Summary:

The costs of freight train delays. Applying results from recent research

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The value of more reliable railway transport to freight customers can be assessed using unit values measuring the cost of the expected delay. In this report we review, compare and discuss the results of our two stated preference (SP) surveys among freight customers. We find that the results are both reasonable and highly consistent. We then explain how the values can be used to calculated the benefits of increased train reliability, considering both the application of our values in the statistical decision support tool developed in our research project and in traditional cost-benefit analysis of large infrastructure projects. We also discuss how the benefits of reliability related to lower transport costs should be included in the calculations, and review some recent international experience in this field.

There is wide agreement that the benefits of increased reliability should be included in cost benefits analyses of infrastructure projects along with the traditional calculations of the benefits of transport time savings. This is especially important in the PUSAM project, where we have developed a decision support tool aimed at promoting actions which can improve reliability in the short run, based on detailed statistics showing performance of the rail network. For moderate improvements, the impact on reliability can be much more important than the impact on scheduled transport time, since the timetable is often kept fixed in these cases. The discussions in this report are however also highly relevant for traditional cost benefit analysis (CBA) of large infrastructure projects.

The main focus of the report is the value of increased reliability for railway freight. We have previously conducted two stated preference (SP) surveys investigating the values of transport time savings and reliability for freight – one considering all modes of transport and one dedicated to rail only. The data can be analyzed using different models with different measures of reliability. In this report, we however mainly consider the use of average or ‘expected’ delay.

Although assuming that the disutility of delay is proportional to the length and probability of the delay might be very restrictive, this is a very convenient measure which makes the calculations relatively simple. We would however like to stress that ‘expected delay’ does not mean that the delay is known in advance or is always of a certain length. The cost of unreliability comes from the fact that delays are uncertain, and the problems this uncertainty causes for the users of the network.

International experience

The benefits of transport time savings, and also reliability, are often divided into two components:

1. Benefits related to lower transport costs due to more efficient use of rolling stock and personnel, less administration etc.
2. Benefits directly related to the cargo, i.e. the benefits to society from the fact that the goods spend less time in transport or arrive at time with higher certainty

A recent review by VTI in Sweden of the current practice of CBA in Sweden, the Netherlands, Germany and the United Kingdom shows that only in the former two is the second component included in the value of transport time savings. In the Netherlands, a large stated preference survey covering both components has recently been conducted, and the results will be available soon.

In the case of transport time savings, Inge Vierth at VTI suggests in her resent research to further view the cargo-related component (1.) above as consisting of (A) the benefits of the goods sooner being available for consumption or use in production (B) benefits related to buffer storage costs and the risk of running out of goods. In Norway and Sweden, one has calculated the first part (A) using the national freight models and so far ignored the latter part (B). The freight model typically yields very moderate values of transport time savings. In Sweden, the values used in CBA are however based on a calculation where some parameters are adjusted such that the values become higher.

In a study which was launched earlier this year, VTI together with TØI and Significance will study the value of reliability in railway freight from a buffer-stock perspective. The rationale behind is that the more uncertain delivery time is, the higher buffer stocks firms need to have to ensure a certain level of service. Comparing the results from using this approach and data from the Swedish freight model, the results of case studies and the Norwegian and Dutch SP results, we will be able to say more about how large the economic benefits or reliability in railway freight.

Norwegian stated preference (SP) studies

In Table 1, we show the values derived from the results of the SP study conducted among railway freight customers in the PUSAM project. The sample interviewed in this study consisted mainly of forwarding agents operating on behalf of the owners of the goods, except for a few firms which ship their own goods and have direct contracts with the train operator CargoNet. We assume that the forwarding agents take into account the preferences of their customers and have no direct interest in the cargo themselves. The choice experiments in the survey were related only to the railway part of the transport chain.

The values are considerably higher than those which have previously been used in Norway and which are taken from the Norwegian freight model. We believe this could be due to the fact that the freight model only takes into account the cost of the unproductive time goods spend in transport, and not costs related to buffer stocks and other effects on the internal logistics of firms.

Table 1. Values of transport time savings (VTTS) and reliability from the stated preference study in PUSAM, NOK per hour and NOK per hour per tonne.

Unit value	Consolidated goods	Non-consolidated	All goods
Value of transport time savings per shipment (NOK/hour)	404	113	192
Value of transport time savings per tonne (NOK/hour)	47	7	13
Value of expected delay per shipment (NOK/hour)	2545	764	1245
Value expected delay per tonne (NOK/hour)	278	35	72

In Table 2 we show the results of some new analyses conducted on the data from our previous SP survey in the GUNVOR project, covering both road and rail transport. The analyses differ from the earlier analyses of this data in three respects:

- Random error terms are assumed to enter multiplicatively in the model, resulting in remarkably higher model fit for most estimations
- Values of transport time savings and reliability are measured per tonne per hour in order to make results comparable to those from PUSAM (since the definition of a shipment is not the same)
- Lexicographic choice behaviour is taken into account[1] using self-reported behavior and not observed behavior. This is also in order to make the results of the two studies more comparable.

We emphasize that the results are not fully comparable, because transport time and reliability in the GUNVOR study was defined at the destination, not on the railway link as in the PUSAM project.

[1] The approach involves eliminating attributes (e.g. transport time) which the respondent did not consider. For the third choice experiment (CE3), we were unable to do this because the multiplicative model specification would then not work with this experiment design. The results shown for CE3 are hence without any attribute elimination.

Table 2. Values of transport time savings (VTTS) and reliability from the stated preference study in GUNVOR, NOK per hour per tone and 95 percent confidence interval

Experiment		GUNVOR study, road transport	GUNVOR study, rail transport
Time savings experiment	VTTS (confidence interval)	11,9 (9-15)	26,7 (10-43)
	Adj. rho-squared	0,302	0,295
	Respondents	384	42
Variability experiment	Value of mean transport time (confidence interval)	14,1 (10-19)	23,9 (10-38)
	Value of standard deviation (confidence interval)	18,0 (9-27)	43,6 (16-71)
	Adj. rho-squared	0,240	0,355
	Respondents	335	38
Expected delay experiment	Value of expected delay (confidence interval)	49,7 (1-98)	89,4 (22-157)
	Adj. rho-squared	0,032	0,161
	Respondents	319	35

In Table 3, we show the main results from both studies. Here, VTTV denotes the values of a unit reduction in the standard deviation. The ‘reliability ratio’ is the ratio between the value of reducing variability and mean transport time from the second choice experiment. Since we were unable to retrieve any valuation of variability from this experiment in PUSAM, the cells in these two columns are left blank. We see that the unit values are in the same order of magnitude, something which strengthens our trust in the results.

Table 3. Summary of results from SP studies in GUNVOR and PUSAM, NOK per ton-hour

Sample	VTTS	VTTV	’Reliability ratio’	Value of delay
Road, GUNVOR	12	18	1.3	50
Rail, GUNVOR	27	44	1.8	89
Rail general, PUSAM	47	--	--	278
Rail pallet, PUSAM	7	--	--	35
Rail all (weighted), PUSAM	13	--	--	72

Application and potential weaknesses

Applying the values in a calculation of socioeconomic costs of changes in reliability is computationally relatively simple. For this, one needs

- The impact of the change on expected delay per train to the terminals
- The total amount of goods of each type (consolidated and non-consolidated) delivered to each terminal in the period considered

Multiplying the unit values in Table 1 by the amount of goods and the change in expected delay, we get the change in economic benefits related to the cargo.

As mentioned, the assumption that the economic costs of delays are linear in the expected delay could be too restrictive. In our survey we asked the respondents how long a delay needs to be in order to have consequences for the delivery of the goods. The distributions of such critical delay limits is shown on Figure 1. We see that most firms are suffer consequences when delays exceed a couple of hours, but for some firms delays need to be much longer to involve any costs.

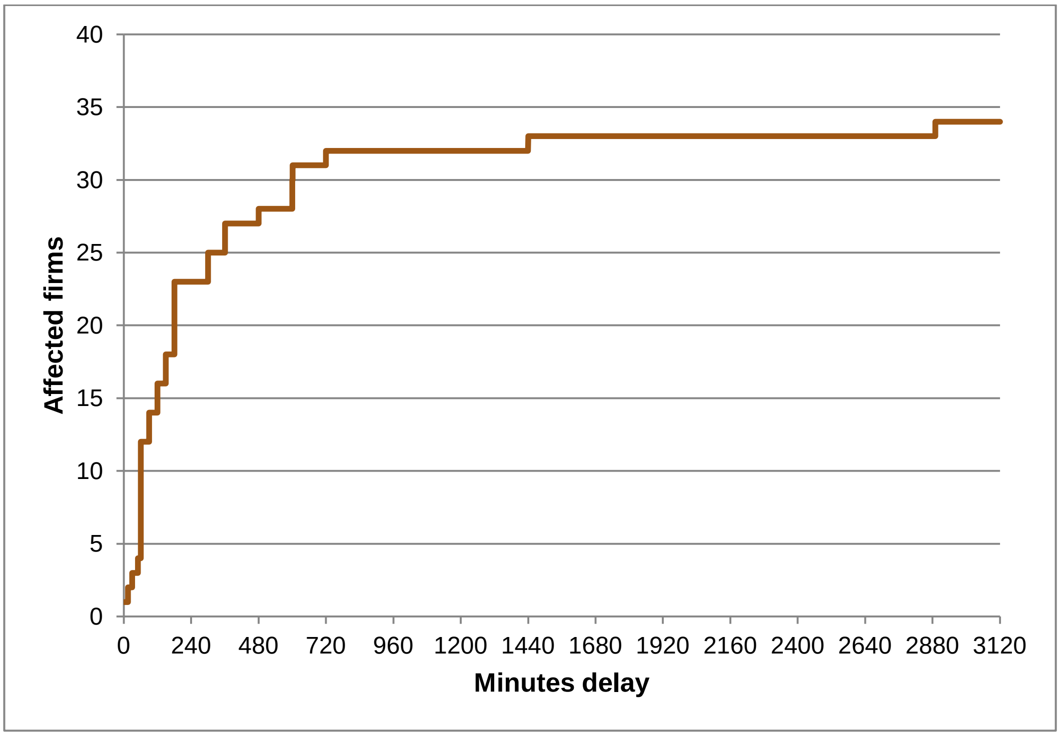

Figure 1. The critical limits of delay length reported by the firms in our sample

According to theoretical intuition, once the critical delay limit is passed, the affected firms (the forwarding agents and their customers) will need to do some rescheduling. The costs will hence not necessarily keep increasing in the length of the delay above this limit. Hence the costs of delay for an individual railway customer would be something like a stepwise function, while the cost for the entire population of customers will appear as an increasing function which is more smooth, and presumably concave.

In the results reported earlier from the two SP studies, we find clear indications that the (relative) willingness to pay to avoid delays does indeed decrease with the length of the delay. We would however not feel very confident in trying to account for this in valuation using our results, since both the functional relationship and the parameters would be very uncertain. Instead we recommend that when using our results to value changes in expected delay, one should consider whether the length of the delays in the railway system where the values are to be applied are comparable to those in the study. In our SP study on rail delays, delays of more than 4 hours make up for about a quarter of the choice situations, and very few delays are shorter than 30 minutes.

Another issue is the fact that the cost of very short delays is hard to assess because the operator and the customers have adjusted such that there is some slack in the planned time of delivery. This slack is not without costs, but we would recommend to use caution in applying our results to estimate the benefits of higher reliability if this mainly involve reducing delays which are only of a very moderate length in the first place.

On Figure 2 we show the distribution of actual arrival times of freight trains coming to Trondheim station in January 2012. We see that among those trains that would be considered as delayed by normal standards (more than 5-10 minutes delay), moderate delays of less than one hour make up for a large part, but there is also a considerable share of trains which are much more delayed.

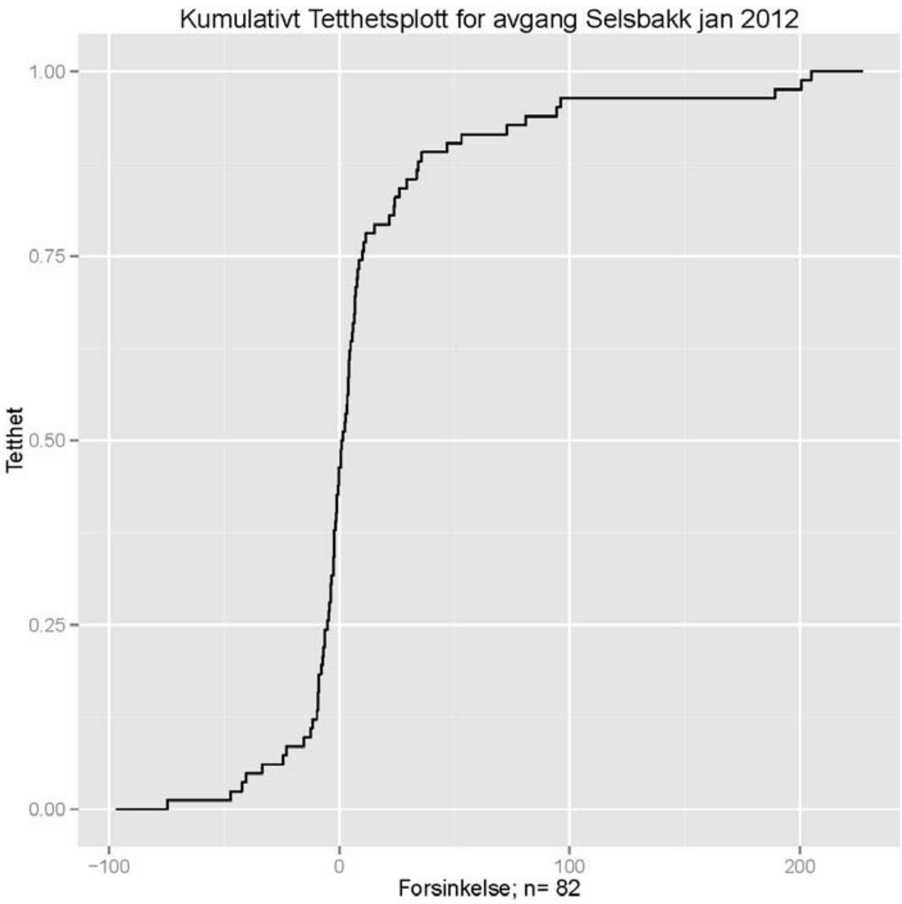

Figure 2. Cumulative density (‘tetthet’) of arrival times to Trondheim station in January 2012. Minutes delayed (‘forsinkelse’).

Benefits of reliability related to lower transport costs

The major part of this report concerns the value of reliability related to delivery of the cargo. Reduced uncertainty does however also imply that the rail operators can reduce some costs, yielding lower transport costs which result in either lower fares or higher profits (or both).

It would be convenient if these benefits could also be measured in terms of some reliability unit, for instance the expected delay per train. For some type of costs, this seems reasonable. There are however some costly precautionary measures which the operators undertake in order to achieve a certain level of reliability which could have been reduced had the infrastructure been more reliable. The costs of these measures are difficult to relate to the observed unreliability, since the former could increase while the latter decreases, and vice versa.

We have identified four cost components for which the rail operator has some cost estimates:

1) Costs of personnel, especially locomotive drivers
2) Costs of replacement transport
3) Costs of administration
4) Costs of backup rolling stock

The costs in items (1)-(3) can relatively easily be related to the amount of delays. Item (4) is on the one hand an example of costs which the operator pays to ensure a certain level of reliability. On the other hand, the need for backup rolling stock is also related to the observed reliability. It is however not very clear at what levels of reliability this cost can be reduced.

Recommendation and further research

As seen earlier, many of the delays identified in actual data are relatively short, around 5-10 minutes. As our SP-study mostly involves hypothetical situations with much longer delays, we would not be very confident in applying the results to a situation where a large share of the delays are this short. It also seems like the forwarding agents and their customers have adapted to the uncertainty by having some slack in their schedules, implying that avoiding very small delays give little direct benefits in the short run. This slack is however not without cost, and we recommend developing methods for assessment which also includes the benefits of avoiding small delays and reducing slack.

Another important issue when measuring railway performance is that a change in for instance variability or delay at an individual railway link might not result in a very easily identifiable change in performance measured at the destination. It is hence important to investigate how one could estimate changes at the network level by aggregating changes at the link level. This could also give us a measure of changes in slack in the timetable: If an improvement in for instance mean driving time at a link does not give an equivalent improvement in transport time and delays at the destination, this should imply that the amount of slack has increased.

Within the field of valuing reliability in transportation economically, we think that the most important research topic in Norway is to develop ways to predict changes in reliability after some action is taken. For railways, the questions related to aggregating link-level reliability and measuring slack are highly relevant for this. One should also look at how changes in reliability affects demand for transportation services, and compare different measures of reliability and how the choice of measure affects the results of the calculations.