The valuation of arrival and departure delays in the UK passenger rail using satisfaction survey data

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SHORT SUMMARY

Stated preference surveys are typically used to derive reliability multipliers, defined as a trade-off between a minute of lateness and scheduled journey time. In this study, travel satisfaction data from the National Rail Passenger Survey in the United Kingdom is used to estimate the impact of scheduled journey length and delays on passenger satisfaction. An ordered logit model with OD fixed effects is estimated and reliability multipliers are subsequently derived. The estimated values are slightly larger than previously suggested, ranging from 4 to 9 for arrival delay and 2 to 6 for departure delay. The study offers some degree of novelty in terms of the type of data used in the estimation process. As a result, some caution is needed in using and interpreting the estimated multipliers. On the other hand, this study highlights the potential that satisfaction surveys may have in transport economics.

Keywords: lateness valuation, passenger satisfaction, rail economics, reliability multiplier, transport economics and policy

1. INTRODUCTION,

Transport researchers are interested in the impact that journey lengths, fares and delays have on passengers. Ticket sales data is often used to estimate the effect that generalized journey time (GJT) components have on rail demand. Following Wheat and Wardman (2017), the demand function is specified as:

$$V = \mu GJT^{\lambda} F^{\gamma} GVA^{\delta} \tag{1}$$

where F is the fare, GVA income, λ, γ, δ are respective elasticities and μ represents all the other factors impacting the demand. Generalised journey time is a composite index specified as:

$$GJT = T + \alpha H + \beta I \tag{2}$$

where T is the station-to-station journey time, H is the service headway and I is the number of interchanges with α and β being the respective penalty multipliers converting interchanges and headway into equivalent journey time.

Extending the demand specification presented in the equation 1, Batley, Dargay and Wardman (2011) used the following relationship between demand and average lateness at the destination prescribed by the Passenger Demand Forecasting Handbook (ATOC, 2005) in the UK:

$$Y = \left[1 + \frac{w(\bar{L}^{+}_{new} - \bar{L}^{+}_{base})}{GJT_{base}}\right]^{\lambda} \quad (3)$$

where Y is the proportionate change in demand, $\bar{L}^{+}_{new}$ and $\bar{L}^{+}_{base}$ represent average lateness at the destination in the base and new scenarios, GJT_{base} generalized journey time in the base scenario, λ is the elasticity of demand to GJT and w is the reliability (lateness) multiplier.

The lateness multiplier w defines the conversion rate of 1 minute of lateness to the equivalent of journey time. It is estimated as the ratio of the utility of lateness to the utility of scheduled journey time. Wardman and Batley (2014) provides a review of estimates of reliability multipliers with most of the initial values being around 2.5 to 3. Similar studies conducted throughout the years generally supported that figure but suggested values of up to 6.5 for airport journeys with Preston et al. (2009) estimating the different reliability multipliers by journey purpose and length as showed in Table 1.

Table 1: Reliability multipliers (Preston et al., 2009)

Journey Purpose	Short	Long
Business	2.70	1.80
Commute	3.22	2.10
Leisure	5.30	1.88

Stated preference (SP) surveys are most often used in studies where reliability multipliers are estimated (e.g. Bates et al., 2001; Preston et al., 2009; Batley and Ibáñez, 2012). In such cases, passengers are presented with alternative hypothetical travel options and make a choice regarding their preferred scenario. The differences in the options presented to the respondent are the ticket prices, scheduled journey lengths and performance. While the SP data can be subjected to biases, such as systematic bias (divergence between hypothetical and actual choices), justification bias (rationalizing actual choices) or strategic bias (influencing policy) (for review see Wardman, 1988), it has become a standard approach as it is often the only possible source of such data (Bates et al., 2001). An alternative to SP data is revealed preference (RP) data where passengers' actual travel choices are investigated. While economists typically prefer data on actual choices, RP data is more difficult to obtain and based on the assumptions of perfect information about the travel alternatives (Wardman, 1988; Bates et al., 2001; Preston et al., 2009).

An alternative to SP and RP surveys can be sought in satisfaction surveys where passengers score their satisfaction with an actual travel experience *ex post*. There is an abundance of literature looking at the impact of different journey aspects on passenger satisfaction (for reviews see de Oña and de Oña, 2014; Rong et al., 2022). In the rail context, Monsuur et al. (2021) used the National Rail Passenger Survey to estimate the impact of delays on passenger satisfaction, suggesting that passengers are very unlikely to remain satisfied with journeys delayed by over 30 minutes. Satisfaction data, typically from longitudinal household panels, have been widely used in economic valuation in labour (Layard, Mayraz and Nickell, 2008), health (Ferrer-i-Carbonell and van Praag, 2002) and environmental economics (Frey, Luechinger and Stutzer, 2009). However, similar approaches have not been as widely used in transport economics, possibly resulting from a lack of transport surveys with such detailed information or from household surveys lacking enough transport-related information. The most important exception is a study by Dickerson, Hole and Munford (2014) looking at the relationship between life satisfaction and commuting.

This piece of work draws on earlier work using SP surveys to estimate reliability multipliers (e.g. Bates et al., 2001; Preston et al., 2009; Batley and Ibáñez, 2012). At the same time, the methodology used in this study is similar to the large body of literature using data from surveys on life satisfaction (e.g. Layard, Mayraz and Nickell, 2008; Dickerson, Hole and Munford, 2014). The major difference is the use of a survey on journey, not life, satisfaction and its cross-sectional nature. National Rail Passenger Survey is used where passengers' satisfaction with a journey is reported on a 5-point Likert scale. The passenger responses are matched to operational data to study the impact of the scheduled journey time and delays on passenger satisfaction. An ordered logit model of passenger satisfaction is used to estimate the utilities of both scheduled journey length and delay (at departure and arrival) that are subsequently used in the estimation of a reliability multiplier.

2. METHODOLOGY

National Rail Passenger Survey (NRPS) dataset

275,000 responses from 10 waves (between 2015 and 2020) of NRPS in the UK were obtained directly from Transport Focus (for more details see Transport Focus, 2020). The data has been used in multiple studies, i.e. Monsuur et al. (2021) looking at the impact of delays on satisfaction, Stead, Smith and Ojeda-Cabral (2019) comparing satisfaction with open access and franchised operators or Lyons, Jain and Weir (2016) looking at passengers' use of in-vehicle time. The responses were subsequently matched with operational data using the Historic Service Performance platform to compute scheduled journey length and corresponding delay lengths for each of the passengers. Following initial analysis, some responses were discarded based on:

1) Frequency of travel
   Out of the 46% of passengers responding to the question regarding the frequency of travel on a given route, 73% admitted to travelling at least every 2 months. It is assumed that only the frequent travellers are affected by potential changes in scheduled journey length on a given route.

2) Journey purpose
   Airport journeys, commuter journeys longer than 60 minutes and passengers using special ticket types were removed from the dataset.

3) Recorded delay length and delay perception
   Responses where a passenger reported late arrival, but no delay was matched using the operational data (5.7%), were discarded as well the delays of more than 30 minutes to remove outliers and possibly erroneous responses.

4) Number of responses for a given origin-destination pair

OD pairs with more than 10 and 25 responses were selected as 792 OD pairs were identified with more than 10 responses over 26,026 responses and 270 pairs with more than 25 responses over 17,695 responses.

The passengers scored their overall satisfaction with their journey on a 5-point Likert scale, from ‘very satisfied’ to ‘very dissatisfied’ as showed in Figure 1. Similarly, passengers scored their satisfaction with the train, station, value for money and service frequency.


4 Your overall opinion of your journey today

Q16 Taking into account Glasgow Central station where you boarded the train and the actual train travelled on after being given this questionnaire, how satisfied were you with your journey today?

Very satisfied	Fairly satisfied	Neither satisfied nor dissatisfied	Fairly dissatisfied	Very dissatisfied	Don't know/no opinion
☐	☐	☐	☐	☐	☐

Figure 1. Overall satisfaction questions (Transport Focus, 2020)

Deriving the reliability multiplier

As the dependent variable (satisfaction) can take one of the five outcome categories, which are in sequential order, an ordered logit model is used for estimating the latent continuous variable y*. In this case, the probability of choosing a satisfaction category *i* is estimated for a given number of *k* categories, thus:

$$P(Y = i) = P(k_{i-1} < y^* \leq k_i) \tag{4}$$

where journey satisfaction is modelled as follows:

$$P(Y = i) = P(k_{i-1} < \beta_0 + \beta_1 SJT + \beta_2 L_D + \beta_3 L_A + \textstyle\sum_{n=1}^{n} \beta_n Sat_n \leq k_i) \tag{5}$$

where SJT is scheduled journey time, L_A and L_D - length of delay at arrival (destination) and departure (origin) and Sat_n is a dummy variable representing passengers’ satisfaction with train or station (models 1-4) and also value for money or frequency (model 4). It takes value of 1 if the passenger is satisfied with a given journey aspect or 0 otherwise.

In models 2-4, OD pair fixed-effects are included in the models by introducing a dummy variable representing each of the OD pairs represented in the sample. This allows treatment of the dataset, which is cross-sectional in nature, as a pseudo-panel of frequent rail travellers to estimate the impacts of both changes in journey times and delays on passenger satisfaction.

The ordered logit model is conceptually most suitable for modelling ordinal data (Dickerson, Hole and Munford, 2014; for review see Boes and Winkelmann, 2006), but its major disbenefit is the difficulty in interpreting the coefficients. However, as noted in Dickerson, Hole and Munford (2014), the ratios of the coefficients in the ordered model can be used to evaluate the trade-offs between variables. In this case, reliability multipliers are estimated as a ratio of utility of departure and arrival delay $\beta_2$and β_3 to the utility of scheduled journey length β_1. The multipliers are calculated separately for the two types of delays, at departure (w_D) and arrival (w_A) following Batley and Ibáñez (2012) for the selected three journey types. In line with the literature (i.e. Bates et al., 2001; Preston et al., 2009; Batley and Ibáñez, 2012), the reliability multiplier represents the value of delayed time respective to the scheduled time.

$$w_D = \frac{\beta_2}{\beta_1} \text{ and } w_A = \frac{\beta_3}{\beta_1} \quad (6)$$

3. RESULTS AND DISCUSSION

The models of passenger satisfaction are estimated using an ordered logit model with estimated coefficients presented in Table 2.

Table 2: Model estimates

	1	t-stat	2	t-stat	3	t-stat	4	t-stat
Constant								
Business	0	.	0	.	0	.	0	.
Commute	-0.0778	-0.93	-0.225	-1.85	-0.186	-1.25	-0.117	-0.69
Leisure	-0.0124	-0.14	-0.0553	-0.48	-0.0223	-0.16	-0.0793	-0.49
Station_Sat								
Business	1.345***	20.32	1.350***	17.26	1.325***	15.10	1.137***	12.27
Commute	1.111***	27.59	1.183***	20.87	1.195***	16.40	0.980***	12.94
Leisure	1.401***	27.85	1.465***	21.53	1.413***	17.07	1.172***	13.56
Train_Sat								
Business	3.059***	45.77	3.066***	38.20	3.127***	34.03	2.866***	28.90
Commute	3.049***	72.16	2.998***	51.96	3.042***	41.61	2.770***	35.98
Leisure	3.438***	62.16	3.418***	46.02	3.401***	36.61	2.999***	30.14
Freq_Sat								
Business							0.803***	8.15
Commute							0.888***	12.25
Leisure							0.919***	9.88
VfM_Sat								
Business							1.049***	15.92
Commute							1.120***	15.00
Leisure							1.123***	19.61
L_ A (β_3)								
Business	-0.0505***	-8.82	-0.0567***	-8.89	-0.0521***	-7.68	-0.0537***	-7.53
Commute	-0.101***	-18.36	-0.1000***	-14.12	-0.114***	-13.05	-0.109***	-12.03
Leisure	-0.0593***	-12.30	-0.0583***	-9.74	-0.0570***	-8.45	-0.0576***	-8.20
L_D (β_2)								
Business	-0.0690***	-7.77	-0.0683***	-6.46	-0.0729***	-5.99	-0.0758***	-6.01
Commute	-0.0522***	-7.71	-0.0472***	-5.20	-0.0296**	-2.60	-0.0349**	-2.97
Leisure	-0.0404***	-6.30	-0.0421***	-5.02	-0.0354***	-3.54	-0.0402***	-3.84
SJT (β_1)								
Business	-0.0009*	-1.99	-0.0120***	-5.43	-0.0121***	-5.00	-0.0134***	-5.27
Commute	-0.0058***	-6.76	-0.0134***	-5.26	-0.0142***	-4.74	-0.0123***	-3.93
Leisure	0.0002	0.53	-0.0105***	-4.95	-0.0102***	-4.34	-0.0125***	-5.06
N	40363		25457		17316		16632	
LL	-36770.8		-22388.3		-15181.8		-13920.9	
r2	0.234		0.246		0.231		0.267	
Fixed effects	X		V		V		V	
VfM and Freq	X		X		X		V	
Minimum N	1		10		25		25	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Model 1 is based on estimating the ordered logit without OD fixed effects. In this model, the delays at arrival and departure both have a statistically significant negative impact on satisfaction while the impact of journey length is less clear. However, it is not expected that passengers simply travelling longer are less satisfied with their journeys, as journey lengths naturally increase with distance. However, it is worth noting the significant and negative coefficient on scheduled journey time for commuters that may be potentially explained by their general dissatisfaction with longer travel for work (irrespective of distance). Nevertheless, it can be expected that respondents who travel on the same OD pair may be sensitive to changes in scheduled journey times and it is further assumed that these impacts are similar for travellers on the same OD. With the introduction of OD fixed effects in models 2-4, the coefficient on scheduled journey length becomes significant and negative for all journey purposes.

Using the estimated coefficients, reliability multipliers for arrival and departure delay are calculated for the models with OD fixed effects as showed in Table 3. The estimated reliability multipliers at arrival are around 4.0-4.7 for business travellers, 7.4-8.9 for commuters and 4.6-5.6 for leisure travellers. The respective departure reliability multipliers are 5.6-6.0 for business travellers, 2.1-3.5 for commuters and 3.2-4.0 for leisure travellers. The reliability multiplier is larger at departure for business travellers, slightly larger at arrival for leisure travellers and much larger for commuters at arrival. This would suggest that 1 minute of delay is valued as around 4 minutes at arrival and 6 minutes at departure for business travellers, 8 minutes at arrival and 3 at departure for commuters, and 5 minutes at arrival and 3 at departure for leisure travellers.

Table 3: Reliability multipliers

Journey Purpose	w_A			w_D		
	(2)	(3)	(4)	(2)	(3)	(4)
Business	4.74	4.31	3.99	5.72	6.02	5.64
Commute	7.43	8.02	8.86	3.51	2.08	2.83
Leisure	5.52	5.61	4.61	3.99	3.49	3.21

4. CONCLUSIONS

This study adds a degree of novelty in using passenger satisfaction data instead of the typically used SP survey data to estimate reliability multipliers. This study combined the previous work using life satisfaction surveys (e.g. Layard, Mayraz and Nickell, 2008) with work using passenger satisfaction surveys to study the impact of delays on passengers (e.g. Monsuur et al., 2021) and studies using SP surveys to estimate reliability multipliers (e.g. Batley and Ibáñez, 2012). Passenger satisfaction data was used to estimate an ordered logit model with origin-destination pair fixed-effects to estimate the utilities of delay and scheduled journey length. Subsequently their ratios were calculated to derive reliability multipliers, a conversion rate between lateness and scheduled journey length.

The estimated reliability multipliers are slightly larger than the ones typically estimated in the SP studies and some caution is needed while applying these values. To the best of our knowledge, it is the first study attempting to use journey satisfaction data in such an application. Therefore, it is believed that the methodology outlined in this study can be applied to similar satisfaction datasets for comparison of results. The study does, however, highlight the potential of using such data in transport economics. One of the key recommendation of this study is to consider including more questions relating to income or fares in journey satisfaction questionnaires that could allow the estimation of more sophisticated metrics, including the value of time.

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