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REPORT

VTTV – Value of Transport Time Variability

Method development and synthesis

Value transfer, measurements, and decomposition of VTTV

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Trafikverket
Postadress: Adress, Post nr Ort
E-post: trafikverket@trafikverket.se
Telefon: 0771-921 921

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Authors: Magnus Landergren*, Moa Berglund**, Inge Vierth*, Christer Persson**, Jonas Waidringer***, Matts Andersson**, Jonas Flodén****

*VTI, **WSP, ***Logistics Landscapers, ****Handelshögskolan vid Göteborgs Universitet,

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Contact: Petter Hill

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1 Introduction

Transport time savings (TTS) and reduced transport time variability (TTV) for passenger and freight transports are important benefits in CBA in the transport sector. One presumption is the monetary valuation of TTS and TTV. Travelers' TTS and TTV are valued based on Stated Preference studies (SP studies). Regarding freight, shippers' value of time savings per tonne-hour (VTTS) is in CBA currently based on the value of the cargo transported. The benefits due to reduced transport time variability (VTTV) are assumed to be twice of the VTTS. Carriers' benefits related to time savings and reduced transport time variability are included in the transport costs.

This project focuses on the freight VTTV. The Swedish Transport Administration funded two pilot studies that addressed this subject in 2013. One was carried out by WSP & partners[1], and one by VTI & partners[2]. The pilot studies were reviewed on a seminar 3 September 2013. Adjacent to the seminar the Transport Administration encouraged WSP and VTI to apply for a joint main study. In November 2013, KTH, WSP and VTI applied for funds for the common project. The work was organized in eight work packages (WP): 1) Value transfer from Norway and The Netherlands, 2) Micro model approach, 3) Precautionary costs approach, 4) How to measure VTTV?, 5) Development of SP-method, 6) Market analysis and sampling, 7) Case studies to get input to all other WP and 8) Synthesis. The Transport Administration decided to fund WP 1) carried out by VTI & partners and WP 4) carried out by WSP & partners and asked VTI and WSP to write a report with common conclusions. This report is presented below. Chapter 2, "WP 4 Decomposition of VTTV" (formerly *Measurements*) is written by WSP & partners and chapter 3, "WP 1 Value transfer" by VTI & partners. The final chapter includes common conclusions.

In chapter 2, measures for quantifying the transport time variability are presented and discussed. Furthermore, by decomposing VTTV into different parts, we show how VTTV should be derived in order to account for different types of costs caused by variation in transport time. We also mathematically derive a model for estimating VTTV, given that cost functions and transport time probability distributions are either known or modelled.

The objective of chapter 3 is to derive commodity specific VTTV that can be used in Swedish cost benefit analysis from the SP studies carried out recently in The Netherlands (covering all modes) and Norway (one study covers all modes, the other is limited to rail). The emphasis is on rail transports as a high share of the delays, early arrivals and cancelled departures in Sweden are caused in the rail transport system. Two aspects are taken into account in order to transfer commodity specific VTTV in an appropriate way: a) differences between The Netherlands, Norway and Sweden when it comes to the products transported, average transport distances, modal split, characteristics of the rail network etc. and b) differences between the three SP-studies, i.e. sampling, response rate, design of choice experiments, measurements and values etc.).

[1] KTH, University of Gothenburg, Transrail, Vectura, WSP Analysis & Strategy (2013)
[2] Krüger et al (2013), Krüger & Vierth (2014)

Sammanfattning på svenska

Transporttidsvinster (TTS) och minskad transporttidsvariation (TTV) för gods- och passagerartrafik är viktiga nyttoposter i de samhällsekonomiska kalkylerna inom transportsektorn. Ett av antagandena som behöver göras är den monetära värderingen av TTS och TTV – VTTS och VTTV. Resenärers värderingar av dessa mått baseras oftast på SP-studier (*Stated Preference*). VTTS för godstrafik baseras på kostnaden för kapitalbindningen i, och därmed värdet av, godset. I nuläget antas VTTV vara lika med det dubbla VTTS. Transportörers nyttor av minskad transporttid och transporttidsvariation beräknas som en del av transportkostnaderna (i andra poster i kalkylen). Detta projekt fokuserar på VTTV för godstransporter.

Den här rapporten består av två delar. Kapitel 2, som är skrivet av WSP, Handelshögskolan vid Göteborgs Universitet och Logistics Landscapers, beskriver WP 4 som handlar om vilket mått som ska användas för transporttidens variation, vilka delar VTTV består av samt härleder en matematisk modell för att beräkna VTTV.

Syftet med WP 4 var ursprungligen att kartlägga och utvärdera olika mått för transporttidsvariationen (TTV). Med mått menas enheten som används för att kvantifiera variationen, som exempelvis standardavvikelsen eller den genomsnittliga förseningen. En litteraturstudie har genomförts där använda mått i 22 tidigare samhällsekonomiska studier i Sverige och utomlands listas. En slutsats av litteraturstudien är att många olika mått använts, vilka kan kategoriseras under

- Standardavvikelse
- Spridning (ofta i form av skillnad mellan percentiler)
- Andel av sändningar som är försenade
- Genomsnittlig försening (om försenad)

Fördelar och nackdelar med de olika måtten diskuteras. En annan slutsats är att valet av mått sällan diskuteras i de genomgångna studierna, utan man verkar ha valt ett mått som passar undersökningsmetoden. Vidare har det undersökts om det används mått inom logistikbranschen som skulle kunna passa TTV inom samhällsekonomin. Slutsatsen är att dessa mått (eller indikatorer) är framtagna med andra syften och för användning på mikronivå (företag eller enskilda transportkedjor) vilket gör det svårt att tillämpa dem på makronivå. Dock finns ett behov av mått på en mesonivå som gör det möjligt att analysera förändringar i transportsystemet ur båda perspektiv – samhällets och enskilda aktörers.

En genomgång och struktur för vilka kostnader som uppstår till följd av förseningar presenteras, där kostnadsdrivare och del i transportkedjan definieras för varje kostnad. Vidare kategoriseras störningar eller förseningar i fyra kategorier beroende på magnitud (förseningens längd) och frekvens med vilken de inträffar.

- Vanligt förekommande och små störningar benämns *Förväntade risker* och absorberas i transportupplägg genom inbyggda marginaler (exempelvis tidsmarginaler eller extrafordon). Dessa störningar får alltså små direkta konsekvenser när de inträffar, men orsakar å andra sidan indirekta, fasta kostnader för de extra marginalerna, som delas av alla sändningar.

- Små eller något större, men mer ovanliga störningar benämns *Eventualiteter* och är händelser som inte är planerade för i transportupplägget. De orsakar därmed större direkta kostnader när de inträffar, men går ändå att hantera. I och med att det är händelser man inte planerat för, orsakar de inte fasta kostnader på samma sätt.

- Mycket stora störningar som inträffar sällan är exempelvis naturkatastrofer och benämns *Katastrofhändelser*. Dessa är inte planerade för i transportsystemet och orsakar mycket stora konsekvenser när de inträffar.

- Slutligen benämns mycket stora störningar som inträffar ofta *System killers*. Ett transportsystem som utsätts för stora störningar med hög frekvens kommer inte att användas och utesluts därför ur analysen.

Katastrofhändelser beskrivs bäst kvalitativt och VTTV bör därför inkludera kostnader för Förväntade risker och Eventualiteter. Sändningar som ej har en större försening än gränsen för vad som anses vara en Förväntad risk, antas inte driva några direkta kostnader, medan sändningar med större försening (eventualiteter) börjar driva direkta förseningar. Dessa kostnader beror på förseningens längd enligt samband som förmodligen har såväl linjära som stegvisa och icke-linjära delar. Sambanden varierar också förmodligen mellan branscher och olika transportkedjor. Kostnaderna för de förväntade riskerna delas av alla sändningar och är därmed oberoende av de enskilda sändningarnas förseningslängd. Gränsdragningarna mellan de olika typerna av störningar samt kopplingarna mellan vilka kostnader som orsakas av vilka störningar, behöver utvecklas vidare och definieras mer rigoröst.

En modell som visar hur företagens kostnader påverkas av att transporttider varierar, har tagits fram med hjälp av den så kallade scheduling-metoden. Den kan i sin tur användas för att härleda uttryck för VTTV. En sådan härledning visar att VTTV för godstransporter kan delas upp i två termer. En term som beskriver hur kostnaderna ändras när TTV ändras och en term som beskriver hur transporttidens fördelning ändras när TTV ändras. Båda termerna bidrar i sin tur till VTTV.

Denna modell fungerar oavsett vilket mått för TTV som väljs. Vilket mått som bör användas är alltså snarare beroende av hur sambandet mellan förseningars magnitud och resulterande kostnader samt hur transporttidens sannolikhetsfördelning ser ut. Kostnadskurvorna byggs upp av fasta kostnader som beror på den generella variationen av transporttiden och dels rörliga kostnader som beror på den enskilda förseningens magnitud. Det exakta utseendet av kostnadskurvor för olika branscher och transportkedjor behöver dock kartläggas genom datainsamling. Valt/valda mått behöver kunna fånga detta utseende och likaså troliga förändringar i transporttidens dannolikhetsfördelning till följd av åtgärder i infrastrukturen. Sådana förändringar uppskattas med hjälp av effektsamband, något som fortfarande till stor del saknas.

Kapitel 3 är skrivet av VTI och undersöker möjligheten att ta fram svenska varuspecifika VTT-värden från tre tidigare utländska SP-studier. Kapitel 3 motsvarar WP 1 i avtalet med Trafikverket (TRV 2014/28389). Av de tre studierna är två norska (GUNVOR och PUSAM) och en nederländsk (VOTVOR). Uppdraget involverar bland annat att jämföra förutsättningarna i de tre länderna; beskriva hur VTT mäts i de olika studierna; förklara skillnaderna i VTT mellan studierna; förklara hur VTT skiljer sig mellan trafikslag och varugrupper och vad som krävs för att överföra de norska och nederländska VTT-värdena till Sverige. Tyngdpunkten ligger på järnvägstransporter eftersom de svarar för den största delen av förseningar i Sverige.

Den övergripande slutsatsen är att det inte går att överföra VTT-värden baserat på de tre studierna på grund av nationella särdrag, bristfällig statistik, brister i vissa av studiernas kvalité samt att de stora skillnaderna mellan värdena i de norska och den holländska studien.

Kapitlet är huvudsakligen indelat i skillnader mellan länderna och skillnader mellan studierna. Den svenska godsmarknaden är mer beroende av järnvägstransporter än den norska och framförallt den nederländska. Förklaringen står troligen att finna i att Sverige är ett stort och avlångt land med mycket basindustri i inlandet, vilket är en konkurrensfördel för järnvägen gentemot lastbilstrafiken. I Nederländerna går stora delar av det lågvärdiga godset (som i Sverige går på järnväg) på kanaler. Enligt den officiella statistiken är varorna som transporteras på järnväg i de tre länderna lika i det avseendet att det huvudsakligen rör sig om lågvärdigt gods. Sverige utmärker sig med stora andelar malm, skogsprodukter, papper och metall. Nederländerna transporter stora mängder kol, vilket inte förekommer i de skandinaviska länderna. Det påstås att den norska järnvägstrafiken kännetecknas av en stor andel högvärdiga konsumentprodukter, detta har vi inte kunnat få bekräftat då den norska statistiken har betydande brister. Fördelningen mellan varugrupper var tänkt att vara den variabel som justerade de utländska värdena till svenska förhållanden, men med brister i statistiken och en avsaknad av varugruppsindelning i de tre underliggande studierna har den ansatsen inte varit möjlig att genomföra.

De tre studierna skiljer sig i omfång. Den nederländska VOTVOR och den norska GUNVOR undersöker flera transportslag, den norska PUSAM undersöker bara järnvägstransporter. Studierna mäter förseningskostnader olika. GUNVOR och VOTVOR använder bland annat VTT och PUSAM använder förseningskostnadernas väntevärde, därmed är en direkt jämförelse av samtliga värden problematisk. Skillnaden mellan värdena är så pass omfattande att dess betydelse inte kan bortses från. Den nederländska studien har fem till tio gånger lägre VTT-värde än de norska studierna. Det är ett betydande skäl till varför en värdeöverföring inte är lämplig. Den stora diskrepansen skapar frågetecken, beror den på studiernas metodik eller ländernas förutsättningar? I avsaknaden av svar på den frågan skulle resultatet av en värdeöverföring bli felaktigt. Det nuvarande svenska genomsnittliga VTT-värdet från ASEK är det klart lägsta i sammanhanget, mindre än hälften så högt som det nederländska värdet från VOTVOR.

GUNVOR och PUSAM har problem med urvalsmetoden och den låga svarsfrekvensen. VOTVOR är bättre i dessa avseende, men för samtliga tre studier är det svårt att bedöma hur väl urvalet representerar populationen. Ett annat övergripande problem att svaren från företagen i SP-studierna inte viktats efter företagens transportefterfrågan. Eftersom några få stora aktörer kan stå för stora delar av den totala transportefterfrågan på järnväg (i Sverige står t.ex. LKAB för ungefär en sjundedel av det totala transportarbetet) blir resultatet missvisande om det inte viktas. I PUSAM är ytterligare ett problem att såväl speditörer som varuägare ingår i valexperimentet vilket gör det svårt att tolka vilka kostnadsdrivare som studien avser att mäta.

Slutligen sammanfattas projektets gemensamma slutsatser. Utöver de slutsatser som beskrivs ovan, konstateras det att för att nå det slutgiltiga målet - som är att kunna inkludera nyttan av minskad transporttidsvariation för godstrafik i de samhällsekonomiska kalkylerna - behövs förutom VTTV även effektsamband som beskriver hur transporttidens sannolikhetsfördelning påverkas av åtgärder man vill analysera.

För att ta fram VTTV är nästa steg att samla in data över hur samband mellan förseningens magnitud och resulterande merkostnader och mellan den generella osäkerheten i transportsystemet och inbyggnad säkerhetskostnader ser ut. Detta behöver undersökas för olika branscher och olika typer av transporter. En sådan datainsamling bör föregås av en analys av godstransportmarknaden för att avgöra vilka och hur många aktörer och transportupplägg som ska inkluderas i datainsamlingen.

2 WP 4 – Decomposition of VTTV

Introduction

The original purpose of this work package was to review and recommend measures for TTV. By *measures for TTV*, we mean the unit used to quantify the *Transport Time Variability (TTV)*. Examples include the standard deviation of the transport time, the mean delay or the fraction of transport times exceeding a certain threshold value relative to the expected transport time. The measure used for TTV thus concerns the probability distribution of the transport time itself, rather than the valuation of the transport time variability. The figure below shows the necessary steps to make a CBA of an infrastructure investment (or achievements other than pure investments). While the estimation of VTTV – the *Value of* TTV – relates to the last step (to value the effects), measurement of TTV is related to the second step as well – to be able to quantify the effects of the investment on the transport time variability, one must choose which measure to use.

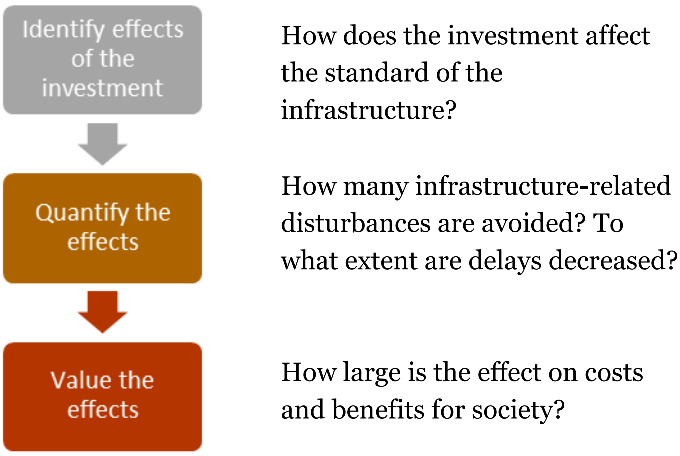

Figure 1 Steps of CBA

The purpose of the work underlying this chapter was originally aimed at reviewing and proposing a measure for *TTV* within the framework of the National Transport Administration in Sweden, specifically SAMGODS and related to the railway system. The valuation of TTV requires an established measure of TTV, and the hypothesis was that the possibilities to make useful valuations of TTV will depend on the choice of measure. However, the study has found that the possibility to make a good valuation of TTV is not dependent on the chosen measure of TTV. It is explained later in this chapter that many different measurements are approximately equally good from a modelling point of view (that said, a measure is still needed for practical reasons – this is elaborated further below). Rather, the appropriate choice of measure of TTV is dependent on how the cost functions of the longer delay effects looks. The overall structure of the cost function, divided into two parts, has been determined and is explained in this chapter as well. However, the final decision on the most appropriate measure depends on the structure of the cost function for the longer delays, which unfortunately is a very complex task to determine and outside the scope of this study.

After an extensive literature study we found that neither research in logistics nor CBA has evaluated suitable measures for the purposes of this study. Measures in logistics focus on the enterprise level, and CBA studies have not addressed the question as such. During the course of the work an opportunity to go further and actually propose a method for estimating the value of delays in goods transport, VTTV (Value of Transport Time Variability) presented itself. This led to a change in focus and a new purpose for the study. By decomposing VTTV into different parts, we show how VTTV should be derived in order to account for different types of costs caused by variation in transport time. We also mathematically derive a model for estimating VTTV, given that cost functions and transport time probability distributions are either known or modelled.

This chapter starts with an introduction to TTV in a CBA context, followed by an overview of existing measurements in the logistics industry. The effects of delays are then investigated and the general cost structure of delays explained. A method to mathematically estimate VTTV is then shown.

Measures of TTV in CBA literature

A literature study on how TTV has been measured before has been conducted and is presented in table 1 below. Except identifying the measures used in the studies, any discussions in the studies on which measure to use has also been analyzed. The result is surprisingly meager. Most studies have used a measurement that suits their survey method, without discussing the general pros and cons of different measures.

For the actual measure used for TTV all studies used one of the following four measures, (1) Standard deviation, (2) spread, usually defined as difference between percentiles, (3) percentage of shipments delayed, and (4) average delay (if delayed). Another way to describe the studies is whether or not a scheduling approach has been used. The scheduling utility approach has been used extensively for passenger traffic. The main feature of scheduling is to consider how an actor’s utility for the activity generating a transport changes as a function of time, often delivery and departure time for a freight transport. This is then used to derive an expression for the utility. Typically, all studies in table 1 where scheduling approach has been used, has used the so called α-β-γ preferences, where α is the marginal utility for travel time and β and γ denotes constant marginal utilities for early and late delivery (often called delay early and delay late). Scheduling approach does not restrict the measures used for TTV. All for measures given above may be used in this approach. When scheduling approach is not used VTTV is typically incorporated in the utility of a choice model by adding a term for a suitable TTV measure multiplied by a parameter.

Of the first eleven studies, from 1981 to 2001, eight used proportion of delayed shipments as a variability measure, while one used standard deviation, one study used a both standard deviation and a scheduling approach and one study used proportion of delayed shipments and a scheduling approach. For the last eleven studies, from 2001 to 2012, five studies used proportion of delayed shipments as variability measure, three studies used standard deviation, two studies used scheduling approaches and one study (Henscher et al. 2005) used a combination of different measures. Though proportion of delayed shipments is the most common measure of variability over the whole period covered, there is an increasing use of standard deviation and scheduling utility approaches in later studies.

Table 1 Summary of VTTV studies

Study	Country	Mode	Type of variation measure	Type
Winston (1981)	USA	Road/rail	standard dev.	SP+RP
Transek (1990)	Sweden	Road/rail	Prop. delayed shipm.	SP
Transek (1992)	Sweden	Road	Prop. delayed shipm.	SP
de Jong et al. (1992)	Netherlands	Road/rail	Prop. delayed shipm.	RP
de Jong et al. (1995)	Denmark, Netherlands, France	Road	Prop. delayed shipm.	SP
Accent and Hague Consulting Group (1999)	UK	Road	Prop. delayed shipm.	SP
Small et al. (1999)	USA	Road	Std. dev., CV and scheduling Expected delay early and late combined with probability of being late	SP
Bergkvist et al. (2000)	Sweden	Road	Prop. delayed shipm.	SP
Kurri et al. (2000)	Finland	Road/rail	Road: Prop. delayed shipm. Rail:expected/Schedule delay	SP
Wigan et al. (2000)	Australia	Road	Prop. delayed shipm.	SP
Bergkvist (2001)	Sweden	Road	Prop. delayed shipm.	SP
de Jong et al. (2001)	France	Road/rail, intermodal	Prop. delayed shipm.	SP+RP
Fowkes et al. (2001)	UK	Road	Spread, and Expected/Schedule delay	SP

			Spread: the time within which 98% of the deliveries takes place minus the earliest arrival time	
INREGIA (2001)	Sweden	Road/rail/air	Prop. delayed shipm.	SP
RAND Europe (2004)	Netherlands	Road/rail/ inland waterways, sea/air	Prop. delayed shipm.	SP+RP
Hensher et al. (2005)	Australia	Road	Multi actor framework (transporter/shipper). No single measure, Probability of on-time arrival (transporter), Slowed-down time (shipper), Waiting time (shipper), Probability of on-time arrival (shipper)	SP
Fowkes (2007)	UK	Road/rail	Scheduling approach; Spread, early start, late arrival, early and late shifts.	SP
Maggi et al. (2008)	Switzerland	Abstract mode	Prop. delayed shipm.	SP
De Jong et al. (2009)	Netherlands	Road,/rail/ inland waterways/ sea/air	Std. dev. Conversion of Rand Europe (2004) to reliability ratios RR	SP
Fries et al. (2010)	Switzerland	Road/rail/ intermodal	Prop. delayed shipm.	SP
Halse et al. (2010)	Norway	Road	Std. dev.	SP
Significance, VU University et al. (2012)	Netherlands	Road/rail/ inland waterways/ sea/air	Std. dev.	SP

The discussion on TTV-measurements could be divided in two parts: what to measure and how to measure.

Several authors have distinguished three possible units of analysis (Massiani, 2003):

1. Delivery time: the time between the arrangement between the shipper and haulier regarding the consignment of specific goods and the arrival of the goods at the consignee.

2. Transportation time: includes all logistics between origin and destination (loading, unloading, etc).

3. Travel time: the duration of the travel from origin to destination.

The terminology has its origin with passenger transport, which makes the name of the units somewhat unusual from a freight transport perspective. However, the original names have been kept here. The broader units of analysis (1 and 2) include all aspects of freight transportation, but may also include issues that are not linked to the value of time (Zhang et al, 2005). Most studies have therefore concentrated on the more limited third measure (Zamparini and Reggiani, 2007). Our review shows that a lot of studies measure even more limited units:

4. Mode time: the duration of travel on a specific mode.

5. Link (or node) time: the duration of travel on a specific link (or node).

The next step is to determine how to measure the effects. *Value of Reliability* (VoR) is often used instead of VTTV. Based on the literature review, the measures of VoR could be grouped in to variants of:

a) Standard deviation

b) Spread (usually defined as difference between percentiles)

c) Percentage of shipments that are delayed

d) Average delay (if delayed)

The most interesting measure is the standard deviation. The benefits of standard deviation are mainly theoretical:

In passenger and freight traffic it is usually considered useful if the value of reliability can be transformed into a reliability ratio, i.e. normed against the value of time (reliability ratio = value of reliability / value of time) The benefits are transferability, VoT (*Value of Time*) is usually available and one wants to be consistent with these, and adaptation to the CBA (de Jong et al, 2009). VoR for passenger traffic is usually measured by standard deviation, which easily transforms into a reliability ratio.

Standard deviation has nice theoretical benefits when using a scheduling model. A scheduling model means that agents hold preferences for timing of activities and that utility is derived from arrival time (being early or late). Provided the standardized distribution is fixed, the optimal departure time as well as the optimal expected cost depends linearly on the mean and standard deviation of the distribution of trip durations. Both the optimal departure time and the value of reliability depend in a simple way on the standardized distribution of trip durations and the optimal probability of being late, which in turn is given by the scheduling costs (Fosgerau and Karlström, 2009). Standard deviation suits most CBA-contexts.

One drawback of standard deviation (or variance) is that it is hard to grasp for respondents when doing data collection. Most freight transport that include the value of reliability, have used SP or combined SP/RP surveys. The concepts of variance and standard deviation are considered as too difficult for the respondents (shippers and carriers), hence most studies use the probability of delay or the percentage not on time instead (de Jong et al. 2004). In the SP-studies, the only discussion that could be found about measurements concerns which measure that is most significant. One possible interpretation is that the type of measure to be used is best decided during the actual study, one is that there is a great need for a systematical overview.

A desirable property of a measurement is that it should be translatable to a distribution curve. The distribution curve should then correspond to both the way that respondents value reliability and the way different policy measures effect reliability. Average delay (if delayed) does not correspond to a distribution curve (if it is not combined with a measure of the percentage of shipments that are delayed): policy measures that diminishes small delays gets a negative utility. Standard deviation and spread both includes costs of arriving early, while percentage of delayed shipments does not. What is correct is determined by whether there is a cost of arriving early and whether the modelling of the effects pics up this effect.

Measures used in the logistics industry

The logistics industry uses key performance indicators (KPI) to monitor their operations. These are often easy to understand and easy to collect values that give managers a quick overview of the operations. The KPI are constantly monitored to support operational decision making and management. Common KPIs are customer satisfaction, order fulfilment rate (% of orders delivered complete), quality (number of defects, mean time between failure), inventory levels etc. However, many types of measurements are used and there are no standard measurements used in all industries. Also, the definition of the KPIs varies. For example, one company might measure “delivered” when the shipment is sent, while another company measures “delivered” as when the shipment is at the receiver. However, one of the main purposes of the KPIs are to show trends within the company for internal use and therefore not to be comparable between organisation. Most KPI are thus used within one organisation and rarely throughout an entire supply chain. Thereby they often only measure one part of the transport chain and are rarely compatible with other KPIs used in the chain.

The use of KPIs is interesting to study to see if there are any general measurements of delays used in the industry today, which there unfortunately is not. The motive for companies, industries and governments to use measures differ. In accordance with their underlying objectives, but independently of their users, measures can be classified into four groups (Andersson et al, 1989; Byrne and Markham, 1991);

- as an important source *to establish a holistic view of the system* under study and to capture how different parts are connected to each other,

- as a source to give feedback *in order to initiate* new and better ways to conduct and handle the measured system,

- as a means to *clarify goals and objectives* to all participants and personnel which means that the measures have to change and new ones need to be introduced when new objectives are introduced,

- and as an *indicator of the overall development over time* and a source to direct policy actions to areas of importance.

An individual company or multi-companies in co-operation (i.e. supply chains), can easily see the importance of the first three goals, while the latter has traditionally been of interest to governments, policy institutes, agencies etc. But the present trend with companies searching for "best practice" means that development over time also becomes an important aspect for supply chain drivers in their desire to gain competitive advantages.

Figure 2 draws on the traditional distinction between industry concern to maximize profit within the constraints given by the governments, and government's focus on overall sustainability and development of society as an entity involving industry, individuals and relations to surrounding societies. Between these perspectives relations exist as the arrows indicate. In logistics and transportation the pace of the processes shaping the two perspectives is different. With the long investment cycles in physical infrastructure, the governments and society focus on long-term trends and forecasts of future changes. For companies constantly evaluated in the financial market place, all opportunities that in the short run can enhance the competitiveness of a company and its supply chain must be considered.

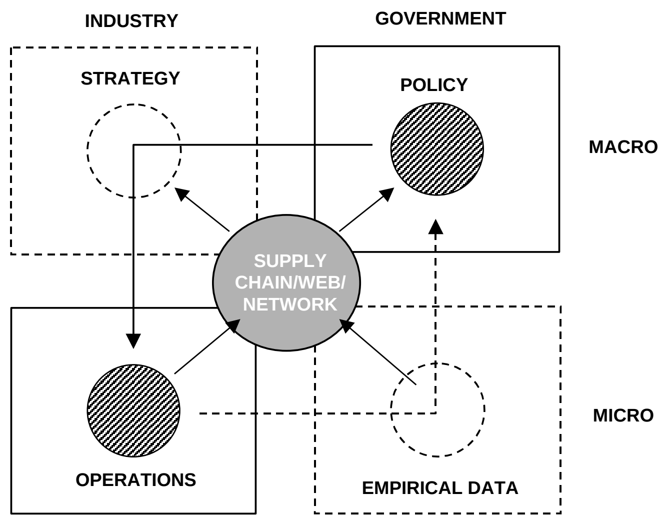

Figure 2 Schematic description of the logistics evaluation problem in a classic perspective

In Figure 2, these measures are grouped in a macro- and micro-perspective. The arrow from government policy via industry strategy to industry operations is obvious, and has been marked by a solid line, accordingly. If, e.g., there is a new government policy for road transport, this will most certainly affect industry demands and result in modification of strategies. The other arrow from industry operations via empirical data to government policy is marked with a dotted line. This reflects that it is much less difficult for industry to obtain data from their operations in a form suitable to support their own strategy modifications than it is for government to obtain empirical data that are suitable for the aggregation necessary to support the formation of new policies.

But the situation for governments is about to change. The fast and unpredictable development of information technology has forced governments to reconsider their long-term goals and focus on shorter perspectives as well. This has led to changes in regulation and the way governments define their role. Today logistics and supply chains to a large extent are built around advances in information and communications. It is inevitable that also in this field societal concerns will shift and as a result will need to address short-term issues in addition to traditional long-term problems.

There are three basic conclusions that can be drawn from this:

- The measures currently in use at both macro- and micro-level are inadequate to handle the performance of supply chains and networks making up the national transport structure.

- A trend towards highly complex supply webs can be identified which makes it nearly impossible to use "normal" measures since this implies a shift towards other values.

- There is a need to develop measures on a meso-level, i.e. in between the macro- and micro-level.

The interaction between the responsibility of industry to create competitive supply chains and the public policy concerns about improving overall efficiency through policy actions requires governmental understanding of the mechanisms affecting the performance of production units, shippers, carriers and other service providers in the supply chain. However, the macro-level focusing on some aspects of welfare maximization can be split into meso-level implying that under subsidiary conditions welfare can be independently maximized for a geographical area or an industry sector. However, as Figure 3 indicates, there is often a linkage between on one hand the macro- and meso-levels and, on the other the supply chain measures aimed to create a win-win situation for the participating companies.

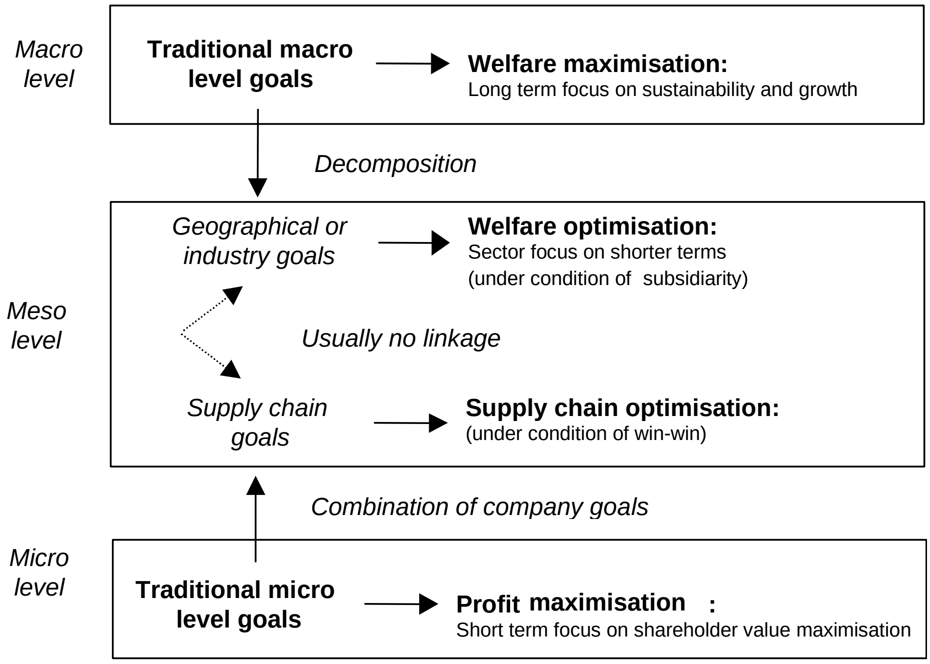

Figure 3 Towards common focus for measures in industry and society

Presently no direct supply chain measures exist. However, our review of other measures currently used in logistics has stressed the importance of suggesting measures, which allow public policy actions to be implemented in a way that supports the desire of industries to develop their competitiveness.

Effects of delays

Freight transport involves a multitude of shipments of different sizes, characteristics and requirements. It involves everything from a 5 000 tonnes slow moving iron ore train to a 100 gram express parcel. The purpose of the shipment could be to deliver a vital spare part that stops the production in an entire factory at huge costs or it could be a load of gravel that just is supposed to be dumped somewhere. This highlights the challenges in determining the effect of delays in the transport chain. The effects of a delay are very contextual. Sometimes a 1 hour late delivery of a single screw can cost millions while in other cases a 1 day late delivery of a shipload of screws can have negligible consequences.

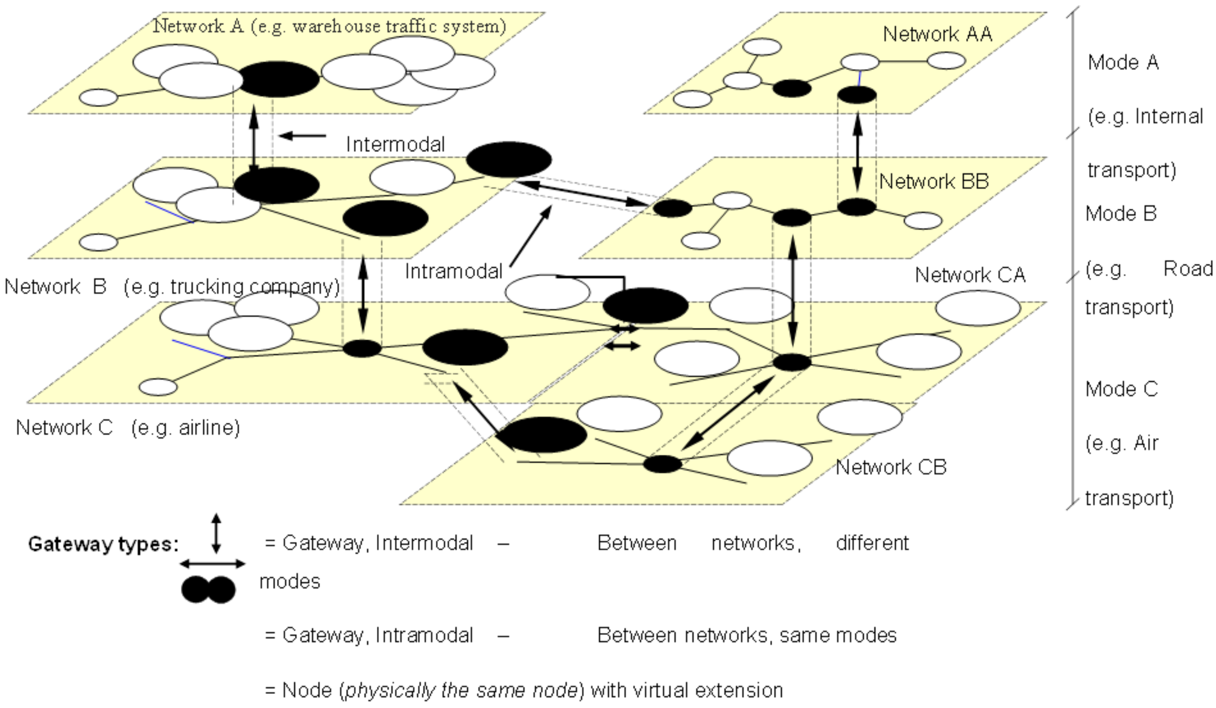

Figure 4 Different modes of transport, networks and gateways (Waidringer, 2001)

Transportation and logistics systems that are the basis for goods transports are quite complex with different modes of transports and interdependencies between buyers, sellers, forwarders etc. The system can be seen as a network of different sub-transport systems connected thorough gateways, which is illustrated in the figure above.

Delays in transport have effect in all parts of the transport network. Direct effects can be seen in longer transport times increasing operational cost of the transport (salary costs, vehicle costs, etc.). Indirect effects can also be seen where the system is affected, not directly by the delay, but by the risk of delays. Transport professionals are well aware of the risk of disruptions in the system and take this into consideration when planning the system. The system thus incurs an indirect cost for backup and flexibility. This can include purchasing more trucks than actually needed to have spare capacity or scheduling an extra train set instead of running a "tight" time table. These effects cannot be allocated to a specific shipment as they are incurred at a system level before the delay has occurred. Further, a disruption also has effects on the transport service quality and thereby on the goods transported and its intended use. For example, production might have to be halted at a receiving factory, overtime cost incurred to catch-up production and customers lost due to failed product deliveries. Table 2 shows common disruption effects in the different parts of the transport system.

Table 2 Activities, link effects, costs and cost drivers for delays

Activity	Category	Cost	Cost driver	Key variables
Transport	**Direct effects**	Time dependant vehicle costs	Longer transport time	Vehicle costs, length of delay
		Distance dependent transport cost	Longer transport distance	Vehicle costs, extra transport distance
		Rescue costs	Redirecting other resources to take over planned transport assignments etc.	Cost of extra transport
	Indirect effects	Indirect costs for backup and flexibility	Unreliable transport system in general	Perceived reliability, cost of backup
	Transport service quality	Goods capital costs	Longer transport time	Goods value, size of shipment, length of delay
Tranship ment	**Direct effects**	Staff cost	Disrupting terminal operational planning	Staff costs
		Terminal storage cost	Missed transhipment	Terminal storage costs, size of shipment, length of delay
	Transport service quality	Goods capital costs	Missed transhipment	Goods value, size of shipment, length of delay
Delivery	**Direct effects**	Staff cost	Disrupting receiver operational planning	Staff costs
Use of goods	**Indirect effects**	Cost for safety stock	Unreliable transport system in general	Perceived reliability, cost of safety stock
	Transport service quality	Direct cost of lack of goods	Missed customer order etc.	Type of industry, type goods and size of shipment, effects of lacking goods
		Indirect cost of lack of goods	Customer choosing other supplier	Type of industry, type goods and size of shipment, effects of lacking goods
Overall chain	**Direct effects**	Propagating delays in the chain causing other delay costs	Too small time margins in the transport chain	Characteristics and complexity of transport chain, other cost drivers

Magnitude and frequency of disruptions

The effects of delays caused by the identified factors and drivers are also influenced by the magnitude and frequency of the disruption causing them. A disruption is some unforeseen occurrence in the transport system that causes a delay, for example a traffic accident, extreme weather, congestion, planning mistake etc. The magnitude of the disruption is the size of it, which can be approximated by the length of the delay it causes.

Most disruptions in the freight transport system are of small magnitude, e.g. traffic congestion causing a 20 minute delay. These are frequently occurring but are also expected by the designers of the transport system. Therefore, most transport systems are designed to absorb these small disruptions only with minor consequences, e.g. by planned margins in the time tables or by safety stock. However, the consequences of the disruption increases once the magnitude of the disruption increases past the planned margins. The large magnitude disruptions are less commonly occurring than the small ones which are why they are not planned for in the design of the transport system. The system designers make plans of disruptions that happen once per week but not for disruptions that happens once every decade. The effects of the magnitude and frequency of disturbance are summarised in the figure below, describing the four main types of disruptions and consequences.

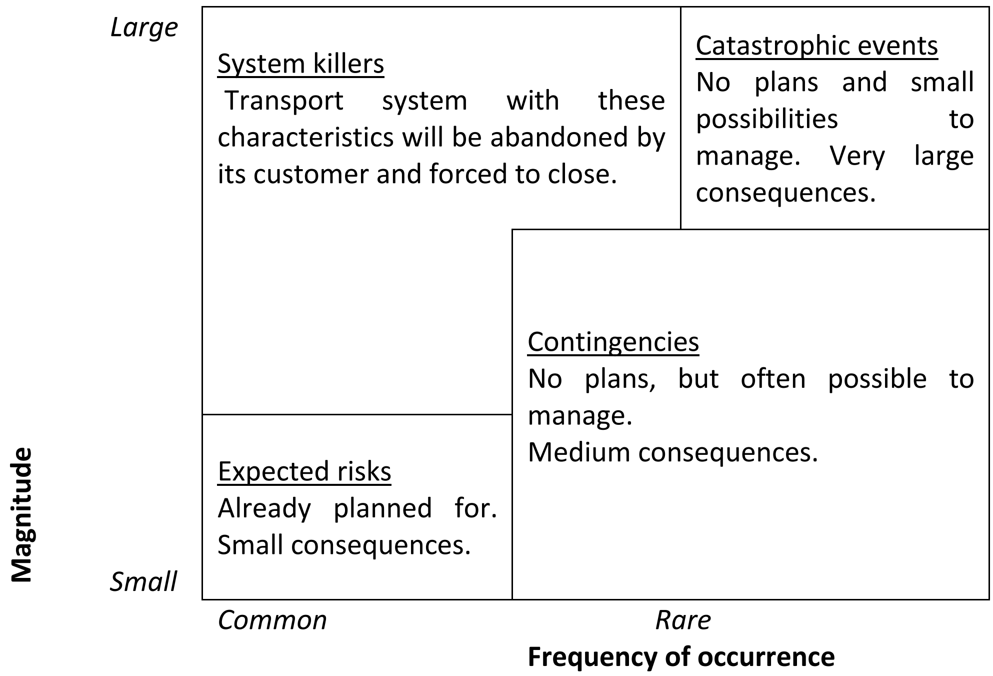

Figure 5 The four types of disturbances

It is noteworthy that also arriving too early can cause disruptions. For example, staff might not be available to receive the shipment, a warehouse might be too full to receive more goods, the unloading area might be occupied by other vehicles etc. Often, these early arrivals can be managed by simply waiting, e.g. a truck parks at the roadside and waits until the agreed delivery time. Although this can be considered a cost in less efficient resource utilisation, this is already included in the Expected risks. However, sometimes waiting is not an option, e.g. a train with no available rail siding, or the receiver might choose to receive the shipment anyway. Smaller earlier delivers are already planned for but, similarly to delays when the early delivery goes outside what is planned for in the Expected risks, an extra cost is incurred as in Contingencies. Costs include mainly disrupted operations and possibly extra warehousing and staff costs. Thus, Expected risks and Contingencies do exist also in early deliveries.

How to measure the effects of disruptions

When estimating the effect of disruptions, the System killers can be ignored since they are unlikely to occur over any longer timeframe as a system with such characteristics will be quickly abandoned by its customers. Catastrophic events are truly catastrophic when they occur. These are disruptions such as major natural disasters, major strikes, terrorist attacks etc. Due to their extraordinary and unpredictable characteristics, these are best analyses as special events in a separate risk analysis. These are unstructured scenarios in need for a qualitative evaluation and disaster planning. This is also in line with current principles for passenger transport in the Swedish national planning where “rare events with very large consequences” are recommended to be described qualitatively (Trafikverket, 2012, p. 22). More interesting are the Expected risks and Contingencies. The costs of the Expected risks are already incurred by the design of the transport system. Thus, the delay itself will cause limited extra costs but at the same time, the transports that are not delayed will also have to share the indirect costs for the planned risk, e.g. in safety stock and buffers. However, as soon as the disruption is significant enough to go outside what is planned for, extra direct costs are incurred. The costs of the unplanned disruptions, Contingencies, therefore only impact the transports that are delayed. Planned risks are therefore appropriately measured as shared costs on all transports, while Contingencies are measured as a combination of the shared costs covered by all shipments and added costs from the extra costs from the large disruptions. Similarly, for early deliveries the focus is also in Expected risks and Contingencies. System killers and Catastrophic events can be ignored for early deliveries as it is hard to imagine any disturbance causing very large early deliveries.

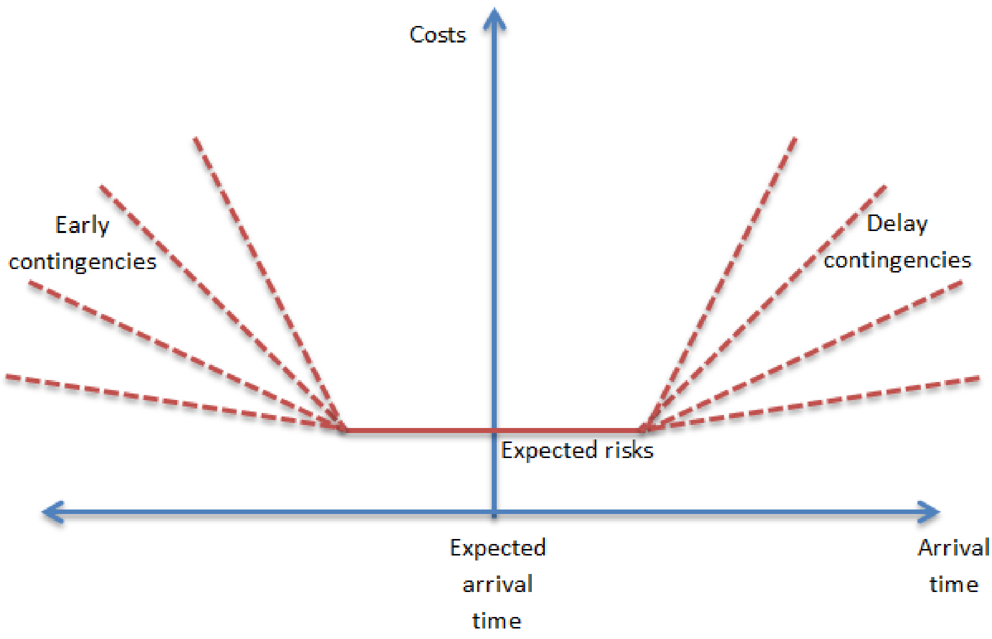

Figure 6 General cost structure of transport time variability

The break point between Expected risks and Contingencies (i.e. how long delay that is expected) will vary between different industries and transport chains. The general cost structure of transport time variations can be explained as inFigure 6. The shape of the contingency curve is currently unknown and will require further studies. The contingency costs consist of several factors that are both linear (e.g. salary costs), step wise (e.g. missed onward connections) and non-linear (e.g. disrupted operations). However, it is important that both the costs associated with the Expected risks and the Contingencies are included in the estimation of VTTV.

Several aspects of this categorization need to be further elaborated before applying the model in practice. Time limits between Expected risks, Contingencies and Catastrophic events need to be defined, and as mentioned above, these will vary between industries and transport chains, as some transports are sensitive to disruptions while others have large built-in margins in their system. Furthermore, it is not obvious which exact costs that can be linked to contingencies and expected risks, respectively. These connections need to be rigorously defined in order to present a complete framework for all costs to be included in VTTV.

A method to obtain VTTV

A method has been developed to mathematically estimate VTTV for freight, extending previous studies on VTTV on passenger transport. For passenger transport the scheduling utility approach has been used extensively to obtain VTTV. In a scheduling utility setting a time varying utility is assumed which is associated with activities performed by an individual. The behavior is then derived by maximizing this utility. A common approach is to use a piece-wise linear utility for activities at the destination (Vickrey, 1969; Small 1982; Fosgerau and Karlström, 2010). Often this approach is called α-β-γ preferences, where α is the marginal utility for travel time and β and γ denotes constant marginal utilities for early and late arrival. Some includes an additional discontinuity in the form of a penalty for being late. This approach has been extended by Vickrey (1973) to explicitly include utilities derived from activities at the origin. A recent application of this is given in Tseng and Verhoef (2008), which in addition replaces the constant marginal utilities with time-varying functions3.

The scheduling approach has been used to obtain VTTV for freight transports (Small et al., 1999; Fowkes et al., 2001; Fowkes 2007). However in both of these freight studies the utility approach from passenger transports has been used. We will reformulate scheduling into using cost functions for the actors involved in freight transports. Assuming the actors are cost-minimizers, similar behaviour as in the utility formulation will be derived. Denoting the conditional, on mode, cost function of a transport by C(m), then the decision problem for the actor is to minimize the cost

$$\min_m C(m),$$

over the given transport modes. If we assume that there are random terms in the cost functions and if we replace the utility with -C(m), then we may estimate VTTV from a discrete choice model as in the studies above. Therefore nothing is lost by switching to a cost formulation of the problem. However, since cost is observable, unlike utility, direct estimation of the cost function, e.g. by a cost-savings method, may be feasible. Hence, formulating the problem in terms of the cost functions of the actors provides more flexibility when estimating VTTV.

There is an essential difference between passenger and freight transport when considering transferring the scheduling utility approach from passenger traffic to freight transports. This is the fact that firms can accommodate increases in transport time variability by planning and taking on cost relate to avoiding disturbances. One such example would be a firm choosing to keep extra safety stock, adding marginal to time tables or investing in spare equipment. Such costs will not be a function of actual transport or delivery times for individual transports; rather these costs will be shared costs for all shipments. The size of the cost, or more precisely how much the company is willing to invest to avoid disturbances, will be a function of the transport time variability σ or more generally, the probability distribution of transport times. We will call these cost abatement costs and denote it as $A(\sigma)$. This represents the Expected risks in the general cost structure. The running costs, in this context, will be functions of the individual transport or delivery times. Typically, these costs will be operative costs for vehicles and cost associated with loading, unloading as well as transhipping. Since the abatement will determine the running costs, they are also functions of transport time variability. Running costs will be denoted as $R(T,D,\sigma)$, where T and D are actual transport and delivery times.

The running costs are, by definition, functions of actual transport and delivery times. Only the running costs will be involved when transferring scheduling utility approach to freight traffic. Scheduling utility (or in this context, cost) will only cover marginal short run effects with respect to transport time variability when abatement cost may be seen as unchanged and the contribution of transport time variability to the running costs are negligible. In this short run case we simple drop transport time variability from the cost components (marginal costs) in the expressions for running costs. When later extending the cost function with abatement costs transport time variability will also be introduced in all cost components.

[3] The authors assume continuity and smoothness of the marginal utilities, this seems to be unnecessary restrictive.

Later when abatement costs is reintroduced in the equations, the resulting VTTV for the total cost has the same form as derived in Andersson et al (2013), which presented VTTV in the following form

(1) $\mathrm{VTTV} = \mathrm{VTTV}_L + \mathrm{VTTV}_\lambda.$

The first term VTTV_L represents the marginal change of abatement and running costs when transport time variability change, and the second term represents the changes in the transport time distribution when variability change. Hence the results from a scheduling utility approach and Andersson et al (2013) are basically the same. The earlier result is more general. The main advantage of deriving VTTV from a scheduling approach is that it clarifies the relation between abatement and running costs, that is, between expected risks and contingencies. Further, the result from scheduling is also compatible with several of the methods presented by Krüger and Vierth (2013).

To formulate the problem as a freight delivery situation, assume that there is a preferred delivery time PDT for the goods. To simplify expressions normalize time so PDT is at time zero. Let t denote the departure time from the origin, and D the actual delivery time, then transport time is T = D – t. If we focus on the actor receiving the goods and assume that the marginal costs for travel time, early arrival and late arrival all are constant with values α, β and γ. Then the receiver's running cost may be written as in (1) which covers the Contingencies in the risk framework developed in the chapter *Magnitude and frequency of disruptions* above,

(2) $$R(T, D) = \alpha T + \beta \max(0, -D) + \gamma \max(0, D)$$

The cost given by (2) has the same form as scheduling utilities with α-β-γ preferences for passenger traffic. Now, with transport time seen as a random variable we will assume that the receiver minimizes the expected cost ER, where R is given by (2). Write transport time as $T = \mu + \sigma X$, where μ is the expected transport time and X is a random variable with EX = 0, representing deviations from the expected transport time. The scale factor σ represents the variability of transport time T. Basically, by applying restrictions on X, σ may be any measure of variability. For example, assuming $\mathrm{Var}(X) = 1$, then σ will be the standard deviation of T. Under these conditions it can be shown (Fosgerau and Karlström, 2010; Fosgerau and Engelson 2011) that the minimum expected running cost is[4]

(3) $$ER^*(\mu, \sigma) = \alpha\mu + (\beta + \gamma)\sigma \int_{\frac{\gamma}{\beta+\gamma}}^{1} F^{-1}(s)ds,$$

where F is the cumulative distribution function (CDF) of X.

The minimum expected running cost in (3) is a function of expected transport time μ and the variability measure σ, but also, through the CDF of X, a function of the probability distribution of transport time. Since information on preferred delivery times may be difficult to obtain, it is an advantage that the entity does not enter the minimum expected cost. Equation (3) provides an immediate expression for the short run VTTV with respect to the variability measure σ, namely

[4] It is assumed that the reciever has a marginal cost for early delivery, i.e. $\beta > 0$.

(4) $$\text{VTTV} = (\beta + \gamma) \int_{\frac{\gamma}{\beta+\gamma}}^{1} F^{-1}(s) ds.$$

To obtain a value for VTTV in a subjective utility formulation of the problem, the marginal utilities α, β and γ needs to be estimated indirectly for example in a choice experiment or an observed discrete choice study. When using the setting of firms as objective cost minimizer's α, β and γ are interpretable as marginal costs, which may be obtained by studying the receiver's resource usage as a function of freight delivery time. Typically these marginal costs will be wage rates and capital cost per time unit. Approximate values for these quantities may also be obtained from officially available statistics. The main issue will be to estimate transport time distributions. Also, an appropriate division into shipment classes should be developed e.g. based on the Samgods structure. Should include characteristics such as: type of commodity, size of shipment, transport mode, industry structure etc.

Now, when going from expected short run running costs to expected total costs, equation (4) needs to be modified by adding abatement cost and reintroduce σ into the running cost. This gives us the following expression for the expected total cost, where $A(\sigma)$ represents the Expected risks and the remaining equation represents the Contingencies :

(5) $$EC^*(\mu, \sigma) = A(\sigma) + \alpha(\sigma)\mu + (\beta(\sigma) + \gamma(\sigma))\sigma \int_{\frac{\gamma(\sigma)}{\beta(\sigma)+\gamma(\sigma)}}^{1} F^{-1}(s) ds.$$

Transport time variability influence the running cost through the marginal costs α, β and γ. In this case equation (5) does not represent the VTTV which is $dEC^*/d\sigma$. VTTV will contain two terms, one term describing the change in abatement and marginal costs when σ changes and the other term describing the change in the probability distribution when σ changes. Hence, the form of VTTV will be as given by equation (1) above. To measure VTTV for the total cost, without restricting the scope to short run marginal changes, a study is necessary on how abatement costs and marginal running costs depend on the level of transport time variability.

When considering the question of which particular measure to use for travel time variability, the approach behind equation (5) is agnostic. This follows from the arbitrariness of the parametrization of a probability distribution. There is typically an infinite set of different parameters that can be used to describe a particular probability distribution; hence there is an infinite set of equally valid variability measures σ. As discussed above, different measures are obtained by applying different restrictions to the distribution of X.

The steps that is necessary for measuring VTTV by equation (5) is to collect data on the cost components Aσ,ασ, βσ and γσ, and to obtain information of the probability distributions for transport times. Also note that the above equations are for individual shipments. Thus, the method developed does not prohibit using unique values for each shipment, although it is appropriate to group shipments into classes to facilitate data collection. An appropriate division into shipment classes should be developed where groups of shipment are assigned the same values, as e.g. cost of transport are similar for similar shipments. This could be based in characteristics such as: type of commodity, size of shipment, transport mode, industry structure etc.

Conclusions

The original purpose of this project was to identify and evaluate possible measures for quantifying TTV. Literature studies showed that previous studies of the area used different measures, mostly without discussing which measure to use, and that key performance indicators used in the logistics industry do not fit the purposes of CBA. Furthermore, this study has found that the estimation of the value of TTV – VTTV – can be (and is) derived mathematically independently of which measure that is chosen for the quantification of TTV. In order to actually estimate VTTV in the end – meaning taking all steps including collection of data, statistically analyze it and mathematically derive values – we need to use one or several measures for the travel time variability. However, the mathematical derivation of VTTV proposed above does not put any restrictions on which measure to use.

The valuation of TTV, which is the ultimate aim to which this study contributes, will be based on the cost functions for delays of freight transport. It is the estimation of these functions that will put restrictions on which measure to use, rather than the valuation. It has been concluded that the cost functions will be built up by two parts: 1) fixed abatement cost (costs for expected risks) originating from activities made to handle the general level of transport time variability in the system influenced by the probability distribution of transport times, and 2) delay costs (costs for contingencies) that are functions of the individual delivery times. The more exact shape of this functions need to be estimated by data collection and after that, any restrictions that they put on which measure to use can be described. It is crucial that the chosen measure(s) captures the certain properties of the transport time probability distributions that have impact on both type of costs described above. Therefore, the shape of transport time probability distributions and cost functions need to be further investigated before determining which measure(s) to use for the variability.

Thus, the next step for obtaining VTTV is to collect data on cost functions. In order to be able to use VTTV in CBA, we also need to be able to model the impact on TTV of investments (or other actions) in the infrastructure, i.e. estimate how the transport time probability distributions are affected in different situations (effect relations). The method chosen for doing this, e.g. using Samgods, could put further restrictions on which measure that would be most appropriate to use.

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3 WP 1 – Value transfer from Norway and The Netherlands

Written by Magnus Landergren and Inge Vierth, VTI.

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Introduction

In order to produce a good CBA for infrastructure and traffic planning it is important to understand the cost of train delays and the uncertainty regarding arrival time for passengers and shippers. Because most delays in Sweden occur in the railway system, this chapter focuses on rail freight delays, see Nelldal (2014) for an illustration of the problems with reliability in the rail system. VTTV has been estimated for passenger traffic in earlier studies but no conclusive results has been found for freight transports in Sweden. The current value of freight transport time variability in ASEK is simply the value of transport time savings (VTTS) multiplied by two. This value and method lacks a scientific basis. The purpose of this chapter is to determine whether a commodity specific value transfer from studies abroad can be used as a foundation for a Swedish value of reduced transport time variability.

We look at three earlier studies of VTTV for freight. Two Norwegian studies, GUNVOR[5] (2010), which looks at trucks and trains - PUSAM[6] (2012), which looks at rail freight in the container segment, and one Dutch study VOTVOR[7] (2013), looking at all modes.

In order for a VTTV transfer to be appropriate, two aspects need to be taken into account. The countries need to have reasonably similar transport markets, unless a detailed commodity classification can be used to adjust for the differences. The studies and results need to be of an adequate quality and detail for a transfer to work. We will begin with discussing the differences between the countries and later the differences between the studies and their results. In the section after that we will draw some conclusions regarding the possibilities to transfer the VTTV to a Swedish context. This study will focus on the possibility of a value transfer, another possible approach would be a method transfer but this will not be analyzed in any detail. For readers interested in methodology we recommend the Swedish Inregia study (2001) which provides some valuable insight into sampling and stratification in an SP setting and Kaul (2013) for an overview of the literature on value transfers. For an overview of what factors Swedish shippers value on the transport market we recommend Sofia Lundberg's (2006) report.

[5] Halse, Askill Harkjerr, et al. Valuation of freight transport time and reliability. No. TOI-1083-2010. 2010.

[6] Halse, Askill Harkjerr, and Marit Killi. Values of transport time and reliability for railway freight. No. TØI report 1189/2012. 2012.

[7] Significance, VU University, John Bates Services, TNO, NEA, TNS NIPO and PanelClix, 2013. Values of time and reliability in passenger and freight transport in The Netherlands. Report for the Ministry of Infrastructure and the Environment, Significance, The Hague.

Value transfer theory

The rationale behind value transfers (or benefit transfers) is quite simple. A valuation of something is needed and instead of conducting an entirely new study, valuations from existing studies are used. This can either be done by directly applying existing values (naïve transfers) or by using the same functional form and estimated coefficients as in earlier studies and adjusting for the new population with new input values (function transfers). The upside with value transfers is that they are cheap, swift and provide a uniform valuation between studies which makes comparisons of the final results easier. The downside is that circumstances might differ, making transferred values misleading; and that the values which are to be transferred might be wrong even in their original context. Circumstances are almost inevitable different, making the real question whether they are sufficiently different and important to merit a study of their own. Unfortunately, in borderline cases you can't know in advance whether a transferred value would be substantially different than an estimated value before the estimation has been done. Post hoc transfer errors can be calculated, by dividing the difference between the transferred estimate and the new study estimate with the new study estimate. Kaul et al (2013) have reviewed all benefit transfer validity studies made in the 20 years up until 2009. Consistent with previous literature Kaul et al finds that function transfers provides more accurate estimates than naïve transfers and that geographical similarity improves outcomes of value transfers. New findings in Kaul et al include that using data from multiple studies improves function transfers.

In this report the term *value transfer* is used mean *function transfer*. In the research directive of this study commodity type is given as the variable which an adjustment can be made with. Other possible adjustment variables could include mode, load unit (container/non-container) and national characteristics.

Differences between countries

Products transported (type and volume)

Sweden transports a lot more goods by rail than Norway and the Netherlands. Measured in tonne-kilometre (tkm) Sweden transports more than three times as much goods by rail as the Netherlands and six times more than Norway.

When comparing VTTV between countries it is essential to take the differences in freight composition into account, as this is likely one of the main explanations why average VTTV varies between countries and it is the objective to derive commodity specific VTTV. The composition of goods differs between the three countries, see Table 3. The statistics are not entirely clear since *unidentifiable goods* constitutes 52% of the total tkm in Norway, 33% in the Netherlands and 21% in Sweden. Furthermore 11% of the goods in Norway is categorized as *grouped goods*, a category which provides little insight into the actual nature of the goods. The large share of *unidentifiable goods* and *grouped goods* makes especially the Norwegian numbers unclear. This makes a value transfer based on official statistics more difficult.

We have been told by our Norwegian counterparts that the unidentifiable goods is to a large extent consumer goods. We have not been able to confirm this claim. In order to make the composition comparable between the countries the unidentifiable goods category is excluded when calculating the percentages, implicitly assuming that the composition of unidentifiable goods is the same as for identifiable goods.

Coal and other crude petroleum products accounts for 40% of the tkm in the Netherlands while being negligible in Sweden and Norway. Conversely, the transported tkm of metal ore is five times as high in Sweden as in Norway and the Netherlands; as a share of identifiable goods transported it is actually higher in Norway, 58% compared to 31% in Sweden and 26% in the Netherlands. Sweden's main characteristics are the relatively large shares of *products of agriculture, hunting and forestry* (with emphasis on forestry); *wood and products of wood* and *basic metal products*.

The differences between the three countries are actually not as big as one might imagine, according to the Eurostat data. Often, the goods that are transported by rail are relatively low value and heavy goods; whether it is ore, wood or coal is of minor importance for the VTTV. Goods of high value are generally transported by trucks in Sweden as they provide a higher reliability, fewer transfers and more flexibility. If the reliability of the railways was higher it is reasonable to assume that more cargo would be transported by rail.

Table 3 Commodity composition on rail (million tkm, including international transports on territory)

Commodity categories	NL	SWE	NOR
Total transported goods (including unidentifiable) (Transported goods - excluding unidentifiable)	6,078 (4,087)	20,763 (16,472)	3,383 (1,613)
Products of agriculture, hunting, and forestry; fish and other fishing products	31 (1%)	2 428 (15%)	86 5%
Coal and lignite; crude petroleum and natural gas	1 652 (40%)	57 (0%)	0 (0%)
Metal ores and other mining and quarrying products; peat; uranium and thorium	1 065 (26%)	5 069 (31%)	943 (58%)
Food products, beverages and tobacco	30 (1%)	244 (1%)	2 (0%)
Textiles and textile products; leather and leather products	0 (0%)	0 (0%)	0 (0%)
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper	88 (2%)	2 650 (16%)	124 (8%)
Coke and refined petroleum products	104 (3%)	335 (2%)	25 (2%)
Chemicals, chemical products, and man-made fibers; rubber and plastic products ; nuclear fuel	391 (10%)	890 (5%)	2 (0%)
Other non-metallic mineral products	92 (2%)	158 (1%)	5 (0%)
Basic metals; fabricated metal products, except machinery and equipment	352 (9%)	3 127 (19%)	33 (2%)
Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus	2 (0%)	34 (0%)	0 (0%)
Transport equipment	127 (3%)	389 (2%)	3 (0%)
Furniture; other manufactured goods n.e.c.	0 (0%)	21 (0%)	0 (0%)
Secondary raw materials; municipal wastes	65 (2%)	583 (4%)	3 (0%)
Mail, parcels	0 (0%)	0 (0%)	0 (0%)
Equipment and material utilized in the transport of goods	69 (2%)	476 (3%)	1 (0%)
Goods moved in the course of household and office removals; baggage and articles accompanying travelers;	4 (0%)	0 (0%)	0 (0%)
Grouped goods: a mixture of types of goods which are transported together	13 (0%)	8 (0%)	383 (24%)
Unidentifiable goods: goods which for any reason cannot be identified	1 991 (-)	4 291 (-)	1 770 (-)
Other goods n.e.c.	0 (0%)	4 (0%)	2 (0%)

Source: Eurostat 2013

Transport distance

The difference in tonne-kilometres by rail between Sweden, Norway and the Netherlands can be divided into its two components: transported weight and distance. Out of the three countries Sweden has both the highest number of tonnes transported and each tonne is on average transported the longest distance. Compared to Norway, Sweden transports twice as many tonnes and a distance which is on average almost three times as long. Compared to the Netherlands the total number of tonnes is 72% higher and the average transported distance is almost twice as long. The calculated distance should be used carefully as empty transports drag the value down. The geography and topography of the two countries also matters. The Netherlands being a small, flat and densely populated country while Norway is a stretched-out, mountainous and sparsely populated country. The mild climate of the Netherlands is more advantageous for railways compared to the harsher climate in the Nordic countries.

Table 4 Distance and weight of rail freight within country

	Million gross[8] tonnes	Million tkm	Km (calculated average distance[9])
Netherlands	39	6,078	312
Sweden	67	20,763	617
Norway	31	3,383	215

Source: Eurostat 2013

Modal split

Railways are more important for freight transports in Sweden than in Norway and the Netherlands. Sweden transports 40% of its goods by rail, compared to 15% in Norway and a negligible 5% in the Netherlands. The Netherlands is an outlier in this case, as almost 40% of its transports are on inland waterways. Inland waterways is a substitute for freight rail to transport low value products. Eurostat does not have data on domestic maritime transports which is more important in Norway and Sweden due to their long coastlines.

Table 5 Land modal split, share of rail freight tkm

Modal Split (%)	Railways	Roads	Inland waterways
European Union (27 countries)	18,2	75,1	6,7
Netherlands	5,1	56,2	38,7
Sweden	39,7	60,3	-
Norway	14,7	85,3	-

Source: Eurostat 2013

Passenger traffic and track length

Passenger traffic by rail also matters since it competes for space on the tracks with freight traffic. The Netherlands has the most passenger-kilometres, 17,700 million, compared to 11,858 million in Sweden and 3,291 million in Norway, according to data from 2013 from Eurostat and Statline (NL).

[8] The weight of the cargo and the train.

[9] Tonne-km/(gross tonnes/2) to approximate for gross tonnes rather than net tonnes.

Sweden's railway network is longer than that of Norway and the Netherlands. With a total length of 15,601 kilometres Sweden's tracks are substantially longer than Norway's 4,224 kilometres and the Netherland's 3,061 kilometres, using 2013 data from Eurostat and ProRail (NL). This statistics rightly measures a kilometer of double track as twice as long as a kilometer of single track.

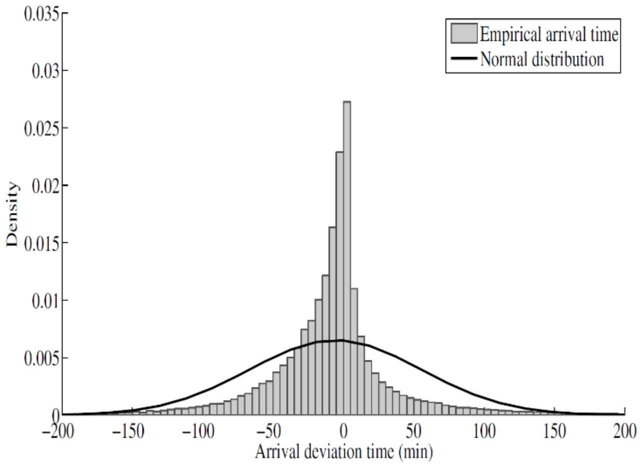
In the Netherlands there are alternative routes when there is a problem with the tracks, while in Norway and Sweden the trains are often confined to a specific single track with little option but to wait when there is a problem. This implies that the risk of a train being delayed for days is higher in Norway than in the Netherlands, ceteris paribus. It also affects the time loading goods in relations to time travelled. With large distances loading times are a relatively small part of total transport time which gives railways a comparative advantage over trucks. Large distances also means more tracks to maintain, raising the cost or decreasing the quality of the tracks, which is one reason behind the variability of arrival time, other reasons can be quality of rolling stock, available infrastructure capacity and weather.

Deviations from time table and costs for firms

Even when trains and infrastructure are working properly there is some variation in arrival time. Freight trains often travel large distances, one heuristic saying is that freight trains can be competitive only on distances longer than 500km. Furthermore freight transports often have low priority in track allocation in Europe. The combination of long distances, low priority and a large network of single tracks makes some variation in arrival time understandable. In Sweden freight rail operators sometimes do not show up to their allocated time slot if they lack goods to transport, which can speed up the journey for other trains making them early. As Figure 7 shows the arrival time is centered on the scheduled arrival time with a slight skew towards early arrivals in Sweden. Given that late arrivals are more costly than early arrivals and slack, firms try minimize cost by adding slack and thereby increasing the likelihood of early arrivals but also decreasing the risk of delays.

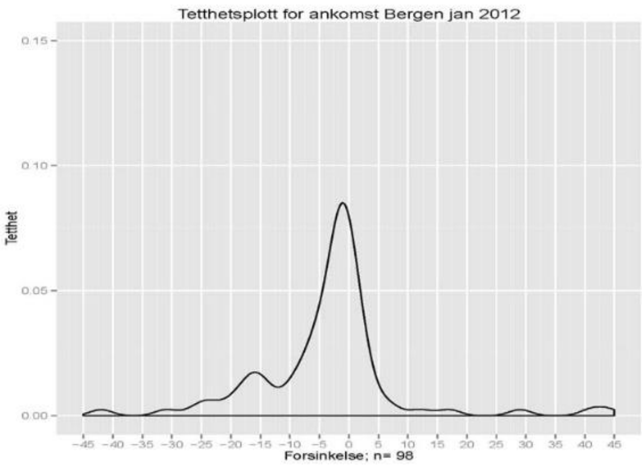
According to our sources at Significance there are no corresponding statistics to Figure 7 in the Netherlands. Norway does not have statistics on an aggregate level but TØI has made graphs on some of the busier stations. Figure 8 shows deviation from planned arrival time in Bergen, just as in Sweden it is skewed towards early arrivals.

Figure 7: Arrival deviation at destination for freight trains in 2009, Sweden



Source: Krüger, N., Vierth I., and Fakhraei Roudsari, F. "Spatial, temporal and size distribution of freight train delays: evidence from Sweden." (2013).

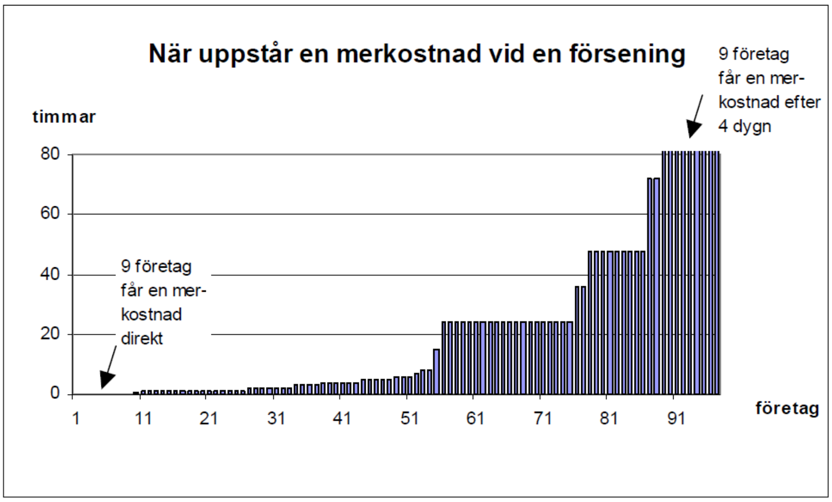
Figure 8: Arrival deviation at Bergen Freight Terminal, January 2012



Source: TØI 1250/2013

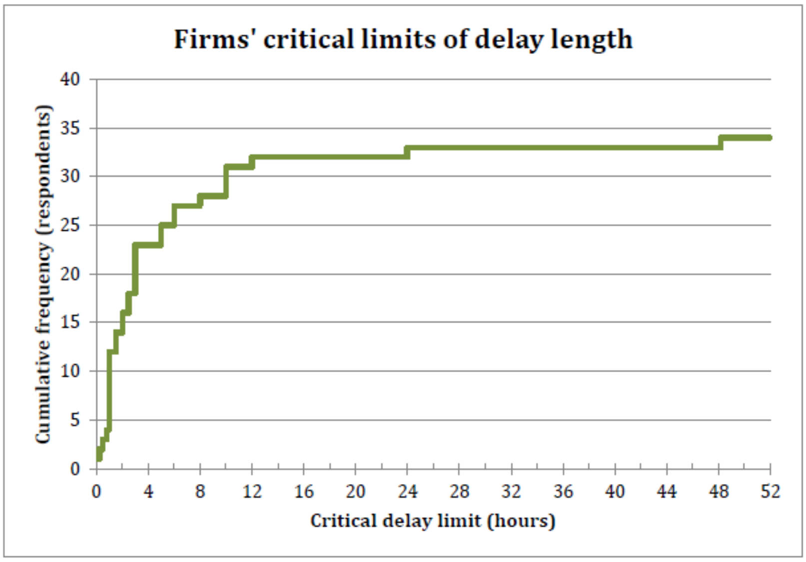
As can be seen in Figure 9 and Figure 10 there is comparable information in Sweden and Norway about when the cost of a delay occurs for a firm. The two figures shows that Norwegian firms are more vulnerable to delays than Swedish firms. In Norway approximately 80% of the surveyed firms get an extra cost from a delay of 8 hours, In Sweden the corresponding figure is around 50% for an 8 hour delay. This difference might be explained by the mix of commodities and the composition of industry in the two countries. It might also be explained by differences in how the two respective surveys have been conducted, such as that the Norwegian study is more focused on forwarders rather than shippers, which is discussed in the next section. Corresponding information is not available for the Netherlands.

Figure 9 When does an additional cost due to a delay occur, Sweden. Firms on the x-axis (99 in total) and hours of delay on y-axis



Source: Lundberg, (2006).

Figure 10 Firms' critical limits of delay length, Norway



Source: TØI 1250/2013

Differences between studies

The previous section looked at actual differences between the countries which can explain differences in VTTV. This section looks at the methodology of the three studies in order to assess their quality and what impact it can have on the results and the possibility of a value transfer.

VTTV measurements and values

How is VTTV measured in the different studies? Which – if any – of these values can be transferred to a Swedish context? Table 6 show the results from GUNVOR, PUSAM and VOTVOR. These values are taken directly from each respective study presented in local currencies at different points in time and with different measures of VTTV, hence the table does not provide comparable values. Direct comparisons between the studies is possible with the information in Table 7, the values are translated into SEK using the appropriate exchange rates and changing the unit in the Dutch study to per tonne-hour instead of train-hour (based on the average weight of 265 net tonnes in the VOTVOR-survey). Table 7 can be used to compare the values but it is important to keep in mind that different measurements are used in the three studies and that the results are not always reliable, which will be discussed later. Here is a short summary of some assumptions and definitions in the three studies:

VOTVOR: 200 Euro/hour per train – Standard deviation for door-to-door transports. Both early and late arrivals included. VTTV is calculated based on replies from shippers in all modes.

GUNVOR: 27 NOK /tonne-hour – Standard deviation for door-to-door transports. Both early and late arrival included. GUNVOR covers all modes, but a second survey - PUSAM – was carried out in order to get more precise and transparent results for rail transport.[10]

PUSAM: 13 NOK /tonne-hour – Value of expected delay (VED) between railway terminals. Only late arrivals included. Based on the largest operator CargoNet's customers, mainly forwarders transporting containers. No ore transports are included

Table 6: VTTV as reported in each respective study

Rail	**VTTS**	**VTTV**	**VED**
GUNVOR - NOK/tonne-hour	27	44	89
PUSAM general - NOK/tonne-hour	47	-	278
PUSAM Pallet - NOK/tonne-hour	7	-	35
PUSAM All - NOK/tonne-hour	13	-	72
VOTVOR Container - Euro/train-hour	-	100	-
VOTVOR Non-container - Euro/train-hour	-	250	-
VOTVOR All - Euro/train-hour	-	200	-

Table 7: VTTV in SEK/tonne-hour

Rail (SEK/tonne*hour)	**VTTV**	**VED**
GUNVOR[11] (NOR)	35.5	71.8
PUSAM[12] all weighted (NOR)	-	62.6
VOTVOR[13] all (NL)	6.55	-
Simple calculation (SWE)	30.2	-
Current ASEK value (SWE)	2.62	-

[10] The results reported here are based on estimations carried out after the publication of the original GUNVOR report, and are documented by Halse and Killi in TOI report 1250/2013.
[11] Using the exchange rate from January 1st 2010, 1 NOK = 1.24 SEK
[12] Using the exchange rate from January 1st 2012, 1 NOK = 1.15 SEK
[13] Calculated with the exchange that for the day the values became policy 01/08-2013, 1 EURO = 8.68SEK, and 265 tonnes per train which is the mean net-weight in VOTVOR.

Table 7 also includes a back-of-the-envelope calculation based on Bo-Lennart Nelldal's report (2014) on extreme delays. Based on data from SSAB, a steel manufacturer, Nelldal has estimated that delays in rail freight cost a total of SEK 1.5 billion. Out of these 1.5 billion 12/19 (=63%), or 0.947 billion, is considered to be losses for the shippers, the remainder for forwarders/carriers. Given that SSAB produces goods which are slightly more valuable than the average in ASEK, 3.30 SEK/tonne-hour compared to the average of 2.62 SEK/tonne-hour, the average calculated value needs to be scaled down. According to the Swedish Transport Administration (2014) there were a total 62191.3 delay hours per year in freight transports and the average train is assumed to have 400 tonnes of cargo[14] . Given that SSAB's values are true and a lot of other underlying assumptions the VTTV can be calculated as follows:

(12/19*1.5*10^9) / (3.30/2.62*62191.3*400) = 30.2 SEK/tonne-hour

This value should be taken with a pinch of salt given that it is extrapolated from one firm and there are many simplifying assumptions.

The current Swedish average VTTV value is 2.62SEK/tonne-hour. It is generally perceived to be low, both by industry groups and by the Swedish Transport Administration who claim that it does not even use the value in its CBA due to the low impact. The current VTTV is the lowest value in

Table 7, which is an indication that it might be too low but that really depends on the reliability and applicability of the other values. If the results of the three studies would have been more similar, it would have made a value transfer more suitable, but the values differ by a factor of ten. This should be seen as a warning sign that there are major differences between the countries and studies.

In Sweden VTTS and VTTV have traditionally been split into the commodity categories. It has been the wish of the Swedish Transport Administration to keep using the NSTR commodity classification but with updated VTTV. Using the suggested value transfer method this will not be possible. Norway does not differentiate between products in GUNVOR or PUSAM. The only categorization which is used is between pallet and general goods. In the Dutch VOTVOR study the only categorization used is container and non-container, but other categorizations such as commodity types has been tested without significant results. The lack of significant results might be because there is no effect or it might be a type 1 error. If the VTTV values should be updated keeping the existing commodity categorization a different method than a value transfer is advisable.

What explains different values of average freight VTTV in the three studies?

There are differences in the results which are due to the differences in methodology in the three studies. A crucial point is which kind of companies have been sampled and if these represent the population as a whole. In PUSAM only customers with direct contracts with CargoNet, the largest rail freight operator in Norway, have been included in the sample. Most of the sample and respondents were forwarders, but also a few shippers were included. Among the forwarders many were subsidiaries of the same firm, creating a potential bias if they respond in a systematic way. CargoNet mainly transport containers. This means that the largest segment in the Norwegian rail freight market, which is metal ores as can be seen in

[14] Sweden has heavier trains than the Netherlands, hence a higher value than 265 tonnes which was used in the VOTVOR calculations

Table 3, is not represented at all the in sample. Other than ore, most freight on rail is transported in containers. Most goods transported in containers is classified as unidentifiable. Our Norwegian counterparts claim that there is a lot of consumer goods and high value goods in the containers which cannot be confirmed by any statistics. One idea has been to use transfer PUSAM only for the Swedish container segment (~20% of the tkm compared to ~60% in Norway) but without a good understanding of what the containers hold it would be a shot in the dark. If the claim that the unidentifiable goods really are consumer goods is true then the Norwegian container segment can't really be compared to the Swedish, as containers in Sweden are mainly filled with metal products and paper according to the 2004/2005 commodity flow survey. In the Dutch VOTVOR study the VTTV for containers is less than half of the value for non-containers.

Whether shippers and forwarders/carriers have been asked also affect the content of Figure 9 and Figure 10 which shows when the extra cost of a delay occurs. The forwarder quickly gets an extra cost since the vehicle and driver cannot be used for other transports and the planned routes are disrupted. The cost for forwarders can quite easily be calculated by wages and vehicle operating cost.

In this project we are more interested in the extra costs for the shippers which is related to the cargo. VOTVOR and GUNVOR have taken this into account, analysis are split into different categories for shippers and forwarders/carriers. In PUSAM both shippers and forwarders are included in the same analysis which makes the results harder to interpret. A related general comment is that a better understanding of the different cost drivers for shippers, forwarders and carriers respectively, would be valuable.

The response rate was low in the two Norwegian studies. GUNVOR contains 42 respondents within rail, out of 757 respondents in total, out of a gross sample of 9826 firms taken from two firm databases. PUSAM has 34 respondents out of 227 asked. The response rate was especially low among shippers. VOTVOR has 47 respondents within the rail segment, it is a bit unclear how many were approached, but we are told by Significance that the consultants who conducted the survey were quite persistent. When calculating VTTV firms within all modes were used. With low response rates it is possible that some sample bias affects the results, but it is not possible to determine in what direction.

How to sample, and what effect it has on the results is a difficult question. The option stands between shippers, forwarders and carriers or a mix of them. The VTTV can differ between the three groups but also within each group. Carriers are likely of lesser importance when it comes to VTTV. GUNVOR and VOTVOR targeted shippers and companies providing transport services. PUSAM only looked at customers of CargoNet which mainly includes forwarders but also a few shippers.

The overall conclusion is that the two Norwegian studies have problems with sampling and response rate. It is our view that it is unsuitable to transfer their VTTV to a Swedish context.

The two step sampling approach in the Swedish SP (INREGIA, 2001) is a good benchmark. In the first step quick questions are asked in order to determine if the firm of the respondent is fit to participate. If so, the firm in included in the second step which contains the choice experiment. With this approach the researcher gets a good understanding of the firms participating and can sort out firms irrelevant to the purpose.

A problem with the Choice Experiments (CE) in VOTVOR, GUNVOR and PUSAM is that the results have not been weighted based on each respondent's transport demand. Put in another way, the model would give equal weights to the answers from LKAB, a large mining firm, as the answers from a smaller firm with maybe only a hundredth of the transport demand. The data is sparse on this issue but it is often claimed that Sweden is unusual in that relatively few firms produce a large share of all rail freight; think of firms in mining, steel, forestry and paper. This implies that the assumption of equal weight to all respondents might be a smaller problem in Norway and the Netherlands than it would have been in a Swedish CE-study, but without proper data this is only a speculation. There is a need for better information on the Swedish freight market structure for future research.

How are the VTTV applied in CBA in Norway and The Netherlands?

Two results from VOTVOR, GUNVOR and PUSAM have been adopted into official CBA-guidelines. In Norway the VTTV for rail freight from PUSAM is used by Jernbaneverket. The cost of a delay is 72 NOK/tonne-hour, with the exception of metal ore transports which are not covered. In the Netherlands the VTTV for road freight from VOTVOR is used. The value for rail freight is not used routinely because there is no standard national method yet to predict rail transport time variability.

Table 8 Applied VTTV

	Rail	Road
PUSAM – Norway	72 NOK/tonne-hour Expected delay	
VOTVOR - Netherlands		14 Euro/hour*vehicle Standard deviation

Conclusions (VTTV)

Can Dutch and Norwegian values be transferred to Sweden? Not directly. This report cannot recommend a value transfer based on the Norwegian studies GUNVOR and PUSAM or the Dutch study VOTVOR. The two Norwegian reports and the transport statistics do not provide a sufficient foundation for a value transfer. The Dutch study is well carried out but the inherent differences between the Swedish and Dutch railway system, such as the Swedish heavy industries’ reliance on rail freight and the importance of the rail mode, makes a value transfer unsuitable based on the Dutch study alone. There are large discrepancies between the results in the three studies which is a cause of concern for value transfer even though the differences might be due to actual differences in the countries.

The three studies do not use any detailed commodity classification which makes it impossible to keep the wish of the Swedish Transport Administration to have a VTTV for each commodity. Even if we had access to detailed commodity specific VTTVs in the two Norwegian studies it would still be difficult to transfer from Norway due to the poor level of detail in the official statistics.

A problem in the GUNVOR-study is the low response rate and the lack of stratification when designing the study. The railway section of GUNVOR has been supplemented by the PUSAM study, on which TØI bases its recommended VTTV.

We are skeptical to PUSAM’s sampling procedure based only on CargoNet’s clients in the container segment. CargoNet has around two thirds of the rail freight market which means that at least one third is left out of the study by design. Even if the remaining third is mainly composed of iron ore we find the method problematic. In addition to that the response rate is low. PUSAM mainly analyses the VTTV for forwarders rather than shippers. We need a better understanding of the cost drivers of the forwarders in order to compare them to the Swedish context.

The Netherlands lacks statistics on deviations from timetables and the critical length of delays for freight trains. This makes it difficult to understand which kind of costs are occurring in case of major delays.

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4 Conclusions

One of the main conclusions from WSP (chapter 2) is that the valuation of TTV, i.e. the process of putting a number on the chosen measure of the transport time variability to obtain VTTV, is not dependent on the measure itself. Thus, the valuation does not put any restrictions on the measure and any measure suitable for the modelling of TTV, e.g. using future versions of the national freight transport model *Samgods*, could be used. However, it is still necessary to choose a measure for practical reasons. But other aspects than the valuation will decide which measure(s) that is/are most suitable. Furthermore, we have presented a complete method to make estimations of VTTV. The model takes into account indirect abatement (precautionary) costs caused by expected risks as well as direct delay costs caused by individual contingencies. This means that once data is in place, VTTV can be estimated.

The main conclusion from VTI (chapter 3) is that a value or function transfer of VTTV for rail freight to Sweden is not a viable option, neither using Norwegian, Dutch nor combined values. The main reasons for this are the lack of detail in the statistics such as commodity classification, methodological problems in the studies and inherent differences between the countries.

This report is one of the necessary steps on the way to be able to include the costs of transport time variability in the freight transport system – and thus the benefits of increased reliability – in Swedish CBA. In order to do this, two sets of knowledge are needed:

- The probability distribution of transport time, i.e. a quantitative description of the probability of delays and early arrivals of different magnitudes for relevant modes. This information could be obtained through statistical data collection, or modelled. In the future, the idea is that a model should be able to estimate how investments in and maintenance of infrastructure affects the probability of delays.

- The societal costs for varying transport times (VTTV).

This report describes the progress made regarding the second point. We now know that it is not suitable to transfer VTTV from the existing studies in order to apply them in Sweden. Furthermore, a method has been developed to calculate VTTV once we have data on delay costs. Thus, the following two main areas should be addressed in future research in order to reach the ultimate aim, to include VTTV in CBA:

1) Collect data from actors on how different types of costs vary depending on the variation of transport time. The dependence on two variables needs to be investigated:

    a. How operational/marginal costs for delays vary with time and e.g. commodity type

    b. How precautionary/abatement costs vary with the general reliability of the transport system and the commodity type

    The data collection should be preceded by an analysis of the transport market, in order to determine which and how many actors to include.

2) Develop methods to quantify TTV, i.e. the probability distributions of transport time, through statistical data collection and/or modelling for the present situation and how it could change due to policy measures such as infrastructure investments.

Detta är baksidan på rapporten. Den måste vara på jämn sida, lägg in en blank sida före om det behövs.

TRAFIKVERKET

Trafikverket, XXX XX Ort. Besöksadress: Gata XX.
Telefon: 0771-921 921, Texttelefon: 010-123 99 97

www.trafikverket.se