1. INTRODUCTION

The purpose of this paper is to make more widely available some important new results on the values of freight journey time reductions and freight journey time variability reductions in Great Britain, broken down by nine commodity groups. These results come from a project on Freight User Benefits funded by the (since abolished) UK Strategic Rail Authority (SRA/FUB), and carried out by a team comprised of Booz Allen Hamilton and the Institute for Transport Studies, University of Leeds (BAH/ITS, 2004). The results given in this paper were obtained using the Leeds Adaptive Stated Preference (LASP) methodology (Fowkes and Shinghal, 2002).

That project also helped us to understand better the context in which freight journey timing decisions are made, in response to the various utilities/disutilities of alternative possibilities. The present paper sets out some of these issues formally, and then gives some insight into the implications for decision making and for the information content of observed actual or hypothetical choices. This insight underlies the analysis that led to the presented results with which the paper ends.

2. HOW DOES THE MOVEMENT OF FREIGHT BENEFIT FROM TRAVEL TIME SAVINGS, AND TO WHOM DO THESE BENEFITS ACCRUE?

2.1 Introduction

Whilst some general idea of the benefits of speeding up freight can be gained by considering passenger transport as an analogy, in order to really get to grips with the matter we should consider the freight situation in some detail. By understanding where the benefits might accrue, we can plan to survey those decision makers who have a trade-off of these benefits against cost, if only in a hypothetical SP experiment.

2.2 Reducing the time spent by goods in transit on vehicles

Some goods deteriorate, as regards value at destination, the longer they are in transit. Obviously, perishable foods with a shelf life of only a few days will be more valuable at the destination the sooner they are there. Some goods may deteriorate in terms of ‘looks’ the longer they are in transit, for example chocolate during hot weather due to ‘blooming’. Some powder traffics in
tankers ‘settle’ or solidify with time in the tank, making discharge more difficult and expensive.

2.3 Getting more use out of the vehicles and other transport equipment

If we can speed up transit times, the vehicle used (and any caging, pallets etc being used) will be freed up that much quicker and be available to carry out more round trips per unit of time. Particular circumstances may severely limit any such gains. For instance, if most customers require deliveries in the morning there will be a peak vehicle requirement at that time. The peak vehicle requirement may not be reduced by speeding up a particular trip. The lorry concerned may just stand for longer waiting for its next load. Eventually, however, as transit time is reduced there will come a point where a peak vehicle gets back in time to complete a second peak journey. Similarly, although ‘lumpy’, speeding up the transit time will eventually allow a given amount of traffic per unit time to be moved with a smaller allocated amount of caging, pallets etc.

2.4 Saving the amount of time for which the driver, and any other persons necessarily travelling with the load, is required

Here there is some difference between the modes, and we shall consider only the road and rail modes. In both cases there is again ‘lumpiness’, with the average benefit being the average of many zeroes and some larger amounts.

For road movements, there is usually just one driver with the load at any one time. If there is a peak requirement for drivers and they are employed for fixed hours each day, then there may be no benefit from speeding up transit times. This, however, is not usually the case. Drivers’ schedules tend to be flexible, with different numbers of hours worked each day, within the driving time regulations. A saving of two hours on a regular round trip movement would certainly reduce the wage bill by two hours. Travel time savings can be particularly valuable if a driver is close to ‘running out of hours’, i.e. is close to needing a legally determined rest break which will either cause substantial delay to the load or require a relief driver to be sent out to take over. This might be avoided by rescheduling the work over two drivers, but that too could be expensive. Avoiding the need for that, or reducing the risk of going ‘out of hours’, is very valuable.

Turning to rail, the load is accompanied whenever it is moving, again usually just by one person. This time, however, one person is not required per ‘lorryload’, but only per train, so the benefits under this heading of speeding up rail services are much less than those of road.

2.5 Allowing a later start from a loading point

If departure time can be put later, due to a travel time saving, then it may be possible to save money by giving greater flexibility in both when the goods are
manufactured / processed and in when they are loaded. In both cases, it may be possible to avoid / reduce working outside of normal hours.

2.6 Gaining benefits by having goods at the destination earlier

The benefits due to perishability and shelf life have already been included in section 2.2 above, but there are additional benefits in having the goods on hand at the destination earlier. For part-load and parcel operators using a hub and spoke system, speeding up travel on the spokes allows later final collection times or earlier delivery times. Speeding up the trunk section offers both of these, but also permits a wider area to be covered by the collection and delivery spokes within standard collection and delivery schedules. Manufacturing companies may be able to schedule production more efficiently with their raw materials available earlier, or else the level of stocks might be reduced.

3. HOW DOES THE REDUCTION OF TRAVEL TIME VARIABILITY BENEFIT THE MOVEMENT OF FREIGHT, AND TO WHOM DO THE BENEFITS ACCRUE?

3.1 Introduction

There are many parallels between the benefits from travel time savings and from travel time variability reductions, but it will be worth retracing our steps from section 2. We define travel time variability as the range between the earliest possible arrival time and the 98th percentile of arrival times. This allows for exceptional events for which it is not sensible to plan. The simplest measure of variability is the standard deviation of the distribution of arrival times. Possibly more useful is the coefficient of variation of arrival times (i.e. standard deviation divided by the mean). When applied to travel times, this has recently been called the ‘Reliability Ratio’ (Bates, 2004).

3.2 Reducing the variability in the length of time of goods are in transit on vehicles

Analogously with section 2.2, many goods will deteriorate or settle in transit as time passes. If the longest acceptable time in transit is set for each load, then the less travel time variability there is, the longer is available for the scheduled (or planned) journey time. That might mean that it was no longer necessary to use a tolled route, or ‘double shift’ the movement (such as when a second driver had been made available to cover the rest break of the first driver). On rail, where missing a ‘booked path’ can lead to great delay, reducing travel time variability has direct benefits in addition to those due to rescheduling.

3.3 Getting more use out of the vehicles and other transport equipment

Because of the importance of punctuality, firms will be reluctant to schedule tight turn round times for lorries (and other transport equipment) following a
job known to take a very variable time for completion. Reducing travel time variability will permit shorter turn round times to be scheduled for the same risk of being late starting the second job. Occasionally this will reduce the number of vehicles (or sets of equipment) needed to cover the workload.

3.4 Getting more useful work out of the driver

Following on from section 3.3, there could obviously be a saving in the number of lorry drivers needed, for a given service quality. The case is again stronger for rail, where a few minutes delay (say resulting from a previous late arrival) can cause hours of delay as the train is looped out of the way of passenger trains. On some routes just one freight train per hour is allowed, at a specific number of minutes past the hour.

3.5 Allowing a later start from a loading point

These benefits are as in section 2.5 above, all other aspects of the schedule being maintained. Reducing travel time variability means that you can depart later with the same chance of being late at the destination.

3.6 Gaining benefits by having goods at the destination earlier

The flip side of the argument in section 3.5 is obviously that a reduction in travel time variability allows you to depart at the usual time but rely on an earlier arrival time without changing the probability of the arrival being late. The arguments of section 2.6 then apply, giving benefits.

4. A THEORETICAL INSIGHT

4.1 Introduction

In this section we will attempt to gain insight into how valuations of different disutilities affect the choice of departure time. The sorts of things that need to be taken into account include length of journey time, variability in journey time, cost of departing earlier and the costs of arriving later. We will begin by examining a diagram which assumes that journey time is known, so that the decision on departure time determines arrival time.

4.2 The diagram

The inability, for whatever reason, to depart at the optimal time, impacts on a business in various ways. Diagram 1 has been drawn on the basis of the following assumptions:

- It is not feasible to depart before time TA (absolutely impossible to have the load ready any earlier, or no vehicle available)
- Time TB is the optimal departure time, against which disutility is measured. Moving from TB to TA incurs disutility due to rushed production, lorry scheduling difficulties, warehouse staff overtime, etc
• The time (TC-TB) is system slack time, which has a positive utility as it can be used only once
• Beyond TC, penalties arise quickly due to stockouts, disruption to production schedules, etc
• Beyond TD, it doesn’t matter any more for whatever reason e.g. the customer has gone elsewhere
• All the lines between TA and TD can be curves. We incorporated such non-linear effects in the SRA/FUB work and elsewhere.

**Diagram 1:** An illustration of the disutility associated with different departure times, with journey time known and zero variability

### 4.3 Insights gained

It is accepted that we have only looked at a simplified situation, where journey time is known and consequently there is no variability. Nevertheless some insights can be gained. Firstly, knowing the disutility rates attached to each of the time segments (e.g. TA-TB etc) is sufficient to draw the diagram. It follows that analysing actual data cannot uniquely determine those disutilities in addition to the disutility of journey time. That is, we have just sufficient information to identify these slopes with no information left over to identify the value of transit time. Statistically we say that the problem is under-identified and contains one too few degrees of freedom.

When making decisions on journey times, a range of factors will be taken into account, including those shown in Diagram 1 plus the disutility of having goods in transit and the problems caused by the travel time variability. The outcome will be a trade-off between these various concerns. The diagram
shows some fixed constraints as is likely to be the case in practice. Within those constraints there are different penalties for moving departure time backwards or forwards. We discussed in section 2 the disutilities related to increased journey time and in section 3 those related to increased journey time variability. To counter the uncertainties it is usual to include some slack time in the system as shown in the diagram (TB-TC). It is to be expected that the true disutility functions will be non-linear, thus the sloped straight lines in the diagram will most likely be curves. We therefore need to include non-linear terms in our estimations using real data and we must accept that it will be impossible to isolate all the different effects we have considered. Our approach will be to quantify the main effects, in particular we wish to quantify values of journey time, values of journey time variability and the ratio between the two. To do this we will have to investigate penalties for late arrival.

5. THE BAH / ITS FREIGHT USER BENEFITS PROJECT FOR THE STRATEGIC RAIL AUTHORITY

5.1 Background

As stated in Section 1, the UK SRA funded work on freight user benefits by Booz Allen Hamilton and ITS Leeds. Following an initial literature review, the SRA decided to proceed with two competing but complementary methods. The first method was an in-depth probing of what costs would be generated by (various amounts of) journey time increases and journey time variability increases. The second method was the Leeds Adaptive Stated Preference (LASP) method, whereby respondents are shown a series of screens each displaying four alternative journeys, and are asked to rate them. Manual and regression techniques can then determine implicit attribute valuations consistent with those ratings. Results for both methods are contained in BAH/ITS (2004).

5.2 The survey

A total of 49 LASP interviews were conducted for this study between September 2003 and February 2004. The aim of these interviews was to investigate freight users' willingness to pay for a range of user benefits. The LASP experiment sought to place interviewees in a situation of having to make a long run choice of mode and service quality for a typical flow when facing a range of available alternatives at stated costs. Due to limitations on the likely believability/credibility to all respondents of large improvements in service quality, usually alternatives with attributes set at worse than current levels were offered, and the required price discount sought. Only road and rail flows were considered.

Each interview consisted of two sections. The first section involved the gathering of background information about (i) the firm and its activities, (ii) the firm's freight movements and (iii) the typical flow chosen for the LASP experiment. The second section of the interview was the LASP experiment, consisting of (usually) 10 screens each containing 4 alternative journeys set...
out in 4 columns, as illustrated in Figure 1. The entire interview was scheduled to last about one hour.

Figure 1: Illustration of the LASP iteration screen

Following consultation within the study team and with the SRA, it was decided to describe the 4 alternatives on the LASP screen in terms of mode (road or rail), latest departure time (set equal in Alternative 1 to the current USUAL departure time), earliest arrival time (if there were no delays not specifically allowed for in the schedule), and the time by which 98% of arrivals will have occurred. These attributes have been abbreviated as: MODE, LATEST, EARLIEST and MOST. In the experimental design, in Column 1, all of these attributes take on their current reported levels. The LASP screen interpolates 90% and 95% times, for purely presentational purposes. In Columns 2 to 4 one or more of the non-cost attribute levels are varied from those in Column 1.

The final attribute is the freight rate offered to the firm by the haulier. This is the haulier's price, but the term ‘price’ is not generally used in this context. To the freight shipper it will be cost. It is displayed in monetary terms and as a cost index (denoted COST) where the current COST is 100. The COST for Alternative 1 is set at 200, to give an alternative with current attribute levels except for cost, which is doubled.
Respondents are asked to rate Columns 2 to 4 relative to the fixed rating of 100 in Column 1. Subsequent screens react to earlier ratings and attempt to induce respondents to change their rankings of columns (i.e. the ordering of the ratings).

5.3 Results

Full results are contained in BAH/ITS (2004) and are summarised here in Tables 1, 2 and 3. The first method of analysis used was the manual method. The manual modelling looked at all occurrences of a ranking change, involving Column 1, where the non-cost attributes had remained unchanged. For example, if a fall in COST from index 180 (i.e. 180% of the actual current freight rate) to index 160 caused a rating change from 90 to 110, then it would be deduced that the value of that column’s service compared to Column 1 was worth between 20% and 40% of the current freight rate (i.e. 200-180 and 200-160, where 200 is the COST for Column 1). The best guess here would be 30%, i.e. halfway between 20 and 40 since 100 (the Column 1 rating) is halfway between 90 and 110. If the only difference between the two columns was that Column 1 was 50 minutes quicker, then value of time would be indicated as being 0.6% of the freight rate per minute.

The second method, regression analysis, involved a number of models for Non-bulks and Bulks separately. These methods are described in Fowkes and Shinghal (2002). Although the dependent variable in the regressions is a logistic transformation of the ratings, standard regression was used and results were interpreted in the usual way. Not all of the models proved useful.

For the Non-Bulks, the useful models were M2, M3, M4 and M5, containing explanatory variables permitting the estimation of the following valuations:

- M2: VM, VJT, VAE, VAESQ, VAL, VALSQ;
- M3: VM, VJT, VSP, VSH2, VALSQ;
- M4: VM, VJT, VSP, VAL, VALSQ;
- M5: VM, VJT, VSP, VESH2, VLSH2, VALSQ.

For the Bulks useful models were:

- M2 (or more exactly M2A): VM, VJT, VAL, VALSQ;
- M4: VM, VJT, VSP, VAL, VALSQ;
- M7: VM, VJT, VSP, VALSQ.

When considering the models the following notation is employed:

- VM – the penalty for using rail in place of road
- VJT – the value of one minute reduction in the duration of the scheduled journey time
- VSP – the value of one minute reduction in the spread of arrival times, from the earliest to the time by which 98% have arrived
- VESH (or VESH2) – the value of starting out one minute earlier than currently; moving the whole journey forward by one minute
- VLSH (or VLSH2) – the value of starting out one minute later than currently, moving the whole journey back by one minute
• VAE – the value of starting out one minute earlier than currently, all other clock times held constant
• VAESQ – the square of VAE
• VAL – the value of arriving one minute later than currently, all other clock times held constant
• VALSQ – the square of VAL

It proved difficult to select preferred models, as there was interest in a range of quantities, not all of which could be estimated in a single model due to the restrictions of linear dependency discussed in section 4. Consequently, when interpreting model valuations, care must be taken to see which other valuations were derived in the same model. For example, VJT valued scheduled journey time, and VAE valued having to start out earlier. If there were an absolute constraint on the arrival time, an increase in the scheduled journey time (JT) of x minutes would be accommodated by starting out x minutes earlier. Consequently, it can reasonably be deduced that, all else equal, the estimated value of VJT in the absence of VAE would be the sum of the estimated values of VJT and VAE were they both to be present. In other words, the VJT estimate when both are present has its early start penalty stripped out of it. A second example is the obvious effect on VALSQ depending on whether or not VAL is included.

Besides the results for the individual firms, grouped results can also be derived (Fowkes and Shinghal, 2002). Table 1 shows actual results from the models for 9 commodity groups using the models with the best adjusted R square statistics. Recommended values are also shown based on considerations of adequacy of fit. Table 2 displays recommended values together with standard errors and coefficients of variation for those estimates. However, it should be noted that the only variation being considered here is that resulting from failure to exactly explain all the reported ratings in terms of the attribute levels being rated. Additional, non-included, error will be present relating to any failure of respondents to rate honestly, and any failure of the limited number of firms sampled to reflect any larger grouping of interest.
<table>
<thead>
<tr>
<th>METHOD</th>
<th>MARKET</th>
</tr>
</thead>
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<td>DESCRIPTION</td>
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<td>BULKS</td>
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<td>METALS</td>
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<td>M4</td>
</tr>
<tr>
<td>M5</td>
<td>M5</td>
</tr>
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<td>M2A</td>
</tr>
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<td>SCHEDULED TIME</td>
</tr>
<tr>
<td>M4</td>
<td>M4</td>
</tr>
<tr>
<td>M5</td>
<td>M5</td>
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<tr>
<td>M2</td>
<td>M2A</td>
</tr>
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</tr>
<tr>
<td>VSP</td>
<td>DELAY SPREAD</td>
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<tr>
<td>M3</td>
<td>M3</td>
</tr>
<tr>
<td>M5</td>
<td>M5</td>
</tr>
<tr>
<td>M2</td>
<td>M2A</td>
</tr>
<tr>
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</tr>
<tr>
<td>YSH1</td>
<td>EARLY SHIFT</td>
</tr>
<tr>
<td>YSH2</td>
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<td>VAE</td>
<td>EARLY START</td>
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<td>LATE SHIFT</td>
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<td>M2A</td>
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<td>LATE ARR SQ</td>
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<td>M2A</td>
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<tr>
<td>M5 (NO VAL)</td>
<td>M5 (NO VAL)</td>
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Table 1: Results from the LASP interviews

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<table>
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<tr>
<th></th>
<th>Coal</th>
<th>Petroleum products and chemicals</th>
<th>Other Bulks</th>
<th>Automotive (i.e. general cargoes)</th>
<th>Finished containers</th>
<th>Containers</th>
<th>Express</th>
</tr>
</thead>
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<tr>
<td><strong>Time</strong></td>
<td>Value</td>
<td>2.40</td>
<td>8.40</td>
<td>1.00</td>
<td>24.00</td>
<td>12.00</td>
<td>24.00</td>
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<tr>
<td>(per hour)</td>
<td>SE</td>
<td>0.60</td>
<td>1.32</td>
<td>0.72</td>
<td>8.04</td>
<td>3.42</td>
<td>9.18</td>
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<tr>
<td></td>
<td>CV</td>
<td>0.25</td>
<td>0.16</td>
<td>0.72</td>
<td>0.34</td>
<td>0.29</td>
<td>0.38</td>
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<tr>
<td><strong>Lateness</strong></td>
<td>Value</td>
<td>2.90</td>
<td>6.50</td>
<td>3.80</td>
<td>24.00</td>
<td>18.00</td>
<td>45.00</td>
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<tr>
<td>(per hour)</td>
<td>SE</td>
<td>0.72</td>
<td>1.56</td>
<td>0.96</td>
<td>11.04</td>
<td>2.47</td>
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<tr>
<td></td>
<td>CV</td>
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<td>0.24</td>
<td>0.25</td>
<td>0.46</td>
<td>0.14</td>
<td>0.33</td>
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<td><strong>Lateness squared</strong></td>
<td>Value</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.14</td>
<td>0.06</td>
<td>0.80</td>
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<tr>
<td>(per hour squared)</td>
<td>SE</td>
<td>0.04</td>
<td>0.14</td>
<td>3.23</td>
<td>0.48</td>
<td>0.05</td>
<td>0.29</td>
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</table>

Table 2: LASP Recommended values (£ per lorryload, 20 tonnes/lorry for Bulks) with standard errors (SE) and coefficients of variation (CV)
Table 2 provides recommended LASP valuations for “Time” and “Lateness” and shows standard errors and coefficient of variance measures. Regarding values of time, large differences between commodity types are apparent. It is hoped that our interviews will have minimised the inclusion of any benefit due to saving driver hours or vehicle operating costs. This is because respondents have been told they were valuing door-to-door services provided by a third party at the price shown. The costs to the third party should be of no direct interest to the respondent.

The value of time found for general bulks is minimal (£1 per hour per lorryload) and not significantly different from zero. Coal does seem to have a higher value of time. Petrol and chemicals appear to have a yet higher value of time. General cargoes (‘Finished’) have a value of time of £12 per lorryload per hour, with a 95% confidence interval of roughly £5 to £20. Containerised goods and automotive seem to be double this. Express goods such as just-in-time movements on short lead times and overnight parcels appear to have much higher values of time, of the order of £1 per minute per lorryload.

Similar findings apply to lateness, though coal is now down with other general bulks at £3 to £4 penalty per hour late per lorryload. The penalty for lateness for general cargoes is estimated to be £18 per hour late per lorryload, with values for containers of £45 and for express of £180 (or £3 per minute late per lorryload). All these results for lateness are significantly different from zero. These values are subject to adjustment in the light of the ‘lateness squared’ penalties to be discussed next.

Estimates for ‘lateness squared’ were generally non-significant, but recommended values have nevertheless been given when the ‘lateness’ estimates assumed their presence. The one hour delay for Express is now valued at £185 per lorryload, a five hour delay at £1020 and a 2-day delay at £20,000. Notwithstanding this, Diagram 1 suggested that some upper limit for disutility/penalty would be reached, possibly once the value of the load was exceeded.

Since completion of the SRA/FUB study, a note by Bates (2004) has proposed the term “Reliability Ratio”, RR, for the ratio of the ‘value of a minute added to the standard deviation of journey time’ to the ‘value of a minute added to the scheduled or expected journey time’. We shall not delay here by entering detailed caveats about considerations of complications such as buffer/slack time, but proceed to calculate RR from the first of the above tables. The numerator of the ratio is taken from the value of an additional minute of late arrival, VAL. For simplicity, we assume that one minute added to the standard deviation of arrival times will add 2.5 minutes to the amount of late time. The numerator is therefore taken as 40% of the VSP figure. The denominator is taken to be the value of scheduled journey time, VJT. Table 3 derives RR figures for 9 commodity groups. While there is still evident variation over commodity types, it is less clear that there is any difference between Bulks and Non-Bulks.
<table>
<thead>
<tr>
<th>COMMODITY</th>
<th>VJT</th>
<th>VSP</th>
<th>RR=0.4*VSP/VJT</th>
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</thead>
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<tr>
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<td>0.20</td>
<td>0.20</td>
<td>0.40</td>
</tr>
<tr>
<td>Metals</td>
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<td>Automotive</td>
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<td>2.00</td>
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<td>TOTAL</td>
<td>0.50</td>
<td>1.00</td>
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</table>

Table 3: Reliability Ratios (RR) calculated from estimated values of journey times and journey time spreads

6. CONCLUSIONS

This paper has reviewed the reasons why those involved with freight movements might be willing to pay to reduce journey times and journey time variability. Consideration of Diagram 1 gave insights into time valuations that would determine optimal departure times. Adding a value of time saved in transit makes estimation from observed real or hypothetical data under-identified. That tells us that no unique monetary valuations can be found for all these time valuations simultaneously. The paper then gave results from a survey founded on this understanding. That survey used the Leeds Adaptive Stated Preference (LASP) methodology. In particular, estimated values of travel time savings and travel time variability reductions were used to form estimates of the Reliability Ratio. Results were presented for nine commodity groups as well as an overall total.

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