The evaluation of delays to freight on the Trunk Road Network

Prepared for Traffic Safety & Environment Division, Highways Agency

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Executive Summary

This report presents results from a project whose objectives were:

i to determine the strategic reactions of freight road users to variability in trunk road travel times resulting from planned and unplanned events affecting preferred routes;

ii to identify the willingness to pay of freight road users to mitigate such variability, for example via road usage tolls;

iii to investigate whether the above reactions and willingness to pay vary significantly between Just-in-Time (J.I.T.) and non-J.I.T. respondents.

The research has utilised the Leeds Adaptive Stated Preference (LASP) survey methodology.

Forty interviews were conducted between November 2000 and March 2001. Few companies declined to participate, and the only difficulty encountered in achieving sufficient responses across the various dimensions of interest was in finding sufficient numbers of short distance movements.

Three distinct types of delay were considered during these interviews:

- A delay resulting from an increased journey time, with fixed departure time.
- An increase in the spread (or range) of arrival times for a fixed departure time.
- A schedule delay where the departure time is effectively put back.

The above types of delay were incorporated into an Adaptive Stated Preference experiment. One interview failed to yield usable information. The remaining 39 interviews produced willingness-to-pay valuations of the three types of delay. These three valuations are referred to as VDT, VSP and VSH respectively.

Comparisons have been made of the magnitude of these values with values in the literature. In particular, the study results have been compared with values taken from a review undertaken in 2001 for the (then) Department of Transport, Local Government and the Regions; the values represent plausible responses given the composition of the sample. The sample is not intended to be representative of any particular population, e.g. the commodity distribution will not reflect the population. However, disaggregate results are presented so that any desired re-weighting can be performed. Very few short distance flows on trunk roads were sampled, and therefore it is not possible to re-weight in this instance.

An unexpected finding was that valuations for third party movements varied greatly depending on whether the interviewee was the shipper or the haulier. Shippers using third party services tended to have much lower valuations. It may that this is because they did not consider the costs to the haulier of increased journey times and these costs may be considerable. For VDT and VSH, own account operators appear to consider both the costs (a) to the load and (b) to the driver and the vehicle, and so sum the third party shipper and haulier values. This does not apply to VSP, where the own account operator is less inconvenienced by unplanned delays than the haulier.

The results in this report are presented as one-dimensional splits, this being all that the sample size will permit. It should be borne in mind that there will be correlations between the various attributes. For example, there is some correlation between operator type and journey distance, with third party journeys being on average some 30% longer than own account journeys. Consequently, what might be taken to be an ‘own account effect’ could be a ‘distance related effect’ (or vice versa).

Despite many difficulties, the LASP experiment successfully returned significant and plausible values for a range of two-way splits of firms. The quantitative values assisted in the understanding of the relative valuations of the three types of delay by different sectors of road freight traffic. In particular, it has been possible to investigate whether the above reactions and willingness to pay vary significantly between J.I.T. and non-J.I.T. respondents. The quantitative finding was that all three valuations were at least twice as high for J.I.T. respondents than for non-J.I.T. respondents.

1 Introduction

This report presents results from a project on the evaluation of delays to freight on the trunk road network which was commissioned by the Highways Agency as part of its ‘Understanding Travel Behaviour’ programme, managed by TRL Limited. The objectives of this work were as follows:

i to determine the strategic reactions of freight road users to variability in trunk road travel times resulting from planned and unplanned events affecting preferred routes;

ii to identify the willingness to pay of freight road users to mitigate such variability, for example via road usage tolls;

iii to investigate whether the above reactions and willingness to pay vary significantly between Just-in-Time (J.I.T.) and non-J.I.T. respondents.

The research has utilised the Leeds Adaptive Stated Preference (LASP) survey methodology (Fowkes and Tweddle, 1988) which is described in Section 2 of this report. Following this, Section 3 describes the sampling procedures and the resulting characteristics of the sample obtained. Results are then presented and discussed in Section 4, followed by a discussion of the range of factors thought to underlie the importance of the need for travel time reliability, as deduced from discussions with survey respondents. The report ends with concluding remarks and a list of references.

2 Research methodology

2.1 Developing the research scenario

Arising out of earlier stages of work for the Highways Agency, it was proposed that we consider the user valuations of various delays affecting freight movements on the trunk road network. After due consideration, our view was that three types of delay could be distinguished. The first of these was increased free-flow journey times. The second was increased spread of actual arrival times, and the third was delay in undertaking the journey. This distinction was of interest to the Highways Agency, as relative valuations of these delays might influence strategy as to management of the trunk road network. For example, schedule delays due to closing a road at night time for routine maintenance may be valued by users more or less highly than greater variance in journey times caused by lane closures during the middle of the day.

2.2 Adaptive SP designs

Stated Preference experiments consist of a set of ratings, rankings or choices between alternatives described by attributes set to particular levels. It is usual, because it provides useful data, to choose attribute levels such that alternatives do not ‘dominate’ each other, i.e. are not better in all respects. Instead, interesting trade-offs are built into the experiment, where respondents are given more of one good (or less of a ‘bad’) in return for less of another good (or more of another ‘bad’). Responses then permit something to be said about respondents’ preferences. With just two attributes, we can say on which side of a line a respondent lies. With more attributes we have a plane in multi-dimensional space. A good SP experiment will seek to hem-in the respondent in this multi-dimensional space, such that their preferences (or utility) weightings can be determined with an acceptably small level of error.

Initially Stated Preference experiments in transport were conducted using pen and paper face-to-face interviews or by self-completion questionnaires, with both methods sometimes involving cards showing one or more alternatives. The responses were later entered into a computer. The growth of computing power, especially in portable machines, made it possible to enter responses at the time of the interview, reducing the possibilities of mistakes, and to show the alternatives to the respondent on the computer screen. Background questions could be asked ahead of the SP experiment, the responses entered directly into the computer and available to ‘customise’ the SP experiment to the respondent.

The term ‘customisation’ has come to denote, within the SP fraternity, the practice of setting the attribute levels ‘around’ the current levels experienced by the respondent. With self-completion questionnaires, that was only possible by using descriptions such as ‘As now’, or ‘As now plus 10 minutes’. It was not always clear that the respondents offered a choice between ‘As now plus 10 minutes’ and ‘As now less 5 minutes’ always appreciated that a 15 minute time saving was on offer. With a computer, respondents can be asked for their current travel time, and the SP experiment can take this into account. In the previous example, a respondent with a travel time of 40 minutes would be given alternatives with travel times of 50 minutes and 35 minutes to choose between. Furthermore the design could offer bigger time savings to respondents currently travelling for a long time. Infeasibly small travel times can be checked for and the experiment amended. Customisation is therefore a big help in SP design.

Adaptive Stated Preference (ASP) takes the process one step further, and amends attribute levels offered in later stages of the experiment in the light of responses to earlier stages. For example, a respondent who would not pay £5 for a new transport facility would not be asked if they would pay £10, until it becomes clear that the earlier response was a mistake.

One great advantage of ASP, when studying freight, is that the experiment will be able to cope with a wide range of ‘true’ valuations. By ‘true’ valuations we mean the unknown population valuation that the experiment is trying to recover. Some commodities will be highly perishable and so have a very high value of scheduled journey time and a great aversion to delays. The firm transporting these commodities might transport other sorts of commodities, so that we could not be sure in advance which commodity they would choose for the experiment. Furthermore, some commodities will have different attribute valuations at different times. For example, a car radio being supplied as a part of a J.I.T. supply chain will have higher journey time and reliability valuations than a car radio moving to a warehouse. The ability of an ASP to adjust its questions quickly, in the light of earlier responses, is clearly very valuable.

2.3 The Leeds Adaptive Stated Preference (LASP) attributes

As discussed in Section 2.1, the LASP experiment needed to consider three different types of delay. These would relate to delay time (DT), an increase in the spread (SP) of arrival times, or a schedule delay (SH) in the initial departure time:

DT: Respondents were asked for the departure time (T) for the movement in question, and the earliest arrival time (EA) if everything went perfectly. DT is the difference (i.e. DT=EA-T). As a shorthand, we could refer to this as the free flow time, although it is not being implied that the vehicle is being continuously driven. Alterations to the road geometry or the imposition of speed limits might increase DT, whilst road improvements might reduce DT.

SP: Having determined the earliest arrival time (EA), respondents were then asked by what time 98% of deliveries could be expected to arrive. This was denoted A98, unless it was within 10 minutes of EA, in which case a 10 minute difference was forced. The difference between A98 and EA was called spread (SP). It would increase if increased congestion made journey times less predictable. It might decrease if extra capacity were provided such that conditions were nearer free flow conditions on all days. We are not here concerned with the effect of congestion on journey times during the course of a single day, but merely its effect on day-to-day variability in journey times.

SH: Having determined when the movement currently departs, we then imposed some delays on departure. We referred to these as schedule delays as they relate to not being able to depart when you want to. Sometimes this might not matter at all, but generally it will result in an arrival later than you would have wished. Such a delay could arise if planned roadworks were either going to completely block the journey, or add so much delay that it was not thought worth starting out until the works were completed.

There is one further attribute in the LASP experiment, namely cost (C). We generally refer to this as the freight rate. This is expressed for most purposes as a percentage of the current cost, $\overline{C}$, although actual monetary costs are also displayed during the experiment. When estimating parameters for an individual respondent, it does not make any difference whether we work in percentages or in pounds. However, when we combine over respondents, some care is required. If the freight rates for the various respondents to be grouped have been expressed in different ways, e.g. £/load, £/pallet, £/time etc, some recalculations will be necessary. On the other hand, while using the percentage of the freight rate is easy, there may be occasions where it is inappropriate, e.g. where distances (and hence freight rates) vary greatly. Care must also be taken, when reading this paper, to distinguish between three different entities:

- The freight rate, i.e. how much a shipper pays for the freight to be moved.
- The value of the load i.e. the worth of the goods and materials being transported.
- The value of a particular attribute e.g. the monetary valuation that a shipper places on reducing a particular type of delay.

2.4 LASP software

LASP is Adaptive SP data collection software designed to be used on a laptop computer. It is designed for use in freight studies (Fowkes & Tweddle, 1988), though it can also be adapted for other purposes. It has been successfully used for freight studies within Great Britain (Fowkes, Nash & Tweddle, 1991) and for Cross Channel studies (Tweddle, Fowkes & Nash, 1995, 1996; Fowkes & Tweddle, 1997). The most recent previous use of LASP was for a study of freight mode choice in India, undertaken by Dr N Shinghal as part of his doctoral research (Shinghal 1999). Shinghal developed a VisualBasic version of LASP, which was used as the basis for the present study. This, and the current state of the LASP methodology, are described in Fowkes and Shinghal (2001). However, considerable modification and development was required before survey work could begin. A screen display from the modified version of LASP is shown in Figure 1.

To begin the LASP experiment, the respondent is first asked to think of a typical flow and provide details. The LASP display uses a four column format. The leftmost column (depicting Alternative 1) resembles the current position regarding the typical flow, but at twice the cost. This then remains unchanged throughout the exercise. Columns 2, 3 & 4 represent hypothetical alternatives to the service shown in column 1. Initially, an attempt is made to get the respondent to prefer these alternatives to that in column 1, by offering a reduced cost. However, each of columns 2 to 4 has one attribute set worse than in column 1. The base alternative (column 1) is given a rating of 100 and the respondent is then asked to give ratings for each of the three alternatives as compared to the base option. Once these ratings have been input, LASP then modifies the attribute levels and moves into a second iteration. A number of iterations are then pursued, each time with the attribute levels modified on the basis of the ratings given in preceding iterations.

In the LASP method, each column has a series of ‘Tasks’ to perform. In this application we have only three tasks, so once a column has completed its task satisfactorily, that column helps out with the other tasks.

The algorithm is designed to induce respondents to alter their ratings of the alternatives (columns) and thereby home in on their valuations that make them indifferent between a column and the first column. The aim is to achieve this in the minimum number of iterations. A ‘Task’ is considered to have converged when the ratings for two alternatives are within a certain ‘tolerance band’. Once a particular task has converged, the column begins its next task.

For example, in Figure 1 the first task for column 2 is to obtain data for estimating the value of the spread of journey time. The cost is varied iteration by iteration until acceptable convergence is reached. If this cannot be reached at any reasonable cost level, the spread is reduced.

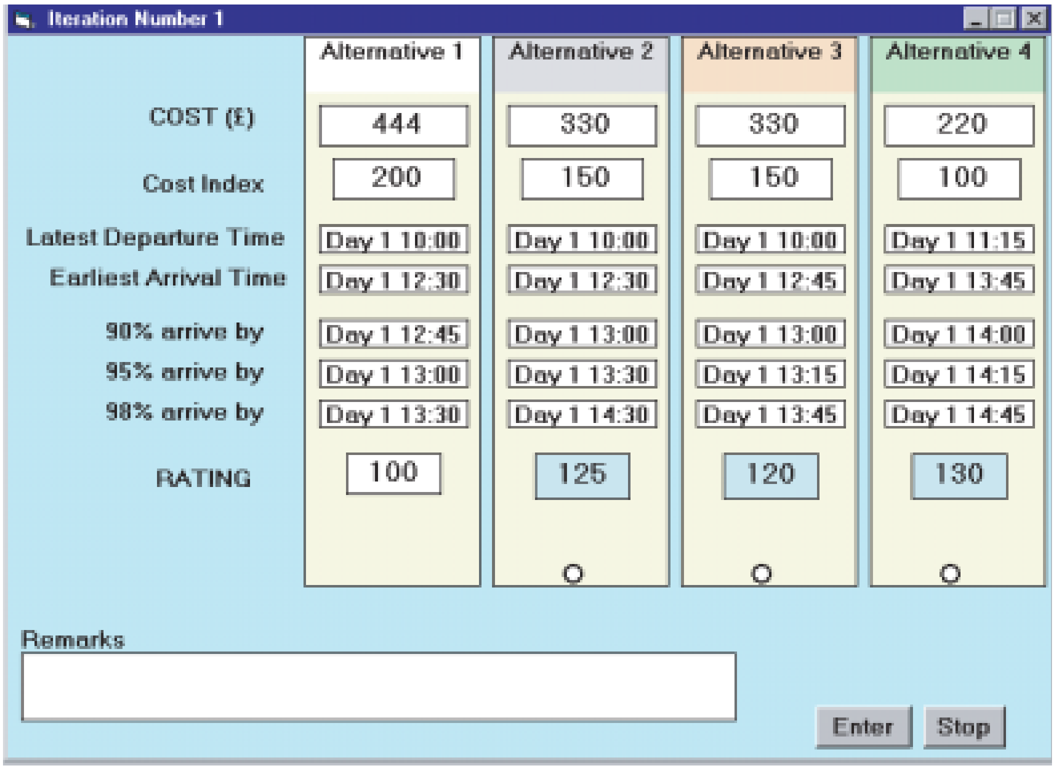

Figure 1 LASP screen format

Otherwise once sufficient convergence is achieved, this column will go on to its next 'task'. Similarly columns 3 and 4 work to value the free flow journey time and schedule delay as their first tasks.

Each respondent is presented with about 9 screens which give us about 54 pairs of binary choice data per respondent (i.e. compare 1 v 2; 1 v 3; 1 v 4; 2 v 3; 2 v 4; 3 v 4 each 9 times). It is, however, possible to terminate the interview earlier if the respondent appears to be getting fatigued. Alternately, it is possible to have more than 9 screens, if sufficient useful data has not been obtained and the respondent is willing to continue.

2.5 Data analysis – Individual level models

The data collected was analysed by creating a utility function which expressed the utility of a mode as a function of the option attributes. So if option 'i' is characterised by a set of n attributes A_{ij}, the utility, V_i is given by:

$$V_i = \sum_{j=i}^{n} \beta_j A_{ij} \qquad (1)$$

where the β_j are the relative importance, or weights, of the attributes. The modelling procedure then adopted was the widely used binary logit model which models the probability of choosing option 1, denoted P_1, over a choice set of 2 different options, as a function of indirect utilities (V_i) of the different options:

$$p_1 = \frac{exp(V_1)}{\sum_{i=1}^{2} exp(V_i)} \qquad (2)$$

Since in each iteration the respondent was asked to provide 3 ratings, there are three degrees of freedom per iteration. With typically 9 iterations, we will have 27 degrees of freedom available for calibration. When we explode each iteration's response to 6 binary choices we are incidentally doubling our sample size, so the standard errors and t statistics presented have been corrected for this. For a given pair of options, e.g. 1v2, the ratings (RATE1, RATE2) were converted into probabilities as follows:

If RATE1 > RATE2 then P_1 = 1- 0.5*RATE2/RATE1 (3)

If RATE2 > RATE1 then P_1 = 0.5*RATE1/RATE2

If we now define a variable X_j as the difference in attribute A_{ij} between option 1 and 2, that is:

$$X_j = A_{1j} - A_{2j} \qquad \forall j \qquad (4)$$

then the model can be re-expressed as

$$Logit_A = 1n \frac{P_1}{1 - P_1} = \sum_{j=1}^{n} \beta_j X_j \qquad (5)$$

which is suitable for estimation by weighted least-squares regression. By regression weights we mean how much weight we attach to each binary choice in the data set. We often find that ratings close to 100 are particularly informative and so give binary choices involving these a higher weighting. In addition, such weightings can be useful in guarding against problems resulting from heteroskedasticity (i.e. non-constant variance of error terms). In the event, three weighting possibilities were found useful: no weights; (squared) proximity of ratings to 100; and theoretical statistical weightings.

Monetary valuations are given by ratios of the parameter estimates to the cost parameter estimate. Since changing the cost variable by 1 is equivalent to changing the freight rate by 1%, estimated values appear as percentages of the freight rate. The variance of the ratios of the coefficients was calculated as:

$$var\left(\frac{\hat{\beta}_k}{\hat{\beta}_c}\right)=\frac{1}{\hat{\beta}_c^2}\left[var\left(\hat{\beta}_k\right)-\frac{2\hat{\beta}_k}{\hat{\beta}_c}cov\left(\hat{\beta}_k,\hat{\beta}_c\right)+\frac{\hat{\beta}_k^2}{\hat{\beta}_c^2}var\left(\hat{\beta}_c\right)\right] \quad (6)$$

where subscript k denotes one of the three non-cost attributes and c denotes cost.

In this application of LASP, all three non-cost attributes are expressed in an absolute unit, minutes. It is therefore appropriate to present our valuations in absolute (as opposed to %) units, and so we multiply the estimates

$$\left(\frac{\hat{\beta}_k}{\beta_c}\right)$$

by the current freight rate ($\overline{C}$) to get valuations in pence per minute. We will here call these estimates $\hat{r}_k$

$$\text{i.e.} \quad \hat{r}_k=\frac{\hat{\beta}_k}{\hat{\beta}_c}\overline{C} \quad (7)$$

(NB 1% of £1 is 1p)

2.6 Data analysis – Grouped models

From here, our procedure is to group respondents together (possibly the whole sample together) and take weighted averages of their individual valuations. The weighting used at this point is the inverse of the variance of the estimate, i.e. the valuation which has the greatest variance (i.e. the poorest estimate) gets least weight. We shall refer to this as the combination weighting.

$$\text{Let} \quad v_k=var(\hat{r}_k)=\overline{C}^2\, var\left(\frac{\hat{\beta}_k}{\hat{\beta}_c}\right) \quad (8)$$

Let us denote the combined estimate as $\hat{r}$ and the variance of the combined estimate v. Then

$$\hat{r}=\frac{\sum \frac{\hat{r}_k}{v_k}}{\sum \frac{1}{v_k}} \quad \text{and} \quad v=\frac{1}{\sum \frac{1}{v_k}} \quad (9)$$

3 The survey

3.1 Sampling methodology

In designing the survey, our intention was to cover a range of dimensions whilst keeping the total sample size to manageable proportions. Typical LASP experiments have had between 30 and 50 successful responses. Because LASP calibrates models for each respondent, larger sample sizes are not required for reasonable statistical accuracy. It is however important to ensure that the sample covers all dimensions of interest.

Forty interviews were conducted between November 2000 and March 2001. Section 3.2 describes one-dimensional subdivisions of the achieved sample. Few companies declined to participate, and the only difficulty encountered in achieving sufficient responses across the various dimensions of interest was in finding sufficient numbers of short distance movements.

The first part of the interview collected information on the company and the nature of its operations. The remainder of the interview then focused on one particular flow of freight on the trunk road network, and conducted a computerised Adaptive SP, as discussed in Sections 2.2 and 2.3.

Eighteen interviews were conducted in the North East of England. The remaining 22 were conducted by interviewers based at Huddersfield University. Locations ranged from Leicestershire and Cheshire north to Merseyside, Greater Manchester and Yorkshire. It must be appreciated that the traffic flows considered stretched into many parts of the country, including London and the Home Counties, East Anglia, the West Country and the South Coast, and north into Scotland.

3.2 Characteristics of traffic flows surveyed

Traffic flows covered a wide range of commodity types, but food and drink and grocery distribution were particularly well represented. Table 1 shows the breakdown for 34 of the respondents. In the remaining six cases, loads were mixed or varied from day to day. For analysis purposes, we took food, drink and grocery as one group, chemicals, chemical products and paint as another group and everything else as a third group.

Table 1 Breakdown of respondent flows by commodity type

Commodity type	*No. of respondents*
Steel	1
Chemicals, chemical products, paint	8
Electrical products and components	3
Food and drink, grocery distribution	15
Other metals	2
Building materials	2
Parcels and groupage traffic	3
Miscellaneous, varies	6
Total	40

One of the principal aims was to investigate differences between J.I.T. and non-J.I.T. operations. As shown in Table 2, our sample contains 27 cases which can be classified as either J.I.T. or Quick Response to the customer.

Table 3 delves a little deeper and looks at the stage of the supply chain involved. As will be seen, our flows are dominated by primary distribution (i.e. movements from manufacturers to customers or into warehouses or distribution depots). For the analysis, we grouped these together with secondary distribution movements (i.e. movements from

Table 2 Nature of flow – J.I.T. or conventional

Nature of flow	*No. of respondents*
J.I.T. or quick response	27
Conventional	13
Total	40

Table 3 Stage of the supply chain

Stage of the supply chain	*No. of respondents*
Inbound materials	5
Inter-plant movement	6
Primary distribution	21
Secondary distribution	4
Other, inter-depot product swaps	4
Total	40

distribution depots to final customers or into the retail trade). The remaining 15 formed a second group.

As can be seen in Table 4, we achieved a good spread regarding the nature of the operation. Eleven interviews were conducted with own account operators, 19 with hauliers handling third party work and 10 with shippers using third party services for the flow in question.

Table 4 Nature of operation – own account or third party

Nature of operation	*No. of respondents*
Own account	11
Third party – haulier interviewed	19
Third party – shipper interviewed	10
Total	40

The vast majority of flows used articulated vehicles (Table 5). Whilst we did not wish to combine the remaining seven (being a mixture of rigid vehicles and drawbar combinations) together for analysis, this was forced on the grounds of sample size.

Table 5 Vehicle type used on selected flow

Vehicle type	*No. of respondents*
Articulated	33
Rigid	5
Drawbar combination	2
Total	40

Table 6 shows that only two flows used containers. This did not permit any analysis.

In similar vein, only one of our interviewees had a rail connection suitable for the traffic at either the origin or the destination (Table 7). However, Table 8 shows that 13 respondents indicated some positive degree of feasibility of using rail or intermodal transport for the flow selected. These 13 include the two containerised movements and the one movement with a rail connection.

Table 6 Nature of operation – conventional or containerised

Nature of operation	*No. of respondents*
Conventional vehicle and/or trailer	38
Containerised	2
Total	40

Table 7 Existence of rail connection at traffic origin and/or destination

Rail connection at site	*No. of respondents*
No	39
Yes	1
Total	40

Table 8 Feasibility of using rail or intermodal transport for the flow selected

Feasibility of rail/intermodal	*No. of respondents*
None	27
Slight or very unlikely	10
Possibly	1
Good alternative available	2
Total	40

Table 9 shows our estimate of the value per load for each flow i.e. the value of the goods or materials being moved. This must not be confused with the monetary valuations of journey attributes such as the ‘value of delay time’. It should be noted that some valuable commodities move in relatively small amounts and so may not constitute a valuable load. It is probably also the case that respondents will have been reluctant to give fully accurate information when asked about the value per tonne. In some cases we have had to estimate the consignment weight, particularly when loads are volume constrained by the vehicle size. For these reasons, we do not believe Table 9 to be as reliable as the other tables. In any event, analysis based on the groupings in this table failed to produce helpful results.

Table 9 Value per load on selected flow

Value per load	*No. of respondents*
Less than £10,000	9
£10000 – £50000	22
More than £50000	7
Varies, or is not known	2
Total	40

Our biggest disappointment was the failure, despite major efforts, to find a big enough sample of flows travelling less than 100 kilometres to support analysis. Table 10 shows that only four such flows were found. We came across some additional cases, where a short distance movement was part of a multi-drop delivery round, with significant amounts of time spent at various customer premises. No cost data was available for any particular leg, and only part of the load was ultimately heading for that destination anyway, so such cases did not seem suitable for the LASP experiment.

Table 10 Distance of selected flow

Distance of selected flow	*No. of respondents*
Less than 100 km	4
100 – 250 km	10
More than 250 km	26
Total	40

Twenty-six of our flows were over 250 kilometres. These flows had an average distance of 362 kilometres, the overall average being 282 kilometres. It is clear therefore that our sample contains flows of much greater distance than the average traffic mix on trunk roads.

Table 11 shows the frequency with which the flows operated. It is perhaps not surprising that our interviewees did not select any flows operating less than weekly. Only two flows were said to operate weekly. Twenty-one flows were said to operate more frequently than once per day. Table 12 shows that the vast majority of our sample flows operated solely during the daytime. Only three flows were described as night trunking. The remaining five could run day or night depending on circumstances, or were 24 hour operations. For analysis purposes, we grouped these with the three night trunkers.

Table 11 Trip frequency

Trip frequency	*No. of respondents*
Less than weekly	0
Weekly	2
More than weekly but less than daily	10
Daily	7
More than one per day	21
Total	40

Table 12 Time of day of selected flow

Time of day	*No. of respondents*
Daytime operation	32
Night trunking	3
Either, or 24 hour operations	5
Total	40

Transport costs varied widely as a percentage of total business costs or sales revenue (as appropriate), as shown in Table 13. This information was not known in all cases, and possibly for this reason the analysis was not very informative. These same comments apply also to Table 14, which shows logistics costs as a percentage of total costs or sales revenue.

Table 13 Transport costs as a percentage of total costs or sales revenue

Transport costs as % of total costs or sales revenue	*No. of respondents*
<1	4
1-5	9
5-10	7
10-20	13
20+	1
Not known or not applicable	6
Total	40

Table 14 Logistics costs as a percentage of total costs or sales revenue

Logistics costs as % of total costs or sales revenue	*No. of respondents*
<5	3
5-10	6
10-20	9
20-30	6
30+	3
Not known or not applicable	13
Total	40

4 Results from the LASP experiment

4.1 The data used for modelling

This analysis is based on 40 interviews. However, two of the 40 interviews yielded an unweighted regression equation with a wrong sign cost coefficient. In one of the two cases use of a weighting remedied this situation. Where there are wrong sign cost coefficients the data for that firm cannot be used, and is therefore given zero combination weighting.

4.2 The overall results

The results of the grouped valuations are presented in Table 15. The results show good t ratios indicating that (reductions in) all three types of delay are significantly positively valued. Several different methods of analysis were tried, Table 15 representing the most robust results. Quadratic models were tried in order to test for non-linearities, but these offered an improvement in only two cases out of the 40. We concluded that non-linearity was not a problem, and avoided the complication of including quadratic forms for just two firms. For 24 firms the weightings tried produced no improvement and so the no weight models have been used for those firms. For ten firms the ‘weight squared’ models performed best (as is often the case in LASP studies), and in six cases a statistical theoretical weighting performed best. The results reported in Table 15 for these 16 firms are those using the best weighting.

In the early stages of the analysis all estimated wrong sign non-cost attribute coefficients were set equal to zero. While this can be justified in itself, it had unfortunate

Table 15 Valuations of Delay Time (VDT), Arrival Time Spread (VSP) and Schedule Delay (VSH) expressed as pence per minute, end-2000 prices *(Table contains averages of n responses, t ratios in brackets)*

n	*Rate (£)*	*Distance (km)*	*VDT (p/min)*	*VSP (p/min)*	*VSH (p/min)*
Whole sample					
40	285.8	281.6	107.1	85.3	65.8
			(15.7)	(13.7)	(26.3)
Own account					
11	227.3	237.2	169.3	89.5	126.0
			(15.4)	(10.0)	(25.0)
Third party (haulier interviewed)					
19	298.2	286.8	155.1	167.6	86.8
			(9.2)	(8.3)	(15.7)
Third party (shipper interviewed)					
10	326.8	320.6	37.2	61.5	31.3
			(3.7)	(6.5)	(9.3)
Distribution					
25	310.2	281.0	183.6	128.7	104.2
			(14.4)	(13.0)	(23.6)
Not distribution					
15	245.3	282.7	76.2	56.9	47.7
			(9.5)	(7.1)	(15.7)
J.I.T./QR					
27	277.9	279.1	128.6	101.8	75.9
			(15.6)	(13.7)	(26.3)
Not J.I.T./QR					
13	302.4	286.8	61.0	46.8	35.6
			(5.1)	(4.1)	(7.2)
Articulated					
33	306.8	291.6	98.4	90.2	63.4
			(12.0)	(11.2)	(22.8)
Not articulated					
7	186.8	234.7	126.6	78.1	74.7
			(10.2) 8	(8.1)	(13.4)
Distance less than 250 km					
14	179.4	132.9	9.9	93.8	59.0
			(9.5)	(11.3)	(17.5)
Distance greater than 250 Km					
26	343.2	361.7	125.0	74.5	74.1
			(12.9)	(7.9)	(19.8)
Chemicals, chem. products, paint					
8	397.3	285.0	224.7	126.6	94.3
			(6.1)	(6.5)	(10.0)
Food, drink, grocery					
15	288.7	298.0	90.9	77.5	48.4
			(11.6)	(10.6)	(15.6)
Other commodities					
17	230.9	265.6	145.7	93.3	97.0
			(9.8)	(6.2)	(20.9)
Rail possible					
13	301.4	300.5	77.9	60.4	56.3
			(6.4)	(5.4)	(12.2)
Rail not possible					
27	278.3	272.6	120.5	96.2	69.6
			(14.6)	(12.9)	(23.5)
Daytime movement only					
32	283.7	268.2	97.3	72.0	61.4
			(14.0)	(10.6)	(15.7)
Some night time movement					
8	294.7	325.5	431.5	159.0	173.9
			(10.7)	(10.0)	(13.7)
North East based interviewer					
18	321.1	275.8	50.5	104.7	49.2
			(4.1)	(7.5)	(13.4)
Huddersfield based interviewers					
22	257.0	286.4	131.4	80.3	80.0
			(16.1)	(11.6)	(23.5)

knock-on effects, relating to the variance to be attributed to these zeros. If we were really saying the coefficient could not be negative, the very concept of giving the zero estimates a Normally distributed variance is questionable. With the present results, merely replacing wrong sign non-cost coefficients by zero made negligible difference to the grouped estimates. While this is primarily due to those replaced estimates having high variances (and hence little weight in the combination), which then are transferred to the zeros, the point to be borne in mind is that we do not really have any better variances to attach to the zeros. We therefore concluded that the wrong sign estimates would be included in the grouped estimates.

We will first comment on the results for the whole sample. Rather contrary to expectation, the value of delay time (VDT) has the highest estimate, followed by value of spread of journey time (VSP) and then schedule delay (VSH). The average distance is just over 280km, and the average cost per km is just over £1. Standard errors of difference are about 7-9p/min, so the gap between adjacent values is about 2 standard errors. Accent Marketing & Research and Hague Consulting Group (1996) recommended an evaluation value of time of 40p/min (in 1994 prices) for freight vehicles, which is roughly 50p/minute in 2001 prices. Our VDT should be higher, since respondents were not given the option of rescheduling their journey earlier (in order to use the cheaper, slower, route and still arrive on time).

The first disaggregation we shall consider is Own Account as against Third Party. Here we come across one of our most interesting findings, namely that we need to disaggregate the Third Party results according to whether we interviewed the shipper or the haulier. The values to the shipper are low, reflecting an interest in the cost to the load, but no interest in what happens to the lorry or driver. The haulier has higher values, particularly for spread, where uncertainty of arrival time is presumably highly detrimental to the organisation of the business. Own Account operators are less worried than hauliers about spread, but more worried about journey time and schedule delay. Perhaps this reflects the shorter distance involved in the Own Account operations surveyed, which might mean an hour's delay has more disruption than for the longer distance Third Party movements.

Next we look at whether the surveyed movement was a (Primary or Secondary) Distribution movement or not. Distribution movements were costing much more per km and their valuations were also much greater. We then considered whether the movement was J.I.T. or not. Again, valuations were much higher for J.I.T., although this time the per km freight rate was lower for J.I.T. than other flows. Type of vehicle used did not have much effect on the valuations, though it was noticeable that articulated lorries were used for the longer distance journeys.

Considering distance explicitly, despite considerable efforts on our part, we were only able to obtain interviews for four journeys below 100km, and this proved too few to generate reliable estimates. We split our sample at 250km. Longer distance journeys had higher values of delay time but lower values of spread. This echoes the point made earlier, that (an absolute amount of) uncertainty is more disruptive for shorter, as opposed to longer journeys.

Looking next at the commodities moved, the sample sizes were too small to permit much disaggregation. Due to our survey area, we had quite a few chemicals related flows, as well as many grocery related. The chemicals related flows were travelling (on average) the same distance as other commodities, but at a cost greatly above average, presumably reflecting the specialist equipment involved and lack of opportunity to obtain suitable return loads (avoiding contamination or cleaning of tanks). They had high valuations. Grocery flows, on the other hand, went further than average, slightly more cheaply than average and had lower than average valuations.

We then looked at flows where rail was a (usually remote) possibility. Such flows were longer than average and had lower valuations than average. Next we considered whether the journey took place partly (or wholly) at night, or was wholly during daytime. Surprisingly, only one fifth of our flows involved night time movement, and these had the highest valuations contained anywhere in the table. Once it had been decided to use night time movements, any form of delay was greatly disliked.

The other dimensions set out in Tables 1–14 were also investigated, but did not yield insightful results. A particularly unfortunate case was value per load (see Table 9). It appeared that high value loads produced very low value of delay time, zero value of spread and low value of schedule delay. We did however have some difficulty in reconciling value of goods to the value of the vehicle load. Small vehicles loaded with high value goods and large vehicles loaded with average value goods could well have loads of equal value.

Lastly, we present the results from our two interview bases, as a way of stressing that the above results are in no way meant to be representative of the mix of traffic on trunk roads. Very different results can arise depending on which area is surveyed. We should emphasise that not all movements used in the LASP experiment were based in the area that the interviews were based in. It was a consequence of having a sampling frame that, if the early interviews appeared to be light in certain categories, we would attempt to fill those categories in later interviews. Indeed, towards the end we were specifically looking for short distance flows. Since the North East based interviews were conducted earlier than the Huddersfield ones, they can be expected to differ for this reason, if no other. The traffic flows forming the basis of the North East and Huddersfield sub-samples are therefore genuinely different.

4.3 Additional analysis

We investigated two further aspects of our LASP results, and these are discussed briefly in this section. Firstly, we considered correlations between the estimates for our three types of delay and secondly we considered a meta model for all the results together.

As can be seen in Table 16, correlations between the percentage estimates for VDT, VSP and VSH over our respondents are low, the highest being 0.35 between VDT and VSP. Consequently, it should not be assumed that the relationship between these values is fixed. The absolute valuations, as presented in Table 15, are much more highly correlated. This is because the percentage valuation has been multiplied by the freight rate common to all three. Hence respondents who have a high value of VDT also tend to have a high value of VSP, merely because both have been multiplied by a high freight rate, such as would occur for a longer distance flow. Our conclusion is that there is considerable variation in the relative importance of each of the three types of delay amongst our sampled firms.

Table 16 Correlations between estimates of the percentage valuation of three types of delay

Type of delay	*VDT*	*VSP*	*VSH*
VDT	1		
VSP	0.35	1	
VSH	0.12	-0.11	1

Secondly, we attempted to fit a simple meta model to the estimated valuations for individual firms. The explanatory variables included those listed in Tables 1–14 (e.g. commodity type). The dependent variables were the estimated valuations of VDT, VSP and VSH. Our limited analysis was unable to find significant effects. Consequently we were not able to develop any meta models. This is an area for consideration for further analysis.

5 The perceived need for travel time predictability

5.1 Introduction

Through discussions with survey respondents as to the nature of the freight flows they had selected for investigation through LASP, it emerged at an early stage that effective operation of many of those flows depended on a high level of certainty as to the expected arrival time of the vehicle, either at the loading point or the unloading point. On further investigation, a wide range of reasons for this certainty requirement emerged, but they can be conveniently divided into three groups:

- highly predictable arrival time to meet demanding conditions laid down by customers;
- highly predictable arrival time to meet other critical deadlines;
- highly predictable arrival time to allow operators to maintain the efficiency of their transport and logistics operations and to meet statutory obligations.

These three groups are discussed in Sections 5.2, 5.3 and 5.4.

5.2 Customer requirements

5.2.1 Just-In-Time deliveries into manufacturing and processing plants

The LASP survey included consignors and shippers responsible for the operation of J.I.T. deliveries of components into manufacturing or assembly processes, or materials into other processing operations. In some cases these represented highly transport intensive operations, with a requirement for several loads per day. Delivery times were specified very precisely in certain cases. It was clear that continuity of production processes would be jeopardised in the event of late arrival.

5.2.2 'Quick response' retail deliveries

Other survey respondents were handling deliveries of food, drink or manufactured goods into the retail trade. Three scenarios can be identified here;

a manufacturers or other suppliers delivering direct to individual retail outlets;

b more commonly, manufacturers or other suppliers delivering into regional distribution centres (RDCs). Some of these were 'Quick response' deliveries with little or no product stock being held at RDCs by the retailers concerned;

c logistics operators working under dedicated contract for major retailers, responsible for deliveries of consolidated loads from RDCs to individual retail outlets.

It was common for deliveries to be time sensitive in all three of these scenarios. The most notable examples related to scenario b), however. Modern practice at retail RDCs is for deliveries to be 'booked in' for unloading at an agreed time. A small window of variability is built around this booked time, with varying penalties for late arrival. In some cases, late arrivals are sent to the back of the queue. A number of respondents noted that in the immediate run-up to the LASP survey, one major grocery retailer had imposed substantial penalty payments on hauliers arriving late at their RDCs.

Another issue relating to both scenarios a) and b) above is that consignors may be given very little notice of the precise content of orders. An example might be that a retailer would transmit the order electronically at midnight, for delivery to their RDC by mid-morning. In such cases the time available to the supplier to undertake order processing, picking of goods, checking, loading, documentation and despatch may be very tight, placing considerable strain on the warehousing system. Another example was found in which full loads of a bulk material are delivered to a processing plant several times a day. The plant has no stock in hand, and in normal circumstances the arrival and discharge of one load acts as the trigger for the next vehicle to be loaded ready for departure. Extended journey times would result in stock shortages, so that this ordering routine would become untenable.

5.3 Other critical deadlines

5.3.1 The need to meet port deadlines

In a number of instances deadlines for arrival at ports were found to exert a strong influence on journey scheduling. Clearly if there is a poor level of predictability of arrival times at ports, vehicles must be scheduled to start their journeys earlier to maintain a reasonable degree of certainty of achieving their preferred or booked sailing. This has cost implications for the operators concerned.

Port deadlines vary significantly, depending in part on the nature of the sea crossing. For high frequency roll-on / roll-off servic.e.s (eg Dover - Calais, or indeed on the Channel Tunnel lorry 'Shuttle' service), booking on a particular sailing may be neither necessary nor desirable. For less frequent services, such as the Irish Sea routes, the need to meet deadlines becomes more pressing, particularly when trailers are to be shipped unaccompanied and hence require towing onto the vessel.

For container traffic in transit to deep-sea ports such as Felixstowe or Southampton, the logistics of port operation dictates that there is a cut-off time for arrival, usually one day before sailing time. On occasion, export loads may be delayed at the factory, so that transit time to port becomes critical. On routes where there might be a choice of UK ports offering reasonable frequency of sailings (such as the North Atlantic), this may even dictate a late change in the port used. A local port may be preferred if there is a chance that a cut-off at a more distant port may be missed.

5.3.2 'Hub and spoke' operations

Express parcels operations are by their very nature time-sensitive. National network operators use 'hub and spoke' networks. Depots located strategically throughout the UK collect parcels and other urgent consignments during the afternoon, and these are shipped during the evening to a central 'hub' for sortation. All sortation must be achieved in a narrow time window so that vehicles can return to their home depots loaded with the parcels for their region. Unpredictable arrival times at the hub will therefore reduce the efficiency of its operation and may delay the sortation of parcels, forcing vehicles to depart late on their return journey. Further delay on that return journey may result in late deliveries to consignees, and possible refunds to customers under the terms of service guarantees.

In the course of the LASP survey, other companies were found to operate similar 'network' operations (typically overnight) across the UK, for example to exchange products between sites depending on their place of manufacture. Again, a high level of certainty of travel time is required.

5.4 The need for operational efficiency and legal compliance

In the face of rising transport costs (e.g. of fuel and drivers), it is apparent that many sectors of the freight transport industry have become used to operating on narrow margins and have devised many and varied strategies for improving their operating efficiencies as a means of survival. Critically, many of these strategies depend on a high degree of certainty as to travel times on the trunk road network.

5.4.1 Two-way loading

A number of flows examined during the course of the LASP survey were operated on the basis of two-way loading. In some cases, both loads would be related to the same industrial operation .(eg. outbound product distribution linked to inbound transport of materials or components). In other cases, hauliers link together work for different customers in order to minimise the amount of empty vehicle mileage. It was commonly the case that such operations depend on a high level of travel time predictability. This is particularly the case when the return load has to be collected within an agreed narrow time window.

5.4.2 Consolidation of deliveries

Certain respondents indicated that they consolidated deliveries to improve efficiency. For example, a food manufacturer in the North of England might despatch two or three consignments on one vehicle, perhaps for various smaller retailers in the South, or for different RDCs for a large retailer. This allows efficient operation of a large articulated vehicle for the trunk haul, whereas otherwise a number of smaller vehicles would be required. Faced with the possibility of less certain travel times, such manufacturers may lose this ability to consolidate, for two reasons. The first reason is that they may well miss their booked unloading time at the second or third call. Service levels to customers may therefore be jeopardised. The second reason is that delays on such schedules may lead to problems with respect to driving time regulations, raising the prospect of expensive double manning.

5.4.3 Driving hours implications

A number of respondents to the LASP survey expressed concern about the driver cost implications of greater travel time variability. In a number of cases delivery schedules had been calculated on the basis of effective use of the driver’s working shift. Delayed journey starts, longer travel times and greater travel time variability would all lead to problems in such cases. Respondents were concerned both about the implications for maintaining legal operations and about the broader cost implications, such as reduced scope for using drivers for other work at the end of the driving day. All these concerns seemed particularly significant in the ‘own account’ sector.

Another example quoted during the LASP survey related to the scope to exchange drivers en route. In some cases, vehicles heading in opposite directions are scheduled to exchange drivers at a convenient point en route, at a time that coincides with their requirement for a break. The scope to do this effectively is reduced if travel times are more variable, because a delay to one of the vehicles is likely to delay the other one as well.

5.4.4 Scope for round-the-clock operation

During the LASP survey, various operations were identified in which the vehicles are operated around the clock, but on different duties during the night. In one example, articulated tractor units were used during the daytime coupled to small trailers suited to urban deliveries. The same tractors were used with larger trailers on overnight inter-depot trunking operations. A delayed return to the depot either in late afternoon or early morning would therefore delay the next operation (although the delay could be minimised by having trailers preloaded).

Parcels carriers also tend to use vehicles day and night. One advantage of drawbar vehicles is that the full drawbar combination is extremely efficient for the night time operations to and from the hub sortation depot. During the daytime, the drawbar trailer will be uncoupled and the resulting rigid vehicle is available for collection and delivery work.

5.4.5 Enforced changes to order management and warehousing regimes

Other respondents expressed concern about the impacts of travel time variability on the effectiveness of their order processing and warehousing operations. Extended travel times or other factors enforcing earlier departure times would place greater pressure on already tight order processing, picking, loading, checking and despatch deadlines. The fear was expressed that earlier or later shifts might have to be introduced at warehouses, at relatively unattractive working times.

5.5 The need for predictability – some conclusions

The general conclusion to be drawn from the factors discussed during this section of the report is that there are many complex and varied reasons why freight transport and logistics operators value a high level of travel time predictability. As more and more sectors of industry have adopted modern logistics and supply chain management techniques, there has been a tendency to look for ever higher levels of efficiency in the supply chain, with significant impacts on the demand for freight transport services. This fundamental impact from the demand side is compounded by the pressures faced by transport operators on the cost side, particularly in the areas of fuel and driver costs. Taking these sets of factors together, it has been in the interests of all players in the supply chain to develop solutions that involve sophisticated scheduling techniques to ensure the achievement of high levels of vehicle and equipment utilisation. The result is that lead times have been progressively shortened and on-time delivery is the general expectation. The generally excellent performance of the trunk road network over recent decades has allowed this to become the norm.

The corollary of this is that any significant deterioration in travel time predictability for commercial vehicles on the trunk road network would have significant implications, not only for the operation of the road freight transport industry itself, but also for the majority of the retail sector, much of manufacturing industry and potentially for the nation’s international trade as well. Some of the more time-sensitive systems put in place by the manufacturing and retail sectors in recent years would become untenable and alternative solutions would have to be found.

6 Concluding remarks

In order to address the objectives set out in Section 1, interviews have been held with 40 decision makers with responsibility for either shipping or transporting goods on the GB trunk road network. Three distinct types of delay were considered during these interviews:

- A delay resulting from an increased journey time, with fixed departure time.

- An increase in the spread (or range) of arrival times for a fixed departure time.
- A schedule delay where the departure time is effectively put back.

The above types of delay were incorporated into an Adaptive Stated Preference experiment. One interview failed to yield usable information. The remaining 39 interviews produced willingness-to-pay valuations of the three types of delay. We refer to these three valuations as VDT, VSP and VSH respectively.

We have compared the magnitude of these values with values in the literature. In particular, we have compared our results with values taken from a review undertaken in 2001 for the then Department of Transport, Local Government and the Regions. We are satisfied that the values represent plausible responses given the composition of our sample. Our sample is not intended to be representative of any particular population, e.g. the commodity distribution will not reflect the population. However, we have presented disaggregate results so that any desired re-weighting can be performed. Very few short distance flows on trunk roads were sampled, and therefore it is not possible to re-weight in this instance. In all other dimensions of interest, we believe we have achieved our goal.

An unexpected finding was that valuations for third party movements varied greatly depending on whether the interviewee was the shipper or the haulier. Shippers using third party services tended to have much lower valuations. We believe this is because they did not consider the costs to the haulier of increased journey times. As was discussed in Section 5, these costs may be considerable. For VDT and VSH, own account operators appear to consider the both the costs (a) to the load and (b) to the driver and the vehicle, and so sum the third party shipper and haulier values. This does not apply to VSP, where the own account operator is less inconvenienced by unplanned delays than the haulier.

Our results in this report are presented as one-dimensional splits, this being all that the sample size will permit. It should be borne in mind that there will be correlations between the various attributes. For example, there is some correlation between operator type and journey distance, with third party journeys being on average some 30% longer than own account journeys. Consequently, what might be taken to be an ‘own account effect’ could be a ‘distance related effect’ (or vice versa).

We conclude this report by considering how successful we have been in meeting the objectives set out in the Introduction. The first objective was to determine the strategic reactions of freight road users to variability in trunk road travel times resulting from planned and unplanned events affecting preferred routes. The interviews have provided considerable insight into this, in particular identifying a wide range of reasons why shippers and hauliers value a high level of travel time predictability. These reasons have been considered in some detail in Section 5. The second objective was to identify the willingness to pay of freight road users to mitigate such variability, for example via road usage tolls. Despite many difficulties, the LASP experiment successfully returned significant and plausible values for a range of two-way splits of firms. Section 4 discussed these results in detail. The quantitative values assisted in our understanding of the relative valuations of the three types of delay by different sectors of road freight traffic. In particular, we were able to consider objective three, which was to investigate whether the above reactions and willingness to pay vary significantly between J.I.T. and non-J.I.T. respondents. The quantitative finding was that all three valuations were at least twice as high for J.I.T. respondents than for non-J.I.T. respondents, a finding consistent with the qualitative assessment set out in Section 5.2.

7 Acknowledgements

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Abstract

Delays to road freight vehicles impose a very high cost on the nation. Delayed arrival time can occur for a variety of reasons. This report presents the findings of a Highways Agency funded study, which has investigated the user valuations of three different kinds of delay:

- A delay resulting from an increased journey time, with fixed departure time.
- An increase in the spread (or range) of arrival times for a fixed departure time.
- A schedule delay where the departure time is effectively put back.

The study centred on an interview survey of forty shippers, hauliers and third party logistics operators. Respondents were asked to consider one of their freight flows on the trunk road network in detail. The report presents user valuations of each kind of delay, estimated using the Leeds Adaptive Stated Preference (LASP) methodology. Various reasons why respondents value a high degree of predictability of journey times on the trunk road network are identified and discussed.

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SR309 *The management of urban freight movements*. The proceedings of a seminar held at the Transport and Road Research Laboratory, Crowthorne, 20 and 21 May, 1976. 1977 (price £20)

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