THE VALUE OF RELIABILITY

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1. INTRODUCTION

Changes in the reliability of travel time are not incorporated in standard appraisals of infrastructure projects and transport policies in The Netherlands or in other countries. Nevertheless, many transport projects and policies will affect not only the average travel time, but also its spread. There are some indications that travellers, shippers and carriers have substantial valuations for an increase in reliability of transport time.

In a project for AVV-Transport Research Centre (Dutch Ministry of Transport, Public Works and Water Management), carried out by RAND *Europe,* the national and international literature on reliability of travel times and on other aspects of quality in passenger and freight transport have been investigated to answer the following questions:
- Which definitions have been used?
- Which aspects have been studied?
- Which monetary values have been obtained?
- Which methods were used for this?
- Can these values be applied in cost-benefit analysis in The Netherlands?
- Which lessons can be learnt for including reliability and other quality aspects in transport models?

In total, 40 reports and articles were studied and summarised in this review. After that, the results were integrated to answer the above questions. In this paper we will present the most interesting results of the literature review and address the questions mentioned above.

Studies have been carried out in several countries that yield values in money units or time units for the reliability of travel times for specific cases. No generally accepted monetary values for reliability and other aspects of quality were found that are used in official national cost-benefit analyses. But the possibilities of establishing such values are being investigated in some

countries (besides in the Netherlands also in the United Kingdom and Sweden). A committee for the UK Department for Transport (SACTRA, 1999), came to the conclusion that by ignoring travel time variability the economic benefits of trunk road schemes were underestimated by 5-50%. This concerns the change caused by some transport project to the product of the amount of unreliability and the value of unreliability.

In contrast to previous reviews on reliability, that give an excellent insight in the theoretical and empirical (especially presentational) issues involved, the emphasis of this paper is on the outcomes of the literature on the value of reliability, both in passenger and freight transport. Bates et al. (2001) focus on the link with scheduling theory, data collection issues and one particular application. Noland and Polak (2002) also provide empirical estimates for the value of reliability from several studies, but practically all the values presented in the current paper have not been included in Noland and Polak (2002).

The policy background for this study is presented in chapter 2. Outcomes for passenger transport are summarised in section 3 of this paper, and values in freight transport are presented in section 4. Conclusions and recommendations can be found in section 5.

2. THE POLICY BACKGROUND

In the year 2000 the Dutch guideline on cost-benefit analysis (CBA) for infrastructure projects (the so called "OEI-guideline") was published (CPB and NEI, 2000). This is the Dutch standard appraisal method for transport projects. According to this method, a CBA must be carried out for large governmental infrastructure projects. The CBA serves as a framework for a transparent description of the economic and social effects of the project. In the CBA all effects of an investment project are systematically evaluated and, when possible, given a monetary value. The result is a profitability analysis. CBA information is useful in almost every stage of policy preparation to facilitate decision-making.

The OEI-guideline was evaluated in 2002. In sum, it was seen to function well but it appeared that some aspects of the method needed further elaboration. Therefore, the Dutch Ministry of Transport, Public Works and Water Management together with the Dutch Ministry of Economic Affairs, started a research program. The results will be published in the form of appendices to the OEI-guideline. An important issue that will be discussed in these appendices is the monetary value of reliability of travel times. Benefits from improved reliability are not included in the current standard Dutch CBA-framework for appraisal of infrastructure projects.

In other words, the current Values of Time (VoT) of the OEI-guideline are only related to reductions in the average travel time. The average travel time includes expected delays. Unexpected delays however, appear much less systematic and lead to variation in travel times. Unexpected delays may be caused by congestion and other factors such as bad weather, accidents, car break-downs or unreliability of public transport modes. We can distinguish two

forms of unexpected delays (Ritsema van Eck et al., 2004). On the one hand the random day-to-day variability that could affect the travel time for journeys undertaken at the same time each day. On the other hand the occasional catastrophic delays as a result of incidents. Thus, in contemplating a journey, the driver has not just to consider the expected average travel time but also its variability, which we can quantify by the standard deviation of the travel time distribution. If the driver wants to reduce the risk of being late at his destination, he will need to allow rather more time than the mean travel time. Monetary values for reliability of travel times relate to reductions in unexpected delays. Time variability must also be considered to influence the VoT.

With respect to reliability, most attention is typically given to arriving too late. However, arriving too early also generates costs, for example: waiting at the destination for your appointment. Unexpected delays in passenger transport generate costs because of: prolonged waiting times, stress among travellers, connections missed, appointments missed, negative effects on business efficiency. In order to reduce the probability of arriving late passengers allow extra time for the journey (the so called safety margin). Unexpected delays in freight transport may lead to: missed connections, waiting periods, missed opportunities for applying JiT (Just-in-Time) to physical distribution, production, and the management of stocks.

As mentioned above, the current VoT's of the OEI-guideline are only related to reductions in the average travel time. However, in the near future many Dutch infrastructure projects will focus explicitly on reliability of travel times. Then, the benefits are not only related to reductions in the average travel time, but also to increased travel time reliability. Currently it is expected that benefits of improved reliability will be of substantial importance in comparison to benefits of reductions of the average travel time. Therefore it is important to find monetary values for reliability of travel times that can be used in CBA's according to the OEI-guideline.

3. VALUES FOR PASSENGER TRANSPORT

In the literature review we focussed on the recent literature (no more than 5-10 years old). In Table 1 of the annex we have listed the values found for reliability of travel time in passenger transport, as well as the methods used and other lessons for research on the valuation of reliability. The overview of quantitative outcomes for the value of reliability of travel time in passenger transport shows that three different methods have been applied to get such values:
   1. **The mean versus variance approach.** Unreliability is measured as the standard deviation (or variance) of the travel time distribution. Data for the valuation of the standard deviation can be obtained by including in a stated preference (SP) survey both a representation of the variance and the mean travel time as attributes.
   2. **Percentiles of the travel time distribution.** Unreliability is measured as the difference between the 80th or 90th percentile of the travel time

distribution and the mean. Again the valuation can be derived from SP experiments among travellers.

3. **Scheduling models.** Unreliability is measured as the number of minutes that one will depart or arrive earlier or later than preferred (schedule delay). This can also be offered as an attribute in an SP experiment, together with other attributes such as journey duration and travel cost.

These three methods are discussed in more detail below.

The mean versus variance approach
A utility function is specified that includes the mean journey duration as well as the variance (or the standard deviation) of the journey duration. Parameters for both variables are estimated, usually on stated preference (SP) data. In the SP interviews respondents are not shown the variance of travel time as such, because this is recognised as too difficult a concept for a large number of respondents. Instead, each choice alternative contains as attribute, besides average travel time and maybe travel costs, a set of 5-15 possible journey durations (sometimes presented graphically). The researcher can calculate the variance that is consistent with each set (or more likely the other way around: generate a set of journey durations that matches a target variance). Average journey time and the variation in travel time presented in the SP can be constructed such that between observations they are not or only lightly correlated. Because both attributes are presented to the respondents in the SP and vary more or less independently, no double-counting will occur when in a cost-benefit analysis one would include travel time and reliability gains, with values for both coming from the SP survey.

From the estimated model, the ratio of the coefficient for the standard deviation to the coefficient for the mean travel time can be calculated. This gives the disutility of a minute standard deviation of travel time in terms of minutes of mean travel time. A monetary value for unreliability can be derived by combining this with a value of travel time (or directly if travel cost is also in the utility function). For the application of these outcomes in practical cost-benefit analyses of transport projects it is necessary that not only the change that the project causes in expected (mean) travel times is predicted, but also the change in the standard deviation of travel time.

Copley et al. (2002) carried out a stated preference survey among commuters in Manchester, who used the car as solo-drivers on the journey to work. They obtained 167 usable interviews. Among the attributes presented for each alternative were a set of travel times (in a bar chart) and average travel time. These data were used to estimate discrete choice models. The results imply that a minute standard deviation of travel time is valued 1.3 times as much as a minute of travel time itself (the authors call the 1.3 the 'reliability ratio'). They did not explicitly distinguish between expected and unexpected congestion. Inasmuch as there is regular congestion for the trips surveyed, congestion will lead to an average travel time that will exceed the free-flow travel time. According to our interpretation, the average expected congestion is already accounted for in the average travel time, and the variation around this is the

result of unexpected congestion and of daily variation in the expected congestion. Therefore, the factor 1 applies to the mean travel time, including the expected regular congestion and the factor 1.3 applies to the standard deviation for the variation around this. Copley et al. (2002) also estimated a scheduling model on data from the same commuters, which gave very different results (see below).

Senna (1991) derived a model with a mean and a variance of travel time explicitly from utility theory, and arrived at a non-linear utility function. However, in practice, linear approximations are most popular. He also did a SP survey (in Porto Alegre, Brasil), and found that the standard deviation was considerably more important (per minute) that average travel time (also per minute).

In an SP survey among bus users in France, MVA (2000) found that the importance of one minute of standard deviation of travel time was only a quarter of the value of a minute of travel time (more specific: in-vehicle time).

Other researchers have found a slightly different solution for the problem that the concepts of variance and standard deviation are not well understood by travellers. The frequency, probability or change of delay have been presented to respondents in SP surveys with some success. As such, these attributes only measure the frequency of the delays (shorter than average journey durations are not included here). The size of the delay is left open in the SP or the attribute included in the SP measures the probability of delay of a certain size. Delay here means a longer than expected travel duration, which is not the same as arriving too late. Travellers may be experiencing a considerably longer than expected travel time and still arrive on time (e.g. because they are applying a safety margin; this of course has a disutility too, that is studied in the scheduling approach).

On the basis of extensive SP research, models for the value of time on UK roads have been estimated (Accent and HCG, 1995). Some of these models include variables for unreliabiliy. Doubling the observed chance of an unexpected delay turns out to be as bad as 13 minutes extra travel time (commuting) or 20 minutes extra travel time (business and other travel). Halving this chance is equivalent to a three minutes reduction in travel time (commuting) or five minutes less travel time (business and other travel). So there are important asymmetries in the value of reliability. These values are not used in actual CBA's.

Rietveld et al. (2001) found in an SP survey among public transport users in The Netherlands that a 50% reduction in the probability of a delay of two minutes is just as bad as 32 Eurocents extra travel time. They also found a value of time of 13 Eurocents per minute. Therefore one 'uncertainty minute' (travelling one minute longer than expected) is equivalent to 2.4 minutes travel time. This implies that the public transport travellers are risk-averse; if they had been risk-neutral, an uncertainty minute would be equivalent to a minute travel time.

Percentiles
This method is closely related to the mean versus variance approach. Unreliability is measured and valued as the 90th percentile of the travel time distribution minus the median (or the 80th percentile minus the median). The left-hand side of the travel time density (shorter than average travel times) is not used, this is regarded as being of little value to the travellers. The 80th or 90th percentile indicates a considerable delay, but the most extreme journey durations are not considered, these are seen as outliers. To obtain a value for unreliability measured like this, models need to be estimated on SP, RP (revealed preference) or combined SP/RP data, in which travel time and the measure of unreliability are separate variables. Again, use of both values in a cost-benefit analysis will not imply double-counting.

Brownstone and Small (2002) provide a review of a number of studies on road pricing in California. One of these is Lam and Small (2001). Lam and Small used RP data (travel time measurements) from studies into the route choice for the State Route 91 (SR 91). Here, car drivers can choose between toll lanes and free, but often congested lanes. On the basis of the RP alone, the values for unreliability, measured as the 90th percentile minus the 50th percentile is 11-14 Euro/hour for males and 28-30 Euro/hour for females. Females have a considerably higher value of reliability, presumably because of stricter time constraint. This operational definition of reliability does not differentiate between expected and unexpected congestion; both forms of variation can influence the degree of unreliability, but the average amount of congestion will be reflected in the median. According to our interpretation, the value of time should be applied to travel time, including the expected congestion, and the value for reliability should be applied to the variation in travel time due to unexpected congestion. Small, Winston and Yan (2002) also use RP data from the SR 91, but in conjunction with SP data. The SP/RP value of unreliability is 26 Euro/hour (males and females). Here, unreliability was measured as the difference between the 80th and the 50th percentile. It can be questioned whether the RP or SP/RP values will be representative for California as a whole. Many travellers in the SR 91 corridor (Orange County) are quite affluent. The values are certainly not representative for the USA as a whole.

Scheduling models
In scheduling models, unreliability is measured as the number of minutes that one will depart or arrive earlier or later than preferred (schedule delay). This can also be offered as an attribute in a SP experiment, together with other attributes such as journey duration and travel cost. These models are based on work by Vickrey (1969) and Small (1982). The monetary values obtained for being early or late are very difficult to implement in a standard cost-benefit framework, because the link to travel time period choice is not made in the cost-benefit analysis (there is no reference to clock time, only to journey durations), and the preferred arrival times are unknown. Scheduling delay values can only be incorporated into a CBA if this could use time period choice outcomes from a transport model, instead of only investigating the travel time gain for existing travellers for some mode and the new travellers (in most models this only refers to modal substitution) aggregated over all

periods. A logsum approach would be suitable for including reductions in scheduling delays (e.g. Koopmans and Kroes, 2003).

Copley et al. (2002) also included arrival time information in their SP, and estimated scheduling models on the SP data. These models indicated that the disutility from a minute early or late was less than from a minute travel time. This outcome is at odds with the outcome of the mean versus variance model on the same SP data (a reliability ratio of 1.3). The authors therefore recommend further research into this matter. The reliability ratio of 1.3 and the scheduling results are not used in project appraisals in the UK.

De Jong et al. (2003) is a SP-based study on the choice of departure time and travel mode in passenger transport in The Netherlands. The sample includes almost 1,000 car and train users, travelling in the extended peak periods. It is therefore not representative for an entire day. The data were used to estimate scheduling models. One of the outcomes was that for all travel purposes, except education, the value of being one minute late or early usually was between one and 1.5 times as high as the value of one minute travel time. The SP experiment was only about reactions to the amount of anticipated congestion (the arrival time shifts are equivalent to the departure time shifts); unexpected congestion is not taken into account. The theory of scheduling models however also allows for the inclusion of unanticipated congestion (Bates et al., 2001).

4. VALUES FOR FREIGHT TRANSPORT

The values for the transport time reliability in the movement of goods found in the international literature are in Table 2 of the Annex. This table also contains information on the methods used to derive the reliability values and on other lessons for research on valuing reliability.

All freight transport studies found 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), just as in passenger transport. Most studies use the probability of delay or the percentage not on time instead. This was for instance done in RAND Europe et al., (2004), a study that provides values for reliability of transport time for road, rail, inland waterways and maritime transport (also described in another paper for the ETC 2004: De Jong et al., 2004). The percentage not on time (and the probability of delay in some studies) is defined in a different way than delay in passenger transport, where it referred to longer than expected journey durations. In freight transport, the probability of delay is often measured as the probability of not arriving at the specified time or within the specified time interval. This could also include being too early, which leads to extra costs at the destination. Therefore, the outcomes are related to those of the scheduling approach. This also means that these outcomes are more difficult to apply in a CBA-framework, since in project appraisal no reference is made to the specified arrival time or time interval. What is needed here is to estimate the impact of the transport project on the probability of reaching the agreements made in terms of delivery time. An

explicit application of the scheduling approach to freight transport has also been undertaken (Small, et al., 1999) yielding remarkably high values of reliability in road transport in the USA, and by Fowkes et al. (2001). The values for reliability in freight transport from the different studies are difficult to compare, because of the differences in the measurement units,

5. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The international literature on reliability of travel times (and on other aspects of quality) in passenger and freight transport has been investigated to find out which monetary values have been obtained, which methods have been used for this, and whether these values are transferable to other regions.

No generally accepted monetary values for reliability and other aspects of quality were found that are used in official national cost-benefit analyses. But the possibilities of doing this are now being investigated in some countries (besides in the Netherlands also in the United Kingdom and Sweden), and studies have been carried out in several countries that yield values in money units or time units for the reliability of travel times for specific cases.

For the definitions as well as for the money values for reliability, three operational definitions were found:
- Unreliability measured as the standard deviation (or variance) of the travel time distribution. Data for the valuation of the standard deviation can be obtained by including in a stated preference (SP) survey both a representation of the variance and the mean travel time as attributes.

- Unreliability measured as the difference between the 80th or 90th percentile of the travel time distribution and the mean. Again the valuation can be derived from SP experiments among travellers.

- Unreliability measured as the number of minutes that one will depart or arrive earlier or later than preferred (schedule delay). This can also be offered as an attribute in an SP experiment, together with other attributes such as journey duration and travel cost.

The monetary values following the third definition are very difficult to implement in the present cost-benefit framework, because the link to travel time period choice is not made in the cost-benefit analysis. In the current Dutch guideline on cost-benefit analysis (CBA) for infrastructure projects (OEI-guideline), there is more scope for applying the first two definitions, but money values that can be regarded as representative for a specific country, especially for car traffic, are lacking. The money values in the present literature come from very specific investigations and are not even used in cost-benefit analyses in the respective countries of origin. All the studies on the value of reliability that were reviewed agree that reliability is a factor **of substantial importance**: there were no studies that concluded that this factor can be neglected.

The reliability of travel time in public transport has been studied in various countries, using stated preference methodologies. In some studies attributes on the probability of delay (of a certain size) are included, together with travel time and costs. In other surveys, each choice alternative contains a range of possible journey durations (possibly represented graphically), as well as average journey time and costs.

For all three valuation methods applied in passenger transport and in freight transport, the use of SP data (or SP/RP) is a logical choice. This is also recommended in Bates et al. (2001) and in Noland and Polak (2002). The estimation of a model that includes a reliability variable on RP data is only possible in exceptional circumstances. In RP data (e.g. for different time-of-day periods or days), reliability, travel time and costs will often be heavily correlated, what hampers the estimation of significant separate parameter values. Furthermore, for these variables, values for the non-chosen alternatives are required, which need to come for instance from assignments. Here too it will be difficult to obtain sufficient variation in the variables of interest. In SP surveys, the researcher can exert control over these attributes, for all choice alternatives, and over their correlation. An exception to the rule, where RP data have been used successfully, was for the choice between a (variably) tolled and an untolled congested route (SR 91 in California).

In principle it would be possible to calculate the costs of transport, distribution and production and on the basis of ad hoc assumptions on the correspondence between cost items and the degree of unreliability, to determine the cost of unreliability. The method (the 'factor cost' method), that uses SP nor RP models, might be applicable for freight transport, but for commuting or business trips one might also try to determine the production cost of delays like this. The main problem with this approach is that the empirical basis is lacking for making plausible assumptions on which cost items (and to which degree) are caused by unreliability.

For freight transport, the value of time study that RAND *Europe* has carried out in 2003/2004 for AVV- Transport Research Centre can offer monetary values for unreliability and some other aspects of quality (frequency, probability of damage) in goods transport by road, rail, inland waterways, sea and air. Results are also available from some other studies.

Existing transport models, such as the National Model System LMS in The Netherlands, do not include explicit variables for reliability and other aspects of quality. But these variables could have influenced the choices of the decision-makers that the models seek to explain. The influence of these attributes will probably be absorbed in the mode-specific constants in mode choice models (but possibly also in coefficients for travel time and costs, if there is correlation with these variables). Simulations of the effects of changes in quality can be carried out by determining the effect of an equivalent change in travel time or costs (on the basis of SP outcomes). Alternatively, the mode-specific constants can be adjusted.

In sum, no generally accepted monetary values for reliability of travel times in passenger transport have been found that can be used in CBAs according to OEI-guideline. Therefore a research agenda has been developed to address the omission. In the second half of 2004, an expert meeting will be organized on this issue by AVV-Transport Research Centre in cooperation with RAND *Europe.* The goals of the expert meeting are the following:

- To validate the values for reliability of travel times in freight transport based on the value of time study that RAND *Europe* carried out in 2003/2004 for AVV-Transport Research Centre.
- To estimate **temporary** values for reliability of travel times for car drivers in The Netherlands.
- To discuss further research needed to find monetary values for reliability that can be regarded as representative for passenger and freight transport in The Netherlands.

To get representative values of reliability, that can be used in cost-benefit analyses of transport projects, we recommend to set up nationally representative SP surveys among car drivers, public transport users, carriers and shippers with choice alternatives described in terms of the following attributes:

- a series of possible trip durations (could also include arrival times), possibly represented graphically; this is a measure of the degree of uncertainty in travel times, which respondents find easier to understand that the variance or standard deviation (the researcher can calculate these for each choice alternative);
- a mean trip duration;
- travel costs.

The outcomes of these interviews then can be used to calculate the value of unreliability, both measured as the standard deviation and as percentiles of travel time.

Finally an issue concerning the use of the value of reliability. In order to appraise the reliability effects of infrastructure projects in CBA's further work is also needed on the traffic forecasting tools. These need to be improved, so that they are able to provide estimates of the standard deviations or percentiles of travel times on links. Current models typically don't have this capability. A first pragmatic attempt to develop such a tool in connection to the Dutch National Model system is currently underway in the Netherlands, but it is anticipated that significant further work will be required here.

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ANNEX. OVERVIEW OF QUANTITATIVE OUTCOMES OF THE LITERATURE REVIEW ON TRANSPORT TIME RELIABILITY

Table 1. Value of reliability (in travel time or Euros of 2003) in passenger transport: quantitative outcomes, methods used and other lessons.

Study	Quantitative outcomes (+definition)	Method	Other lessons
Accent and HCG, 1995	Doubling the chance of delay is equivalent to 13 min. travel time (commuting) or 20 min. (business and other travel); halving the chance of delay: 3 min. (commuting) or 5 min. (business and other travel).	Stated preference (SP) in road transport in the UK, with the following attributes: travel time, provision of information and chance of delay.	For some segments (e.g. business travel, time gains) the value of travel time per minute is higher in congested than in uncongested conditions.
AVV, 2003	Reliability (operating on time) is the most important aspect (importance of 3.58 on a scale from 1 to 5, with 5 being best) for bus, tram and metro, and the actual reliability performance is regarded as mediocre (5.94 on a scale from 1-10, with 10 being best).	SP among 3,387 users of bus, tram and metro in The Netherlands.	
Bates et al., 2001			Underlying theory and recommen-dations for empirical research: scheduling model and SP data.
Bell, 2000			Underlying theory: game theory.
Bonsall, 2003			Underlying theory: prospect theory; Methods: mean versus variance approach, restricted choice set.
Brownstone and Small, 2002	Value for 90th minus 50th percentile of the transport time distribution: 11-14 Euro/hr (males) and 28-30 Euro/hr (females).	RP: travel time measurements on State Route 91 in California, with variable tolls.	Method: can be done with RP data (in special cases such as this), use of percentiles.

Study	Quantitative outcomes (+definition)	Method	Other lessons
Brownstone and Small, 2002	Value for 80th minus 50th percentile of the transport time distribution: 26 Euro/hr.	RP (see above) and SP.	Travel time accounts for two-thirds of the service quality differential between the tolled and the alternative route; reliability one-third.
Bruinsma et al., 1999			Method for estimating delays in public transport.
Copley et al., 2002	The value of the standard deviation of travel time is 1.3 times the value of travel time (both per minute).	SP among 167 car drivers commuting in Manchester; mean versus variance method.	
Copley et al, 2002	1 minute late or early are valued less than 1 minute travel time.	SP (see above); scheduling model.	Method for valuation: mean versus variance approach or scheduling model.
HCG, 1998			Method: SP; The value of travel time can vary by road type and average speed (depending on the amount of congestion on the road).
De Jong et al., 2003	Commuting, business and leisure travel: 1 minute late or early is 1-1.5 times as bad as 1 minute travel time; Education: 1 minute late or early is less important than 1 minute travel time; All purposes: 1 minute longer or shorter participation in activity at destination is less important than 1 minute travel time.	SP among around 1,000 car drivers and train users in the peak periods in The Netherlands; Scheduling model.	

Study	Quantitative outcomes (+definition)	Method	Other lessons
MVA, 2000	The value of the standard deviation of time in the bus is 24% of the value of travel time in the bus (when seated; less for travel time standing; both measured in minutes). The value of the standard deviation of waiting time is 48% of the value of waiting time.	SP among 309 bus users in France; Mean versus variance approach.	
Noland and Polak, 2002			Method: scheduling model or mean versus variance approach (both in combination with SP).
Rietveld et al., 2001	A decrease in the probability of a 15 min. delay from 50% to 0% is worth 2.35 Euro (30% of the value of an hour travel time). A reduction in the probability of a 2 min. delay from 50% to 0% is worth 0.32 Euro (therefore 1 min. delay is 2.4 times as bad as 1 min. travel time: risk-averse).	SP among 781 public transport users in The Netherlands, with the following attributes: travel time, probability of a delay, probability of a seat.	
Rietveld, 2003			Underlying theory on uncertainty and attitude towards risk.
SACTRA, 1999	By ignoring travel time variability the economic benefits of trunk road schemes are underestimated by 5-50% (UK).		
Senna, 1991	The disutility of the standard deviation of travel time is around 2.5 times as high as for travel time.	SP survey among 301 respondents in Porto Alegre (Brasil), with a range of travel times, mean travel time and travel costs as attributes.	Underlying theory: utility theory and attitude towards risk; Methods: SP and mean versus variance approach.
Wardman, 2001			Time in congested conditions is 1.5 times as bad as time in the car.

Table 2. Value of reliability in freight transport (in travel time or Euros of 2003): quantitative outcomes, methods used and other lessons.

Study	Quantitative outcomes (+definition)	Method	Other lessons
Accent and HCG, 1995	A 1% increase in the probability of delay of 30 or more min. is equivalent to 0.45 – 1.8 Euro of 2003 per transport.	Stated preference (SP) in road transport in the UK with the following attributes: travel time, travel costs, provision of information and probability of delay.	Method: SP
Bruzelius, 2001, based on Transek, 1990, 1992	Sweden: for rail transport, a 1% increase in the frequency of delays is equivalent to 4.7-7.0 Euro per wagon; For road transport: 3.5-32.6 Euro per transport.	SP survey among shippers in Sweden in 1989/1990, including the following attributes: costs, transport time and probability of delay.	
Bruzelius, 2001, based on INREGIA, 2001	Sweden: the value of the risk of delay is 6.1 Euro per pro mille per transport for road, 111.3 for rail and 25.7 for air transport.	SP survey among shippers in Sweden in 1999, including the following attributes: costs, transport time and probability of delay.	
Fowkes et al., 2001	UK, road transport: the value of the difference between the earliest arrival time and the departure time is on average 1.18 Euro per min. per transport (more or less the free-flow time); for the time within which 98% of the deliveries takes place minus the earliest arrival time, the value is 1.44 Euro ('spread'); for deviations from the departure time (schedule delay) the value is 1.12 Euro.	SP survey among 40 shippers and carriers in the UK in 1999 with the following attributes: time, costs, latest departure time, earliest arrival time, arrival time for 90, 95 and 98%.	Method: SP

Study	Quantitative outcomes (+definition)	Method	Other lessons
HCG, 1992a	The Netherlands: an increase in the percentage not on time by 10% (e.g. from 10% to 11%) is just as bad as 5-8% higher transport costs.	SP survey in 1991/1992 among 119 shippers and carriers in goods transport by road, rail and inland waterways with the following attributes: time, costs, percentage not on time, probability of damage and frequency.	Method: SP.
HCG, 1992b	A decrease in the probability of delay by 10 index points (e.g. from 15% to 5%) is worth 0.5 – 2 Eurocent per tonne-km.	SP surveys in 1992 in The Netherlands, Germany and France with around 50 interviews per country with the following attributes: time, costs, probability of delay, frequency and flexibility.	Method: SP.
De Jong et al., 2001			Method: SP or joint SP/RP model.
RAND Europe et al., 2004	The Netherlands: a change of 10% in the percentage not on time (e.g. from 10% to 11%) is equivalent to 1.77 Euro per transport for goods transport by road. Also values for rail, inland waterways, sea and air transport.	SP/RP survey among 194 shippers and carriers in road transport with the following attributes: time, costs, percentage not on time, probability of damage and frequency.	Method: SP model.
Small et al., 1999	USA: A reduction in the deviation from the agreed delivery time (schedule delay) by 1 hour is worth $ 393 Euro per transport.	SP survey among hauliers in the USA; Scheduling model.	