TØI report 825/2006
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Oslo 2006, 91 pages Norwegian language

Summary:

Appraising policies to reduce freight transport time and its variability – a new method

This is the final report from the project ”Benefits to firms from quicker and more reliable freight transport”, which was carried out at the Institute of Transport Economics (TØI) under the Swedish Road Administration’s Research, Development and Demonstration Programme. The objective of the project was to contribute to more reliable unit values of time and reliability for use in economic analyses of freight transport.

Values of time and reliability

Our approach has been the following: We add realistic transport costs to a simple logistic cost minimisation problem with uncertain demand and lead time. For the distribution stages, or for the entire transport in case of door-to-door haulage by truck, there will in many instances be a choice of vehicle size. In these cases, the choice of shipment size and vehicle size will depend on each other and be made simultaneously. Thus we assume that the shipper chooses vehicle size, shipment size and reorder point to minimise the annual average logistics costs. Minken (2006) provides documentation of the model in English. Solving the model we derive value-of-time and reliability formulas by differentiating with respect to expected transport time and the standard deviation of transport time and dividing by the number of trips.

The value of time consists of three terms. The first term is the expected time-dependent transport costs, the second term is time-dependent loss of value and the cost of tying up capital in the mobile inventory, and the third term is the marginal increase in uncertainty costs when transport time increases by an hour. Uncertainty costs are the cost of the safety stock and stock-out costs.

The size of the third term of the value of time, and the size of the value of reliability, might be assessed by comparison with the second term of the value of time. Numerical examples suggest that the value of reducing the standard deviation of transport time by one hour might be around 1 to 8 times the cost of the mobile inventory. The relative size decreases with the value of the goods. Also, high relative values exist when lead time is very uncertain, low relative values when lead time is relatively certain but demand is uncertain. The numerical examples suggest that the addition to the value of time because of uncertainty is of moderate size – usually smaller than the time cost of the mobile inventory.

An example is shown in tables S1 and S2. Here, μ_D is expected hourly demand, σ_D is the standard deviation of hourly demand, μ_T is expected lead time and σ_T the standard deviation of lead time. Thus demand uncertainty increases towards the right in the tables, and lead time uncertainty increases as we move downwards in the tables. The example shows a flow of 1000 tonnes per year, transported over a distance of 300 kilometres in shipments of 32 tonnes. The inventory cost per tonne and year is NOK 10 000. The hourly cost of the mobile inventory is NOK 32.50.

Table S1. The value of reliability VOR (the value of reducing the standard deviation of transport time by one hour) divided by the hourly cost of mobile inventory. An example.

	$\sigma_D = 0.0\mu_D$	$\sigma_D = 0.5\mu_D$	$\sigma_D = 1.0\mu_D$	$\sigma_D = 2.0\mu_D$
$\sigma_T = 0.0\mu_T$	0	0	0	0
$\sigma_T = 0.33\mu_T$	4.19	3.81	3.12	2.14
$\sigma_T = 0.67\mu_T$	4.90	4.76	4.43	3.61
$\sigma_T = 1.0\mu_T$	5.30	5.23	5.05	4.49

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Table 2. The increase in the value of time due to uncertainty, divided by the hourly cost of mobile inventory. Same example as S1.

	$\sigma_D = 0.0\mu_D$	$\sigma_D = 0.5\mu_D$	$\sigma_D = 1.0\mu_D$	$\sigma_D = 2.0\mu_D$
$\sigma_T = 0.0\mu_T$	0	0.17	0.40	0.92
$\sigma_T = 0.33\mu_T$	0.02	0.11	0.33	0.85
$\sigma_T = 0.67\mu_T$	0.04	0.10	0.25	0.73
$\sigma_T = 1.0\mu_T$	0.05	0.10	0.22	0.63

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In the same example, table 3 shows how the optimal safety stock increases with uncertainty.

Table S3. The optimal safety stock in tonnes. Same example as in S1 and S2.

	$\sigma_D = 0.0\mu_D$	$\sigma_D = 0.5\mu_D$	$\sigma_D = 1.0\mu_D$	$\sigma_D = 2.0\mu_D$
$\sigma_T = 0.0\mu_T$	0	0.07	0.51	1.54
$\sigma_T = 0.33\mu_T$	0.46	0.57	0.87	2.25
$\sigma_T = 0.67\mu_T$	1.42	1.49	1.70	2.42
$\sigma_T = 1.0\mu_T$	2.53	2.58	2.74	3.32

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While the safety stock increases in both dimensions of uncertainty, the value of reliability is lower for high levels of demand uncertainty. This example is computed with software that is to be made available together with the report on the TØI homepage. The underlying model is documented in appendix 1 and 2.

In addition to the model with an inventory, we also treat the case where the commodity is only supplied after a customer has placed an order. In this case, there are no inventories and no stock-out costs. On the other hand, we assume that a delivery time has been set and that there is a penalty if it is not met. Also, setting a long delivery time will hurt sales. The resulting value of time has a third term as before, but it is more difficult to assess how large it is. The same goes for the value of reliability.

The impact of policies

There must be consistency between the valuation of impacts and the measurement of impacts. For instance, if reliability is measured by the standard deviation of transport time, unit values must have the same metric. To go with our unit values, we outline formulas for the expected transport time and its variance when there is risk of delays due to various forms of incidents. From these formulas the effect of main types of policies to improve reliability and speed can be judged.

Delays may be categorised as capacity related or demand related as shown in the figure.

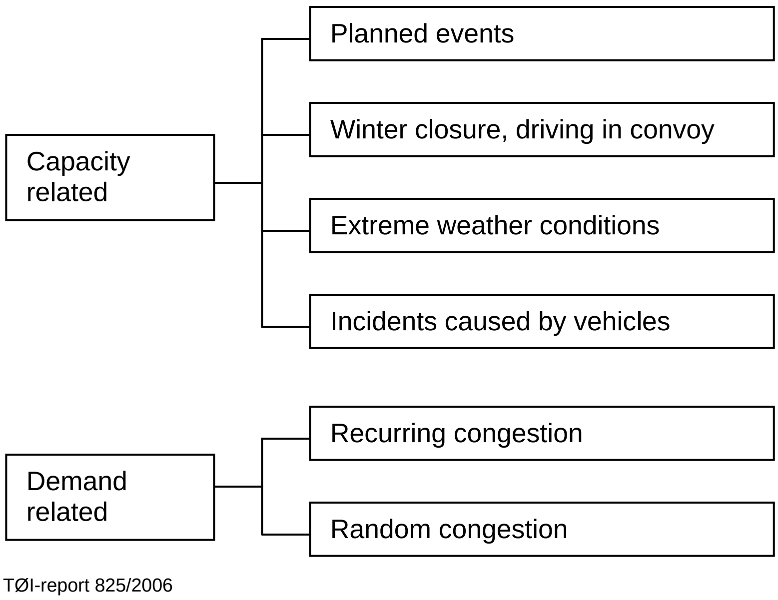

Figure 1: Categories of delay

To assess the impacts of policies in all these cases is a broad and complex task, and only the simplest cases are treated in this report. Primarily, we treat road transport along a highway where incidents of shorter duration may block the road or reduce capacity. Our model of expected transport time and transport time variance on such a road combines the impacts of incidences at certain points (as for instance accidents) and incidences that affect a stretch of the road (as snowfall, road work). In a numerical example we show how reducing the time to clear the road by 25 per cent may reduce expected delay per kilometre by 44 per cent and more than halve the variance of delays per kilometre. In another example a 50 per cent reduction in the probability of having to reduce speed from 80 to 60 kph (as for instance by better snow clearance) reduces expected delay on a 10 kilometre stretch by 3 per cent. Of course these are only illustrations.

We also survey methods of finding the mean and standard deviation in more complex vulnerable or degradable road networks and the extension to other modes and terminals. These subjects are only touched upon in the project.

Data requirements

Our methods require data that are not routinely collected or updated by transport authorities today. On the valuation side, this concerns data on commodity flows at the level of the firm. Surveys must be carried out to establish such data. With respect to the impacts of policies, our method requires detailed data on typical incidences leading to delays. We have outlined what the data requirement is, existing sources of data in Norway and Sweden, and ways to provide the missing data. If the authorities want to reduce uncertainty in transport and improve reliability in the future, it is necessary to improve data quality and accessibility. This is true regardless of the method one wants to apply to appraise policy measures in this field in the future.

In our view, the valuation method proposed here is more easily implemented than the impact model, which not only needs better data, but also validation and calibration. In short, we need more empirical knowledge about the uncertainty of freight transport time.