Swedish respondents if they had Swedish set as the default language in their internet browsers. The survey consisted of 6 separate pages.

Page 1:

Survey on how freight stakeholders use modelling.

My name is Robert Olofsson and I am a student at Royal Institute of Technology (KTH) in Stockholm. This survey is a part of my Master Thesis in the field of logistics. The purpose of this survey is to determine how different stakeholders in freight transportation use modelling for strategic and tactical purposes. The results will be compared with existing research and macroscopic trends, in order to see if researchers and practitioners have different views on modelling.

Hopefully, combining in-depth knowledge on how modelling is done in practice with state-of-the-art research into models can create more reliable models in the future.

Thank you in advance for participating.

General questions (1 of 6)

What is your main function/position at your company?

In which country is your company based/registered?

What is your company’s main role in freight?

- [ ] Shipper or Freight Customer (sender/buyer of the service)
- [ ] Freight Forwarder (organising transport solutions for customers/shippers)
- [ ] Transport Operator (carrying out the transports)
- [ ] Transshipment Facility Owner (i.e. a freight terminal or port etc, where the goods is organised between different modes)
- [ ] Transshipment Facility Operator (i.e. a freight terminal or port etc, where the goods is organised between different modes)

What transport modes are your company currently involved with? (for intermodal you can select more than one)

- [ ] Deep sea freight
- [ ] Inland Water Way freight
- [ ] Road: Heavy Goods Vehicles (trucks)
- [ ] Road: Light Goods Vehicles (vans)
- [ ] Railway
- [ ] Air Cargo: Air cargo airline
- [ ] Air Cargo: Passenger airline

What types of goods do you handle/transport?
- Bulk
- Containers
- Tempered goods (perishable)
- Hazardous goods
- Small units (Parcels, packages or single pallets)
- Other: [Input field]

In what markets is your company operating?
- Local transports
- Regional transports
- National/interregional
- International
- Other: [Input field]

How many employees does your company have?
[Input field]
Survey on how freight stakeholders use modelling.

General questions on modeling

Is mode choice (e.g. lorry, inland waterway, air freight...) strategical, tactical or operational for your company?
You can select more than one alternative.

☐ Strategic
☐ Tactical
☐ Operational
☐ I don’t know
☐ Other:

What methods do you use to make decisions on mode choice (what type of transports to use)?

Do you use time based models?
These models translate time into monetary terms or look at how much you are willing to pay to save a certain amount of transport time. Often referred to as “Value of Time” or “Opportunity cost of time”.

☐ Yes, in strategical models
☐ Yes, in operational models
☐ Yes, in tactical models
☐ No
☐ I don’t know
☐ Other:

Is transport time variability included in your models/evaluations?
In other words: Do you take into account the costs inflicted by varying transport times?

☐ Yes, in strategical models
☐ Yes, in operational models
☐ Yes, in tactical models
☐ No
☐ I don’t know
☐ Other:
Is transport reliability included in your models/evaluations?
In other words: Do you when making decisions consider how reliable the different alternatives are?
- Yes, in strategical models
- Yes, in operational models
- Yes, in tactical models
- No
- I don’t know
- Övrigt: __________________________

Are your models able to cope with randomness/stochastic variables?
In other words: Is your system deterministic?
- Yes, in strategical models
- Yes, in operational models
- Yes, in tactical models
- No
- I don’t know
- Övrigt: __________________________

Do you use dynamic models?
In other words: Does your model update itself in real time?
- Yes, in strategical models
- Yes, in operational models
- Yes, in tactical models
- No
- I don’t know
- Övrigt: __________________________

Are your models capable of handling multimodal transports?
In other words: Can you model logistics chains where more than one mode (lorry, rail, inland waterway etc.) are involved?
- Yes, in strategical models
- Yes, in operational models
- Yes, in tactical models
- No, we are only interested in one mode
- No, we model one mode at a time
- No
- I don’t know
- Övrigt: __________________________
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Strategic Modelling

Does your company use computer models/simulation for strategic decisions?
Strategic decisions are long term decisions for determining the overall direction of the enterprise (usually 1-5+ years horizon). E.g. markets to operate on, type of services to offer etc.

- Yes
- No
- I don't know
- Övrigt: 

What programs or methods do you use? (for operational decisions)
Please write down the name of the computer program or method.

Is demand modelling an important tool for strategic decision making in your company?

1 2 3 4 5 6 7 8 9 10

No, we never use it ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Yes, it is very important ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

On what detail level do you model time (in strategic modelling)?

☐ Seconds
☐ Minutes
☐ Hours
☐ Days
☐ Weeks
☐ Months
☐ Years
☐ I don't know / I don't model time
☐ Övrigt: 

« Bakåt  Fortsätt » 50 % fyllt
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**Tactical Modelling**

Does your company use computer models/simulation for tactical decisions?
Tactical decisions are medium term decisions for determining what actions to take in order achieve the strategic goals of the enterprise (usually 6-12 month horizon). E.g. how to market the company’s services, budgeting, allocation of company resources between projects etc.

- Yes
- No
- I don’t know
- Övrig: __________

What programs or methods do you use? (for tactical decisions)
Please write down the name of the computer program or method.

Is demand modelling an important tool for tactical decision making in your company?

1 2 3 4 5 6 7 8 9 10

No, we never use it ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Yes, it is very important ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

On what detail level do you model time (in tactical modelling)?
- Seconds
- Minutes
- Hours
- Days
- Weeks
- Months
- Years
- I don’t know / I don’t model time
- Övrig: __________
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Operational Modelling

Does your company use computer models/simulation for operational decisions?
Operational decisions are short term decisions for determining how to carry out the day to day operation. E.g. route choice.

○ Yes
○ No
○ I don’t know
○ Other:

What programs or methods do you use? (for operational decisions)
Please write down the name of the computer program or method.

Is demand modelling an important tool for operational decision making in your company?

1 2 3 4 5 6 7 8 9 10

No, we never use it ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ Yes, it is very important

On what detail level do you model time (in operational modelling)?

☐ Seconds
☐ Minutes
☐ Hours
☐ Days
☐ Weeks
☐ Months
☐ Years
☐ I don’t know / I don’t model time
○ Other:

83% Sfyllt
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Data Collection

How difficult do you find gathering data for models?

1 2 3 4 5 6 7 8 9 10

- Very easy (I get the data I want and it is as accurate as I want it to be)
- Very difficult (not available or not accurate)

How do you gather data?
- Surveys - Stated Preference (SP)
- Statistics - Revealed Preference (RP)
- Experience based (based on knowledge)
- Övrigt:

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100 %: Du är klar.