REPORT
VTTV – Value of Transport Time Variability
Method development and synthesis
Value transfer, measurements, and decomposition of VTTV
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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 & partners1, and
one by VTI & partners2. 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)
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 ofta 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 transporttids 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 mätten 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 undersöfts om det används mått inom logistikbranschen som skulle kunna passa TTV inom samhällsekonomin. Slutsatsen är att dessa mått (eller indikeror) 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 benämnings *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 benämnings *Katastrofhändelser*. Dessa är inte planerade för i transportsystemet och orsakar mycket stora konsekvenser när de inträffar.

- Slutligen benämnings mycket stora störningar som inträffar ofta *System killer*. 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-linejära 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 och 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.


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 måts 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.


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 transportförråd. Eftersom några få stora aktörer kan stå för stora delar av den totala transportförråd 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 transporttidsens 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

How does the investment affect the standard of the infrastructure?

How many infrastructure-related disturbances are avoided? To what extent are delays decreased?

How large is the effect on costs and benefits for society?
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

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Mode</th>
<th>Type of variation measure</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winston (1981)</td>
<td>USA</td>
<td>Road/rail</td>
<td>standard dev.</td>
<td>SP+RP</td>
</tr>
<tr>
<td>Transek (1990)</td>
<td>Sweden</td>
<td>Road/rail</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>Transek (1992)</td>
<td>Sweden</td>
<td>Road</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>de Jong et al. (1992)</td>
<td>Netherlands</td>
<td>Road/rail</td>
<td>Prop. delayed shipm.</td>
<td>RP</td>
</tr>
<tr>
<td>de Jong et al. (1995)</td>
<td>Denmark, Netherlands, France</td>
<td>Road</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>Accent and Hague Consulting Group (1999)</td>
<td>UK</td>
<td>Road</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>Small et al. (1999)</td>
<td>USA</td>
<td>Road</td>
<td>Std. dev., CV and scheduling</td>
<td>SP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Expected delay early and late combined with probability of being late</td>
<td></td>
</tr>
<tr>
<td>Bergkvist et al. (2000)</td>
<td>Sweden</td>
<td>Road</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>Kurri et al. (2000)</td>
<td>Finland</td>
<td>Road/rail</td>
<td>Road: Prop. delayed shipm. Rail: expected/Schedule delay</td>
<td>SP</td>
</tr>
<tr>
<td>Wigan et al. (2000)</td>
<td>Australia</td>
<td>Road</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>Bergkvist (2001)</td>
<td>Sweden</td>
<td>Road</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>de Jong et al. (2001)</td>
<td>France</td>
<td>Road/rail, intermodal</td>
<td>Prop. delayed shipm.</td>
<td>SP+RP</td>
</tr>
<tr>
<td>Fowkes et al. (2001)</td>
<td>UK</td>
<td>Road</td>
<td>Spread, and Expected/Schedule delay</td>
<td>SP</td>
</tr>
<tr>
<td>Study</td>
<td>Country</td>
<td>Mode</td>
<td>Measure</td>
<td>Method</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------</td>
<td>-------------------------------</td>
<td>-----------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>INREGIA (2001)</td>
<td>Sweden</td>
<td>Road/rail/air</td>
<td>Prop. delayed shipm.</td>
<td>Spread</td>
</tr>
<tr>
<td>Hensher et al. (2005)</td>
<td>Australia</td>
<td>Road</td>
<td>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)</td>
<td>SP</td>
</tr>
<tr>
<td>Fowkes (2007)</td>
<td>UK</td>
<td>Road/rail</td>
<td>Scheduling approach; Spread, early start, late arrival, early and late shifts.</td>
<td>SP</td>
</tr>
<tr>
<td>Maggi et al. (2008)</td>
<td>Switzerland</td>
<td>Abstract mode</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>De Jong et al. (2009)</td>
<td>Netherlands</td>
<td>Road/rail/inland, waterways, sea/air</td>
<td>Std. dev. Conversion of Rand Europe (2004) to reliability ratios RR</td>
<td>SP</td>
</tr>
<tr>
<td>Fries et al. (2010)</td>
<td>Switzerland</td>
<td>Road/rail/intermodal</td>
<td>Prop. delayed shipm.</td>
<td>SP</td>
</tr>
<tr>
<td>Halse et al. (2010)</td>
<td>Norway</td>
<td>Road</td>
<td>Std. dev.</td>
<td>SP</td>
</tr>
<tr>
<td>Significance, VU University et al. (2012)</td>
<td>Netherlands</td>
<td>Road/rail/inland, waterways, sea/air</td>
<td>Std. dev.</td>
<td>SP</td>
</tr>
</tbody>
</table>
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](image)

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.
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.
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.

Figure 4 Different modes of transport, networks and gateways (Waidringer, 2001)
<table>
<thead>
<tr>
<th>Activity</th>
<th>Category</th>
<th>Cost</th>
<th>Cost driver</th>
<th>Key variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>Direct</td>
<td>Time dependant vehicle costs</td>
<td>Longer transport time</td>
<td>Vehicle costs, length of delay</td>
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<td></td>
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<td></td>
<td>Distance dependent transport</td>
<td>Longer transport distance</td>
<td>Vehicle costs, extra transport distance</td>
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<td></td>
<td></td>
<td>Rescue costs</td>
<td>Redirecting other resources to take over planned transport assignments etc.</td>
<td>Cost of extra transport</td>
</tr>
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<td></td>
<td>Indirect</td>
<td>Indirect costs for backup and flexibility</td>
<td>Unreliable transport system in general</td>
<td>Perceived reliability, cost of backup</td>
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<tr>
<td></td>
<td>Transport service quality</td>
<td>Goods capital costs</td>
<td>Longer transport time</td>
<td>Goods value, size of shipment, length of delay</td>
</tr>
<tr>
<td>Transshipment</td>
<td>Direct</td>
<td>Staff cost</td>
<td>Disrupting terminal operational planning</td>
<td>Staff costs</td>
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<td></td>
<td>effects</td>
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<tr>
<td></td>
<td></td>
<td>Terminal storage cost</td>
<td>Missed transhipment</td>
<td>Terminal storage costs, size of shipment, length of delay</td>
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<td></td>
<td></td>
<td>Goods capital costs</td>
<td>Missed transhipment</td>
<td>Goods value, size of shipment, length of delay</td>
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<tr>
<td>Delivery</td>
<td>Direct</td>
<td>Staff cost</td>
<td>Disrupting receiver operational planning</td>
<td>Staff costs</td>
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<tr>
<td>Use of</td>
<td>Indirect</td>
<td>Cost for safety stock</td>
<td>Unreliable transport system in general</td>
<td>Perceived reliability, cost of safety stock</td>
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<tr>
<td>goods</td>
<td>effects</td>
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</tr>
<tr>
<td></td>
<td>Transport service quality</td>
<td>Direct cost of lack of goods</td>
<td>Missed customer order etc.</td>
<td>Type of industry, type goods and size of shipment, effects of lacking goods</td>
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<td></td>
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<td>Indirect cost of lack of goods</td>
<td>Customer choosing other supplier</td>
<td>Type of industry, type goods and size of shipment, effects of lacking goods</td>
</tr>
<tr>
<td>Overall</td>
<td>Direct</td>
<td>Propagating delays in the chain causing other delay costs</td>
<td>Too small time margins in the transport chain</td>
<td>Characteristics and complexity of transport chain, other cost drivers</td>
</tr>
<tr>
<td>chain</td>
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</table>
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](image)

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 deliveries 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.
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 in Figure 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 \( \alpha - \beta - \gamma \) preferences, where \( \alpha \) is the marginal utility for travel time and \( \beta \) and \( \gamma \) 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 functions.

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 $\sigma$ 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.

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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

\[ VTTV = VTTV_L + VTTV_\lambda. \]

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 are constant with values \( \alpha \), \( \beta \) and \( \gamma \). 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,

\[ R(T, D) = \alpha T + \beta \max(0, -D) + \gamma \max(0, D) \]

The cost given by (2) has the same form as scheduling utilities with \( \alpha - \beta - \gamma \) 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 \( \mu \) is the expected transport time and \( X \) is a random variable with \( EX = 0 \), representing deviations from the expected transport time. The scale factor \( \sigma \) represents the variability of transport time \( T \). Basically, by applying restrictions on \( X \), \( \sigma \) may be any measure of variability. For example, assuming \( \text{Var}(X) = 1 \), then \( \sigma \) 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

\[ \text{ER}^*(\mu, \sigma) = \alpha \mu + (\beta + \gamma) \sigma \int_{-\infty}^{\sigma^{-1}(s)} F^{-1}(s)\,ds, \]

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

The minimum expected running cost in (3) is a function of expected transport time \( \mu \) and the variability measure \( \sigma \), 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 \( \sigma \), namely

\[ \text{VTTV} = \text{ER}^*(\mu, \sigma). \]

\[ \text{It is assumed that the receiver has a marginal cost for early delivery, i.e. } \beta > 0. \]
To obtain a value for VTTV in a subjective utility formulation of the problem, the marginal utilities $\alpha$, $\beta$ and $\gamma$ 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 $\alpha$, $\beta$ and $\gamma$ 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 $\sigma$ 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:

$$EC^*(\mu, \sigma) = A(\sigma) + \alpha(\sigma)\mu + (\beta(\sigma) + \gamma(\sigma))\sigma \int_0^1 F^{-1}(s) ds.$$ (5)

Transport time variability influence the running cost through the marginal costs $\alpha$, $\beta$ and $\gamma$. 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 $\sigma$ changes and the other term describing the change in the probability distribution when $\sigma$ 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 $\sigma$. 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 $A\sigma, \alpha\sigma, \beta\sigma$ and $\gamma\sigma$, 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.
References


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\textsuperscript{5} (2010), which looks at trucks and trains - PUSAM\textsuperscript{6} (2012), which looks at rail freight in the container segment, and one Dutch study VOTVOR\textsuperscript{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.

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

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Million gross(^8) tonnes</th>
<th>Million tkm</th>
<th>Km (calculated average distance(^9))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>39</td>
<td>6,078</td>
<td>312</td>
</tr>
<tr>
<td>Sweden</td>
<td>67</td>
<td>20,763</td>
<td>617</td>
</tr>
<tr>
<td>Norway</td>
<td>31</td>
<td>3,383</td>
<td>215</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Modal Split (%)</th>
<th>Railways</th>
<th>Roads</th>
<th>Inland waterways</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Union</td>
<td>18,2</td>
<td>75,1</td>
<td>6,7</td>
</tr>
<tr>
<td>(27 countries)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>5,1</td>
<td>56,2</td>
<td>38,7</td>
</tr>
<tr>
<td>Sweden</td>
<td>39,7</td>
<td>60,3</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>14,7</td>
<td>85,3</td>
<td>-</td>
</tr>
</tbody>
</table>

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).

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\(^8\) 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 Netherlands' 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 relation 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


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


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.  

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>
<thead>
<tr>
<th>Table 6: VTTV as reported in each respective study</th>
<th>Rail</th>
<th>VTTS</th>
<th>VTTV</th>
<th>VED</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUNVOR - NOK/tonne-hour</td>
<td>27</td>
<td>44</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>PUSAM general - NOK/tonne-hour</td>
<td>47</td>
<td>-</td>
<td>278</td>
<td></td>
</tr>
<tr>
<td>PUSAM Pallet - NOK/tonne-hour</td>
<td>7</td>
<td>-</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>PUSAM All - NOK/tonne-hour</td>
<td>13</td>
<td>-</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>VOTVOR Container - Euro/train-hour</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>VOTVOR Non-container - Euro/train-hour</td>
<td>-</td>
<td>250</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>VOTVOR All - Euro/train-hour</td>
<td>-</td>
<td>200</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 7: VTTV in SEK/tonne-hour</th>
<th>Rail (SEK/tonne-hour)</th>
<th>VTTV</th>
<th>VED</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUNVOR11 (NOR)</td>
<td>35.5</td>
<td>71.8</td>
<td></td>
</tr>
<tr>
<td>PUSAM12 all weighted (NOR)</td>
<td>-</td>
<td>62.6</td>
<td></td>
</tr>
<tr>
<td>VOTVOR13 all (NL)</td>
<td>6.55</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Simple calculation (SWE)</td>
<td>30.2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Current ASEK value (SWE)</td>
<td>2.62</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

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:

\[
\frac{(12/19*1.5*10^9)}{(3.30/2.62*62191.3*400)} = 30.2 \text{ SEK/tonne-hour}
\]

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

<table>
<thead>
<tr>
<th></th>
<th>Rail</th>
<th>Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUSAM – Norway</td>
<td>72 NOK/tonne-hour Expected</td>
<td>14 Euro/hour*vehicle</td>
</tr>
<tr>
<td></td>
<td>delay</td>
<td>Standard deviation</td>
</tr>
</tbody>
</table>
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.
References


ProRail (2013) Track length in the Netherlands [data].


Trafikverket (2014). Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 5.1 Kapitel 8 Tid och kvalitet i godstrafik.

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 VT (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.
Appendix VTTV - case study and assessment 2016

Background

This appendix describes a case study conducted in Sweden based on a large retail company that does not want to be identified by name in the report. Therefore, we refer to it simply as a large retail company. This study is directly related to previous work presented in a report to the Swedish Transport Administration 2015, *Time Variability Method development and synthesis - WP 1 – Value transfer and WP 4 – Decomposition of VTTV*, and in an article accepted for the WCTR 2016 conference, *A method for measuring and valuing transport time variability in logistics and cost benefit analysis*. In that article, a method and model for estimating a new value for transport time variability for goods transport are suggested, and this appendix is a case study to test that model.

It should be pointed out that the assessment and validation are done on a single case study for a single company in one industry, and thus conclusions cannot be drawn for a general VTTV value based on these results only.

Data input

The data was kindly provided by a larger retail company in Sweden that has a nationwide coverage with an intermodal concept, hub terminal(s), and retail stores. The data consist of statistics for transports, delays, and costs associated with these delays. An assessment has been made based on discussions about the different costs and whether they are related to the transport time variability or not. We would like to point out that the costs discussed below are not all related to the calculations and estimations made later; rather, this chapter should be seen as a wider input and frame of reference for what costs are affected by transport time variability for a company.

![Figure 11 Schematic description of different cost components related to transport time variability](image_url)
The figure above shows the different costs related to the supply chain and the consequences over time as a function of delay time. The base in the diagram is the traditional buffer stock that is always necessary to handle normal variations in, for example, demand and is not related to transport time variability. The focus of this report is the other parts directly or indirectly related to uncertainties in transport time and the variability. It can be divided into four (4) parts:

1. costs for an extra buffer to absorb the variability due to transport time variations
2. costs for extra personnel and transports
3. direct costs for lost sales
4. indirect costs for lost sales and customers

The costs we have focused on and include in our estimations are the second part above, costs for extra personnel and transports for railway, which are 45% of the total transport volume for our case study company.

We would also like to point out that we do not include lost sales (parts 3 and 4 above) in our calculations, nor do we suggest that they be included in the calculations made later in this appendix or that they be included in a CBA. We include them in the discussion to give a full picture of all the costs that can be related to transport time variability.

The perspective taken is that of a larger retailer with a main warehouse on why costs can be divided into inbound as well as outbound. The inbound costs are related to the extra buffer stock as well as extra personnel required at the warehouse for delays. The outbound costs are related to extra personnel and transports, to and in the stores, as well as costs for lost sales.

The diagram below is translated from a Swedish report that looked into what happened in a store if an article the customer wanted was sold out.

---

15 ECR – Minskut slut hyllan – Skapar en bättre kundupplevelse och lönsammare affärer
What can be seen is that a small part of the customers (9%) refrain from purchasing altogether, and a fair portion postpones the purchase (17%). The rest of the customers either switch to another article of the same brand (16%) or another brand (31%) or simply buy the article in another store (27%).

Taking these figures into consideration, we see that the actual loss for the store is the sum of the customers that do not purchase the article at all, the customers purchasing the article at another store, and a portion of the customers who switch to another brand. This gives a sales loss at 43% for that specific retailer if and when the article is not in store. Part of the 16% (no purchase and reduced sales) plus the transactional costs for searching for another store that carries the desired article (27%) should be included in the CBA.

Figure 12 Customers decisions/actions when an article is sold out

Figure 13 The effect of the customers’ decisions on the stores sales
The figure below is a schematic picture of a supply chain in the retail industry. S = Supplier, W = Warehouse, IS = Intermediate Storage (can be a larger shop), R = Retailer. We have studied the costs related to a part of the whole supply chain, from W1 to W2; they occur in W2 as a consequence of delays between W1 and W2. Out of these discussions, we have used the costs for extra personnel and transports related to delays of goods carried by train, which constitutes 45% of the total transports.

![Schematic figure of a supply chain in the retail industry](image)

Altogether, the combinations of the statistics for both inbound and outbound transports and delays over a two-year period with the actual costs for extra personnel, transports, and the loss of sales gave a fairly detailed distribution of costs over the entire supply chain.

Model assessment

A model for $VTTV$ was presented in Berglund, M. et al. (2016). It was derived from scheduling utility theory by translation of a concept from passenger traffic. However, no information from first-order conditions in the cost minimization of the firm was used. Such a derivation is performed in this section. Therefore, the model is presented once again here.

Literature references are given in Berglund, M. et al. (2016). An expression for $VTTV$ will be derived, which can be interpreted in the scheduling framework. The difference from the $VTTV$ given in Berglund, M. et al. (2016) is that some terms in that expression cancel out. The resulting computed value for $VTTV$ will be the same, but the new expression for $VTTV$ implies less of a burden for collecting data.

Following Berglund, M. et al. (2016), we divide the costs for the firm receiving a freight shipment into **abatement costs** and **operating costs**. Abatement costs are costs associated with measures to mitigate consequences of delays. Typical abatement costs are costs for keeping a safety stock, adding margins to time tables, or investing in spare equipment. The distinguishing feature of abatement costs is that they do not depend on actual delivery or transport times. Abatement costs are determined in advance of any specific transport; hence, they cannot depend on the actual delivery or transport time of that transport. For simplicity but without restriction for the derived expression of $VTTV$, we will assume that abatement measures can be summarized by a single index $a$. We will denote the abatement costs implied by abatement measure $a$ as $f(a)$. Operating costs, in this context, are costs that are associated with specific delivery and/or transport times of specific transports. Typically, these costs will be time-dependent operative costs for vehicles and time-dependent costs.
associated with loading, unloading, and transhipping. The actual delivery or transport time associated with a specific transport will be denoted by $T$, and operating costs will be a function of $T$. However, since abatement measures mitigate consequences of delays, operating costs will be a function of $a$ as well. Operating costs will be denoted by $r(a,T)$.

Since delivery or transport times are not known in advance, the firm will be assumed to minimize the expected total cost for a delivery. Further, we assume that the expectation is taken over a probability distribution of $T$, parametrized by mean $\mu$ and a measure of variation (e.g., standard deviation) $\sigma$. This expectation operator is denoted by $E_{\mu\sigma}$. The firm can choose its optimal level of abatement measures, and we have the firm perform the following cost minimization:

\[
(1) \quad C(\mu, \sigma) = \min_a E_{\mu\sigma} \left[ f(a) + r(a, T) \right],
\]

where $C(\mu, \sigma)$ is the cost obtained at the optimal $a = a^\ast$. Now, $f(a)$ is deterministic since it is not a function of the random variable $T$. Hence, we may write (1) as

\[
(2) \quad C(\mu, \sigma) = \min_a \left\{ f(a) + E_{\mu\sigma} \left[ r(a, T) \right] \right\};
\]

At optimum, the derivate of the expected cost with respect to $a$ must be zero, that is\textsuperscript{16}

\[
(3) \quad \frac{df(a)}{da} + E_{\mu\sigma} \left[ \frac{\partial r(a, T)}{\partial a} \right] = 0.
\]

$VTTV$ is defined as the cost-derivative with respect to the measure of transport time variation $\sigma$, that is

\[
(4) \quad VTTV = \frac{\partial C(\mu, \sigma)}{\partial \sigma}.
\]

\textsuperscript{16} The fact that the derivative "passes through" the expectation operator has been used in equation (3).
This can be derived directly from the envelope theorem, which results in the following expression for \( VTTV \) (assuming the optimal value of \( a \)):

\[
(5) \quad VTTV = \frac{\partial}{\partial \sigma} E_{\mu, \sigma} [r(a, T)].
\]

\( VTTV \) is the derivative with respect to \( \sigma \) of the expected operating cost. The reason why \( VTTV \) does not contain any entity derived from the abatement cost \( f(a) \) is that from the first-order condition at optimality, any marginal change in abatement cost is cancelled out by the marginal change of expected operating cost with respect to abatement measures. This corresponds to the assumption of the firm as a cost minimizer. The firm will only take on an additional investment in abatement costs, \( df(a)/da \), if it will be fully compensated by a decrease in expected operating. This decrease is \( E_{\mu, \sigma} [\partial r(a, T)/\partial a] \). \( VTTV \) is then the uncompensated change in the expected operating cost, which gives expression (5).

Assume that the distribution of \( T \) has an absolutely continuous density \( h \), which depends on the mean \( \mu \) and the variation measure \( \sigma \). Then \( VTTV \) in (5) may be written as

\[
(6) \quad VTTV = \frac{\partial}{\partial \sigma} E_{\mu, \sigma} [r(a, T)] = \frac{\partial}{\partial \sigma} \int_{-\infty}^{+\infty} r(a, t) h(t, \mu, \sigma) dt = \int_{-\infty}^{+\infty} r(a, t) \left( \frac{\partial h(t, \mu, \sigma)}{\partial \sigma} \right) dt.
\]

In this sense \( VTTV \) is the change in expected operating cost when the distribution of transport time changes in its measure of variation \( \sigma \). This expression for \( VTTV \) is cumbersome to interpret and difficult to estimate from data. It would be more natural to interpret \( VTTV \) if it were expressed in terms of marginal costs \( \partial r(a, T)/\partial t \), and it would ease estimation if the expectation were kept.

It is possible to reach both these aims by a change of variable in the rightmost integral in equation (6). The first step in achieving this is to express the probability distribution of \( T \), transport time, in such a way that its dependency on the parameters \( \mu \) and \( \sigma \) is made explicit. We will assume that the variation measure is a so-called scale parameter. Then \( T \) may be written as

\[
T = \sigma Z + \mu,
\]

where \( Z \) is a random variable having mean zero and scale one, that is, it has density

\[
h(t, 0, 1).
\]
The random variable $Z$ is only a reference distribution that is used to show how the parameters $\mu$ and $\sigma$ affect the transport time distribution $T$. $Z$ will not be a part of the expression for $VTTV$. With this in mind, it can be shown that $VTTV$ can be written as

\begin{equation}
VTTV = E_{\mu \sigma} \left[ r_T(a,T) \frac{T - \mu}{\sigma} \right],
\end{equation}

where $r_T(a,T)$ is the marginal operating costs, i.e., the partial derivative of $r$ with respect to transport time $T$. Even though it is beyond the scope of this study, it is worth noting that the value of transport time ($VOT$) can be similarly written as

\begin{equation}
VOT = E_{\mu \sigma} \left[ r_T(a,T) \right],
\end{equation}

that is, $VOT$ is just the expected marginal operating cost with respect to transport time.

Since the standard deviation $\sigma$ determines the probability distribution of transport times $T$, the expectation in equation (7) will itself be a function of $\sigma$. Therefore, $VTTV$ will in general be a function of the standard deviation $\sigma$. This functional dependence is troublesome for using $VTTV$ for several reasons. One problem is that $VTTV$ is used in cost benefit analysis to approximate an integral. If $VTTV$ depends on $\sigma$, this approximation will be less accurate. Another problem with the functional dependence of $\sigma$ on $VTTV$ is that $\sigma$ will likely vary between different modes of transport and between different links in the transportation network. As a consequence, $VTTV$ will vary between different modes of transport and between different links. Of these two problems, we will not address the approximation error further, but we will provide an initial attempt at addressing the need for using different $VTTV$ when $\sigma$ varies.

The functional dependence of the standard deviation on $VTTV$ is easily derived for some quadratic cost functions. The simplest case is the cost function $r(T) = \gamma(T - \mu)^2$, which has $r_T(T) = 2\gamma(T - \mu)$ as marginal cost function. Then by using the definition of the variance of $T$, that is $E(T - \mu)^2 = \sigma^2$, we get from equation (7) that

\begin{equation}
VTTV = E_{\mu \sigma} \left[ 2\gamma(T - \mu) \frac{T - \mu}{\sigma} \right] = \frac{2\gamma}{\sigma} E_{\mu \sigma} (T - \mu)^2 = \frac{2\gamma}{\sigma} \sigma^2 = 2\gamma \sigma.
\end{equation}
If \( T \) is measured as the deviation from a scheduled delivery time, then \( \mu \) is the average deviation, and this cost function assumes that an early arrival with \( t \) minutes is as costly as a \( t \) minute delay. This is highly unrealistic in a freight setting since typically there are no costs associated with early arrival. A more realistic cost function would be

\[
(9) \quad r(T) = \begin{cases} 
0, & \text{when } T \leq \mu, \\
\gamma(T - \mu)^2, & \text{when } T > \mu.
\end{cases}
\]

This cost function reflects the fact that early arrivals do not incur any costs. It gives a \( VTTV \) that is exactly half of the \( VTTV \) in equation (8), that is

\[
(10) \quad VTTV = \gamma \sigma.
\]

The analytical expressions for \( VTTV \) given in (8) and (10) are independent of the specific transport time probability distributions. This is not true in general. One such example is a linear (in \( T \)) cost function. The data that are available now are such that it is difficult to test the suitability of different cost functions. Therefore, we will estimate \( VTTV \) according to equation (10) for the quadratic cost function given in (9). In addition, a direct estimation of \( VTTV \) is made for a linear cost function. It is direct in the sense that it is estimated directly from data and that no attempt has been made to determine its functional dependence on \( \sigma \).

In a strict sense, the \( VTTV \) obtained is only applicable for marginal changes from the current situation of the retailer company. But it is given partly as a check on the \( VTTV \) obtained by (10) and partly because it may be a less sensitive alternative if the quadratic cost function is seen as less plausible.

Given the function for the time-dependence of the operating costs, the cost function – direct estimates of \( VTTV \) as given by (7) – is readily obtained from observed data on transport times. If we have \( n \) observed transport times \( t_i \), \( VTTV \) can be estimated as the sample mean

\[
(11) \quad VTTV = \frac{1}{n} \sum_{i=1}^{n} r(t_i) \frac{\hat{t}_i - \hat{\mu}}{\hat{\sigma}},
\]

where \( \hat{\mu} \) and \( \hat{\sigma} \) are the sample mean and standard deviation (if the scale parameter \( \sigma \) is the standard deviation) estimated from the \( \hat{t}_i \). Note that \( T \) and its estimator \( \hat{t}_i \) may be transport times or delivery times or, for example, delays, i.e., deviation from a scheduled
time. \( VTTV \) will be the same in all cases since the difference \( T - \mu \) will be the same in all three cases.

**Estimation of \( VTTV \)**

Estimation of \( VTTV \) has been done by applying equations (9)-(11) on observed data for all train arrival times to the warehouse of the retailer during 2014, one train per day, 365 trains in total. The observed times \( t_i (i=1, ..., 365) \) was the deviation from scheduled arrival time.

The sample mean and standard deviation were found to be \( \mu = 5.71 \) minutes and \( \sigma = 73.8 \) minutes. The additional costs for delays (or positive deviations \( T \)) are wage costs from having staff waiting to unload the train (including any overtime salary). The retailer company has estimated its cost for these activities as a total cost over the whole year. This cost will be denoted \( TOTCOST \) below.

The full marginal cost function \( r_T(a, T) \) should give the marginal cost associated with a measure \( a \). This is evaluated at the current situation for the retail company; hence, we do not try to model any functional cost relation between different abatement measures and deviations in arrival time \( T \). Therefore, the marginal cost function will be written as \( r_T(T) \).

\( VTTV \) will be estimated by using the truncated quadratic cost function and given by equation (9) above and also by using a truncated linear cost function. \( VTTV \) based on these two alternative cost functions are motivated in the preceding section. Since there is an increasing likelihood that overtime compensation sets in when the delay increases, and since \( VTTV \) based on a quadratic cost function provides an explicit dependency on the standard deviation, we see the \( VTTV \) based on the quadratic cost function as the main alternative.

**Estimating \( VTTV \) using a quadratic cost function**

To estimate \( VTTV \) according to equation (10), the parameter \( \gamma \) in the quadratic cost function given by (9) needs to be estimated. The data available are the total cost of delayed trains and the deviations/delays for individual train arrivals. Then, given that the total cost has been generated by the cost function (9), the parameter can be estimated as

\[
\gamma = \frac{TOTCOST}{\sum (t_i - \mu)^2},
\]

where the summation is over terms where \( t_i > \mu \). This estimation assures that the costs obtained by applying the cost function on each train arrival agree with the observed total cost. Performing the estimation on observed data gives the following result:

\[
\gamma = 0.287 \text{ SEK/(min}^2 \text{ train)}.
\]
Then applying equation (10) to compute $VTTV$ gives

$$VTTV = \gamma \sigma = 0.287 \times 73.8 = 21.2 \text{ SEK/(min * train)}.$$  

When estimating the average load of a train arriving at the inventory to 383 tonnes, $VTTV$ per tonnes hour is estimated to be

$$VTTV = \gamma \sigma = 3.3 \text{ SEK/(hour * ton)}.$$  

This $VTTV$ is for the current situation of the retail company. By expressing $\gamma$ in units of hour and tonnes, we may give the general expression for $VTTV$ (given the quadratic cost function given by (9)) as

$$VTTV = 2.7 \sigma \text{ SEK/(hour * ton)}.$$  

This assumes that the unit of the standard deviation is hours.

### Direct estimation of $VTTV$ using a linear cost function

The linear (and truncated) cost function used in this estimation is constructed under the following assumption that there are no additional costs for the train arriving early (negative deviations $T$). This gives a cost function of the following form

$$r(T) = \begin{cases} 
0, & \text{when } T \leq 0, \\
\beta T, & \text{when } T > 0. 
\end{cases}$$

This implies a piecewise constant marginal cost function.
Then, given that the total cost has been generated by this cost function, the parameter $\beta$ can be estimated as

$$
\beta = \frac{\text{TOTCOST}}{\sum \hat{t}_i},
$$

where the summation is over terms where $\hat{t}_i > 0$. This estimation assures that the costs obtained by applying the cost function on each train arrival agree with the observed total cost. Performing the estimation on observed data gave the following result

$$
\beta = 58.6 \text{ SEK/(min * train)}.
$$

Then by using the estimated sample mean and sample standard deviation of the observed deviations $\hat{t}_i$ and computing equation (11) using the marginal cost function determined by (14), we get the following $VTTV$ per minute train delay:

$$
VTTV = 13.3 \text{ SEK/(min * train)}.
$$

Estimating the average load of a train arriving at the inventory to 383 tonnes, $VTTV$ per tonnes hour is estimated to be

$$
VTTV = 2.1 \text{ SEK/(hour * ton)}.
$$

**Costs to include in $VTTV$**

Freight transports typically take place in complex environments called supply chains or, for that matter, supply networks. The organizational structure of a supply chain is not fixed. Sometimes a supply chain is completely contained within one firm, but typically several firms are involved. $VTTV$, as given by equation (5) for a cost-minimizing firm as stated in (1), does not address the question of how to aggregate $VTTV$ over firms when several firms...
are affected by a change in standard deviation of transport times. A typical question to address is whether or not fines for late deliveries should be included when estimating \( VTTV \). Below we will see that in this approach for estimating \( VTTV \), fines should not be included.

The easiest way to motivate using values such as \( VTTV \) in CBA for freight transports is in a setting with perfectly inelastic (vertical) demand and perfectly elastic (horizontal) supply\(^\text{17}\). In this case the consumer’s surplus (CS) for an intervention is exactly the same as the cost savings attained at the firms involved in the transport. When performing a CBA, we will be focusing on conditions in the long run. In the long run, all fixed costs can be monetized into running costs; we may also assume that marginal costs are constant. In this case, the number of firms does not influence the total cost of production in a sector of the economy. Then to see which costs to include when estimating \( VTTV \) and which \( VTTVs \) we may add, we can start with the case that the whole sector is only one firm. This firm may be depicted as the supply chain in Figure 4 above. If the nodes and links (corresponding to transports) in Figure 4 are numbered \( 1, \ldots, n \), the costs generated at the nodes and links are denoted \( c_1, \ldots, c_n \). The costs are only the resource usage in the forms of labor, capital cost, and inputs produced outside the sector (i.e., the firm). Let the revenue of the firm from its end consumer be denoted by \( r_n \). Then the profit of the firm may be written

\[
\pi = r_n - \sum_{i=1}^{n} c_i .
\]

If we write

\[
c = \sum_{i=1}^{n} c_i ,
\]

then for an intervention, the change in cost \( \Delta c = \sum_{i=1}^{n} \Delta c_i \) is the consumer’s surplus of the intervention. In our case, the \( VTTV \) is used to approximate the change in cost, that is

\[
\Delta c = \frac{\partial c}{\partial \sigma} \Delta \sigma = VTTV \cdot \Delta \sigma .
\]

However, from (17) we get that

\(\text{\textsuperscript{17}}\) This assumption on demand and supply may be seen as restrictive; however, in a CBA considering long-term effects, it is a rather plausible assumption.
\begin{equation}
VTTV = \frac{\partial c}{\partial \sigma} = \sum_{i=1}^{n} \frac{\partial c_i}{\partial \sigma} = \sum_{i=1}^{n} VTTV_i.
\end{equation}

Hence, \( VTTV \) for the intervention is equal to the sum of the individual \( VTTV_i \)s for the components of the costs (\( VTTV_i \) is set to zero for cost components that are not affected by the change in \( \sigma \)).

A typical sector of the economy will involve more than one firm. To get an understanding of which costs to include when estimating (and applying) \( VTTV \), a case is considered in which each node and each link in the supply chain (Figure 4) is a single firm. To simplify notation, let's assume that the supply chain is a simple chain in which the single output from one firm is used as the input of the next firm. The chain starts with firm 1, and firm \( n \) is selling its output to the end consumer. Then the first firm has a profit of the form \( \pi_1 = r_1 - c_1 \), whereby the assumption \( c_1 \) is the same cost as \( c_1 \) used in (16). All the other firms have profits \( \pi_i = r_i - (r_{i+1} + c_i) \), where the revenue of the preceding firm turns up as a cost since the firm buys the output of the preceding firm. Once again, by the assumptions, \( c_i \) is exactly the same as \( c_i \) in (16). For all firms, \( c_i \) corresponds to the resource usage of firm \( i \). Now by summing the profits for all firms we obtain

\begin{equation}
\begin{align*}
\pi_1 &= r_1 - c_1 \\
\pi_2 &= r_2 - (r_1 + c_2) \\
&\vdots \\
\pi_{n-1} &= r_{n-1} - (r_{n-2} + c_{n-1}) \\
\pi_n &= r_n - (r_{n-1} + c_n) \\
\sum_{i=1}^{n} \pi_i &= r_n - \sum_{i=1}^{n} c_i
\end{align*}
\end{equation}

The transactions between firms \( (r_1, \ldots, r_{n-1}) \) cancel out, and the cost that affects the end consumer is \( \Delta c = \sum_{i=1}^{n} \Delta c_i \), as in equation (16) for the case when the whole sector consisted in one firm only. It also follows that the \( VTTV \) for an intervention is the same in both cases and can be obtained by adding the \( VTTV_i \)s, as in equation (19), for the individual nodes and links in the chain/sector, whether or not they correspond to different firms or are contained in one firm. This was illustrated for the case when the sector was structured as a simple chain. However, that the transactions between firms cancel out is true for more complex sector structures as well. For freight transport applications the natural sector is a supply chain and the conclusions are:

- \( VTTV \), at a node or a link for an intervention, should be estimated only on costs representing resource usage at the nodes or at the link (no transactions between
**Conclusions**

This case study was made with the purpose of validating the method and model for estimating VTTV that was developed in the main study, *Time Variability Method Development And Synthesis – WP 1 – Value Transfer And WP 4 – Decomposition Of VTTV*.

Using the input data and estimations made by the case company together with the assumptions given above, we arrive at a new estimated value of:

\[ 3.3 \text{ SEK/ton-hour} \]

This is the value given by equation (12) obtained by using the quadratic cost function.

Using valuations recommended by ASEK 5.2, the total VTTV including time-value for the goods and time-dependent operative costs is \( 10.3\text{-}12.4 \text{ SEK/ton-hour} \). The values include VAT and are at 2010 prices. Assumptions made:

- Each train carries on average 383 tons of goods (based on data and calculations for 2015)
- Delay time-value for foodstuff is 5.28 SEK/ton-hour (year 2010), according to ASEK 5.2 table 8.4
- Time-dependent operative costs can be calculated in two alternative ways:
  - either using values given per ton of goods transported using ASEK 5.2 table 14.4, for combi trains: 5.003 SEK/ton-hour (however, it seems that this valuation does not take the tara weight of the trailers into consideration),
  - or by using the parameters in ASEK 5.2 table 14.5 together with the recommended formula for SEK/train-minute. The choice for wagon types is either with two or four axles. However, the studied train has 18 wagons with 6 axles. Thus, we include the cost for 18 wagons with 2 axles and 18 wagons with 4 axles, giving a resulting cost of 45.5 SEK/train-minute.

In 2013, Krüger et al. performed VTTV calculations for the same case as in this study, but using a different approach. They concluded that the VTTV for precautionary costs (safety stock) for the specific case was 34 SEK per ton-hour and operative costs for delays were 69 SEK/per ton-hour, giving a resulting total value of \( 103 \text{ SEK/ton-hour} \) (they also suggest costs for cancellations, which are not included here).
The main purpose of this study was also as stated above to validate the method and model and not to produce a new estimate to be used for VTTV in the models.

The example given above of estimating VTTV will only include costs directly related to VTTV as given by equation (5). The estimated VTTV is only for one node in the supply chain, a warehouse. Following the conclusions from section “Costs to include in VTTV”, the VTTV given above for delay time-value and time-dependent operative costs, which corresponds to the railway transport to the warehouse, can be added to the VTTV for the warehouse node. However, VTTV for the warehouse node is given as hours measured by standard deviation while the other two VTTVs are measured in delay-hours. Hence, they do not have comparable units, and there is little relevance in adding them together.

The VTTV obtained by Krüger et al. may be added to the other VTTVs if it corresponds to costs generated in the shops and no costs generated in the warehouse or relating to the transports to the warehouse.

VTTV as given by equation (5) is strict in the sense that it only includes costs that are variable with respect to delivery times T. This follows immediately from the definition of VTTV as a partial derivative. However, when delays increase, there are other costs that will be transferred to the end consumer causing a welfare loss through an increase in prices of transported goods. One example would be if the firm needs to invest in a larger warehouse. Then the investment cost and the additional warehouse operating cost will result in a raise in the prices of the affected goods.

The framework for cost-benefit assessments currently used by the Swedish Transport Administration does not include changes in prices for transported goods. Hence, there may be a need for incorporating costs in the VTTV transferred through prices on transported goods. The example of inventory costs has been given above; there will also be some costs on the sales side that are candidates for inclusion in such an extended VTTV. One such example is costs related to cassation of goods.

References

Berglund, M. et al. (2016), A Method For Measuring And Valuing Transport Time Variability In Logistics And Cost Benefit Analysis, accepted WCTRS, Shanghai, China

Data input – Large Retail Company in Sweden, interviews and statistics


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