



Contents lists available at ScienceDirect

## Research in Transportation Economics

journal homepage: [www.elsevier.com/locate/retrec](http://www.elsevier.com/locate/retrec)

## A method for measuring and valuing transport time variability in logistics and cost benefit analysis

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### ARTICLE INFO

#### Article history:

Received 18 June 2016

Received in revised form

28 February 2017

Accepted 6 March 2017

Available online xxx

#### JEL codes:

L91 – Transportation: General

L92 – Railroads and Other Surface

Transportation

R41 – Transportation: Demand, Supply,

Congestion, Safety and Accidents

R42 – Government and Private Investment

Analysis

H54 – Infrastructures, Other Public

Investment and Capital Stock

#### Keywords:

Logistics

Freight

Transport

CBA

Value of transport time variability

Delay

Risk

Model

### ABSTRACT

The freight transport system is subject to delays and disturbances, which influence investment and planning decisions made by governments and infrastructure authorities. Traditionally relying on Cost Benefit Analysis (CBA) they are dependent on correct and up-to-date input data. So far, little success has been reached in estimating the effects of disturbances for freight.

This paper aims to contribute to the understanding of disturbances in freight transport by reviewing and classifying the effects occurring due to transport time variability (TTV) and to suggest a calculation model to estimate the value of transport time variability (VTTV). In order to validate the model and its usability it was successfully tested in a case study for a large Swedish retail company.

The effects of delays can be divided into four main types: System Killers, Catastrophic Events, Expected Risks, and Contingencies, of which the last two are relevant for VTTV. The model applies these in a two-step cost function with a fixed and variable part, building on previous studies of VTTV for passenger transport based on the scheduling utility approach. A main theoretical result is that the estimation of VTTV is derived mathematically independently of which measure that is chosen for the quantification of TTV.

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### 1. Introduction

Transport systems are constantly subjected to disturbances, whether they be traffic accidents, congestion, strikes, or some other

kind of disturbances. Increasing traffic flows have caused congestion and gridlocks to be a common sight on our highways, at the same time as our dependency on reliable transport has increased due to more advanced production set-ups with, for example, just-

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in-time manufacturing, and global supply chains expecting reliable transport systems. The risk of disturbances in the transport network can be defined as vulnerability in the transportation system that makes it susceptible to incidents that can result in considerable reductions in network serviceability (Berdica, 2002). Naturally, these disturbances have a negative impact on the transport system and, thus, on society as a whole. This calls for actions to be taken to reduce these negative effects, for example by investing in more reliable vehicles, building new roads, or increasing the maintenance in the rail network. This influences the investment and planning decisions made by governments and infrastructure authorities. These authorities traditionally rely on Cost Benefit Analysis (CBA) as an input to their decisions, which is based on economic calculations (Bristow & Nellthorp, 2000; Hayashi & Morisugi, 2000). Therefore, in order to competently consider disturbances in the CBA, it is necessary to be able to quantify and value the effects of the delay or disturbance.

CBA calculations are most predominantly made as the base for national infrastructure investments, where most countries require CBA analysis to be made before making any investments and applying different modelling systems as a part of the analysis (Daly, 2000). Reduced transport time variability (TTV) for transports are important, but often overlooked, components in CBA in the transport sector. Typically, the value of time is included, but the value of transport time variability (VTTV) is often not considered (Bristow & Nellthorp, 2000) or assumed to cost the same as the ordinary value of time. An important reason for this is most likely the lack of good cost estimates for delays. Largely, this is due to the complex and context dependent nature of disturbances and thereby obvious difficulties in estimating the effects. For example, the Swedish national transport planning assumes the cost of delay to be two times the cost of ordinary transport time, although there is no scientific foundation or explicit reasoning behind this (Trafikverket, 2012). The few estimates that have been made have reached very different values and are hard to compare (de Jong, 2000). Attempts to transfer cost estimates between different countries have failed due to the context dependent nature of the estimation (Krüger, Vierth, de Jong, Halse, & Killi, 2013). Previous studies have used four main approaches to measure TTV (standard deviation, spread, share of delayed shipments, and average delay) but without reaching a common conclusion on which method to use. Similarly, previous studies also differ in what to measure, as delivery time, transport time and travel time have been used. See section 5 for a review of previous studies.

There is a need to support decision makers with better estimates of TTV in the transport system in order for them to make better informed decision. In particular, this need is evident to support the national infrastructure planning. Previous modelling attempts also differ significantly in methodology, scope and results, indicating a need to review and expand on previous attempts. The aim of this study is to contribute to the understanding of disturbances in freight transport by reviewing and classifying the effects occurring due to transport time variability (TTV) and to suggest a calculation model to mathematically estimate the value of transport time variability (VTTV). This paper will not suggest any values for VTTV but will set the framework for such estimations.

By *measures for TTV*, we mean the unit used to quantify the *Transport Time Variability (TTV)*. Examples include the standard deviation of 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. Fig. 1 shows the necessary steps to make a CBA of an infrastructure investment (or achievements other than pure investments). While the estimation

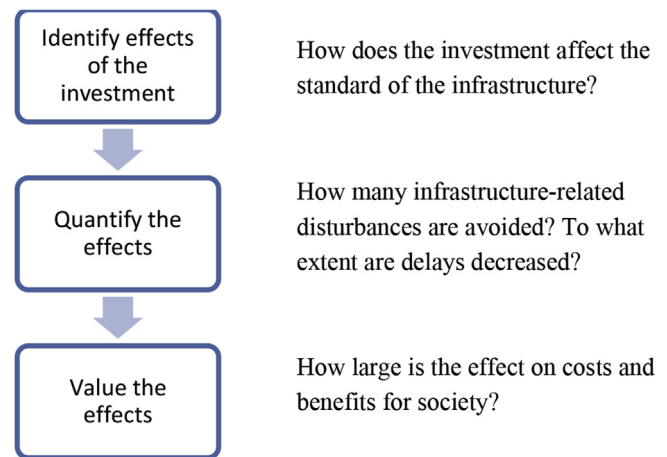


Fig. 1. Steps of CBA.

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.

The article starts with an investigation of the effects of delays and the general cost structure of delays. Effects of delays are analysed and mapped in an activity framework of Transport, Transshipment, Delivery, Use of Goods and Overall Chain Effects. Based on this mapping, four main types of disturbances are identified based on Magnitude and Frequency, followed by a suggestion on how these disturbances should be managed in a VTTV perspective. This is followed by a review on TTV in a CBA context. An extensive literature review has been performed on the existing methods to measure TTV and VTTV, which is detailed in Section 5. Except for identifying the measures used in the studies, any discussions in the studies on which measure to use have also been analysed. A method to mathematically estimate VTTV for freight is then proposed. The method extends previous studies on VTTV for passenger transport based on the scheduling utility approach and links to the previous defined framework of the four main types of disturbances. Finally, a case study is performed, estimating VTTV at a large Swedish retail company.

## 2. Effects of delays

Freight transport involves a multitude of shipments of different sizes, characteristics and requirements. It involves everything from a 5000-tonne slow-moving iron ore train to a 100-g 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 is just 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 one-hour late delivery of a single screw can cost millions, while in other cases, a one-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 Fig. 2.

Delays in transport affect all parts of the transport network. Direct effects can be seen in longer transport times, increasing operational costs of the transport (salary costs, vehicle costs, etc.).

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