TRANSPORT SCOTLAND
COMHDHAIL ALBA

TRANSPORT SCOTLAND 2015

Improving the evidence base on journey time reliability on the Trunk Road Network in Scotland

Tony Fowkes, Jeremy Shires, Gerard de Jong, James Laird, and Haibo Chen

Institute for Transport Studies
University of Leeds

CONTENTS

Executive Summary

This Final Report is for the research project "*Improving the evidence base on journey time reliability on the trunk road network in Scotland*." awarded by Transport Scotland to the Institute for Transport Studies, University of Leeds in November 2013. The views expressed in this report are those of the authors and should not be taken to represent the views of Transport Scotland.

MAIN FINDINGS

- Views of companies, both involved in freight movement and not, were obtained via surveys.
- Trunk road reliability in Scotland was perceived to have deteriorated in recent years, but this did not appear to be a matter of great concern to most companies responding.
- Analysis of Automatic Traffic data Collection figures showed a range of journey time variability by month and detection site, but generally the journey time variability did not seem particularly great.
- An approximate linear relationship was found between the standard deviation of average speeds, for days taken at monthly intervals, and the inverse of speed. Such a relationship might prove useful in forecasting journey time variability.

SURVEY RESULTS

The study looked at the concept of Journey Time Reliability (JTR) and its valuation. Surveys were conducted of Scottish businesses, both of Freight Users (F), sample size 33, and those not involved with freight (NF), sample size 116. In broad terms, the perception was that JTR had got worse on the Scottish Trunk Road network in recent years, but that this had not yet become a pressing matter for the vast majority of respondents.

For the F survey, respondents views regarding whether travel times on the Scottish Trunk Road Network had become less or more reliable over the last 5 years are reported in Table 1. The majority indicated that the reliability of travel times has become worse, though that result may be biased somewhat if those who felt that were more likely to participate in our survey.

Table 1 Perceived Change in the Reliability of Travel Times on the Scottish Trunk Road Network in the last 5 Years (F Survey)

PERCEIVED CHANGE	NUMBER OF RESPONDENTS	%
Less reliable	19	58%
The same	7	21%
More reliable	6	18%
Don't know	1	3%
TOTAL	**33**	**100%**

For the NF survey, Table 2 disaggregates by the different sectors of the economy. The Tourism/Ferries sector reports no deterioration in reliability. For Manufacturing, also, the percentage saying more reliable outweighs those saying less reliable. The Financial sector, on the other hand, felt that reliability has worsened.

Table 2 Perceived Change in Reliability of Travel Times on the Scottish Trunk Road Network in the Last 5 Years by Sector (NF Survey)

SECTOR	LESS RELIABLE	THE SAME	MORE RELIABLE	DON'T KNOW	TOTAL RESPONSES
D – Digital etc	38%	38%	25%	0%	8
E – Energy/Forestry	56%	22%	22%	0%	9
F – Financial	88%	13%	0%	0%	8
R – Retail/Food/Drink	28%	44%	11%	17%	18
L – Life Sciences etc	42%	58%	0%	0%	12
T – Tourism/Ferries	0%	75%	25%	0%	8
C – Construction	50%	50%	0%	0%	8
M – Manufacturing	25%	25%	33%	17%	12
S – Services	52%	30%	17%	0%	23
G – Government	30%	60%	10%	0%	10
TOTAL RESPONSES	**47**	**47**	**17**	**5**	**116**
%	**41%**	**41%**	**15%**	**4%**	

Table 3 reports responses regarding actual impacts on companies of trunk road unreliability in the last year.

Table 3 Reliability Impacts over the last year (NF Survey)

IMPACT	NO	YES	NO REPLY
Reduced Productivity/Sales	86	28	2
Additional Transport Costs	75	38	3
Delays to time-critical Deliveries	86	27	3
Additional Staff Costs	81	33	2
Difficulty in Attracting Customers	100	12	4
Difficulties with Staff Travel (on business, and commuting)	46	69	1

Table 4 provides detail on why firms would like to see Scottish trunk road reliability improved. Respondents were asked to choose the 5 most important impacts, from the list of 9 shown in the table, and rank them 1 (for most important) to 5 (for least important).

Table 4 Perceived most important reasons to improve reliability, ranked here from 1 for most important down to 9 for least. (NF Survey)

IMPACT	IMPORTANCE RANKING
Access to Customers	1
Productivity	2
Transport Costs	3
Attractiveness of area	4
Staff Recruitment	5
Access to Suppliers	6
Links between firm's locations	7
Business Confidence	8
Exports	9

As can be seen from Table 5, the chief causes of unreliability were felt to be the concentration of traffic at particular times and roads being insufficiently large to cope. Road works came in third place, with the remainder only being awarded "half marks". By location, road design received the highest rating in the Inverness (IN) area. That area, ignoring 'Others' (OT, ie. outside Scotland), also gave the highest rating to road size, with Glasgow (GL) giving it the lowest rating. Concentration of traffic at particular times was felt to be particularly impactful in the Aberdeen (AB) area, but not a great worry in the South West (AY) and the Inverness area. Road works were particularly blamed in Edinburgh (ED), Tayside (TY) and 'Others'. The weather did not appear to have been much of a problem in terms of unreliability, the previous 12 months having been unusually clement in Scotland. Accidents were felt to have particular impact in the Inverness area, but received in Edinburgh the lowest rating in the whole table. The Central (CE) area was usually in the middle of the pack.

Table 5 Ratings (out of 10, with greater impacts given higher ratings) of the Scale of Various Impacts on Unreliability, by Location. (NF Survey)

IMPACT	AB	AY	CE	ED	GL	IN	TY	OT	ALL
Road Design	5.5	4.1	4.9	4.7	4.3	6.6	4.2	6.5	5.2
Roads not large enough	7.6	6.0	7.1	7.0	5.6	8.1	6.8	8.8	7.1
Traffic concentrated at particular times	8.4	5.6	7.6	7.5	7.0	5.4	7.7	7.3	7.1
Road works	6.2	5.9	6.1	6.8	5.6	6.4	6.7	7.4	6.4
Weather	4.8	5.1	5.1	4.7	4.6	5.3	5.0	4.6	4.8
Accidents	4.5	4.4	5.1	4.0	5.1	6.7	5.2	4.8	4.9

The study looked closely at the topics of JTR and its valuation, both in the literature and in STAG. The latter seemed well up to date with the state of the art, and no major revisions were suggested. Both in STAG and in the literature, the accepted way of encapsulating the value of JTR changes is via the measure known as the Reliability Ratio (RR). For **private road vehicles** RR is defined as:

Reliability Ratio = (Value of $\Delta\sigma_T$) / (Value of ΔT) = VOR / VOT

where: VOR: value of reliability; VOT: value of travel time; $\Delta\sigma_T$: a change in the standard deviation of travel time; ΔT: an identical change in scheduled travel time.

The study has found the best estimate of RR for Freight to be 0.48, and for Non-Freight, say 'cars', to be 0.3. As the sample sizes were small, and the estimation uncertain, the recommended values more generally reflect values found in the recent international literature.

The recommendation of this report is that the following values be mentioned in STAG:

CAR JOURNEYS: Recommended value RR=0.8. If a sensitivity test value is required, take RR=0.4.

PUBLIC TRANSPORT: Not studied in this project. Note that for RAIL the ATOC (2002) range is RR=0.6 to RR=1.5. Note that the Expert Workshop of 2004 recommended RR=1.4. Note that recent is suggesting splitting by journey purpose, with RR=1 for BUSINESS and RR=0.6 for other modes. This project finds little ground for recommending different values for PT than for CARS, ie RR=0.8, with a sensitivity test alternative of RR=0.4.

FREIGHT: From the values available in the literature, supplemented to a limited extent by the results from the present study, the recommended best single value is RR=0.6, but with such uncertainty that a sensitivity test range of RR=0.4 to RR=0.8 is strongly advised.

AUTOMATIC TRAFFIC DATA COLLECTION

The study also looked at the data currently available that could be used to gauge Journey Time Reliability on the Scottish Trunk Road Network. The most useful source of data was found to be from Automatic Traffic data Collection sites, some of which recorded Vehicle By Vehicle data, showing vehicle type and speed. Should resources be available, this data could be converted to a common coding and aggregated in various ways. The study was able to mount a pilot investigation. Amongst other interesting findings, it was found possible to establish an approximate linear relationship between the standard deviation of average speeds, for days taken at monthly intervals, and the inverse of speed. It appears that around half of the variation in that standard deviation can be explained in that way. Since speed is routinely predicted, this opens the way to building a forecasting model of the standard deviation of speeds. Future appraisals might then be able to estimate both the mean and standard deviation of speeds on links affected by a scheme.

1. Introduction

This Final Report is for the research project "*Improving the evidence base on journey time reliability on the trunk road network in Scotland*." awarded by Transport Scotland to the Institute for Transport Studies, University of Leeds in November 2013. The views expressed in this report are those of the authors and should not be taken to represent the views of Transport Scotland.

The Project Officer at Transport Scotland was Jonathan Dennis, economist in Transport Analytical Services within Transport Scotland. Several members of Transport Scotland staff provided assistance and encouragement, the greatest burden falling on Stuart Hay, part of the National Traffic Database Systems Team within Transport Scotland who had to manually extract automatic Vehicle-by-Vehicle records in a manner suitable for the reported analysis.

The staffing of this project is as follows: Dr Tony Fowkes, led the project; Jeremy Shires, was the main person carrying out the work, with special responsibility for organising the survey and data gathering; Professor Gerard de Jong, provided theoretical guidance and his expert knowledge of past studies in this area; Dr. Haibo Chen, carried out the programming work to analyse the data sets received; Dr James Laird, provided local knowledge and his experience in drafting material suitable for inclusion into the STAG guidance.

2. Aims and Objectives

The requirements of the research were set out in the Tender Document published by Transport Scotland on 11 October 2013. The principal aim of this research was to generate first hand evidence from road users in Scotland on journey time reliability. Further aims were to assess the usefulness of the data that exists within and outwith Transport Scotland on journey time reliability and, together with the principal aim, evaluate how this information might be used to update and improve the appraisal guidance on assessing journey time reliability impacts in Scotland.

In furtherance of those aims the following key objectives were targeted:

- ***Bring together the latest evidence and understanding of current patterns of journey times (not limited to Scotland) along with likely causes of unreliability and the impact this uncertainty has on businesses;***

This objective is addressed in sections 3 and 4 of the current report.

- ***Capture relevant first hand journey time data and information from businesses using the trunk road network in Scotland;***

This objective was achieved by a two part survey of road users. The initial approach was to contacted trade bodies, and similar, covering a range of activities within Scotland, and obtain a list of persons to contact by phone. Unfortunately, very few of those people contacted declared themselves available to take part in the survey at that time, so it was decided to move to the first fall-back position, the provision of an on-line version, to be filled in without the help and guidance of interview staff. Gratifyingly, the response to the on-line survey was quite good, both in terms of quality and number. However, with the responses somewhat clustered as regards activity sector, and still insufficient in number, it was decided additionally to buy in to a commercially available pre-recruited regular survey panel to fulfil the data requirement. The key results are presented in section 5.

- ***Review the usefulness of available journey time reliability data (data sources within Transport and Traffic Scotland and any potentially useful external data sources).***

Having received early returns from Transport Scotland staff, Moving Observer data was first considered. This involves noting the times at which points are passed when making (repeated) trips along specific roads, and making well known adjustments for the numbers of vehicles ‘overtaken’ and ‘overtaken by’ in each road section. A good estimate of the underlying speed of traffic on those sections at the time of the run can be obtained. However, on further investigation it became apparent that only a small number of locations were covered and it appeared that generally only raw data was available, requiring a great deal of analysis to be performed (even if the data on overtakens and overtakers could be found), which ruled out this route of enquiry.

Turning to large data bases, such as those generated by automatic data capture, the main data set is held in the Scottish Roads Traffic Database (SRTDb) and revolves around traffic counts. With the help of the relevant team within Traffic Scotland, it was possible to get access to the raw Vehicle By Vehicle (VBV) data for a limited number of sites. Having access to the raw data was excellent but, as different sites had this data coded in several different ways, data handling was time consuming. Resource constraints restricted the analysis to one day's data for each month of 2013 for 38 sites. Results based on the 31 sites with usable data are reported in Section 6.

- ***Consider the implications of findings for appraisal guidance on journey time reliability.***

Consideration of how the findings from this work might be reflected in STAG guidance are reported in Section 7.

3. What is Reliability and why is it important?

3.1 Journey Time Reliability versus Journey Time Variability

The impact of unreliability manifests itself in two parts: the level of unreliability, and the impact of each unit of unreliability. The former can be studied from past records and the interrogation of traffic data bases, while the latter will be estimated using literature search (see section 4) supplemented by an analysis of a suitably specified question in the survey of companies (see section 5).

This section will begin by teasing out some of the relevant concepts, and labelling them, firstly distinguishing between the Expected Journey Time and the Actual Journey Time. In statistical parlance, the former is just the arithmetic mean of the latter, and that definition will be adopted here. A journey undertaken in free-flow conditions can be taken to have the same Actual Journey Time on each occasion, and that will be equal to the Expected Journey Time. If planned road works forced a diversion over another road in free-flow conditions, the Expected Journey Time will increase. Avoiding such an increase will have a value to users, called the Value of a Travel Time Saving (VTTS), sometimes referred to more loosely as the Value of Time (VOT).

VTTS can be taken as made up of two parts. Firstly there are the costs of travelling for the extra time. For example, drivers might dislike spending time in slow moving traffic; bus passengers might dislike spending extra time on a bus; and slower freight movements will result in extra driver hours and vehicle operating costs. Secondly, there will be scheduling costs, for example: what utility might have resulted from having that time available to use in another way; and what disutility/costs might arise from having to set out earlier or arrive later? When considering changes in Expected Journey Times, it is implied that travellers can choose to minimise the impact on them by starting out earlier in cases where that is not prevented by some other fixed constraint (e.g. the time at which a play ends).

If journeys do not all take the same time, there will be Journey Time Variability (JTV), which can be measured (given sufficient data) as a standard deviation, for example. However, clarity is required over what dimension that variability is being calculated in. For example, journey times might vary over the hours within a day, but may be constant over days at a given time of day. Road users travelling at the same time each day would experience zero JTV, while those using the road at different times each day would experience a positive JTV. In both cases, however, it can be said that the travel times are reliable, as they are predictable from day to day, whilst being variable within the day.

The next consideration is whether the JTV could have been predicted before the journey began, in which case the start time could be chosen to minimise any adverse impact of unexpected delays. In the face of known JTV, travellers may be able to avoid the worst impacts of late arrivals by departing earlier, but may find themselves arriving too early at their destination on some occasions. In other cases, it will be impossible to start out earlier, both due to fixed constraints, and where the journey is already underway when the likelihood of delays becomes apparent. It is clear that disutility/cost is caused by JTV, and it is this that is usually valued as Journey Time Reliability (JTR).

3.2 Measuring Journey Time Reliability and its Value

The first (and sometimes only) step in measuring journey time (un)reliability is to measure JTV. Accordingly, the study obtained data on the variability of speeds, in 10 minute intervals, for the second Friday in each month of 2013, at selected trunk road sites across Scotland. The results from this work are reported in section 6. Regarding its value, VOR, a suitable question was included in both the Freight and Non-Freight surveys of companies. In the Freight survey companies were asked what costs would be incurred due to unexpected delays to a typical shipment, chosen by them. The Non-Freight survey asked what amount of delay once in every five journeys respondents would value equally to a specified fixed delay for all 5 days.

3.3 Strategies for Reducing Journey Time Variability

It follows from what has been said earlier, that not all JTV is worth removing, or even bad at all. However, there are cases where JTV reduction is likely to have significant value. Those are the cases where JTV leads to costly unreliability in arrival times. The first case is where the JTV **within a day** is so large, i.e. the 'peak' speeds were so much less than the free-flow speed, that there would be good grounds for imagining that the road would be subject to great instability of journey times in response to minor incidents or inclement weather conditions. This will be because the road is already operating close to its capacity at those times. In rural areas, considerable benefits might be obtainable by easing bottlenecks or generally providing more road capacity. In urban areas, benefits might be achieved by suitable traffic management measures – such as diverting some traffic, banned turns, reversible lanes, using variable message signs to alter speed limits, or queuing traffic in rear of locations unable to cope with the traffic offering.

The second case is where journey times at a given time of day and day of week are observed to vary from **month to month**. In this case the variability is probably due to either the weather, or varying seasonal demand for using that road. Rather than working with averages, road planning is improved if this variability is taken into account. Bad weather might slow down traffic seriously on a particular road, but that might increase demand on roads providing an alternative route, which should be catered for if possible. Routes that are busy just in the summer, with mainly recreational trips, might then suffer sufficient congestion that alleviation measures would pass Cost-Benefit tests, provided the appropriate data is used (i.e. not averages).

The data analysed in section 6 is for just one day per month, usually the second Friday, but this captured enough of the essence of travel time variability that the work will have wider lessons. Firstly, considering speeds in the peaks, the sample will have hit some holidays, which should not be ignored. Otherwise, it might be said that what has been captured is captured 'Day-To-Day' (DTD) variability (free of day of week effects), plus some seasonal effects. If a reasonable estimate of DTD variability can be isolated, it can be valued by inputting a suitable slack time allowance in all trips and a penalty for late arrival. Note that this speed variability will not be confined to the peaks. A much larger number of trips might therefore be affected, but probably to a much lower extent than in the peaks. Where the speed variability is great, actions such as those listed above for within-day variability may be appropriate. More likely is that amelioration would come in the form of improved strategies to deal with incidents, and to provide information to drivers.

In both cases, however, it is important to note that information for motorists should be managed. This will need to take into account what sources of traffic information are available to motorists, and actually being used by them at that time. For example, if the only information source was a single radio channel, and all drivers were tuned into that channel, then all drivers might follow any advice given simultaneously. If the incident in question is merely halving the capacity of a link, then it is not desirable to divert all the traffic onto an alternative route, but only a portion. Conversely, if an incident is considered too trivial to mention, then no drivers will divert. In response to a range of potential circumstances, there needs to be a range of possible responses to be chosen between - in the light of the current best guess of the proportions of drivers receiving various sources of information, and their perceived willingness to act on it. Rather than taking no action in the case of a minor incident, it might be worth advising just HGVs to divert to an alternative route. With increasing in-vehicle electronic information sources available, it should become much easier to smooth out the perturbations that do occur. By giving out carefully chosen information designed to optimise the system, drivers may come to trust the information provided, so that the crucial point will be to understand how each driver is likely to respond to that information. That will require a good understanding of traveller values of (uncertain) time in the vehicle and their value of late arrivals.

The study’s work is naturally limited, but it throws light on the potential costs and benefits of taking this work further, should decision makers find that desirable.

4. Theoretical Background and Current Best Practice

4.1. The current appraisal framework

In section 9.2.2.9 of Transport Scotland's "STAG Technical Database Section 9", see Transport Scotland (2012), reliability for **private road vehicles** is expressed by means of the reliability ratio (RR), defined as:

Reliability Ratio = Value of SD of travel time / Value of travel time

We prefer to write that as:

RR = (Value of $\Delta\sigma_T$) / (Value of ΔT) = VOR / VOT

where:
VOR: value of reliability
VOT: value of travel time
$\Delta\sigma_T$: a change in the standard deviation of travel time
ΔT: an identical change in scheduled travel time.

For example, we might have an estimate of the value of a travel time saving as £6/hour for some group. That means that the value of a $\Delta T = -10$ minutes is estimated at £1. We now need to know the value of reducing the standard deviation of travel times also by 10 minutes. From the literature, the consensus of opinion is that RR is often around 0.8, in which case the value of reducing the standard deviation of travel times would be about £4.80 per hour, and so the value of reducing the sd by 10 minutes would be £0.80.

For **public transport** however, the RR is defined in STAG differently. The justification given for this is the existence of a timetable. They say that in "the general case one minute of average lateness is valued by passengers as being equivalent to three minutes of scheduled journey time". This value of 3 is referred to as a Lateness Factor. Passengers are said to be concerned less about journey time variability per se, but more about lateness relative to the timetable. They say that, broadly, "the value of average lateness for public transport is expected to be the same as the value of time spent waiting for public transport, that is, at 2.5 times the value of in-vehicle time". The reliability ratio, for public transport is defined as:

Reliability Ratio = Value of SD of lateness / Value of lateness

We prefer to write that as:

RR = (Value of $\Delta\sigma_L$) / (Value of ΔL) = VOR / VOL

where:
VOL: Value of (mean) lateness = f . VOT
(f is a factor to be estimated or taken from the literature, currently recommended as 2.5)
$\Delta\sigma_L$: a change in the standard deviation of lateness

ΔL: an identical sized change in lateness (= A_i - A^S, where A_i is the actual arrival time of trip i and A^S is the timetabled arrival time referring to that trip; with $A_i – A^S \geq 0$, i.e. early arrivals are treated as being on time).

For example, we might have an estimate of the value of a travel time saving as £6/hour for some group. That means that the value an hour's lateness is £15 (using the recommended f value of 2.5). From the literature, the recommended RR value for public transport is given as 1.4. In that case the value of increasing the standard deviation of lateness would be about £21 per hour.

4.2 The problem

The question now is what would be the most appropriate definition of reliability:

- the reliability ratio based on the standard deviation of travel time;
- the reliability ratio based on the standard deviation of lateness; or
- another definition of reliability one might think of, notably involving the expected value of schedule delay early (SDE) and schedule delay late (SDL), following a classic Vickrey-Small scheduling model to which uncertainty in travel time has been added (see Bates et al., 2001), where:
  - SDE: the number of minutes one arrives earlier than the preferred arrival time PAT (for early arrivals);
  - SDL: the number of minutes one arrives later than the preferred arrival time PAT (for late arrivals).

Some observations:
Lateness in the sense of actual arrival time minus scheduled arrival time exactly corresponds to delay in the sense of actual travel time minus scheduled travel time (assuming that there are no other delays in the actual departure time):

$$A_i – A^S = T_i - T^S$$

where:
T^s : the scheduled travel time.

Consequently, the standard deviation of lateness is equal to the standard deviation of transport time delays.

One can also substitute free-flow or expected for the "scheduled" in the text above: there is also a formulation of this that holds for private (e.g. road) transport. This result simply follows from the fact that the only delays considered are those in the travel time of the mode studied.

For **road** transport, lateness might be defined with respect to free flow time:

$$L_i = T_i - T^F$$

where:

T^F: free flow travel time

If the free-flow time T^F is constant (e.g. for all trips on different days on a given route), then the value of lateness (VOL) will be equal to the value of time (VOT), and the standard deviation of T_i will equal the standard deviation of T_i-T^F :

$\sigma_T = \sigma_L$

In this case, the two first options given in the beginning of this section give the same result. This result hinges on the constancy of free flow travel time: in that case subtracting it from actual travel time affects the mean, but does not affect the standard deviation. As soon as one compares trips over different routes, the free flow travel time will vary, and the equality no longer holds.

4.3 The current view by experts in the field

In a project for the German Federal Ministry of Transport, Building and Urban Development, international experts[1] on travel and transport time reliability were interviewed (Significance et al., 2012) on a number of related, but somewhat broader issues than the question posed by Transport Scotland. One of the questions was which operational definition of reliability they would recommend for including reliability in the CBA in the next 2-3 years (for Germany, Scotland, and almost every national or regional transport model used across the world for appraisal that do not include explicit Vickrey-Small scheduling models). Below is a chart of the frequency distribution of the answers of the experts. From Figure 4.1 it is very clear that the standard deviation has most support among the experts as a measure of reliability that can be included in the CBA in 2-3 years from now. This is the standard deviation of travel time, not of lateness. Some experts however, expressed a preference for using lateness relative to the timetable (expressed in Figure 4.1 as “punctuality”), but only for modes that use a published timetable.

Significance et al. (2012) also reviewed the literature on arguments for and against different operational definitions of reliability and asked the experts to give their arguments for and against. With respect to the standard deviation the following arguments were obtained.[2]

Arguments for using the standard deviation (again referring to travel time) are:

(i) It has an indirect base in theory, since Fosgerau and Karlström (2010) showed the formal equivalence with the scheduling model (at least for modes without timetables, such as the car; for public transport this argument does not hold).
(ii) It can be empirically measured.

[1] John Bates, Richard Batley, Maria Börjesson, Jonas Eliasson, Leonid Engelson, Mogens Fosgerau, Tony Fowkes, Joel Franklin, Justin Geistefeldt, Askill Halse, Bruce Hellinga, David Hensher, Yaron Hollander, Juergen Janssen, Anders Karlström, Paul Koster, Hao Li, Tim Lomax, Hani Mahmassani, Rich Margiotta, Kai Nagel, Juan de Dios Ortúzar Salas, Stefanie Peer, John Polak, Farideh Ramjerdi, Piet Rietveld, Henrik Swahn, Lori Tavasszy, Erik Verhoef, Inge Vierth, Peter Vovsha, Tom van Vuren, Mark Wardman, Pim Warffemius.
[2] Arguments for and against other measures can be found in Significance et al. (2012).

(iii) It is relatively easy to include in standard transport models (since it does not require including a scheduling model to the transport model, but only an extra reliability term in choices like mode and route choice).
(iv) Related to the previous, since it requires no formal scheduling model, it also does not require preferred arrival times (PATs), for which specific survey interviews would be needed or reverse engineering (Kristoffersson, 2011).
(v) It often provides a good fit to stated preference (SP) data (choices between alternatives that differ in terms of reliability are often well explained by a model that includes the standard deviation).
(vi) It can capture a residual (non-scheduling-related) value (e.g. anxiety).
(vii) It is a natural way to summarise a distribution (together with the mean).

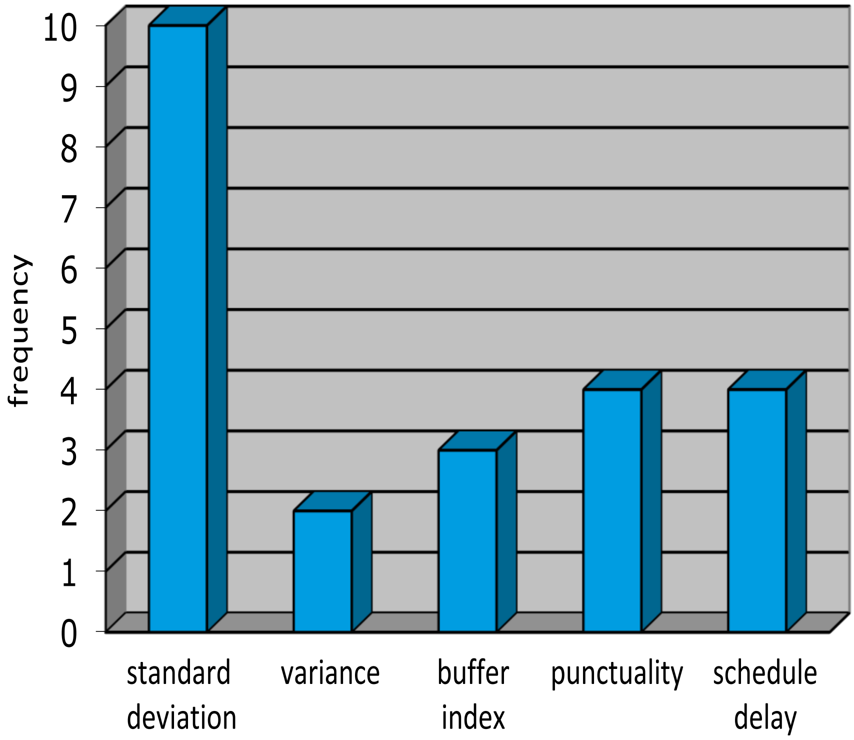


Figure 4.1: Most appropriate definition of reliability for use in CBA: Frequency distribution of answers of the experts

Arguments against using the standard deviation are:
(i) It is rather sensitive to outliers.
(ii) It does not properly pick up the form of the tail and skew (i.e. it ignores the higher ‘moments’ of the distribution).
(iii) It is not additive over links: even when link travel times are independent of each other, simple summation of standard deviations (unlike the variance) over links will not give the standard deviation of the route that uses these links. Choosing to use the variance would resolve the latter argument for independent link travel times. However, in a congested network, congestion spreads backwards from the original bottleneck, creating dependence among the travel times of adjacent links, so that the variance is not additive over links either.

Given that in most countries there will not be a national departure time choice model in the next 2-3 years, there is no other choice really than to use a dispersion measure instead of schedule delay. This also applies to Scotland. So the option mentioned in section 4.2 of using schedule delay early and late is not feasible in the short run; it is possible to get a monetary value, but there is no forecasting model that can support this definition of reliability.

Significance et al. (2012) recommended using the standard deviation of travel time (in the long run, it might be possible to switch to the scheduling model), both for private transport (passenger and freight) and for public transport. In the recent Dutch VOTVOR study (Significance et al., 2013) the standard deviation of travel time was also chosen as the measure of reliability for all modes (including public transport) in passenger and freight transport. This study could have chosen to use the standard deviation of travel time for non-scheduled modes and the standard deviation of lateness for scheduled modes, but it preferred using the standard deviation of travel time for all modes because:

- The advantage of consistency of definition across modes.
- When one uses travel time, both early and late arrivals are included, lateness only looks at late arrivals.

In summary, for the appraisal of trunk road schemes there are many, mainly practical, arguments for using the standard deviation of travel time (valued as part of an RR). Most experts support this choice, at least for the short to medium run. For public transport, where there are scheduled services, the selection of the best definition is less straightforward. A measure based on lateness relative to the timetable is a serious contender to the standard deviation of travel time. The theoretical argument for the standard deviation does not hold here, because the Fosgerau-Karlström model assumes a free choice of departure times. Nevertheless some of the most recent studies (Germany, The Netherlands) have selected the standard deviation of travel time even for public transport.

4.4 Some Numerical Results for the RR

The following overview of numerical results for the RR in passenger transport is taken from Significance et al. (2013). The results are summarized in Table 4.4.1, which is mostly concerned with passenger trips. All results use the RR definition based on the standard deviation of travel time. It should be noted that the table includes their own results, from Stated Preference surveys carried out in 2009 and 2011 in The Netherlands. The findings of an Expert Workshop, held in 2004, are also shown. The consensus for the RR of car travelers is around 0.8. For Public Transport the position is less clear, but the value of 0.8 again looks reasonable.

The same table also presents results for road freight transport (all from SP studies). The RR using the standard deviation of road freight transport time in Significance et al. (2013) is around 0.4. This is substantially lower than the preliminary (highly provisional) value of 1.2 (for road transport) from de Jong et al. (2009); In the new Dutch VOTVOR survey, unreliability, its context and its consequences were made much more explicit and the presentation format is much more suitable for measuring unreliability in terms of the standard deviation of transport time (or scheduling terms), so the 2013 values are to be preferred. Other recent empirical studies, notably Halse et al. (2010) and Fowkes (2006) also found similar low RRs in freight (when including the valuation of transport staff time and vehicles from the carriers in the values of reliability and time).

Table 4.4.1. Summary of the empirical findings on the reliability ratio in passenger and freight transport (the value of the standard deviation of travel time versus the value of travel time)

Study	Country	RR
Car		
MVA (1996)	UK	0.36 – 0.78
Copley et al. (2002)	UK	Pilot survey: 1.3
Hensher (2007)	Australia	0.3 – 0.4
Eliasson (2004)	Sweden	0.30 – 0.95
Mahmassani (2011)	USA	NCHRP 431: 0.80 – 1.10 SHRP 2 CO4: 0.40 – 0.90
Expert workshop of 2004	*The Netherlands*	*0.8*
Significance et al. (2013)	The Netherlands	Commuting: 0.4 Business: 1.1 Other: 0.6
Train		
ATOC (2002)	UK	0.6 – 1.5
Ramjerdi et al. (2010)	Norway	Short trips: 0.69 Long trips: 0.54
Expert workshop of 2004	*The Netherlands*	*1.4*
Significance et al. (2013)	The Netherlands	Commuting: 0.4 Business: 1.1 Other: 0.6
Bus/tram/metro		
MVA (2000)	France	0.24
Ramjerdi et al. (2010)	Norway	Short trips: 0.69 Long trips: 0.42
Expert workshop of 2004	*The Netherlands*	*1.4*
Significance et al. (2013)	The Netherlands	Commuting: 0.4 Business: 1.1 Other: 0.6
Air		
Ramjerdi et al. (2010)	Norway	0.20

Significance et al. (2013)	The Netherlands	Business: 0.7 Other: 0.7
Road freight		
Fowkes (2006)	UK	Shippers: 0.38 Own-account: 0.19
Halse et al. (2010)	Norway	Shippers: 1.2 Carriers: 0 Overall: 0.11
Significance et al. (2013)	The Netherlands	Shippers: 0.9 Carriers: 0.28 Overall: 0.37

5. Results from the survey of companies

5.1 Survey Conduct

In order to provide a snapshot of the views on reliability of companies and organisations using the Scottish Trunk Road Network, the survey proposed to contact approximately 80 companies by telephone, with the option of online completion for those too busy to reply there and then. Considerable efforts were made to establish telephone interviews, with much “ringing back” but in the end only one telephone interview was successfully conducted. However, several of those approached by phone agreed to complete the questionnaire online.

As part of the construction of a list of names/numbers to contact, a range of organisations that could broadly be described as ‘trade bodies’ were also approached. Some of these refused to provide individual contacts, but agreed to publicise the on-line survey in their newsletters (and the suchlike) provided to their members. Obviously, there was no control over the timing of those newsletters, and when to expect responses. There were a pleasing number of early responses, but then the rate of responses fell to virtually zero.

At that stage a total of 28 telephone or online responses had been received. As that was only about 40% of the agreed target, a market research company was engaged, which was able to buy in to a large pre-recruited panel. Pleasingly, after some negotiation, agreement was reached to specify a two-way matrix of desired respondents by location and industry sector. Panel members appearing to have managerial responsibilities within their company were favoured. Naturally, not all such grades were available over every combination of location and industrial sector, and there was no control over who would actually respond. In order to be sure of meeting the contractual minima specified, the market research firm chose a pessimistic projected response rate, taking into account that the questions were much more difficult than most that are posed to such panels. In the event, the panel members approach evidently found the questions to be of greater interest than projected, and so 139 responses resulted from this source alone. There were concerns that the respondents might not take the survey seriously, but these proved unfounded.

The total achieved sample size was therefore 167, all obtained between 05/03/14 and 12/05/14. There were two separate questionnaire designs. One was particularly tailored to the effects of unreliability on freight movements and 45 responses to this Freight (F) questionnaire were achieved. Of these, only 33 were judged to be sufficiently complete to be analysed. Only four of the freight respondents was actually a road haulier, i.e. engaged in third party ‘hire & reward’ work. Others answering the freight questionnaire were mainly those companies involved in ‘shipping’ (i.e. sending out) freight, either on ‘own account’ or via a road haulier. Some respondents were receivers of freight. Those respondents who had no significant freight movements to report completed the second, Non-Freight (or NF), questionnaire. This looked at impacts of unreliability on the organisations’ staff and customers. It attracted 122 responses, of which 116 were judged to be sufficiently complete to take forward. The total useable sample, to both questionnaires, was therefore 149.

5.2 Results from the Freight (F) Survey.

The spread of Freight respondents over company ‘sector’, self-chosen as best describing their company’s activities, is shown in Table 5.2.1. Almost a third (10) of the Freight respondents are Manufacturers. With another 5 involved in Energy or Construction, about half of the respondents are clearly involved in production. A further 3 companies report themselves as Food and Drink (but not Retail or Services) so they may also be producers. Four respondents are broadly involved with transport and distribution. Services, Retail, Financial and Creative/Digital account for 8 companies, leaving 3 Government respondents.

Table 5.2.2 shows the distribution of the freight sample by location. Two respondents claimed to have company premises all over Scotland, and one claimed to be in Northampton. Over half of the sample is in the ‘central belt’, but there is good coverage of the north, though not many in the south west of Scotland.

Table 5.2.1 Freight Survey Respondents by Sector

SECTOR BEST DESCRIBING COMPANIES ACTIVITIES	NUMBER OF RESPONSES
Road Haulage	1
Postal Service	1
Commercial Seaport	1
Warehouse and Distribution	1
Energy	3
Construction	2
Food & Drink	3
Manufacturing	10
Creative/Digital	1
Services	4
Retail	1
Financial	2
Local Government	2
Central Government	1
TOTAL	**33**

Table 5.2.2 Freight Survey Respondents by Location

NEAREST CITY/TOWN	NUMBER OF RESPONDENTS
Fort William	1
Inverness	4
Aberdeen/Peterhead/Inverurie/Montrose	4
Stirling/Livingston/Grangemouth	3
Glasgow/Paisley/Motherwell	10
Edinburgh/Cowdenbeath/Glenrothes	5
Kilmarnock/Irvine	3
"All Scotland"	2
Northampton	1
TOTAL	**33**

Due to the small sample size, splitting respondents into groups for analysis will not generally be robust. Cross-tabulating firms by sector and location, for example, might also permit the identification of some firms; which respondents had been led to believe would be protected against. Anonymised data has been prepared for passing to Transport Scotland.

Table 5.2.3 shows a large range of size of operation, measured as the total tonnage for all that firm's flows p.a. Responses were obtained from 23 firms. A couple hardly moved any freight at all. Typically, several thousand tonnes were moved p.a., and that is reflected in the reported Median. The distribution of tonnages was heavily skewed, so that there is a long tail of high tonnages. Consequently, the Mean tonnage is three times the Median, being around a quarter of a million tonnes p.a., probably involving around 50 lorry loads per working day. The biggest annual tonnage, from a seaport, was almost three million tonnes p.a., no doubt involving over 300 lorry loads per working day.

Table 5.2.3 Reported Annual Tonnages for all Flows

	Minimum	Median	Mean	Maximum
Annual Tonnage	3	8000	260000	3000000

In order to introduce the concept of Journey Time Reliability, respondents were asked to indicate their feeling regarding whether travel times on the Scottish Trunk Road Network had become less or more reliable over the last 5 years. Table 5.2.4, shows that the majority indicate that the reliability of travel times has become worse. However, it is more than likely that those feeling that way will be over-represented in a survey of reliability with such a large element of self-selection in as in the present case. Stratifying the sample would not have helped, since there would be a divergence of opinion within any feasible strata, and those concerned about reliability within each stratum would be more likely to respond. Hence, it would be unwise to place too great a weight on this result.

Table 5.2.4 Perceived Change in the Reliability of Travel Times on the Scottish Trunk Road Network in the last 5 Years

PERCEIVED CHANGE	NUMBER OF RESPONDENTS	%
Less reliable	19	58%
The same	7	21%
More reliable	6	18%
Don't know	1	3%
TOTAL	**33**	**100%**

Respondents were asked to provide data on a typical freight flow. Table 5.2.5 reports their responses when asked about the nature of the freight concerned. Note that, while respondents generally gave just a single answer, the listed categories are not mutually exclusive. For example, pallets can be containerised. However, it does appear that the sample includes a range of natures of freight. It is not thought surprising that Palletised accounts for a third of the total, as that is the standard form of moving loads of individually small items, e.g. retail goods.

Table 5.2.5 Nature of the Freight for the Selected Sample Flow

NATURE OF THE FREIGHT	NUMBER OF RESPONDENTS	%
Carried in Tankers	2	6%
Containerised	5	15%
Palletised	11	33%
Boxed/Crated	3	9%
Metal loads etc.	3	9%
Other	6	18%
TOTAL	**33**	**100%**

Table 5.2.6 summarises the 26 responses received to the question of tonnage shipped and lorries dispatched per year for the typical flow. Two respondents did not give tonnage, and another couple reported such a small flow that excluding them was considered, but they are in. Some responses were vague, so some judgement has been used, and somewhat rounded figures given. The load per lorry cannot be determined from the table, but varied between 0.125 tonnes and 30 tonnes. Looking at Table 5.2.6 shows a wide spread of tonnages and numbers of lorry loads shipped in a year. Very occasionally, the traffic moved as a part load. The typical (median) flow was of roughly a lorry load per working day, and carried around 5000 tonnes. Both distributions were highly skew, so that the means were more than 6 times higher than the medians. Seven flows reported more than 1000 lorry loads p.a. and three flows were over 100,000 tonnes p.a., the highest being 500,000 tonnes p.a.

Table 5.2.6 Annual Tonnages and Lorry Loads Shipped for the Typical Freight Flow

	Minimum	Median	Mean	Maximum
Annual Tonnage	1.5	5000	33000	500000
Lorry Loads p.a.	5	275	1700	25000

As the survey specifically refers to trunk roads, the typical journeys reported are quite long, taking a mean of 7.3 hours and a median of 4 hours. Table 5.2.7 shows the distribution of Scheduled Journey Times, the shortest being 30 minutes and the longest being 48 hours. No response was obtained from 5 firms.

Table 5.2.7 Scheduled Journey Time for the Typical Freight Flow

JOURNEY TIME	NUMBER	PERCENTAGE
Less than 2 hours	4	14%
From 2 to less than 4 hours	7	25%
From 4 to less than 6 hours	8	29%
From 6 to 10 hours	4	14%
From 10 to 20 hours	1	4%
From 20 to 30 hours	3	11%
From 30 to 50 hours	1	4%
Total	**28**	**100%**

Table 5.2.8 shows the distribution of arrival times, relative to the scheduled arrival time, for the typical freight flows. Each respondent was asked to give a distribution for their flow (egg. 50% arrives On Time, and the remaining 50% arrives within 30 minutes), and Table 5.2.8 shows those figures averaged over the 27 respondents who answered this question. For some receivers, on time deliveries are a must (egg. supermarket distribution centres), and so some slack time is built into schedules. It should not, therefore, be surprising to see 55% of arrivals on time, but it is certainly impressive that another 35% arrive within the hour (given the average journey time was seen in Table 5.2.7 to be 7.3 hours). Of the remaining 10%, half arrives within a further hour, giving 95% within 2 hours. The remaining 5% is spread down quite a long tail. From that distribution it is possible to calculate the mean lateness as 40 minutes and the standard deviation of lateness as 3 hours. That latter figure looks high, but results from the very long tail of the distribution. Median lateness is close to 30 minutes.

Table 5.2.8 Distribution of Arrival Times for the Typical Freight Flow (i.e. Lateness)

ARRIVAL TIME RANGE	MEAN PERCENTAGE
On Time	54.9%
Up to 30 mins. Late	24.5%
Between 30 & 60 mins. late	10.5%
Between 1 & 2 hrs. Late	5.1%
Between 2 & 4 hrs. Late	2.4%
Between 4 & 12 hrs. Late	0.8%
Between 12 & 24 hrs. late	1.0%
Over 24 hours late	0.8%
TOTAL	**100%**

Table 5.2.9 reports the stated relationship between the respondent's company and the typical flow of freight. Four respondents did not provide a response to this question, and the quoted percentages ignore those firms. The company is the shipper in about 80% of the cases where an answer was provided. In 34% of cases, the company only shipped the goods, with someone else proving transport. In 38% of cases, the company both shipped and transported the goods. In another 2 cases (7%), the company was both shipper and receiver, i.e. the load moved between company premises. In 14% of cases the company was only the Carrier for the freight. Those 4 cases include the Road Haulier shown in Table 5.2.1, plus a Warehouse/Distribution firm, and two firms in the Services sector. The final two responses were the Seaport and a case where the respondents company was the Receiver only.

Table 5.2.9 Company's Relationship to the Typical Freight Flow

RELATIONSHIP TO FREIGHT	NUMBER OF RESPONDENTS	% OF REPLIES
Shipper Only	10	34%
Shipper & Own Account Carrier	11	38%
Shipper & Receiver	2	7%
Carrier Only	4	14%
Receiver Only	1	3%
Seaport	1	3%
No answer	4	
TOTAL	**33**	**100%**

Respondents were asked to estimate how many management hours were taken up dealing with the consequences of a single lorry load of this traffic arriving a day late. Ten respondents had "No idea". The remaining 23 respondents reported a total of 35 hours, so an average of one and a half hours. Naturally, delays as large as one day would be rare, but it can be deduced from the data that a 4 hour delay would not require more than 90 minutes management time, on average, and that 15 minutes might be a reasonable value to take. STAG 2012 (see Transport Scotland, 2012) reports work values of time at around £40/hour (for car travellers) in 2010, reflecting the gross wages of such travellers. Making the appropriate adjustments to 2014 prices and income levels raises that to about £50/hour. Assuming that the management hours referred to in the survey were fairly senior, it was thought sensible to use here a gross wage rate of £80/hour. Hence 15 minutes of such time would imply a cost of £20 from a 4 hour delay. In the absence of better estimates, this provides a very rough estimate of one component of the cost of unreliability (£5/hour of delay).

Another question asked about the effect on Buffer Stocks of a sustained reduction in the incidence of late arrivals. Five respondents did not provide a reply, and 22 more said there would be no effect. The remaining 6 respondents reported an average of 16% reduction in Buffer Stocks, with all responses being in the range 10% to 20%. Some of the non-respondents would have found the question irrelevant, for example the seaport and those merely involved in carrying the goods. At least one of the firms reporting no reduction had no Buffer Stock to begin with. If were assumed that about 18 firms would have no reduction, then averaging these with the 6 reporting a 16% reduction would give an overall 4% reduction in Buffer Stocks. The value of that will obviously vary from case to case, not least with the value of the goods concerned, but 4% could be a quite significant saving in the working capital involved.

Table 5.2.10 reports the greatest impact on reliability of freight movements is felt to be that roads are insufficiently large to cope. This is closely followed by the concentration of traffic at particular times. Road works came in third place, with Road Design not far behind that. Weather and Accidents were not felt to be particularly important in themselves. The closeness of the Mean and Median results suggests that these views are shared over different sections of the sample.

Table 5.2.10 Ratings of the Scale of Various Impacts on Unreliability (F Survey)

IMPACT RATING (out of 10)	MEAN	MEDIAN
Road Design	6.4	6
Roads not large enough	7.7	8
Traffic concentrated at particular times	7.3	7
Road Works	6.7	7
Weather	4.9	5
Accidents	5.3	5

Table 5.2.11 shows the cost to the firm, per shipment of the typical flow, if road conditions were such that the scheduled journey times had to be increased by stated amounts. A lot of firms failed to identify any cost, possibly because they used Road Hauliers who charged by distance, not appreciating that such charges would be bound to rise, to cover driver wages and vehicle provision for more hours. Most respondents did report some costs for journey time increases of 60 minutes or more. The Median cost given for 60 minutes was £15, rising to about £80 for 2 hours, and rising linearly above that. For 2 hours increased journey time and more, these

amounts are above drivers' wages, and several reasons for the costs were given. In some cases penalties were set out in a contract, though if journey times were scheduled to be longer a different contract would surely be drawn up. In other cases additional overtime was mentioned (egg. for warehouse staff), and in one case vessel docking charges were mentioned. The latter were very high compared to most other costs considered, and will have contributed to the Mean costs being much greater than the Median costs.

Table 5.2.11 Reported Costs Arising, for a Single Shipment, from Increases in the Scheduled Journey Time for the Typical Flow

	30 MINS LONGER	60 MINS LONGER	2 HOURS LONGER	4 HOURS LONGER
Median	Nil	£15	£82	£160
Mean	£69	£170	£527	£849

The mean costs start out at near £70 for the first 30 minutes, then increase their rate per minute, so that 60 minutes extra journey time is costed at £170, and 120 minutes at over £500, but the cost per minute then falls, giving £850 for 4 hours. The view was taken that the cost of delays, rather than a scheduled journey time increases, are being picked up. It may have been that respondents interpreted the word "scheduled" as implying that the trip would be rescheduled for that amount of time later, therefore resulting in late arrivals. Accordingly, the responses to this question were amended, inserting a minimum £16 per hour for firms engaged in moving traffic (in respect of driver's wages) and deleting all costs that would only apply to unscheduled time changes. There were so many of the former that they constituted the median, while the mean figures were much reduced. This is shown in Table 5.2.12. The figure of £16/hour is consistent with the figures in Table 9.15 of STAG 2012 (see Transport Scotland, 2012) for "Values of Time per Vehicle". Those figures are £13/hour for HGVs (there called OGVs) and £15.60 for LGVs, in 2010 values and prices, at market prices. Adjusting for forecast income growth (3.3%) and actual inflation (14.4%) over the 4 years to the time of the survey (as just one example of what might be done) raises those figures to £15.35/hour and £18.40/hour for HGVs and LGVs respectively. There is no one exact answer, but £16/hour is clearly a reasonable rough estimate.

Table 5.2.12 Amended Reported Costs Arising, for a Single Shipment, from Increases in the Scheduled Journey Time for the Typical Flow

	30 MINS LONGER	60 MINS LONGER	2 HOURS LONGER	4 HOURS LONGER
Median	£8	£16	£32	£64
Mean	£11	£21	£37	£78

Table 5.2.13 looks not at scheduled time increases but at unscheduled ones, i.e. unexpected lateness. Two main influences are at play. Firstly, as the delay is unexpected, some contingency expenditures may need to be made on all days (even when there happen to be no delays) in order to manage efficiently on days when such delays do occur. Secondly, since delays, as was seen in Table 5.2.8, do not occur on

all days, the delay cost averaged over all shipments will be much less than for a single late shipment. That said, the results in Table 5.2.13 are something of a puzzle. Even more firms can find no costs arising from occasional lateness, presumably thinking that their Road Hauliers have built in some allowance for delay costs and will not be raising their charges in the light of increased delay. In any event, the Median figures are very small. The Mean costs follow those for extra scheduled delay (Table 5.2.11) closely, suggesting that respondents would deal with both forms of delay similarly. It should be noted that the sample mainly contained shippers, rather than receivers, so costs may have fallen elsewhere.

Table 5.2.13 Reported Costs Arising, for a Single Shipment, from Unscheduled Journey Time Increases, i.e. Unexpected Lateness, for the Typical Flow

	30 MINS LATE	60 MINS LATE	2 HOURS LATE	4 HOURS LATE
Median	Nil	£15	£112	£204
Mean	£82	£164	£541	£889

As discussed in relation to Tables 5.2.11 and 5.2.12, it was again felt appropriate to amend the data to impose a minimum £16 per hour cost for those (many) firms involved in carrying freight, as was done in deriving Table 5.2.12. The equivalent table for Unscheduled Journey Time increases is Table 5.2.14. The differences between Tables 5.2.13 and 5.2.14 are not large, so the amendment has had minimal impact in this case. The amendment was made principally to be consistent with Table 5.2.12 and the analysis provided for the case of Scheduled Journey Time changes.

Table 5.2.14 Amended Reported Costs Arising, for a Single Shipment, from Unscheduled Journey Time Increases, i.e. Unexpected Lateness, for the Typical Flow

	30 MINS LATE	60 MINS LATE	2 HOURS LATE	4 HOURS LATE
Median	£8	£23	£112	£204
Mean	£85	£170	£549	£866

From Table 5.2.14, the median figure of £23/hr of lateness will be used as a starting point for the calculation of the reliability ratio, RR. The STAG definition of RR for Road was given (in rewritten form) in section 4.1 as:

$$RR = (\text{Value of } \Delta\sigma_T) / (\text{Value of } \Delta T) = VOR / VOT$$

It was decided to work with medians as there were worries about some of the higher costs reported (egg. the vessel docking charges) which have raised the mean greatly above the median (which will have been little affected by outliers or mistakes in the data). The median Values of Time (VOT), for a one hour longer journey, are reported in Tables 5.2.11 and 5.2.12 as £15 and £16 respectively. The choice of which will make little difference, the latter being chosen. Table 5.2.8 gives the reported distribution of lateness, and it was noted that the standard deviation of the reported distribution of lateness was 3 hours (181.6 minutes). In order to estimate VOR, two extremes were considered. The first added a fixed amount of additional lateness to all arrival times in the distribution. This, obviously, left the σ_T unchanged. Secondly, all lateness amounts were increased in proportion. This had the disadvantage of leaving all on-time arrivals as still on-time. Following experimentation, it was decided to take a weighted average of these two extremes: roughly 25% fixed and 75% variable. Experiments included a 20 minute increase to lateness, which raised σ_T by 60 minutes, and a 60 minute increase to lateness, which raised σ_T by 180 minutes. In both cases the resulting distributions of lateness looked plausible. Having checked for a 'scale' effect, it was deduced that one minute of lateness increased SD of lateness by 3 minutes. Working with values per hour, it was concluded that an extra hour of SD of lateness was valued at the value of 20 minutes of lateness. Therefore, one third of the (median) value of 1 hour lateness (£23 in Table 5.2.14) is the value a standard deviation of lateness. Hence, RR can be calculated as follows:

$$RR = (23/3)/16 = 0.48$$

There are a number of important caveats that need to be stated. Firstly, only 18 firms provided data on their value of lateness, and that is too small a number to be more than indicative. Secondly, the Value of Time figure is probably somewhat too low, resulting from the decision to work with medians. It is still felt that the original mean value of 60 minutes reported in Table 5.2.11 as £170 is far too high, the revised figure (£21) reported in Table 5.2.12 is equally well based as the figure used (£16). Replacing £16 by £21 would reduce RR to 0.37, not that big a change.

In order to try to throw further light on this matter, and at the risk of working with even smaller samples, it was decided to investigate 'within observation' calculations (i.e. time distributions and valuations by respondent), from which means and medians could be taken, either for the whole sample or for subgroups. Due to sample size considerations, only two subgroups could be identified: Transporters (i.e. Own Account operators plus hauliers) and Others (ie. everyone else, mostly shippers not undertaking Own Account operations). It should be noted that results reported below are for all respondents in those groups answering the stated questions, rather than just those that answered *all* of the relevant questions for the calculations undertaken.

Table 5.2.15 presents a mixed picture regarding arrival times. Using the *median* figures (of the Mean and Standard Deviation of the individual arrival time distributions by respondent) gives typical movements arriving 14.5 minutes late with a standard deviation of 18.4 minutes (indicating a long tail). The two groups of respondents do not differ much, in that regard. Taking *mean* values (of mean and s.d.), however, shows average lateness at 42.1 minutes (consistent with Table 5.2.8), with a standard deviation of 75.9 minutes. Both figures are pulled up by the 'Transporters'. None of the standard deviation figures comes remotely close to the 3 hours, from Table 5.2.8, used above when calculating RR. The 3 hour figure arose because data from 4 firms reporting lots of 24 hour late arrivals was averaged to say all firms had some arrivals 24 hours late. Working with the distributions of individual firm data gives just 4 very high figures among 27. The remaining 23 dominate, so the SD is estimated at roughly 60 mins and 90 mins for the 2 groups, and at 76 minutes rather than 180 minutes for 'All Respondents'.

Table 5.2.15 Means and Standard Deviations of Current Arrival Times, Averaged over respondents (in minutes)

	TRANSPORTERS	OTHERS	ALL RESPONDENTS
MEAN			
Median	10.8	15.8	14.5
Mean	53.1	28.4	42.1
S.D.			
Median	18.4	21.0	18.4
Mean	89.4	59.1	75.9

Table 5.2.16 considers valuations for Scheduled and Unscheduled journey time increases, but only for 60 minutes, with valuations for other amounts of delay ignored. Starting with the median scheduled delay (VOT), it can be seen that the £16 assumed figures for drivers' wages dominates for Transporters, but 'zero' dominates for those who do not do transporting. The mean values, however, go the other way, indicating some high disutility of longer journey times by 'Others'.

Moving on to Unscheduled journey time increases (VOL), Transporters have much lower values than the Others. As was found for 'All Respondents' (repeated from Table 5.2.14), the Means are much higher than the medians. Following the reasoning given earlier for the calculation of the overall RR from the distribution of arrival times pooled over all respondents, VoR figures were obtained by dividing the VOL figures by 3.

Table 5.2.16 Reported Costs Arising, for a Single Shipment, from Scheduled & Unscheduled 60 Minute Journey Time Increases

	TRANSPORTERS	OTHERS	ALL RESPONDENTS
SCHEDULED (VOT)			
Median	£16	NIL	£16
Mean	£17	£35	£21
UNSCHEDULED (VOL)			
Median	£10	£125	£23
Mean	£69	£421	£170

Table 5.2.17 uses figures from Table 5.2.16 to derive RR values. As previously discussed, working with means gives very high values for RR, which cannot be said to derive directly from responses to the survey since implausibly high mean VOT figures were replaced. Had that not been done, the reported high values would have been avoided. There can therefore be no complaint about dropping the 'mean' estimates.

Table 5.2.17 Reliability Ratio (RR) Calculations, (based on the individual lateness distributions for each respondent)

	TRANSPORTERS	OTHERS	ALL RESPONDENTS
CALCULATION			
Median	(10/16)/3	(125/0)/3	(23/16)/3
Mean	(69/17)/3	(421/35)/3	(170/21)/3
ANSWER			
Median	0.21	Infinity	0.48
Mean	1.35	4.01	2.70

Turning to the ‘median’ estimates, there is the problem that the zero estimate for ‘Others’ VOT leads inevitably to an estimate of infinity for that RR. It was felt that the best course of action was to apply the relativity of ‘Others’ to ‘All’ RR values using means to the ‘All’ estimate using medians, i.e. 0.48*(4.01/2.7) = 0.71. The preferred RR estimates for Freight are therefore:

FIRMS CARRYING GOODS RR = 0.21
FIRMS JUST SHIPPING OR RECEIVING GOODS RR = 0.71
ALL FIRMS INVOLVED WITH FREIGHT MOVEMENTS RR = 0.48

These values fit well with the literature, see Table 4.4.1, where Carriers have been found to have very low values of RR, while Shippers have much higher values. Note that the overall “All Firms” result merely reflects the mix between the two sub-groups in the sample, and so has no particular significance. Presumably by pure chance, it is equal to the result for the whole sample when pooling over all respondents. Naturally, the previously stated caveats still apply. If more robust estimates are required, then a much larger sample would be necessary.

5.3 Results from the Non-Freight (NF) Survey

Table 5.3.1 shows how the 116 respondents to the Non-Freight (NF) Survey described their position within the organisation. Their descriptions were free-form, so there has been some grouping and simplification to arrive at the 16 categories listed. The most popular of those categories (with 26) was the one covering a myriad of types of “manager”, including some “senior” ones, but excluding General Managers (another 3), Financial (another 4) and Managing Directors (another 6). A surprisingly large number, 21, of respondents claimed to be Owners, Partners, or Proprietors. A further 16 described themselves as “Directors”, 2 as CEOs and 4 more as Chairpersons. The above accounts for 82 of the 116 respondents, without yet getting to the more technical and specialist grades. It is clear that the sort of respondents targeted have been reached.

Table 5.3.1 Respondent's Position Within the Company

POSITION IN COMPANY	NUMBER OF RESPONDENTS
Accountant/Tax Adviser	2
Business Analyst	3
CEO	2
Chairperson	4
Customer Advisor/Sales	5
Director	16
Doctor/Medic	2
Finance Manager/Cashier	4
General Manager	3
Managing Director	6
Manager (Other)	26
Owner/Partner/Proprietor	21
Supervisor	7
Team Leader	2
Technical/Analyst/Contractor	7
Other	6
TOTAL	**116**

Table 5.3.2 shows the reported company location for the respondents. There is a good coverage of all parts of Scotland. There is certainly no shortage of respondents in the north of the country. Compared to the Freight Survey, the Edinburgh area response has overtaken that from the Glasgow area, with both being substantial. Where responses lie between those places named in a given category they are not necessarily reported in the table. The descriptions should therefore be taken as areas, rather than a full list of places mentioned. Surprisingly, there were 7 responses from England and one each from continental Europe and the USA. These have been left these in the analyses reported below.

Table 5.3.2 Non-Freight Survey Respondents by Location

NEAREST CITY/TOWN	NUMBER OF RESPONDENTS	CODE
Inverness/Elgin/Golspie/Fort William/Skye/Oban	16	IN
Aberdeen/Inverurie/Dyce/Fraserburgh	19	AB
Tayside: Dundee/Arbroath/Perth/Pitlochry	6	TY
Central: Stirling/Livingston/Falkirk	7	CE
Glasgow/Motherwell/Greenock	21	GL
Edinburgh/Dunfermline/Inverkeithing	27	ED
South West: Ayr/Irvine/Dumfries/Stewarton	7	AY
Other: Nationwide/Outside Scotland/No Answer	13	OT
TOTAL	**116**	

Table 5.3.3 shows the spread of responses by (self-selected) sector. It had been hoped to recruit more from the Life Sciences and Creative sectors, but it proved necessary to pool over headings to get groups large enough for cross-tabulations. The largest group of respondents classified their firms as ‘Services’, with ‘Financial’ coming second. There were insufficient ‘Food & Drink’ to separate them from ‘Retail’. Another 12 respondents represented some form of ‘Government’. By combining ‘Tourism’ with ‘Ferries’ a group of 10 was obtained. Similarly, by combining ‘Energy’ with ‘Forestry’ gave obtained a group of 8. Other sectors were straightforward.

Table 5.3.3 Non-Freight Survey Respondents by Sector

SECTOR DESCRIPTION	NUMBER OF RESPONDENTS	CODE
Construction	8	C
Digital, Creative, Telecoms	9	D
Energy and Forestry	8	E
Financial and Business Services	18	F
Government	12	G
Life Sciences, Medical, Veterinary, Academic and Training	7	L
Manufacturing	8	M
Food, Drink and General Retail	12	R
Services	24	S
Tourism and Ferries	10	T
TOTAL	**116**	

The results by considering impressions of reliability change are considered first. The general order will be to cross-tabulate by location first and then by company sector. Table 5.3.4 shows the overall result, and the results by location. Overall, 41% of respondents feel that roads have become less reliable, with an equal number noticing no difference. 15% thought roads were becoming more reliable, and 5% expressed no opinion. Trying to interpret those figures by looking by area, it was seen that those in the north (Aberdeen and Inverness areas) drove that result, along with the ‘Other’ location category. For the bulk of Scotland, only about 20% to 30% felt that reliability was getting worse, with 22% feeling that roads were getting more reliable. That last figure is, though, heavily driven by the 48% reporting that in the Glasgow area.

Table 5.3.4 Perceived Change in Reliability of Travel Times on the Scottish Trunk Road Network in the Last 5 Years by Location (NF Survey)

SECTOR	LESS RELIABLE	THE SAME	MORE RELIABLE	DON'T KNOW	TOTAL RESPONSES
AB	74%	21%	0%	5%	**19**
AY	29%	43%	29%	0%	**7**
CE	29%	57%	0%	14%	**7**
ED	22%	63%	7%	7%	**27**
GL	29%	24%	48%	0%	**21**
IN	44%	44%	13%	0%	**16**
OT	69%	31%	0%	0%	**13**
TY	17%	50%	17%	17%	**6**
TOTAL RESPONSES	**47**	**47**	**17**	**5**	**116**
%	**41%**	**41%**	**15%**	**4%**	

Table 5.3.5 looks at reliability as seen by the different sectors. The Tourism/Ferries sector reports no deterioration in reliability. For Manufacturing, also, the percentage saying more reliable outweighs those saying less reliable. The Financial sector, on the other hand, is heavily of the view that reliability has got worse.

Table 5.3.6 reports responses regarding actual impacts on companies of trunk road unreliability in the last year. The only impact to have affected more than half of respondents was difficulty with staff travel. By contrast, only 10% of respondents reported any difficulty in attracting customers in this regard. Roughly 30% of respondents reported the remaining four impacts (Reduced productivity/Sales; Additional Transport Costs; Delays to Time-Critical Deliveries; and Additional Staff Costs).

Table 5.3.5 Perceived Change in Reliability of Travel Times on the Scottish Trunk Road Network in the Last 5 Years by Sector (NF Survey)

SECTOR	LESS RELIABLE	THE SAME	MORE RELIABLE	DON'T KNOW	TOTAL RESPONSES
D – Digital etc.	38%	38%	25%	0%	8
E – Energy/Forestry	56%	22%	22%	0%	9
F – Financial	88%	13%	0%	0%	8
R – Retail/Food/Drink	28%	44%	11%	17%	18
L – Life Sciences etc.	42%	58%	0%	0%	12
T – Tourism/Ferries	0%	75%	25%	0%	8
C – Construction	50%	50%	0%	0%	8
M – Manufacturing	25%	25%	33%	17%	12
S – Services	52%	30%	17%	0%	23
G – Government	30%	60%	10%	0%	10
TOTAL RESPONSES	**47**	**47**	**17**	**5**	**116**
%	**41%**	**41%**	**15%**	**4%**	

Table 5.3.6 Reliability Impacts over the last year (NF Survey)

IMPACT	NO	YES	NO REPLY
Reduced Productivity/Sales	86	28	2
Additional Transport Costs	75	38	3
Delays to time-critical Deliveries	86	27	3
Additional Staff Costs	81	33	2
Difficulty in Attracting Customers	100	12	4
Difficulties with Staff Travel (on business, and commuting)	46	69	1

Respondents were asked if there were particular causes for the trunk road unreliability affecting their company, but there were not many responses and few that came up more than once (indicated here with grouped frequency in brackets). Reasons mentioned were:

- Badly planned road works (2);
- Lack of motorways north of Glasgow;
- Inadequate planning for weather/accidents/flooding (3);
- Lack of maintenance, potholes, drainage (3);
- Lack of investment (3);
- Unnecessarily low speed limits;
- Badly timed traffic lights.

Respondents were also asked to give examples of a journey where there had been a problem with unreliability, and that elicited a wider range of concerns, but expressed in a way very specific to the journey in question, and therefore not suitable for listing (egg. the closure of a particular road following a fatality; and "Amounts of Traffic at 1500 on a Thursday during the school holidays"). Table 5.3.7, however, reports average ratings of the scale of various impacts on trunk road reliability, together with a break down by location.

As can be seen from Table 5.3.7, the chief impacts on reliability are felt to be the concentration of traffic at particular times and roads being insufficiently large to cope. Road works came in third place, with the remainder only being awarded "half marks". By location, road design received the highest rating in the Inverness area. That area, ignoring 'Others', also gave the highest rating to road size; with Glasgow giving it the lowest rating.

Concentration of traffic at particular times was felt to be particularly impactful in the Aberdeen area, but not a great worry in the South West and the Inverness area. Road works were particularly blamed in Edinburgh and Tayside (and Others). The weather did not appear to have been much of a problem, the previous 12 months having been unusually clement in Scotland. Accidents were felt to have particular impact in the Inverness area, but received in Edinburgh the lowest rating in the whole table.

Table 5.3.7 Ratings (out of 10, with greater impacts given higher ratings) of the Scale of Various Impacts on Unreliability, by Location. (NF Survey)

IMPACT	AB	AY	CE	ED	GL	IN	TY	OT	ALL
Road Design	5.5	4.1	4.9	4.7	4.3	6.6	4.2	6.5	5.2
Roads not large enough	7.6	6.0	7.1	7.0	5.6	8.1	6.8	8.8	7.1
Traffic concentrated at particular times	8.4	5.6	7.6	7.5	7.0	5.4	7.7	7.3	7.1
Road works	6.2	5.9	6.1	6.8	5.6	6.4	6.7	7.4	6.4
Weather	4.8	5.1	5.1	4.7	4.6	5.3	5.0	4.6	4.8
Accidents	4.5	4.4	5.1	4.0	5.1	6.7	5.2	4.8	4.9

Table 5.3.8 Ratings (out of 10, with greater impacts given higher ratings) of the Scale of Various Impacts on Unreliability, by Sector (NF Survey)

IMPACT	C	D	E	F	G	L	M	R	S	T
Road Design	4.0	5.6	6.0	3.7	5.2	6.8	5.3	6.0	5.0	5.2
Roads not large enough	7.5	5.7	9.3	5.8	6.3	6.8	9.4	7.3	7.5	7.3
Traffic concentrated at particular times	7.6	5.8	7.5	7.6	7.8	6.8	8.1	6.1	7.4	6.4
Road works	5.8	6.7	5.6	6.0	7.0	6.3	6.6	6.3	6.4	7.5
Weather	5.3	4.0	5.6	3.9	5.6	5.1	4.3	4.3	5.0	6.0
Accidents	5.1	5.0	4.4	4.2	5.3	6.4	4.0	3.9	5.3	5.6

Ratings of impacts by sector are shown in Table 5.3.8. Starting with Construction (C), they highly rate traffic concentration and road size, but not road design. Digital etc. (D) rate road works highest, but not weather. Energy/Forestry (E) rate size of roads very highly, but accidents lowly. Financial (F) rate traffic concentration highest, and accidents lowest. Government (G) also rate traffic concentration highest, but with both road design and accidents lowly rated. Life Sciences etc. (L) rate everything very closely, except a low rating for weather. Manufacturing (M) give the highest rating in the whole table, and that goes to road size. Conversely, they give accidents and weather particularly low ratings. Retail, Food & Drink (R) rate road size highest, and accidents lowest. Services (S) rate road size and traffic concentration highest, with accidents and road design lowest. For Tourism (T) it is road works and road size that have the largest impact, with road design rated lowly.

Table 5.3.9 gives some insight into respondents' need for access to certain groups of people. Asked to provide a rating going up to 10 for most important, respondents declared that access to Customers came highest with a median rating of 8, and mean rating of 6.7. Access to a skilled work force was close behind with median 7 and mean 6.0, whilst access to suppliers was deemed relatively unimportant with a median of just 5 and a mean of 5.3.

Table 5.3.9 Importance of Access to Various Groups (NF Survey)

IMPORTANCE FOR BUSINESS	MEDIAN RATING OUT OF A MAXIMUM OF 10	MEAN RATING OUT OF 10
Access to Customers	8	6.7
Access to Suppliers	5	5.3
Access to Skilled Work Force	7	6.0

Table 5.3.10 disaggregates these importance ratings by location. Naturally, the variations in the figures will be largely driven by the range of industries forming the sample in the various areas. Access to customers is most important in the Tayside and Inverness areas, and relatively unimportant in Edinburgh, the South West and Central areas. Access to suppliers was most important in the Inverness and Aberdeen areas, but very lowly rated in the South West. Access to a skilled workforce was most important in the Aberdeen area, and least important in the South West.

Table 5.3.10 Importance of Access to Various Groups, by Location (NF Survey). Ten is most important.

IMPORTANCE	AB	AY	CE	ED	GL	IN	TY	OT	ALL
Access to Customers	7.1	5.3	5.1	5.5	6.2	8.2	8.6	8.2	6.7
Access to Suppliers	6.4	2.3	5.0	4.7	5.1	6.9	5.0	5.7	5.3
Access to Skilled Work Force	7.1	2.7	5.6	5.5	6.4	6.3	5.6	6.8	6.0

Table 5.3.11 gets to grips with the differences by sector. Access to customers was most important in the Life Sciences etc. sector and the Tourism/Ferries sector. It was also important in the Digital etc. and Services sectors. Those four sectors do seem the most likely to need access to customers. Possibly surprisingly, though, it was least important for the Manufacturing sector. Access to suppliers was most important in the Retail/Food&Drink sector, which seems sensible. It was least important for the Life Sciences etc. sector, which again seems sensible. Other sectors expressing low importance for access to suppliers were: Services; Government; and Financial. Access to a skilled workforce was most important for the Energy/Forestry sector, and also relatively important for the Digital etc. and Financial sectors. It was least important for the retail etc. and Tourism/Ferries sectors.

Table 5.3.11 Importance of Access to Various Groups, by Sector (NF Survey). Ten is most important.

IMPORTANCE	C	D	E	F	G	L	M	R	S	T
Access to Customers	6.6	7.4	5.9	5.9	6.0	8.4	4.5	6.8	7.3	8.1
Access to Suppliers	6.1	5.6	6.7	4.9	4.6	3.1	5.4	7.4	4.4	6.7
Access to Skilled Work Force	4.9	7.3	8.4	7.0	6.2	5.1	6.3	4.4	5.9	4.2

Table 5.3.12 provides added detail on why firms would like to see Scottish trunk road reliability improved. Respondents were asked to choose the 5 most important impacts, from the list of 9 shown in the table, and rank them 1 (for most important) to 5 (for least important). There were many non-responses, and lots of cases where the response was not the expected 5 digits 1 to 5 spread over the 9 columns. It was virtually the last question and fatigue may have set in. Making the best of what there is, by cleaning and averaging the responses, the table presents a composite ranking. In that ranking, 1 denotes the impact the respondents seemed to feel was most important, down to 9 for least important. The two most important appear to be “Access to Customers” and Productivity, in that order. Not far behind were Transport Costs. Then there is a big gap back to “Attractiveness of area” in 4th place, followed by “Staff Recruitment” and “Access to Suppliers”. By far the worst ranked was “Exports” though, as that was the last in the list presented, it may just be that respondents had used their 1 to 5 by then.

Table 5.3.12 Perceived most important reasons to improve reliability, ranked here from 1 for most important down to 9 for least. (NF Survey)

IMPACT	IMPORTANCE RANKING
Attractiveness of area	4
Productivity	2
Access to Suppliers	6
Staff Recruitment	5
Access to Customers	1
Transport Costs	3
Links between firm's locations	7
Business Confidence	8
Exports	9

Table 5.3.13 provides detail by location. Here the individual rankings from 1 down to 5 have been averaged, together with '6' used for all unranked reasons. A low score, therefore, indicates that the stated reason has been deemed important. Improving the attractiveness of the area is felt to be important in Glasgow and Tayside and, to a lesser extent in the Aberdeen, Edinburgh and Inverness areas. Enhancing productivity was a very important reason in the Aberdeen area, and was important everywhere except Tayside. Better access to suppliers was an important reason in Glasgow, and borderline important in the Aberdeen and Inverness areas. It was judged unimportant in the Tayside and Central areas. Better staff recruitment was felt an important reason in Glasgow, and borderline important in the Aberdeen, Central and Edinburgh areas. It was felt unimportant in the Inverness area. Better access to customers was an extremely important reason in Tayside, and very important in the Central and (to a lesser extent) South West areas. It was important in all other areas. Improved transport costs were important in all areas. Linking firms' locations was only important in the Central area. It was deemed unimportant in the South West and Inverness areas. Improving business confidence was only important in the South West. Helping with exports was nowhere important, and in the South West was awarded the 'perfect 6', i.e. totally unimportant.

Table 5.3.13 Averaged Rankings of Reasons to Improve Reliability (ranked from 1 for most important down to 5, with all unranked being given 6; hence a low score means important), by Location. (NF Survey)

IMPACT	AB	AY	CE	ED	GL	IN	TY	OT	ALL
Attractiveness of area	3.8	4.7	4.3	3.8	3.5	3.9	3.6	4.4	3.9
Productivity	2.6	3.8	3.9	3.0	3.2	3.5	4.6	3.4	3.3
Access to Suppliers	3.9	4.5	5.1	4.2	3.6	3.9	5.0	4.2	4.1
Staff Recruitment	3.8	5.3	3.9	3.9	3.1	5.1	4.2	4.4	4.0
Access to Customers	3.9	2.8	2.1	3.4	3.2	3.3	1.4	3.2	3.2
Transport Costs	3.5	3.0	3.7	3.4	3.4	3.5	3.6	3.0	3.4
Links between firm's locations	4.4	5.2	3.7	4.0	4.2	5.2	4.4	3.4	4.2
Business Confidence	4.6	3.8	4.9	4.4	4.0	4.4	4.2	4.4	4.3
Exports	4.9	6.0	5.0	5.2	4.1	5.0	5.8	4.5	4.9

Table 5.3.14 looks at the responses by sector. Improving the attractiveness of the area was important for the Financial sector and Tourism/Ferries sector, and less so for the Digital etc., Life Sciences etc., and Manufacturing sectors. Improving productivity was a very important reason in the Energy/Forestry and Services sectors, and was important in all other sectors than Tourism/Ferries. Improved access to suppliers was important in the Creative, Digital and Retail sectors. Better staff recruitment was a very important reason in the Manufacturing sector, and important for the Financial sector. Improved access to customers was particularly important in the Life Sciences etc. and Retail sectors, and also very important in most other sectors. Improved transport costs were a very important reason in the Construction and retail sectors, and important in most other sectors. Links between firms' locations were never judged as an important reason. Improving business confidence was very important in the Life Sciences etc. sector, and important in the Financial sector. Finally, help for exports was never judged an important reason.

Table 5.3.14 Averaged Rankings of Reasons to Improve Reliability (ranked from 1 for most important down to 5, with all unranked being given 6; hence a low score means important), by Sector (NF Survey)

IMPACT	C	D	E	F	G	L	M	R	S	T
Attractiveness of area	4.6	3.7	4.9	3.1	4.2	3.7	3.7	4.1	4.1	3.3
Productivity	3.7	3.3	2.7	3.1	3.5	3.5	3.7	3.6	2.6	4.1
Access to Suppliers	3.4	3.3	3.9	4.5	5.2	4.3	4.7	3.3	4.0	4.3
Staff Recruitment	4.9	3.9	4.1	3.0	4.5	3.8	2.5	5.1	3.8	5.2
Access to Customers	3.0	3.0	4.9	3.5	3.2	2.3	4.0	2.3	2.9	3.1
Transport Costs	2.7	3.6	3.7	4.1	3.5	3.7	3.0	2.4	3.2	3.5
Links between firm's locations	3.9	4.6	4.6	4.1	4.4	4.7	4.2	3.9	4.2	4.2
Business Confidence	4.6	4.2	5.0	3.4	4.8	2.7	4.8	4.8	4.6	4.6
Exports	5.8	4.7	5.0	4.3	4.7	4.2	5.2	4.9	4.9	5.7

Finally, the responses to two interesting questions are reported. Firstly, respondents were asked for a “guesstimate” of the value to their company from improvements that would make the road network totally predictable and reliable. This was envisaged as giving an upper bound on the value of reliability to users. Only 23 respondents felt able to provide a numerical estimate, of which 6 replied zero. The median response was £3000, which seems plausible, while the mean (£485,000) was clearly swayed by two responses of £5 million.

Secondly, respondents were asked to estimate the travel time for one day in 5, where the remaining 4 were all “as now”, that would make that set of 5 journeys equally desirable to a set of 5 days where travel time was always 10 minutes longer than now. This is a somewhat complex question, and it was pleasing when the pilot respondents were able to provide responses. Essentially, there are two situations: in the first there is travel time variability; in the second there is no travel time variability but 4 out of 5 journeys will take longer than now (i.e. currently). The Median response was 30 minutes, and the Mean response was 35 minutes. It was preferred to work with the median as it excludes outliers, who may not have properly understood the question.

Denote the current travel time as T, the value of a minute of standard deviation of travel times by VOR, standing for value of reliability, and the value of a minute of travel time as VOT. The standard deviation of option 2 is zero, as travel time is (T+10) minutes each day. Then denote the standard deviation of option 1 by S, and the travel time reported for the 5th day by (T+X). Working in minutes gives:

OPTION 1:	(T, T, T, T, T+X)	TIME1 = 5T+X	SD1 = S
OPTION 2:	(T+10, T+10, T+10, T+10, T+10)	TIME2 = 5T+50	SD2 = 0

It is known, by design, that the two options are equally valued, so we have *per day*:

(VOT)(T+X/5) + (VOR)(S) = (VOT)(T+10) + (VOR)(0)

whence (VOT)(10 – X/5) = (VOR)S

The reliability ratio, RR, was defined in Section 4 as

RR = (VOR)/(VOT)

which here gives

RR = S/(10 – 0.2X)

Essentially, some extra travel time, (10 – 0.2X), is being accepted in return for avoiding the unreliability, measured by standard deviation, resulting from the travel time being X minutes one time in 5 and zero otherwise. If the unreliability was zero valued, respondents would just judge on travel times, and report an X value of 50 minutes. RR would then be zero. Both options would take 50 minutes for the 5 days, and it would not matter how the travel times were distributed over the 5 days. Hence, reported X values should be below 50. There were actually 16 above 50, those respondents presumably having misunderstood the question. By working with the median, these large values will just be treated as a value above the median (and the magnitude ignored).

The median response was X = 30, so S = sd(T, T, T, T, T+30) = 13.42,

RR = (10 – 6)/13.42 = 0.3

This value is at the bottom end of values found in the literature, suggesting that reliability is valued less likely by the company respondents in Scotland than by the respondents to earlier surveys.

6. Results from automatic data capture

A requirement of the study was to investigate the data on journey time reliability available within Transport and Traffic Scotland and other potentially useful data on transport time reliability. A key issue here is whether these data are sufficient for the development of empirical models that can predict travel time reliability and that can be integrated into the existing large-scale traffic model systems. As found in the literature from empirical studies (among others, in the US and the Netherlands – see Mahmassani, 2011, and de Jong and Bliemer, 2015), there seems to be a near-linear relationship between the route travel time standard deviation and the route travel time divided by the route distance. In other words, the route standard deviation is a (near) linear function of the inverse of the average speed on the route. Other researchers (e.g. in England and Sweden – see Bates et al, 2001, and Eliasson, 2004) have found a different time-based specification with the relative standard deviation as a function of the congestion index (the ratio of actual travel time to free-flow travel time). The study first looked into what data was available.

A “Congestion Data Report 2006”, produced in 2008 for TS, was inspected. This report used data taken from automatic traffic counters located at fixed monitoring sites throughout the Scottish trunk road network. The counters provide data on traffic volumes and speeds, both broken down by vehicle type, in 15 minute intervals (or bins). This point data was scaled to particular road sections using “Floating Vehicle” or “Moving Observer” surveys. Such surveys are conducted by driving a vehicle along the section of road concerned, noting the number of times other vehicles (of that type) overtake, or are overtaken. About 260 trips were made at each site. Various measures of Journey Time Reliability were produced. The report itself gave no data usable in the present study, but helped point to the sort of data available.

The study inspected some Moving Observer studies of journey times, but these appeared to be very limited. Even as many as 260 trips at a given site reduces to small numbers when split over months of the year, days of the week, and times of day. With 12 months in the year, 7 days in the week, and four periods within each day, 336 trips would be required just to get one observation in each cell. Each vehicle needs a Driver and Observer, and so the method is expensive even for low levels of statistical accuracy. The method might have some applicability if used in connection with data from automatic traffic count sites, such as was done in the Congestion Data Report. In any event, other data appeared to be insufficient to meet the needs of the study.

Preliminary investigation of speed data obtained automatically from fixed road sites suggested there might be a good spread of such sites by region and road type. Further enquiries found that while data was routinely extracted in one hour bins, and could easily be made available to the study, there was an alternative of obtaining data in 15 minute bins, but with a non-trivial cost. Both these alternatives looked poor. The 60 minute bins would water down any peak effects, which might occur for 10 minutes either side of the hour, for example. The 15 minute bins proved too costly for the study. A third option emerged, that of using Vehicle by Vehicle (VBV) data, and specifying the bin width. This had obvious merits, though it imposed a severe data extraction burden on expert Transport Scotland staff. This extraction proved to be very time consuming, so the study extremely grateful for the efforts made to extract as much data as they could for the study.

At the time of briefing on this data source, 1791 ATC sites were stated as producing reliable data. Such data goes back to about 2002. Of those sites, 1441 were stated to have speed data available, and 511 sites had VBV data availability. After consulting interested parties within Transport Scotland, data for 38 sites was requested, giving a good coverage both geographically and by road type. Not all had usable data and there was a limit to the time available (both 'input' and 'elapsed') for extraction, so that the study actually received data for only 31 sites, but that was judged adequate.

Several problems arose. The data collection systems clearly came in several forms. The processed data, which was relatively well documented, had clearly used different coding conventions to the extracted raw data. This extracted data came in 4 different formats for which the study had to document, and probably another 2 which were never properly understood. For some sites a high proportion of vehicles could not be classified due to their code falling outside of the notified ranges. It was decided to exclude "Cycles", but otherwise all vehicles have been included as ALL. Those with appropriate codes have been classified as either CARS or HEAVIES. In at least one case the average speed of the HEAVIES is over 100 kph, and little lower than that for CARS, suggesting that the classification has not worked correctly at that site. Nevertheless, this site has been kept in the analysis, as have the few oddities encountered. To have done otherwise would have been ad-hocery, and might have given a misleading impression regarding how well behaved the data is. Data for quite a few of the months is missing, and this has been dealt with differently according to circumstance.

It was decided to aggregate the data into 10 minute bins, partly to be different and partly to see if the data would stand that. The original data files were very large, are even the reduced data set had entries for a potential 6x24 = 144 ten minute bins; for 3 vehicle types (ALL, CARS, & HEAVIES); for the 12 months of 2013, for 31 sites. That gives some 160,000 rows. On each row the records show the 10 minute bin, the number of vehicles observed, and the average speed of vehicles.

The initial inclination was to take the average speed for a quiet period (03.00 to 05.00 was chosen) as a proxy for the free-flow speed. That speed was then divided into the average speed for 08.00 to 08.10, to try to get a measure of the speed reduction in the peak. However, about half the values returned were greater than unity, suggesting that 08.00 to 08.10 was not a peak on that road – indeed it was often very quiet at that time! As the data was mostly two-directional, it had been expected that there would be a speed reduction at 08.00 in at least one direction big enough to give a ratio below unity. Since it appeared that conditions varied from site to site, no better times (than 08.00 to 08.10) for use in this method could be identified, and so the approach was dropped. Instead, the rather simplistic approach of taking the ratio of the lowest speed to highest speed over all available 10 minute periods was adopted. There seemed to be no problem with the highest speed calculations, but some of the lowest speed calculations were very low indeed, suggesting particular incidents affecting the traffic. This is a potential problem of outliers affecting the results, for this approach. However, there did not seem to be many obvious cases of this, and any severe incidents may have affected several 10 minute periods, so just excluding the lowest speed was not expected to make much difference.

Alternative methods would have been to take the ratio of the lower quartile speed, the mean speed, or the median speed, to the highest speed. All of those, though, would have muffled the observed variability in the ratios, which was not that great to begin with. Trunk roads often have sufficient capacity that any increases in traffic at particular times have little effect on average speeds then. Indeed, at busy times drivers may feel impelled to keep up with other vehicles, while at quiet times they may dawdle at their own preferred speed. On trunk roads in built-up areas, the speed limit may also limit the degree of variability of speeds over 10 minute intervals.

On average, over the 31 sites, the data indicates that 10 minute average speeds fall by about 35% from the fastest to slowest. That degree of variability seemed sufficient to analyse, but not so large that it became desirable to replace the “slowest” with one of the alternatives just listed. To have chosen to work with ratios of highest to mean or median might reasonably have been expected to reduce the average fall in speeds to about 20%, with consequent increased difficulty in separating signal from noise.

Table 6.1 presents the results for the ratios of minimum speed to maximum speed, for CARS. The 31 sites are listed in the first 4 columns, showing: their reference number (so that readers can cross check with other sources); the road number; a brief description of where the location is; and an indicator where only one lane is involved (Northbound or Southbound). Then there are columns for each month of 2013, showing: the ratios, their mean; their median; the rank of each, followed by a judgemental rank; and finally a grouping of months based on their ranks. The final 5 columns give similar averages, ranks and grades, but this time for the individual sites. The Grand Mean is shown as 0.64 and the Grand Median as 0.65, but these are of no particular significance since the sample of roads is neither random nor representative of all Scottish Trunk Roads.

Beginning by looking at the results by month, it can be seen that there is surprisingly little variability in the means or medians of the ratios – all lying between 0.59 and 0.69. It must be remembered that there is noise in the data, but surely not sufficient to account for this lack of variability. Perhaps surprisingly, March shows the smallest amount of travel time variability on average. As it is usually the 8th of March that is taken, this cannot be due to Easter, nor half term. Second best is August, when the weather is good (relatively) and Schools and Universities are not in term. When the missing observations are replaced by their row means, October to December remain the worst 3 months, so that result is not driven by the data gaps. These ‘INFILL’ results may not be at all correct, since the unobserved data may actually have followed the trend of the observed data, rather than being at the site average. Accordingly, it is preferred to keep with the results shown in Table 6.1.

Turning to the results by site, filling in the blanks with the row means obviously has no effect on the row means, and little effect on row medians, and so Table 6.1 can be taken at face value. The ‘good’ roads (for journey time variability) are: A90, Forfar; M73, Gartcosh; M9, near jn 10; and M876, Bonnybridge; i.e. mostly motorways. The worst motorway was the M80, at Haggs. The spread of mean ratios over the sites was much greater than over months, suggesting that ‘noise’ in the data is not a great problem. On the best road, the ratio only falls to 0.86 at any time during the day, i.e. peak speeds are only 14% less than free-flow speeds. The worst road for reliability, ranked 31 both on mean and median, was the A90, Ferrytoll. Thus, the A90 was both the best and the worst, at different places. One explanation for the ‘worst’ result might be that traffic was only recorded in the southbound direction, so the opportunity (at most other sites) to average out peak direction slowness with contra-peak normal running was not available. Even so, the average ratio of worst 10 minute speed to free-flow speed, for this site, was only 0.37, i.e. not much more than a third. It is, of course, possible that the data is unreliable for some reason. Without knowing the 31 sites more intimately, it would not be sensible here to speculate further on what might be going on.

Table 6.2 repeats the analysis of Table 6.1, but for HEAVIES rather than CARS. HEAVIES are everything not included in CARS that were neither coded as a cycle, or given an ambiguous code. Buses and coaches are certainly included. As previously remarked, the study may have inadvertently included too much in HEAVIES due to failing to adequately understand the multiplicity of undocumented coding schemes relating to the (prized) raw data. Any future work with this raw data would need to take extra care, and seek to rigorously document the vehicle type codings. Looking at the results, it can be seen that the average fall of speeds (from the free-flow speed) is over 40%, noticeably higher than for CARS. That was unexpected, as many heavies have a lower maximum legally permitted speed than cars. However, that is what the data says, consistently over most sites and all months.

Starting with the results by month, perhaps not surprisingly the ordering is very similar to that for CARS. However, this time March stays the ‘best’ month (i.e. least reduction from free-flow speed on that day) even when the missing observations are infilled with their row means (not shown). Both methods agree that November and December are the worst months. October is very bad for CARS, but not for HEAVIES.

Table 6.1: Ratios of Minimum to Maximum Car Traffic Speeds: Cars

SITE	Road	Location	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	*MEAN*	*MEDIAN*
108370	A82	CRIANLARICH	0.48			0.57	0.53	0.61	0.59	0.35	0.68	0.51	0.56		*0.54*	*0.56*
113120	M8	HARTHILL	0.67	0.57	0.78	0.81	0.83	0.80	0.76	0.75					*0.75*	*0.77*
115322	A75	CASTLE DOUGLAS	0.64	0.68	0.70	0.63	0.60				0.59	0.68			*0.65*	*0.64*
122402	A90	FORFAR	0.71	0.75	0.78	0.87	0.89	0.81	0.82	0.84	0.76	0.89	0.73	0.82	*0.81*	*0.82*
130094	A68	JEDBURGH	0.67	0.40	0.59	0.63	0.69	0.55	0.26	0.55	0.54				*0.54*	*0.55*
136700	A73	AIRDRIE	0.75	0.70	0.62	0.70	0.75	0.63	0.72	0.74	0.71	0.69	0.72		*0.70*	*0.71*
183200	M73	GARTCOSH	0.86	0.85	0.82				0.90	0.87	0.85				*0.86*	*0.86*
185150	M898	ERSKINE BRIDGE	0.76	0.84	0.87	0.84	0.72	0.83	0.76	0.63	0.64	0.37	0.57	0.54	*0.70*	*0.74*
236265	A95	BOAT OF GARTEN	0.50	0.57	0.62	0.45	0.63	0.57	0.67	0.60	0.63	0.59			*0.58*	*0.60*
JTC00013	M9	S OF J10	0.80	0.80	0.81	0.85	0.87								*0.83*	*0.81*
JTC00050	M9	S OF A9 J, NEWBRIDGE, NTH	0.69	0.70	0.71	0.72	0.82	0.66	0.77	0.81	0.65	0.60	0.62	0.78	*0.71*	*0.71*
JTC00270	A8	BAILLIESTON LIGHTS - 200M	0.59	0.78	0.86	0.80	0.77	0.79	0.70	0.73	0.72	0.87	0.68	0.65	*0.75*	*0.75*
JTC00313	A9	AVIEMORE			0.77	0.60	0.51	0.59	0.68	0.64	0.62				*0.63*	*0.62*
JTC00366	A77	ARDWELL BAY, S OF GIRVAN	0.58	0.64	0.20	0.55	0.58	0.62	0.55	0.63	0.42	0.74	0.68	0.56	*0.56*	*0.58*
JTC00373	A702	S OF BIGGAR, N OF A72	0.60	0.63	0.52	0.46	0.40	0.58	0.57	0.69	0.58	0.67	0.69	0.59	*0.58*	*0.59*
JTC00378	A76	DUMFRIES, GLASGOW RD			0.76		0.73	0.83	0.74	0.66	0.46	0.74	0.71	0.44	*0.67*	*0.73*
JTC00523	A96	INVERURIE RD						0.45	0.58	0.71	0.53	0.46		0.44	*0.53*	*0.50*
JTC00534	A82	DUMBARTON, MILTON		0.92	0.80	0.74	0.76	0.78	0.72	0.88	0.73	0.91			*0.80*	*0.78*
JTC00536	A85	5.5KM W OF TYNDRUM			0.56	0.60	0.61	0.60	0.56	0.59	0.68	0.51	0.67	0.46	*0.58*	*0.60*
JTC00538	A78	FAIRLIE, MAIN RD	0.50	0.54	0.62	0.57	0.55	0.57	0.58	0.60	0.41	0.56	0.59	0.51	*0.55*	*0.57*
JTC00539	A737	DALRY, KILWINNING RD	0.65	0.46	0.58	0.59	0.67	0.55	0.60	0.68	0.56	0.62	0.60	0.62	*0.60*	*0.60*
JTC00573	A91	STIRLING BYPASS, S OF A907	0.64	0.66	0.57	0.67	0.45	0.68	0.68	0.67	0.64	0.66	0.64	0.66	*0.64*	*0.66*
JTC00604	A71	RICCARTON	0.64	0.68	0.68	0.69	0.50	0.71	0.69	0.74	0.64	0.61	0.34	0.64	*0.63*	*0.66*
JTC00614	M74	E OF J2, CAMBUSLANG, NTH	0.82	0.32	0.83	0.85	0.85	0.86	0.85	0.84	0.80	0.34	0.29	0.73	*0.70*	*0.83*
JTC00616	M80	E OF J7, HAGGS, NTH	0.31	0.66	0.77	0.52	0.42	0.78	0.67	0.81	0.65	0.43	0.40	0.73	*0.60*	*0.66*
JTC03031	A90	FERRYTOLL, STH						0.20	0.48	0.26	0.38	0.53	0.38		*0.37*	*0.38*
JTC08199	A7	LANGHOLM	0.45	0.64	0.64	0.71	0.71	0.78	0.64	0.64	0.74	0.77	0.64	0.48	*0.65*	*0.64*
JTC08216	A84	DOUNE	0.67	0.46	0.53	0.62	0.64	0.63	0.43	0.56	0.59	0.60	0.53	0.47	*0.56*	*0.58*
JTC08225	A9	DORNOCH	0.72	0.74	0.61	0.62	0.57	0.59	0.58	0.53	0.52	0.21	0.70	0.66	*0.59*	*0.60*
JTC08236	M876	BONNYBRIDGE	0.78	0.82	0.84	0.84	0.82	0.77	0.87	0.87	0.87	0.71	0.81	0.85	*0.82*	*0.83*
JTC08338	A83	W OF ARROCHAR	0.61	0.45	0.52	0.58	0.59	0.50	0.52	0.59	0.63	0.66	0.52	0.69	*0.57*	*0.59*
MEAN			*0.64*	*0.65*	*0.68*	*0.67*	*0.66*	*0.65*	*0.65*	*0.67*	*0.63*	*0.61*	*0.59*	*0.62*	**0.64**	
MEDIAN			*0.65*	*0.66*	*0.69*	*0.63*	*0.66*	*0.63*	*0.67*	*0.67*	*0.64*	*0.62*	*0.63*	*0.63*		**0.65**

Table 6.2: Ratios of Minimum to Maximum Car Traffic Speeds: Heavies

SITE	Road	Location	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	*MEAN*	*MEDIAN*
108370	A82	CRIANLARICH	0.54			0.61	0.47	0.52	0.64	0.50	0.54	0.69	0.54		*0.56*	*0.54*
113120	M8	HARTHILL	0.74	0.56	0.86	0.88	0.88	0.87	0.83	0.76					*0.80*	*0.85*
115322	A75	CASTLE DOUGLAS	0.68	0.72	0.70	0.64	0.74				0.65	0.77			*0.70*	*0.70*
122402	A90	FORFAR	0.74	0.73	0.69	0.74	0.83	0.85	0.56	0.80	0.82	0.75	0.74	0.83	*0.76*	*0.75*
130094	A68	JEDBURGH	0.48	0.58	0.45	0.51	0.52	0.35	0.06	0.47	0.59				*0.45*	*0.48*
136700	A73	AIRDRIE	0.58	0.54	0.69	0.53	0.72	0.55	0.66	0.63	0.51	0.59	0.58		*0.60*	*0.58*
183200	M73	GARTCOSH	0.90	0.88	0.90				0.89	0.75	0.87				*0.87*	*0.89*
185150	M898	ERSKINE BRIDGE	0.56	0.70	0.70	0.57	0.34	0.65	0.56	0.71	0.38	0.33	0.34	0.44	*0.52*	*0.56*
236265	A95	BOAT OF GARTEN	0.65	0.58	0.63	0.62	0.58	0.56	0.56	0.63	0.64	0.62			*0.61*	*0.62*
JTC00013	M9	S OF J10	0.80	0.88	0.85	0.82	0.87								*0.84*	*0.85*
JTC00050	M9	S OF A9 J, NEWBRIDGE, NTH	0.75	0.67	0.68	0.73	0.80	0.69	0.78	0.82	0.74	0.63	0.73	0.73	*0.73*	*0.73*
JTC00270	A8	BAILLIESTON LIGHTS - 200M	0.55	0.58	0.69	0.67	0.64	0.61	0.60	0.73	0.74	0.57	0.63	0.68	*0.64*	*0.64*
JTC00313	A9	AVIEMORE			0.72	0.77	0.68	0.76	0.68	0.68	0.75				*0.72*	*0.72*
JTC00366	A77	ARDWELL BAY, S OF GIRVAN	0.65	0.65	0.63	0.58	0.54	0.63	0.72	0.62	0.67	0.70	0.63	0.68	*0.64*	*0.64*
JTC00373	A702	S OF BIGGAR, N OF A72	0.50	0.57	0.59	0.40	0.39	0.51	0.54	0.68	0.48	0.49	0.59	0.49	*0.52*	*0.51*
JTC00378	A76	DUMFRIES, GLASGOW RD			0.68		0.55	0.56	0.71	0.57	0.33	0.72	0.64	0.42	*0.58*	*0.57*
JTC00523	A96	INVERURIE RD						0.31	0.52	0.60	0.58	0.30		0.36	*0.45*	*0.44*
JTC00534	A82	DUMBARTON, MILTON		0.61	0.79	0.52	0.72	0.37	0.76	0.80	0.60	0.75			*0.66*	*0.72*
JTC00536	A85	5.5KM W OF TYNDRUM			0.61	0.45	0.61	0.53	0.45	0.52	0.54	0.61	0.47	0.54	*0.53*	*0.54*
JTC00538	A78	FAIRLIE, MAIN RD	0.48	0.32	0.45	0.40	0.42	0.36	0.50	0.43	0.43	0.42	0.40	0.53	*0.43*	*0.43*
JTC00539	A737	DALRY, KILWINNING RD	0.53	0.53	0.62	0.36	0.57	0.50	0.48	0.56	0.55	0.56	0.48	0.50	*0.52*	*0.53*
JTC00573	A91	STIRLING BYPASS, S OF A907	0.50	0.59	0.43	0.57	0.59	0.66	0.35	0.56	0.46	0.64	0.51	0.61	*0.54*	*0.57*
JTC00604	A71	RICCARTON	0.37	0.46	0.41	0.28	0.37	0.51	0.37	0.45	0.42	0.51	0.30	0.53	*0.42*	*0.42*
JTC00614	M74	E OF J2, CAMBUSLANG, NTH	0.69	0.35	0.78	0.73	0.76	0.74	0.78	0.76	0.70	0.37	0.39	0.75	*0.65*	*0.74*
JTC00616	M80	E OF J7, HAGGS, NTH	0.36	0.72	0.82	0.49	0.44	0.75	0.69	0.78	0.72	0.41	0.41	0.70	*0.61*	*0.70*
JTC03031	A90	FERRYTOLL, STH						0.17	0.43	0.25	0.28	0.48	0.30		*0.32*	*0.29*
JTC08199	A7	LANGHOLM	0.43	0.43	0.59	0.56	0.40	0.63	0.48	0.57	0.62	0.69	0.41	0.63	*0.54*	*0.57*
JTC08216	A84	DOUNE	0.58	0.60	0.37	0.48	0.58	0.59	0.38	0.55	0.53	0.42	0.60	0.54	*0.52*	*0.55*
JTC08225	A9	DORNOCH	0.52	0.52	0.60	0.59	0.44	0.50	0.59	0.50	0.62	0.49	0.57	0.48	*0.54*	*0.52*
JTC08236	M876	BONNYBRIDGE	0.77	0.78	0.72	0.64	0.74	0.76	0.77	0.74	0.78	0.69	0.75	0.75	*0.74*	*0.75*
JTC08338	A83	W OF ARROCHAR	0.56	0.48	0.57	0.58	0.61	0.45	0.41	0.49	0.53	0.60	0.44	0.52	*0.52*	*0.53*
MEAN			*0.60*	*0.60*	*0.65*	*0.58*	*0.60*	*0.57*	*0.58*	*0.62*	*0.59*	*0.57*	*0.52*	*0.59*	**0.59**	
MEDIAN			*0.56*	*0.58*	*0.68*	*0.58*	*0.59*	*0.56*	*0.56*	*0.62*	*0.59*	*0.60*	*0.53*	*0.54*		**0.58**

Table 6.3: Mean Car Speeds

SITE	Road	Location	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	*MEAN*	*MEDIAN*
108370	A82	CRIANLARICH	91.1			87.4	86.1	85.6	86.1	83.4	86.2	87.2	86.3		*86.60*	*86.20*
113120	M8	HARTHILL	107.3	102.6	102.0	104.0	105.8	106.5	95.2	84.6					*101.00*	*103.30*
115322	A75	CASTLE DOUGLAS	88.2	88.8	87.8	87.4	88.6				88.9	88.8			*88.36*	*88.60*
122402	A90	FORFAR	107.9	108.0	107.0	108.9	108.5	109.5	109.7	109.2	109.0	109.4	107.9	106.7	*108.48*	*108.70*
130094	A68	JEDBURGH	49.7	50.1	50.3	50.8	49.9	49.9	42.9	49.7	50.0				*49.26*	*49.90*
136700	A73	AIRDRIE	62.9	61.7	62.0	62.5	63.7	63.2	64.4	63.0	62.7	63.6	62.3		*62.91*	*62.90*
183200	M73	GARTCOSH	104.7	104.3	102.0				107.2	105.2	103.7				*104.52*	*104.50*
185150	M898	ERSKINE BRIDGE	89.8	92.2	93.3	97.0	88.3	94.2	95.2	92.8	86.7	47.4	58.8	68.4	*83.68*	*91.00*
236265	A95	BOAT OF GARTEN	83.8	85.2	86.3	87.8	86.5	84.9	84.6	84.8	85.6	85.7			*85.52*	*85.40*
JTC00013	M9	S OF J10	108.9	109.1	109.5	108.8	109.6								*109.18*	*109.10*
JTC00050	M9	S OF A9 J, NEWBRIDGE, NTH	74.0	74.0	74.4	75.8	76.5	77.2	77.9	77.3	76.4	75.2	75.1	75.3	*75.76*	*75.55*
JTC00270	A8	BAILLIESTON LIGHTS - 200M	45.7	45.8	45.3	46.6	45.9	46.1	46.7	46.8	45.8	46.5	45.6	45.7	*46.04*	*45.85*
JTC00313	A9	AVIEMORE			58.7	59.3	59.8	58.8	58.8	57.6	58.6				*58.80*	*58.80*
JTC00366	A77	ARDWELL BAY, S OF GIRVAN	53.3	53.3	53.6	52.4	53.2	52.4	52.5	52.1	53.5	53.0	52.9	53.0	*52.93*	*53.00*
JTC00373	A702	S OF BIGGAR, N OF A72	38.6	38.0	38.1	37.8	36.8	38.9	38.8	38.3	38.2	38.9	38.4	38.7	*38.29*	*38.35*
JTC00378	A76	DUMFRIES, GLASGOW RD			30.6		30.9	30.1	31.3	30.6	29.9	29.6	30.4	30.1	*30.39*	*30.40*
JTC00523	A96	INVERURIE RD						82.0	85.7	84.8	84.2	79.3		81.4	*82.90*	*83.10*
JTC00534	A82	DUMBARTON, MILTON		38.1	37.0	38.2	38.4	38.0	37.6	37.5	37.3	37.4			*37.72*	*37.60*
JTC00536	A85	5.5KM W OF TYNDRUM			60.8	61.3	60.0	59.3	61.2	59.7	60.3	61.1	59.6	58.5	*60.18*	*60.15*
JTC00538	A78	FAIRLIE, MAIN RD	32.4	32.5	32.5	33.0	32.8	33.2	32.3	32.1	32.2	32.1	31.7	32.0	*32.40*	*32.35*
JTC00539	A737	DALRY, KILWINNING RD	30.0	26.7	30.1	30.4	29.9	29.8	30.2	29.8	29.6	29.4	29.3	29.2	*29.53*	*29.80*
JTC00573	A91	STIRLING BYPASS, S OF A907	82.5	83.0	84.4	83.8	82.9	83.5	84.4	83.5	84.4	84.2	83.2	82.7	*83.54*	*83.50*
JTC00604	A71	RICCARTON	66.9	67.2	67.5	68.8	66.3	68.6	69.9	68.4	68.7	68.1	64.7	67.4	*67.71*	*67.80*
JTC00614	M74	E OF J2, CAMBUSLANG, NTH	101.0	101.2	103.5	102.4	102.7	103.7	104.5	104.3	103.0	99.2	99.1	101.9	*102.21*	*102.55*
JTC00616	M80	E OF J7, HAGGS, NTH	94.4	105.4	109.2	104.5	104.0	110.1	110.2	109.8	108.6	104.8	101.7	105.3	*105.67*	*105.35*
JTC03031	A90	FERRYTOLL, STH						63.5	68.0	58.7	59.4	61.6	57.4		*61.43*	*60.50*
JTC08199	A7	LANGHOLM	61.8	62.9	64.3	64.0	64.4	63.7	64.2	64.1	63.0	64.9	61.5	62.5	*63.44*	*63.85*
JTC08216	A84	DOUNE	85.7	86.0	86.7	85.8	86.7	85.0	82.6	82.9	83.9	85.3	84.6	86.2	*85.12*	*85.50*
JTC08225	A9	DORNOCH	79.3	79.1	79.4	79.8	79.0	79.6	79.1	78.3	78.8	79.0	78.3	78.7	*79.03*	*79.05*
JTC08236	M876	BONNYBRIDGE	103.4	103.2	102.6	104.6	105.5	106.5	107.5	106.1	105.5	105.3	103.3	103.1	*104.72*	*104.95*
JTC08338	A83	W OF ARROCHAR	77.6	76.9	77.4	75.7	75.8	73.9	74.5	74.4	75.8	75.5	76.6	76.8	*75.91*	*75.80*
MEAN			*76.84*	*75.01*	*72.73*	*74.03*	*72.09*	*70.63*	*71.83*	*70.68*	*70.69*	*68.94*	*67.67*	*69.18*	**71.69**	
MEDIAN			*82.50*	*79.10*	*75.90*	*75.80*	*76.15*	*71.25*	*74.50*	*74.40*	*75.80*	*71.65*	*63.50*	*71.85*		**75.15**

Turning to the results for HEAVIES by site, Table 6.2 clearly shows the M73 at Gartcosh as having the smallest speed reduction relative to free-flow, at less than 10%. However, only 6 months are observed, including the ‘best’ (March), but excluding the two ‘worst’ (November and December), so this result may not be reliable. In second place, the M9 south of Junction 10, has even more data missing. In third place, the M8 at Harthill, again has both of the worst months missing. Notwithstanding this missing data, it seems that it is no coincidence that these 3 best sites are all Motorways, appearing to give a very good service to the HEAVIES. Turning to the worst site, this is again the A90 at Ferrytoll, with minimum speeds less than a third of the free-flow speed. The remaining 27 sites obviously lie between the extremes just discussed, but there is no obvious connection of sites that would justify any speculation here as to causes.

The final table in this section, Table 6.3, shows actual mean speeds for CARS, in the same format. This time there is a noticeable difference between the Grand Mean (71.69 kph) and Grand Median (75.15 kph). Both show average speeds around 45 mph, but this is not important in itself as the sample’s mix of urban and rural sites is neither random nor representative. The ordering of Median greater than Mean shows that there is negative skew. That means that, compared to a symmetric bell shape, there is a longer tail of lower speeds than of higher speeds. Given that there are some urban 30mph limited roads, that should not be surprising. At the top end, the 70 mph limit gives a cluster just below that speed, as will be seen.

Looking first at the results by month, the observed data gives a simple, and rather surprising picture. Moving through the year in conventional order, January and February are the ‘fastest’ months (above 75 kph), followed by March to May (some 3 kph slower), then June to September (slower still), and finally October to December the lowest (with mean speed below 70 kph). Very neat, but rather hard to explain. On the second Fridays of January and February, one might expect traffic to be heavy, visibility to be poor, and the weather to be disruptive; but, apparently, that is as good as it gets for Scottish trunk road traffic. Infilling unobserved cells with their row means changes the picture enormously. The INFILL rankings and gradings (not shown) report June and July as the best months, followed by March to May, then Jan & Feb, then Aug & Sep, and finally October to December as worst. So, it is sure which months are worst, but not which months are best. The missing data for A90 Ferrytoll at the beginning of the year is obviously favouring those months. Further scrutiny of individual sites suggests that the INFILL results, this time, really are the more reliable. The difference in speeds between sites is so great that to average over different sites each month clearly distorts the results, in a way that was not clearly the case for the ‘ratio’ data on Tables 6.1 and 6.2. It is therefore concluded that June and July really are the ‘fastest’ months.

Turning now to the individual sites, the ‘fastest’ are the M9 south of Junction 10, and the A90 at Forfar. Both have average speeds above 108 kph (67 mph). This is understandable for the Motorway, but it does seem high for an A road. Not much ‘slower’ are the M8 at Harthill, the M73 at Gartcosh, the M74 at Cambuslang, the M80 near Haggs, and the M876 at Bonnybridge; all Motorways so no raised eyebrows. The ‘slowest’ road is the A737 Kilwinning Road in Dalry, but this is just one of the several urban sites with appropriate average speeds of around 20 mph.

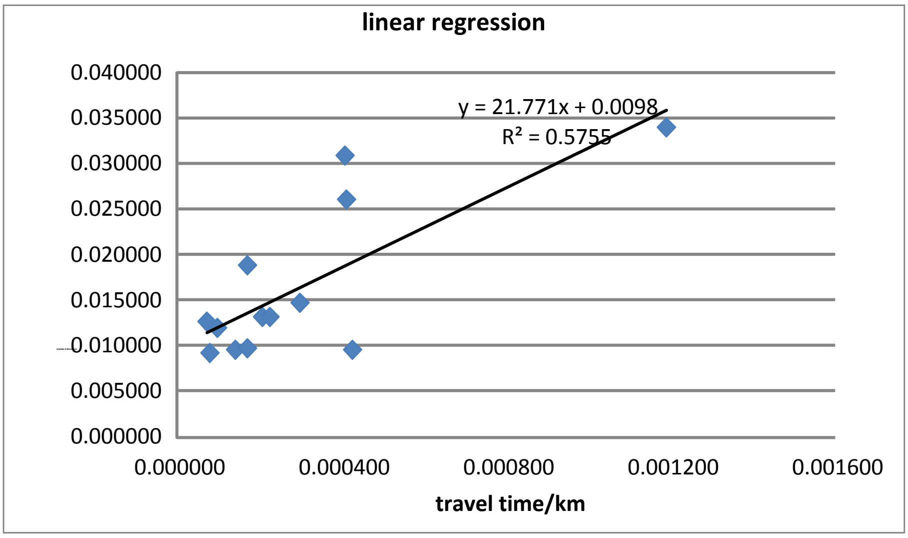
An important aspect of Table 6.3 is that it shows the degree to which average speeds vary from month to month for a given site. This goes directly to the reliance car travellers can place on their expected journey times. On Motorways there is very little variation from month to month, as might be expected, but the variation is not that great for the other road types either. Individual observations may merely reflect incidents on the day in question, with no clear cases of sites where car speeds are greatly worse at some times of years than others. The nearest case to that is the M898 Erskine Bridge, where the October to December mean speeds of 47.4 kph, 58.8 kph, and 68.4 kph differ greatly from the 12 month mean of 83.7 kph. This, though, does appear to be exceptional.

From the theory set out on Section 4, the study was led to look for a linear relationship between the standard deviation of speeds over the (12 days of the) year against the inverse of speed. Table 6.4 reports the findings. Only 17 sites had data for all 12 months, and one of those was excluded as being a clear outlier. A good R-sq was obtained with those 16. Another two sites had major data interruptions on some days, but excluding them made hardly any difference to the results. Finally, a site which had one bad afternoon was excluded. This actually made the R-sq slightly worse, but the intercept and slope were again hardly affected. This regression line is shown in Figure 6.1. Section 8 will speculate on how such a model might be taken forward to be of use.

Table 6.4 Effect of Data Cleaning on the Linear Regression of Standard Deviation of Monthly Speeds against the Inverse of Speed

NUMBER OF SITES	INTERCEPT	SLOPE	R – SQ
16	0.0102	21.602X	0.5433
14	0.0096	21.992X	0.5799
13	0.0098	21.771X	0.5755

Figure 6.1 Linear Regression of Standard Deviation of Monthly Speeds against the Inverse of Speed



7. Implications for STAG Results from the review of current best practice and the survey of companies

7.1 The Current Position

Reliability impacts form part of the Economy criterion in the Scottish Transport Appraisal Guidance (STAG). Within the Economy Criterion, two separate analyses are undertaken, a Transport Economic Efficiency (TEE) analysis which is a cost-benefit analysis, and an Economic Activity and Location Impacts (EALI) analysis. Improvements in journey time reliability can contribute to both analyses.

A fundamental aspect of predicting the impacts of reliability is modelling the supply side - i.e. how journey time reliability will change in relation to changes in transport quality/infrastructure. STAG currently recommends the use of the ARUP INCA computer model for dual carriageways and inter-urban motorway. It also recommends the use of a model that predicts changes in the standard deviation of travel times from changes in expected travel times in urban areas. STAG contains no guidance for single carriageway rural roads. Some of the Scottish Government's stated investment priorities include upgrading such roads, including the A9 Perth to Inverness and the A96 Aberdeen to Inverness. Both of these roads suffer journey time reliability problems. INCA is also only appropriate for dual carriageways and inter-urban motorways that operate below capacity. As some dual carriageway/inter-urban motorways in Scotland already operate at or above capacity in peak times, and more capacity problems are expected in the future this presents some difficulties in appraising the impact of better reliability on dual carriageway/inter-urban motorways currently operating or expected to operate at or above capacity.

Within the TEE the value of reliability is determined using the reliability ratio (see section 4). For car journeys, this ratio relates the value of an increase in the standard deviation of journey time to the value of an equally sized increase in scheduled travel time. STAG currently only suggests a single reliability ratio of 0.8. This is for trips by car and is for all journey purposes (business, commuting, other). No recommendations are contained for freight vehicles, either LGVs or HGVs. For public transport effects, STAG defines a reliability ratio, but offers no recommended value. also Instead, it offers the analyst the possibility of calculating reductions in average lateness, with the current evidence base on the value of being late contained in the rail Passenger Demand Forecasting Handbook (ATOC, 2013).

7.2 Implications for STAG from the Review of Current Best Practice.

Current best practice was discussed in Section 4, along with the theoretical background. The results of the Expert Workshop held in 2004 in the Netherlands were known to the writers of the current version of STAG, and were appropriately incorporated. Since that time, no equivalent consensus of view that has advocated changes from those values. Some additional evidence is presented in Section 4, and this will be borne in mind when formulating recommendations for values later in this section.

It will have been noticed that the STAG definitions were there reworded, and it is recommended that those rewordings are carried forward in a revision of STAG. In particular, the following material is preferred to that currently in STAG:

The reliability ratio for car travel is defined as:

Reliability Ratio = (Value of $\Delta\sigma_T$) / (Value of ΔT) = VOR / VOT

where:

VOR: value of reliability
VOT: value of travel time
$\Delta\sigma_T$: a change in the standard deviation of travel time
ΔT: an identical change in scheduled travel time.

For example, one might have an estimate of the value of a travel time saving as £6/hour for some group. That means that the value of a $\Delta T = -10$ minutes is estimated at £1. One now needs to know the value of reducing the standard deviation of travel times also by 10 minutes. From the literature, the consensus of opinion is that RR is often around 0.8, in which case the value of reducing the standard deviation of travel times would be about £4.80 per hour, and so the value of reducing the sd by 10 minutes would be £0.80.

For **public transport** however, the RR is usually defined differently. The justification for this is the existence of a timetable. Following ATOC (2013), and working in broad terms, the evidence base appears to say that one minute of average unexpected lateness is valued by passengers as being equivalent to three minutes of scheduled journey time. This value of 3 is referred to as a Lateness Factor. Since some lateness is successfully advertised to intending passengers in time for them to adjust to (egg. turning up later at a station for a train known to be running late, or catching a delayed earlier train running close to the path of the delayed intended train), the recommended average Lateness Factor is 2.5.

i.e. VOL = 2.5VOT

The reliability ratio, for public transport is defined as:

Reliability Ratio = (Value of $\Delta\sigma_L$) / (Value of ΔL) = VOR / VOL

where:

VOL: Value of (mean) lateness = f . VOT
(f is a factor to be estimated or taken from the literature, currently recommended as 2.5)
$\Delta\sigma_L$: a change in the standard deviation of lateness
ΔL: an identical sized change in lateness (= $A_i - A^S$, where A_i is the actual arrival time of trip i and A^S is the timetabled arrival time referring to that trip; with $A_i - A^S \geq 0$, i.e. early arrivals are treated as being on time).

For example, one might have an estimate of the value of a travel time saving as £6/hour for some group. That means that the value an hour of lateness is £15 (using the recommended f value of 2.5). From the literature, the recommended RR value for public transport is given as 1.4. In that case the value of reducing the standard deviation of lateness would be about £21 per hour.

7.3 Implications for STAG from the Findings of the Surveys

Section 5 of the present study has found the best estimate of RR for Non-Freight, say 'cars' to be 0.3. That is right at the low end of values previously found in studies. This may be because Scotland is different, because the respondents were answering on behalf of their businesses (rather than as themselves), or because the question was misunderstood. In any event, the sample was not particularly large nor particularly targeted at estimating this value as its top priority. Accordingly, it would not be wise to do more than report the finding in STAG and suggest that it might be used in sensitivity testing alongside the currently recommended, and internationally supported, value of 0.8.

For Freight the sample was much too small to determine STAG guidance. Currently, STAG has no recommended value for freight. The sample estimate found for RR, 0.48, is of no significance in its own right, but when disaggregated gives the interesting values of 0.21, for those firms engaged in carrying goods, and 0.71 for those firms merely shipping or receiving goods. Since all goods must be shipped and received, this suggests that a composite RR, for firms that ship, carry, and receive goods should be at least 0.71. However, that RR is only so high because not all firms in that group carried freight, and therefore had low VOT due to not directly having to pay drivers' wages and vehicle costs resulting from increases in scheduled journey times. It is therefore felt that the RR value found for all respondents (both by working with average values and by averaging over individual values) is the best guide to the composite RR for the freight movement. That value was 0.48. Were that value to be based on a large representative sample then that value should be included in STAG as the recommended value to use. In the light of the small sample size, however, it is felt right to place more reliance on international findings.

For Road Freight, Table 4.4.1 reported a wide range of estimates of RR, with some disaggregation between Shippers and Carriers. As just discussed, the Shippers will probably have had relatively low VOT values, since they do not immediately bear the costs of increases in scheduled journey times resulting from extra drivers' wages and other movement costs. Eventually, Shippers will have to cover those costs, but they will not accrue immediately to Shippers and so are unlikely to be reported. On the other hand, Shippers might also understate VOR if they do not appreciate costs of unreliability for the Receiver. However, such costs are often reflected in penalties for late arrival, and these will usually fall on the Shipper.

The lower RR values reported in the literature for Carriers and Own Account operators may well reflect higher VOT values resulting from drivers' wages. Receivers' penalty charges for late arrival will probably fall more on the Shippers than themselves. The estimated RR values for this group are therefore probably too low for a complete freight movement. The appropriate value for appraisal probably lies somewhere between the Shipper and Carrier values. Knowledge is not strong, and a range of 0.2 to 1.0 is probably a safe bet to include Road Freight RR in most circumstances. It cannot be denied that that range is centred on 0.6. If there was an absolute demand for a single value then it would be difficult to suggest a better one. More sensible would be to use 2 values 0.4 and 0.8 for sensitivity testing.

Within the EALI component of STAG there are no recommendations or guidance regarding how changes in journey time reliability may impact on the business performance (increased operating surpluses and increased production/employment). The present study has provided no quantitative relationships that might be used to extend STAG guidance in this area, but the questionnaire responses do point to the areas where unreliability has the biggest impact on company performance.

In summary, the recommendation of this report is that the following values be mentioned in STAG:

CAR JOURNEYS: *Recommended value RR=0.8. If a sensitivity test value is required, take RR=0.4.*

PUBLIC TRANSPORT: *Not studied in this study. Note that for RAIL the ATOC (2002) range is RR=0.6 to RR=1.5. Note that the Expert Workshop of 2004 recommended RR=1.4. Note that recent is suggesting splitting by journey purpose, with RR=1 for BUSINESS and RR=0.6 for other modes. This study finds little ground for recommending different values for PT than for CARS, i.e. RR=0.8, with a sensitivity test alternative of RR=0.4.*

FREIGHT: *From the values available in the literature, supplemented to a limited extent by the results from the present study, the recommended best single value is RR=0.6, but with such uncertainty that a sensitivity test rand of RR=0.4 to RR=0.8 is strongly advised.*

7.4 Implications for STAG of the findings from the study of ATC data.

This was investigated in Section 6. Somewhat surprisingly, given various data limitations, it was found possible to substantiate the theoretical conjecture that had been verified elsewhere, that the standard deviation of vehicle speeds was strongly linearly related to the inverse of vehicle speed. Over half of the variation in the former could be explained by the variation in the latter. Since traffic speeds are routinely forecast, the prospect of accompanying such forecasts with estimates of their spread appears feasible. Depending on context, the fit of the relationship should obviously be enhanced by the inclusion of such relevant variables as were available. For example, if forecasting for a road in December, the spread of speeds might be larger than in a neutral month. A model of standard deviation of speed could include not just the inverse of speed but also dummies for month etc. At the present time, the relevant data is not being routinely collected, and any data collection is irksome for various reasons, but this study has demonstrated that the appropriate recording is currently being done automatically at many sites. Should it be desired to calibrate models of the type described, a particular effort would need to be mounted to facilitate that, at not insignificant cost. Beyond that, real time feedback of ATC data might be used to make forecasts of traffic conditions in the following minutes, which might inform actions – including broadcasting useful advice to drivers. Exactly how much of the above is suitable for inclusion in STAG is a matter for its editors.

8. Final Remarks and Conclusions

This report has looked at the concept of Journey Time Reliability (JTR) and its valuation. The background is given in Section 3, and a survey of current best practice and appraisal valuations is presented in Section 4. Surveys were conducted of Scottish businesses, both of Freight Users (F) and those not involved with freight (NF). The survey results are in Section 5. In broad terms, the feeling was that JTR had got worse on the Scottish Trunk Road network in recent years, but that this had not yet become a pressing matter for the vast majority of respondents. Detailed results are presented, many disaggregated by location and activity sector.

The topics of JTR and its valuation in the literature were compared with current advice in STAG. The latter seemed well up to date with the state of the art, and no major revisions were suggested. Both in STAG and in the literature, the accepted way of encapsulating the value of JTR changes is via the measure known as the reliability ratio (RR). This is discussed in some detail in the report. It has some weaknesses, can be difficult to calculate, and can only be transported to other times and locations with great care. RR values have been calculated for both the F and NF samples.

For the Freight sample plausible RR values were obtained for all respondents, and separately for those involved in actually transporting the goods and those not. However, the useful sample size was very small and the estimated value varied greatly as assumptions were changed. The disaggregation provided extra insight, and provided estimates consistent with the literature. It was not felt that the survey value was sufficiently well based to affect the value chosen for use in appraisal. If more robust estimates are required, a much larger sample would be needed, probably involving face-to-face surveying using an Adaptive Stated Preference experiment.

For the, much larger, NF sample, a robust estimate of RR was obtained, at the bottom of the range of values suggested by the literature. This may have been because respondents were representatives of firms, rather than individual travellers. In other words, they were being asked to think of the effect of unreliability on others', rather than their own, travel. The low value is, in any event, consistent with the qualitative responses which indicated that JTR was not currently a major problem for firms. In the light of the findings, it was suggested that for appraisal purposes STAG should recommend the use of the central value found in the literature, taken to be 0.8, together with a lower value, 0.4, closer to the value found in the NF survey, 0.3.

The study also looked at the data currently available that could be used to gauge JTR on the Scottish Trunk Road Network, and the findings are reported in Section 6. The most useful source of data was found to be from Automatic Traffic data Collection sites, some of which recorded (and output) 'Vehicle–By-Vehicle' data covering the speed of passing traffic, by vehicle type. Given resources not currently available, this data could be converted to a common coding and aggregated in various ways not currently attempted. The study was able to mount a pilot investigation of this. Amongst other interesting findings, it was found possible to establish an approximate linear relationship between the standard deviation of average speeds, for days taken at monthly intervals, and the inverse of speed. It appears that around half of the variation in that standard deviation can be explained in that way. Since speed is routinely predicted, from speed/flow curves for example, this opens the way to building a forecasting model of the standard deviation of speeds incorporating additional variables such as weather conditions, road capacity, etc. Future appraisals might then be able to estimate both the mean and standard deviation of speeds on links affected by a scheme. Any change in standard deviation could be factored by RR and added to the change in travel time, then valued by using a Value of Time value as at present. There would no doubt be many other uses for such a model, but it must be stressed that it is not yet known how portable such a model would be, so that there might be a requirement to regularly collect input data which is, at present, irksome.

9. References

Association of Train Operating Companies (ATOC) (2002, 2013) Passenger Demand Forecasting Handbook, London.

Bates, J., Polka J., Jones, P. and Cook, A. (2001) The valuation of reliability for personal travel, Transportation Research E (Logistics and Transportation Review), 37-2/3, 191-229.

Copley, G., Murphy, P. and Pearce, D. (2002) Understanding and valuing journey time variability; European Transport Conference – 2002, Cambridge.

Eliasson, J. (2004) Car drivers' valuations of travel time variability, unexpected delays and queue driving, *Proceedings of the European Transport Conference*, 2004.

Fosgerau, M. and Karlström, A. (2010) The value of reliability, *Transportation Research Part B*, 44(1), 38-49.

Fowkes, A.S. (2006) The design and interpretation of freight stated preference experiments seeking to elicit behavioural valuations of journey attributes, ITS, University of Leeds.

Halse, A., H. Samstad, M. Killi, S. Flügel and F. Ramjerdi (2010) Valuation of freight transport time and reliability (in Norwegian), TØI report 1083/2010, Oslo.

Hensher, D.A. (2007) Valuation of Travel Time Savings, prepared for the Handbook in Transport Economics, edited by André de Palma, Robin Lindsey, Emile Quinet, Roger Vickerman, Edward Elgar Publisher.

Jong, G.C. de, M. and M.C.J. Bliemer (2015) On including travel time variability of road traffic in appraisal, *European Journal of Transportation Research A* (73), 80-96.

Jong, G.C. de, M. Kouwenhoven, E.P. Kroes, P. Rietveld and P. Warffemius (2009) Preliminary monetary values for the reliability of travel times in freight transport, in *European Journal of Transport and Infrastructure Research,* Issue 9(2), 83-99.

Kristoffersson, I. (2011) Impacts of time-varying cordon pricing: validation and application of mesoscopic model for Stockholm, *Transport Policy*, DOI:10.1016/j.tranpol.2011.06.006.

Mahmassani, H.S. (2011) Application to the New York metropolitan region of an integrated model of user responses to pricing and reliability with a state of the art simulation-based dynamic traffic assignment tool, Presentation to NYMTC, New York City.

MVA (1996) Benefits of reduced travel time variability; Report to UK Department for Transport.

MVA (2000) Etude de l'impact des phénomènes d'irregularité des autobus – Analyse des resultats, MVA, Paris.

Ramjerdi, F., Flügel, S., Samstad, H. and Killi, M. (2010) Value of time, safety and environment in passenger transport – Time. TØI report 1053B/2010, Institute of Transport Economics, Oslo

Significance, Goudappel Coffeng, and NEA (2012) Erfassung des Indikators Zuverlässigkeit des Verkehrsablaufs im Bewertungsverfahren der Bundesverkehrswegeplanung: Schlussbericht. Bundesministerium für Verkehr, Bau und Stadtentwicklung, Berlin, Germany.

Significance, VU University, John Bates Services, TNO, NEA, TNS NIPO and PanelClix (2013) Values of time and reliability in passenger and freight transport in The Netherlands, Report for the Ministry of Infrastructure and the Environment, Significance, The Hague.

Transport Scotland (2012) STAG Technical Database, Section 9, Economy.

APPENDIX 1 FREIGHT SURVEY

Transport Scotland & Leeds University - Reliability of Scottish Trunk Road Survey

Thank you for helping us with our survey.

This survey is being undertaken by the University of Leeds on behalf of Transport Scotland. We are interested in how changes to the reliability of travel on Scotland's trunk road network may impact on various aspects of your business. The survey should last no longer than 30 minutes and all data collected will be held anonymously and securely.

If you experience any problems or require further information please contact **Jeremy Shires, j.d.shires@its.leeds.ac.uk, t 0113 343 5347**.

Please use the "Continue" button at the bottom of each page to navigate through the survey. Once you hit this button you won't be able to return to your answers.

The Disruption Affecting You

We would now like to record some details about you and your company to help us ensure we have a representative sample of Scottish businesses.

1. What is your position within your company?

2. What is the name of your company/organisation?

3. Where is your company/organisation located? (please record the nearest city/town)

4. Which of the following sectors best describes your company's activities?

- Academic
- Financial
- Manufacturing
- Retail
- Local Government
- Energy
- Forestry
- Food & Drink
- Life Sciences
- Tourism
- Creative Industries (including digital)
- Services
- Other *(please specify)*:

In this section we would like to ask you your opinion of the current trunk road network in Scotland. By trunk roads we mean the motorways and roads linking major centres in Scotland, and the border with England. They are shown with a green or blue background on road signs.

5. Do you feel that over the last 5 years that travel times on the Scottish Trunk Road network have become more reliable, less reliable or remained the same?

- More reliable

- ○ Less reliable
- ○ The same
- ○ Don't know

6. How have the following impacted on levels of unreliability on the Scottish trunk road network? Please rate the following, using a scale of 0 to 10 where 0=no impact and 10=major impact?

	Scale of Impact
a. Design of roads	
b. Roads not large enough to cope with the amount of traffic	
c. Traffic is concentrated into particular time periods	
d. Road works	
e. Weather	
f. Accidents	

7. Is there anything else you think might have led to unreliability on Scotland's trunk roads that is not mentioned in Q6? If yes, please record in the text box below and rate the impact (0 to 10).

A Typical Freight Flow

We would now like you to consider a significant freight flow (preferably greater than 50 miles in length), involving at least one Scottish trunk road, for which you have responsibility for or knowledge of?

8. For this flow, can you please give GB origin and destination for each leg (i.e. trans-shipments, if any, and ignoring portions of trips outside GB).

	From:	To:
a. Leg 1		
b. Leg 2		
c. Leg 3		
d. Leg 4		
e. Leg 5		

9. How long does the end-to-end journey usually take (within GB)?

a. Days	
b. Hours	
c. Minutes	

10. Can you please estimate what percentage of loads arrive at the following levels of lateness?

	Percentage
a. On time	
b. Up to 30 minutes late	
c. Between 30 and 60 minutes late	
d. Between 60 and 120 minutes late	
e. Between 2 and 4 hours late	
f. Between 4 and 12 hours late	
g. Between 12 and 24 hours late	

h. Over 24 hours late	

11. Can you please tell us what are your re-planning contingencies and recovery processes to deal with lateness, irregularities, cancellations etc?

12. What is the nature of the freight (e.g. is it containerised, palletised, liquid etc.)?

13. What is the value of the freight (at the time of its movement)? (please record as £ per tonne)

14. Can you please tell us how much is carried by each vehicle on average? Please record in tonnes if known - if not then in another appropriate measure.

	Vehicle Type	Tonnes	Other measure (please indicate)
a. Amount carried			

15. How many lorry loads are there shipped each year?

16. Can you please tell us what is the annual tonnage moved for that flow (if total freight moved is not known in tonne terms, please supply in whatever form is most appropriate)?

	Tonnes	Other measure (please indicate)
a. Annual movement		

17. Can you please tell us what is the total tonnage for all of your flows per annum?

	Tonnes	**Other measure (please indicate)**
a. All your flows per annum.		

18. What is your company's relationship to this freight?

- Shipper only
- Shipper and Own Account Carrier
- Carrier Only
- Receiver
- Other *(please specify)*:

Journey Time Sensitivity

The following question is framed in the long run, when everything can be re-planned.

19. For the example freight flow discussed earlier what extra costs (if any), for a single shipment, would your company incur if the scheduled journey time was increased by the following times and why?

	Extra Costs (£s)	Why?
a. 30 minutes		
b. 1 hour		
c. 2 hours		
d. 4 hours		

Costs of Lateness

In this final section we consider the actual arrival time, not the scheduled arrival time.

20. What are the cost implications of unexpected late arrivals for a single shipment of the example freight flow? (e.g. penalty clauses, extra staff costs, stock-outs, emergency shipments, deterioration of goods, management time etc)?

21. How many management hours are taken up dealing with the consequences of a single lorry load of this traffic arriving a day late.

22. Would a sustained reduction in the incidence of late arrivals allow you to reduce buffer stocks held?

- Yes
- No

If yes - by what percentage?

23. Would a sustained reduction in lateness offer any savings in the amount of equipment used for the example flow per shipment (e.g. quicker turnaround of lorries, containers, pallets etc)?

- Yes
- No

If yes - by how much (please record in £s)

24. What costs (in total) would be incurred if **lateness** for a single shipment of the example movement was at the following levels (**compared to a situation where all arrivals were on time**)?

	Cost (£s)	Why?
a. 30 minutes late		
b. 1 hour late		
c. 2 hours late		
d. 4 hours late		
e. 12 hours late		
f. 24 hours late		
g. 48 hours late		

25. If you wish to receive an electronic copy of the findings of this study please indicate below.

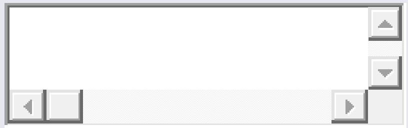
○ Yes ○ No

If yes please provide your email contact details in the text box below.

26. Do you have any contacts in other organisations who you feel might welcome a chance to give their experience via this survey?

	Name	Contact Details
a. Contact 1		
b. Contact 2		
c. Contact 3		
d. Contact 4		
e. Contact 5		

27. Please use the text box below to provide any further comments you may have regarding the level of unreliability on the Scottish trunk road system and its impact on your company/organisation.



Thank you

Thank you for completing this questionnaire.

APPENDIX 2 NON-FREIGHT SURVEY

Transport Scotland & Leeds University - Reliability of Scottish Trunk Road Survey

Thank you for helping us with our survey.

This survey is being conducted by the University of Leeds for Transport Scotland. We are interested in how changes to the reliability of travel on Scotland's trunk road network may impact on various aspects of your business. The survey should take around 20 minutes to complete, with all data collected being held anonymously and securely.

If you experience any problems or require further information please contact **Jeremy Shires, j.d.shires@its.leeds.ac.uk, t 0113 343 5347**.

Please use the "Continue" button at the bottom of each page to navigate through the survey. Once you hit this button you won't be able to return to your answers.

The Disruption Affecting You

We would now like to record some details about you and your company to help us ensure we have a representative sample of Scottish businesses.

1. What is your position within your company?

[ ]

2. What is the name of your company/organisation?

[ ]

3. Where is your company/organisation located? (please record the nearest city/town)

[ ]

4. Which of the following sectors best describes your company's activities?

- ○ Academic
- ○ Financial
- ○ Manufacturing
- ○ Retail
- ○ Local Government
- ○ Energy
- ○ Forestry
- ○ Food & Drink
- ○ Life Sciences

- Tourism
- Creative Industries (including digital)
- Services
- Other *(please specify)*:

General Opinion of the Service Provided by Scottish Trunk Roads

In this section we would like to ask you your opinion of the current trunk road network in Scotland. By trunk roads we mean the motorways and roads linking major centres in Scotland, and the border with England. They are shown with a green or blue background on road signs.

5. Do you feel that over the last 5 years that travel times on the Scottish Trunk Road network have become more reliable, less reliable or remained the same?

- More reliable
- Less reliable
- The same
- Don't know

6. How have the following impacted on levels of unreliability on the Scottish trunk road network? Please rate the following, using a scale of 0 to 10 where 0=no impact and 10=major impact?

	Scale of Impact

a. Design of roads	
b. Roads not large enough to cope with the amount of traffic	
c. Traffic is concentrated into particular time periods	
d. Road works	
e. Weather	
f. Accidents	

7. Is there anything else you think might have led to unreliability on Scotland's trunk roads that is not mentioned in Q6? If so please record in the text box below along with a rating of the impact (

8. In the last year, has unreliability on the Scottish Trunk Road network impacted on your firm in any of the following ways?

	Impact

a. Reduced productivity/sales	
b. Additional transport costs	
c. Delays to time-critical deliveries	
d. Additional staff costs	
e. Difficulty in attracting customers	
f. Difficulties with staff business travel/commuting	

9. Is there anything else you think might have caused unreliability on the Scottish Trunk Road network that has not been mentioned in Q8?

10. If you did identify any impact from unreliability in Q's 8 or 9 can you please provide one of more examples of where trunk road unreliability has caused particular problems for your firm, and v think ought to be taken by Transport Scotland to avoid their re-occurrence. If you did not identify any impacts from unreliability in Q's 8 or 9 then please go straight to Q15.

From	To	Purpose	Problem	Solution

a. Example 1					
b. Example 2					
c. Example 3					

11. We would now like you to think about 2 alternative scenarios with regards to reliability and journey times on the Scottish trunk road network:

In scenario 1 the journey times for **all** your company/organisation's journeys are 10 minutes longer than **now**.

In scenario 2, **four** out of five of all your company's journeys are the same as **now**, but the **fifth** journey is longer.

Can you please tell us **how much longer (in hours & mins) this fifth journey (in scenario 2) would have to be to make you indifferent** between the two alternative scenarios, e.g. you would no
other.

Your Company's Need for a Good Road Network

In this final section of the survey we would like to ask you how your company might benefit from an improvement in the road network?

12. Can you please rate out of ten how important each of the following factors are for your business/organisation, were 0 represents 'not at all important' and 10 represents 'extremely important'.

	Rating
a. Access to customers	
b. Access to suppliers	
c. Access to skilled workforce	

13. We would now like to understand what value to your company you would see from improvements to the road network that made road journeys TOTALLY PREDICTABLE AND RELIABLE this question please respond with don't know)

If you feel able, could you provide a guesstimate of the **annual monetary value** (£s) to your company of moving from the present situation to having totally predictable and reliable road journeys (company would be willing to pay to move to that situation).

14. In order for us to understand why increased journey time reliability has a value for your firm, we would like you to **RANK THE TOP 5** improvements listed below, where 1=Most important a important. **Please only rank 5 improvements overall and provide a different ranking for each**.

	Ranking

a. Increased attractiveness of your area for investment.	
b. Increased productivity	
c. Improved access to suppliers	
d. Improved staff recruitment	
e. Improved access to customers	
f. Reduced transport cost	
g. Improved links between your firm's business locations	
h. Improved business confidence	
i. Increased exports	

15. If you wish to receive an electronic copy of the findings please indicate below?

- ◯ Yes - I would like to receive a copy of the report
- ◯ No thanks

If yes please leave your email details below.

16. Do you have any contacts in other organisations who you feel might welcome a chance to give their experience by taking part in this survey.

	Name	Contact details
a. Contact 1		
b. Contact 2		
c. Contact 3		
d. Contact 4		
e. Contact 5		

Thank you

Thank you for completing this questionnaire.

Further copies of this document are available, on request, in audio and large print formats and in community languages (Urdu; Bengali; Gaelic; Hindi; Punjabi; Cantonese; Arabic; Polish).

اس دستاویز کی مزید کاپیاں آڈیو کیسیٹ پر اور بڑے حروف کی چھپائی میں اور کمیونٹی کی
زبانوں میں طلب کیے جانے پر دستیاب ہیں، برائے مہربانی اس پتہ پر رابطہ کریں:

এই ডকুমেন্ট-এর (দলিল) অতিরিক্ত কপি, অডিও এবং বড়ো ছাপার অক্ষর আকারে এবং সম্প্রদায়গুলোর ভাষায় অনুরোধের মাধ্যমে পাওয়া যাবে, অনুগ্রহ করে যোগাযোগ করুন:

Gheibhear lethbhreacan a bharrachd ann an cruth ris an èistear, ann an clò mòr agus ann an cànain coimhearsnachd. Cuir fios gu:

इस दस्तावेज़/काग़ज़ात की और प्रतियाँ, माँगे जाने पर, ऑडियो टैप पर और बड़े अक्षरों में तथा कम्यूनिटी भाषाओं में मिल सकती हैं, कृपया संपर्क करें:

ਇਸ ਦਸਤਾਵੇਜ਼/ਕਾਗ਼ਜ਼ਾਤ ਦੀਆਂ ਹੋਰ ਕਾਪੀਆਂ, ਮੰਗੇ ਜਾਣ ’ਤੇ, ਔਡਿਓ ਟੇਪ ਉੱਪਰ ਅਤੇ ਵੱਡੇ ਅੱਖਰਾਂ ਵਿਚ ਅਤੇ ਕੰਮਿਉਨਿਟੀ ਭਾਸ਼ਾਵਾਂ ਦੇ ਵਿਚ ਮਿਲ ਸਕਦੀਆਂ ਹਨ, ਕ੍ਰਿਪਾ ਕਰਕੇ ਸੰਪਰਕ ਕਰੋ:

此文件有更多備份，如果需要，語音版本和大字體版本及少數種族語言版本也可提供，請聯絡：

يمكن أن تطلب النسخ الأخرى من هذا المستند كالتسجيل الصوتي والخط المكبر ونسخ بلغات أخرى، يرجى الإتصال على:

Aby otrzymać niniejszy dokument w innej wersji językowej, na kasecie lub w wersji z powiększonym drukiem, prosimy o kontakt:

Transport Scotland, Buchanan House,
58 Port Dundas Road, Glasgow, G4 0HF
0141 272 7100
info@transportscotland.gsi.gov.uk
www.transportscotland.gov.uk

ISBN: 978-1-909948-46-4

Any enquiries regarding this document / publication should be sent to us at info@transportscotland.gsi.gov.uk

This document is also available on the Transport Scotland website: www.transportscotland.gov.uk

Published by Transport Scotland, May 2015

An agency of
Buidheann le

The Scottish Government
Riaghaltas na h-Alba