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CONSUMER BENEFITS AND DEMAND IMPACTS OF REGULAR TRAIN TIMETABLES

Mark Wardman*, Jeremy Shires, William Lythgoe

Institute for Transport Studies, University of Leeds

Jonathan Tyler

Passenger Transport Networks, York

ABSTRACT

This paper reports novel research into the benefits that rail travellers receive from more regular features of timetables over and above any benefits of improved frequency. A Stated Preference (SP) exercise amongst rail travellers was conducted to estimate these benefits and the generally plausible results have been used to enhance a rail demand model which in turn has been used to forecast the effect on demand of more regular timetables for a range of situations. Not surprisingly, the demand impacts are generally relatively small, although they would be welcome additional benefits in the evaluation of a regular timetable.

KEYWORDS

Railways, Regular Timetables, Passenger Benefits, Stated Preference

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* Corresponding author. Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, UK. Email: mwardman@its.leeds.ac.uk. Tel: 00 44 113 343 5349. Fax: 00 44 113 343 5334

1. INTRODUCTION AND OBJECTIVES

As a result of the decision making of railway planners and/or politicians, timetables in some European countries, notably Switzerland, the Netherlands and much of Germany, are designed with strong and sensible patterns of regular intervals, good connectivity and departures at the same time each hour. The conviction is that their consistency, memorability and ease of use are critical in creating a favourable image of rail transport which reaps benefits in terms of increased consumer satisfaction and ultimately increased demand.

The experience in Britain, as in most countries, is mixed. The Southern Railway introduced clockfaced, even interval timetables on its suburban and inter-urban services which coincided with its extensive electrification programme in the 1920's and 1930's. In the post war years of the nationalised British Railways, regular timetables experienced a generally patchy existence but were prominent on many suburban networks. Many services had regular departures from principal stations, particularly London, but lost the pattern along the route as a result of varied running times and stopping patterns. A system was perpetuated in which some services had the features of regularity, others strived after them but suffered from extensive variations and others were deliberately planned train by train.

In the immediate aftermath of privatisation, the concept of regular timetables was neglected, with timetable planning characterised by train companies bidding for paths, Railtrack having 'flexing rights' to retime trains by a few minutes in the interests of capacity, and the absence of any champion of regularity, co-ordination and connectivity. However, the weaknesses of the post-privatisation planning system, exacerbated by congestion on the network, became increasingly apparent. The Strategic Rail Authority adopted a capacity utilisation policy followed by route utilisation strategies (SRA, 2003) in order to rationalise the process of planning, and they have shown increased interest in regular timetables. In addition, there is currently strong interest from some train operating companies such as Virgin Cross Country and Great North Eastern Railway.

This paper focuses upon the issues surrounding the characteristics of train timetables, a much neglected area of research but one where it can be speculated that there are benefits to consumers. In particular, it is concerned with consumers' benefits of regular timetables and the impacts on the demand for rail travel. We report on a Stated Preference (SP) exercise which provides estimates of the valuations travellers place on improved timetable features and use those values within a demand model to forecast the revenue benefits. Practical issues involved in developing regular timetables are discussed in detail in Tyler (2003).

The structure of this paper is as follows. Section 2 covers background issues relating to the representation of service frequency within demand forecasting models in the rail industry in Great Britain and different desirable features of timetables. Section 3 sets out the methodology used in this study followed by a discussion of the results in section 4. The use of these results to enhance rail demand models is discussed in section 5 and section 6 illustrates potential demand impacts. Concluding remarks are provided in section 7.

2. BACKGROUND

2.1 The Impact of Service Frequency

Rail users either have to plan their activities around scheduled departure times, which involves planning costs along with some amount of wait time, or else turn up at the departure point at random, which reduces the planning costs but incurs additional waiting time. Improving service frequency reduces the inconvenience, and studies demonstrate that individuals are prepared to pay to achieve better frequencies and that changes in frequency impact on rail demand.

Wardman (2001) conducted a large scale review of service quality values including 159 values of service headway and 61 values of wait time. Headway and wait time values were found to depend upon overall journey distance, mode used and income levels whilst the headway values also depended upon journey purpose and the elasticity of the wait time values with respect to the level of wait time was estimated to be 0.16. As far as the effects on demand are concerned, numerous studies have examined the impact of frequency changes either within aggregate models based on ticket sales data (Jones and White, 1994; Wardman, 1994; Lythgoe and Wardman, 2002) or more commonly within disaggregate mode choice models (See reviews by Wardman 1997a, 1997b).

At least in Britain, the impact of frequency has often been examined within aggregate rail demand models as part of the composite generalised journey time (GJT) service quality variable (Rail Operational Research, 1989, 1993; Steer Davies Gleave, 1999; Transportation Consultants International 1997; Wardman, 1994). This variable forms the basis of the procedure widely used to forecast demand within the rail industry in Great Britain (ATOC, 2002). It covers the timetable related service quality features of station-to-station journey time (T), service headway (H) and the number of interchanges required (I) and is represented as:

$$GJT = T + aH + bI \qquad (1)$$

The parameters a and b are frequency and interchange penalties respectively which convert service headway and interchange into equivalent amounts of time. A change in service headway between the base (b) and forecast (f) period will influence the volume (V) of rail demand through its effect on GJT as:

$$\frac{V_f}{V_b} = \left(\frac{GJT_f}{GJT_b} \right)^g \qquad (2)$$

The effect on demand will depend upon the GJT elasticity (g) used and the proportion that service headway forms of GJT.

2.2 Representation of Service Frequency

The procedure used in the railway industry in Great Britain to represent service frequency involves its conversion into equivalent units of time. It distinguishes between those who plan to catch a specific departure and those who turn up at the station at random and recognises travellers' preferences towards travelling at different times.

Travellers are likely to turn up at a station at random when service frequencies are high, as is commonplace on metro systems, or where they are constrained by other activities, such as a meeting. Service frequency will here impact in terms of the waiting time that must be endured. Waiting time will on average be half the average interval between trains. If travellers plan to catch a specific departure, which is more likely when services are infrequent, they incur an amount of displacement time as the difference between when then can depart and when they would ideally like to depart. In addition, there will inevitably be a small amount of waiting time and the costs involved in acquiring information and planning the journey, which together can be represented as a planning penalty.

The proportion of individuals who turn up at random or plan to catch specific departures will depend on the attractiveness of each option. A logit model is therefore used to allocate travellers to one type of behaviour or the other according to the planning penalty, the amount of displacement time and its value and the amount of expected waiting time and its value. This is done for the service interval at the time at which travellers wish to depart, with the day split into 15 minute desired departure time profiles.

The value of the parameter a in equation 1 which converts headway into an equivalent amount of time is based on the overall time penalty in each time period weighted by the demand profile. In any time period, the overall penalty is the sum of the expected wait time weighted by the proportion of random arrivals and the combined displacement time and planning penalty weighted by the proportion of planned arrivals.

If there are two trains per hour at equal intervals, departing at say 00 and 30 minutes past the hour, the expected wait time would be 15 minutes and the average displacement time would be 7½ minutes since the minimum and maximum displacement times are zero and 15 minutes. Given a time value of displacement time of 1.6, a time value of waiting time of 2 and a planning penalty of 15 minutes, the proportion of random arrivals for full fare ticket users is predicted to be 29%. An overall time penalty (aH) of 27.9 minutes is therefore implied.

However, if the two departures were instead at 00 and 15 minutes past the hour, the time penalty for those wanting to travel between 00 and 15 would average 15.8 whilst it would be 33.1 for those wanting to travel between 15 and 00. The overall value would be 28.8. If the two trains departed at 00 and 01, which is effectively an hourly service, everyone would be predicted to plan their arrival and the time penalty would increase to 39.0 minutes.

2.3 Timetable Patterns

We have demonstrated that the forecasting procedure outlined above will assign a benefit to a more equal pattern of departures. However, some other desirable aspects of timetables are not accounted for. Even though service headway is a standard feature of the representation of rail within disaggregate mode choice models, forecasting applications of these models are invariably crude, involving a standard number of implicitly even interval departures per hour with at best different peak and off-peak levels of service.

What we have termed regular timetables have a number of desirable features which are set out below.

Even Interval Departures

Timetables can clearly be planned so that the interval between departures is the same, whereupon the interval is equal to 60 minutes divided by the number of trains per hour. Given a uniform distribution of desired departure times across an hour, an equal interval timetable will minimise the expected waiting time on average amongst those arriving at random and will minimise displacement time amongst those who plan their journey. If there are departures at 00 and 30 minutes past the hour, then the expected wait time would be 15 minutes for those who want to travel between 00 and 30 and also for those who want to travel between 30 and 00. If instead the two departures are at 00 and 15, the amounts of expected wait time in the two periods are 7.5 and 22.5 minutes, which sums to the same 30 minutes of the previous example, but whereas 25% of travellers would reduce their expected wait time by 7.5 minutes, 75% of them would suffer a 7.5 minute increase. When departing from even interval departure times, the reductions in expected wait time and displacement time are experienced by fewer travellers than are the increases.

The benefits in terms of displacement time and expected wait time are already incorporated within the forecasting procedure used in the railway industry in Great Britain and outlined above. However, we might expect additional benefits from even interval timetables. Service frequency becomes easier to remember, thereby reducing the costs of acquiring information on train departure times, and conveys an impression of an orderly, well planned and reliable system which instils confidence and thereby encourages its use. This might be particularly important where interchange is concerned, where an even interval of connecting services reduces the risks associated with changing trains.

There are transaction cost and convenience benefits to be obtained from being able to turn up at the station at random, otherwise travellers would always plan where they are able to do so, and these benefits accrue at higher levels of frequency. It may well be that at a given level of frequency an even interval timetable is more likely to encourage the behaviour that allows these benefits to materialise. However, we must recognise that there may be those who prefer departures to be bunched close together to reduce the risks associated with late running or crowded trains.

Clockfaced Departures

This represents the repeating pattern of departures across the day. A perfectly clockfaced timetable involves departures at the same minutes past the hour every hour.

Possibly to a greater extent than with even interval timetables, clockfaced timetables might be regarded to convey the impression of a well planned railway which instils confidence in its efficiency and reliability and encourages use. This can be expected to be particularly important for journeys that involve interchange, and hence a greater degree of risk and uncertainty; what might be perceived to be independently planned services tend to reduce confidence in the system. If only because travellers believe that clockfacedness is a 'good thing', there will be some benefit in attracting new travellers and in retaining existing ones.

Clockfaced timetables also allow departures to be more easily memorised. This is not only of use in planning journeys but can also reinforce that a good level of service is offered where this is in fact the case. The memorability aspects of clockfacedness might not be of any great value to regular travellers who depart at the same time, such as commuters, but may be important for inter-urban travellers who make journeys less frequently and of greater value on the return leg of the journey where there tends to be more uncertainty about departure times and when the journey will be made. The memorability benefits may be greater where there are more trains per hour to remember.

With the exception of an hourly service, a clockfaced timetable need not be even interval, and thus the benefits accruing to memorability and reduced transaction costs are to some extent separate if not entirely independent. Given that there is little sense in an operator offering an even interval but not clockfaced timetable, the first benefit to accrue is that of clockfacedness with a subsequent benefit of even interval given clockfacedness.

Memorable Departures

Both even interval and clockfaced timetables contribute to memorability. However, some departure times are more easily remembered than others. For example, departures at 00, 15, 30 and 45 minutes past the hour may well be more memorable than departures which are on the 5 minutes but do not start on the hour, such as 5, 20, 35, and 50 minutes past the hour, which in turn can be expected to be more memorable than those departure times which are not divisible by 5, such as 8, 23, 38 and 53 minutes past the hour.

It might be argued that memorable departure times are more important as the number of trains per hour, and therefore the number to be remembered, increases. Moreover, individuals may tend to want to depart at memorable times, such as on the hour or half past, rather than uniformly across the hour as is essentially assumed in procedures used to determine schedule delay.

2.4 Previous Research into Regular Timetables

The introduction of regular timetables in Britain and on a larger scale in Europe has not been supported by analysis of their potential effect on demand. This is to a degree understandable given the complex issues that need to be addressed and often the absence of sufficient reliable data relating to actual schemes. However, the absence of large scale and closely controlled post-implementation monitoring of the demand effects is regrettable.

The only relevant research of which we are aware was conducted by Rail Operational Research (1995) who analysed time-series ticket sales data to establish whether variables relating to what we have termed clockfaced, even interval and memorable impacted on demand. None of the coefficient estimates were significantly different from zero. This is perhaps unsurprising since the effects will be relatively small, much smaller than, for instance, cross elasticities with respect to other modes which have proved notoriously difficult to estimate in models of this form.

3. METHOD

There is generally a preference amongst behavioural researchers, and particularly economists, for basing analysis on the actual decisions made in real world situations. In this context, Revealed Preference (RP) data might be even more preferable given the difficult timetable concepts involved and that the benefits of regular timetables relate to trip planning and information acquisition which need to be evaluated in the context of all potential future travel on a route rather than the specific past journey typical of SP approaches. Although we do not have before and after rail demand data where there has been the introduction or removal of a regular timetable, it is possible to examine demand on different routes with varying degrees of regular timetable and we report demand models that have attempted to discern the impact of more regular timetables in section 5.2. However, at the outset we recognised, on the basis of previous findings and because we were searching for a relatively minor effect, that the chances of developing a robust RP model with significant and plausible estimates of the effects of regular timetables were slim. This led us to conclude that there was here a role for SP based analysis. We did, however, recognise the greater uncertainties that would be involved, since the timetable attributes are inherently more difficult concepts to represent and evaluate than the time and cost attributes that more commonly characterise SP experiments. Moreover, these would have to be evaluated in the context of possible future journeys in order to capture the planning benefits. Not only can the results of an SP exercise contribute to isolating the demand impact, the valuations obtained would also prove invaluable for social cost benefit analysis.

The SP approach adopted asked rail travellers to rank in order of preference sixteen different scenarios in the context of possible future journeys. Each scenario related to a single variation upon the current situation in terms of either timetable features, journey time or fare. Thus the respondent might indicate that the preferred scenario would be a 5 minute time saving, the second best scenario would be a 20 pence cost saving and the third best scenario would be a half hourly even interval timetable, and so on until all the scenarios had been evaluated.

Two versions of the questionnaire differed in terms of whether the respondent was asked to consider that the timetable related to the outward leg of the journey or to the return leg of the journey.

The timetable scenarios to be ranked are listed in Table 1. To cover the range of timetable features, two different designs were used. They contained nine scenarios, with those based around hourly service frequency and the current timetable common to both. In addition to the nine timetable scenarios, respondents also had to evaluate four journey time reductions of 2, 5, 10 or 15 minutes and three fare reductions of either 50 pence, £1, and £2, or £1, £2.50 and £4. Three sets of service frequency of 1, 2 and 4 trains per hour were offered in order to value different levels of frequency per se and also to enable analysis of whether preferences towards clockfacedness, even interval departures and memorability are influenced by the level of frequency.

TABLE 1

We would not normally countenance the use of a ranking of 16 scenarios where, in the conventional form, each scenario was characterised by a number of different attributes which varied across scenarios. Here the task is simpler since it involves a one-dimensional evaluation involving the identification of that attribute variation which is most preferred, second preferred and so on.

Whether the scenario is clockfaced, memorable or even interval is indicated in Table 1. Note that since clockfacedness implies even intervals when there is only one train per hour, the number of scenarios to be considered is reduced when the frequency is hourly. In addition, the final column indicates the penalty in equivalent time units (GJT-H) that would be assigned to each timetable as part of the GJT term within the demand forecasting procedure widely used in the rail industry in Great Britain and outlined in section 2. It can be seen that the penalty is lower when the timetable is even interval, as well as when the service is more frequent, but that there are no differences according to the other timetable features.

The inclusion of GJT-H allows us to identify whether there are any benefits to even interval services over and above those attributed using the standard procedure alongside the estimation of the additional benefits of clockfacedness and memorability.

4. STATED PREFERENCE RESULTS

4.1 Data Collection

Given the resources available for data collection, the SP exercise was administered as a self completion questionnaire amongst rail travellers. Surveys were conducted on Great North Eastern Railway's services between

York and London and between Leeds and London, and also on Virgin Cross Country services between Leeds and Birmingham.

Two versions of the questionnaire, involving different means of presenting the SP exercise, were piloted in November 2002. This indicated that, as expected, many individuals did not know a great deal about current timetable patterns and that the difficult concepts being covered by the SP exercise were not conducive to the very high completion rates usually experienced in on-train surveys. With some slight modifications, the main survey was conducted in December 2002.

Details of response rates are given in Table 2. However, major disruptions to Virgin's services in this period as well as serious overcrowding on some trains severely hampered the survey, resulting in fewer questionnaires handed out on these services and a lower response rate.

TABLE 2

4.2 Estimation of Even Interval, Clockfaced and Memorability Benefits

The exploded logit model has been used to estimate the importance attached to each attribute from the rankings supplied (Chapman and Staelin, 1982). This treats the first ranked alternative as a choice for that alternative from the full set of sixteen, the second ranked alternative as a choice for that alternative from amongst the remaining set of fifteen, and so on until the ranking is exhausted. The coefficient estimates indicate the relative importance of a variable and, given the linear-additive form of utility expression used, monetary values are derived as the ratio of the coefficient estimate for the variable in question and the cost coefficient.

The repeat sampling jack-knife procedure (Cirillo et al., 2000) has been used within the ALOGIT software package (Hague Consulting Group, 2000) to correct the standard errors of estimated coefficients to allow for error correlation amongst the multiple choice observations per person.

The models developed here contain the element of GJT that represents the frequency component, as described in section 2.2 and which is reported in the final column of Table1 (GJT-H), and also specify variables to discern any additional benefits of whether the timetable is clockfaced (*CLOCK*) and memorable (*MEM*) and any unaccounted for benefits of even interval (*EVEN*).

Models for business and leisure travellers are reported in Tables 3 and 4 respectively. They have several desirable features. Firstly, the ρ^2 goodness of fit measures, which are specified with respect to a constants only specification[1], are broadly in line with values obtained from SP models estimated in more conventional choice contexts. Secondly, the parameters are right sign and generally estimated with a high level of precision. Thirdly, the implied relative values generally appear plausible.

[1] This measure is provided since the ρ^2 with respect to chance is arbitrarily affected by the proportion choosing each alternative. The measure given here indicates the improvement achieved over the explanation of the market share of each alternative solely in terms of alternative specific constants.

The term *Cost-In* is an incremental effect for those who were asked to consider the timetable features for the inbound journey. It seems that they have not considered cost to the same extent as those who evaluated the timetable features for the outward journey. This may be because typically return tickets are used and these would have been purchased prior to the return journey whereupon the cost variations could have been neglected. Surprisingly, there were no other clearcut differences in parameters according to whether the outward or return leg had been considered.

All the coefficients in the business travel model are of the correct sign and are significant at the usual 5% level. Since the GJT-H variable expresses the frequency penalty in equivalent units of time, its coefficient ought to be broadly similar to the time coefficient. It is encouraging that the two coefficients are not very dissimilar: unless the SP responses were of at least reasonable quality, there is no reason why the two coefficients should be remotely similar.

No significant coefficients were estimated for frequency variables which were entered. Thus the frequency benefits for business travellers are not different to those attributed by GJT-H.

An even interval hourly departure is the same as an hourly clockfaced timetable and is considered below. Additional terms were specified to determine whether there were any benefits of even interval over and above those covered by GJT-H when the frequency was better than hourly. The coefficients estimated to even interval departures for two and four trains an hour were very similar and hence combined into a single term (*Even2_4*). This indicates a relatively strong additional benefit from even interval timetables.

TABLE 3

The value of clockfaced timetables depends upon whether there are one (*CLOCK1*), two (*CLOCK2*) or four (*CLOCK4*) trains per hour with a monotonic increasing effect. As for memorability, there was a significant value for a single train per hour (*MEM1*) and higher but insignificantly different values for two and four trains per hour (*MEM2_4*).

Model II examined the impact of removing the allowance for the even interval effect on the grounds that it could be argued that GJT-H ought to discern the majority of this effect. Not surprisingly given that there is a degree of association, the result is that the even interval benefit is transferred to the clockfaced variables whose coefficients experience some relatively large increases. There is also an impact on the GJT-H coefficient of the expected form.

All the reported coefficients in Model I for leisure travel are right sign and only the memorability coefficient for one train per hour (*MEM1*) was not statistically significant and was therefore removed. The benefits of clockfaced timetables for 2 and 4 trains per hour were very similar and insignificantly different and hence the two terms have been combined (*CLOCK2_4*). The same is true of memorability (*MEM2_4*) although the coefficients for even interval departures for two (*Even2*) and four (*Even4*) trains per hour were significantly different.

We again observe that there is a tendency for the benefits of even interval timetables, clockfacedness and memorability to increase as the service frequency increases and in this instance there is a very close correspondence of the GJT-H and time coefficients which is encouraging.

Model II additionally specifies terms for whether there were two (*FREQ2*) or four (*FREQ4*) trains per hour. According to a likelihood ratio test, the estimated χ^2 of 14.0 is far greater than the tabulated value for two degrees of freedom. Nonetheless, we are inclined to prefer Model I since the inclusion of the two frequency terms has dramatically impacted upon the GJT-H coefficient, which was consistent with the time coefficient in Model I but somewhat different and indeed not statistically significant in Model II. This is presumably the result of the large correlations of 0.76 between the *GJT-H* and *FREQ2* coefficient estimates and 0.90 between the *GJT-H* and *FREQ4* coefficient estimates. Model III again removes the even interval variables, and again the clockfacedness variables discern some of the effect previously attributed to them.

TABLE 4

Overall, the results that have been obtained are reasonable and precisely estimated; we would not expect to obtain high values for timetable related features. The estimated values of time of around 39 pence per minute for business travel and around 9 pence per minute for leisure travel are plausible and there is an encouraging degree of similarity between the time and GJT-H coefficients. A number of plausible findings have also been obtained for the timetable features. There might, however, be concerns of confounding effects since the SP exercise presents thirteen different timetables plus the current one for evaluation whilst Model I for business travellers estimates seven timetable related coefficients and Model II for leisure travellers estimates eight. The highest correlations of estimated coefficients in the business model are –0.55 between *MEM1* and *CLOCK1* and –0.48 between *MEM2_4* and *CLOCK2*. All others are less than 0.4. In the leisure model, the highest correlations involve *GJT-H* and the frequency coefficients as outlined above. However, in Model I which does not contain the frequency variables, the highest correlation is –0.50 between CLOCK2_4 and MEM2_4 and the remainder are all less than 0.4. These correlations amongst the coefficient estimates are of no cause for concern.

The most striking feature of the results is that the even interval, clockfaced and memorability benefits increase as the number of trains per hour increases. This does not seem to be the discernment of the benefits of improved frequency since the correlations between the coefficient estimates relating to timetable features and the frequency coefficients when the latter were entered were not high. Indeed, the inclusion of the frequency variables did not greatly impact on the coefficient estimates other than, as expected, for GJT-H.

For both business and leisure travel, a slightly better fit was obtained when scenarios TT2 and TT7 were defined as memorable. Thus memorability here covers all timetables that have departure times divisible by 5. The value increases with the number of departures, presumably because it is more difficult to remember departure times as the number of departures increases. Additionally, respondents may simply feel that as more trains per hour are offered it increasingly makes sense to provide them at memorable times. There is also the possibility that individuals do not want to depart at times uniformly distributed across the hour but instead want to depart at the more memorable times. Therefore the more departures that are offered at memorable times then the greater the coincidence between actual and desired departure times and the lower is scheduled delay.

The increasing value of clockfaced and even interval timetables as frequency improves may also stem from the greater difficulty of otherwise remembering more departure times. Again, there may also be a feeling that it makes increasingly little sense not to have clockfaced and even interval timetables as frequencies are improved. The argument that clockfacedness reinforces that a good level of service is offered might also contribute to the larger benefits at higher frequency.

As far as even interval timetables are concerned, the benefits could increase with frequency since the benefits that can be obtained from random arrivals at stations that accrue to high frequencies may be stimulated more if the departures are even interval. To the extent that the current GJT formulation understates the benefits to even interval timetables as frequency increases, there will be a compensating effect of the form observed in Tables 3 and 4.

5. MODELLING EFFECT ON RAIL DEMAND

5.1 Data and Indices

We have developed cross-sectional models of rail demand to ticket sales data for the financial year 1999/2000. The data covers 10324 inter-urban flows of over 40 kilometres. A clockfaced index (CI) was specified as a function of the rounded up integer value of paths per hour (PPH) and the number of different departure times (NDDT):

$$CI = \frac{PPH}{NDDT} \tag{3}$$

where:

$$PPH = \frac{NT - 1}{SS} \tag{4}$$

and NT is the number of trains and SS is the service span in hours. The purpose of subtracting one is to make the index less sensitive to the inclusion of a single additional service which strictly speaking breaks a clockfaced pattern.

CI will be 1 for a perfect clockfaced timetable or one where there is a single departure deviation from it. Its minimum value is driven by the service span. For an 18 hour service span and the maximum of 60 different departure times provided by the minimum of 60 departures gives a CI index of 0.066.

The memorability index (MI) was simply specified as the ratio of the total number of memorable departures, however defined, and the total number of departures, and ranges between 0 and 1.

The key issue with cross-sectional models is the adequate specification of the station catchment areas since these fundamentally influence the magnitude of trips between stations around which there is variation due to changes in the attractiveness of rail. We have done this by expressing the volume of rail demand between two stations (i and j) as:

$$V_{ij} = \mu e^{\sum_{i=1}^{p-1} \gamma_i O_i \sum_{j=1}^{q-1} \delta_j D_j} GC_{ij}^{\omega} \tag{5}$$

The O_i and D_j are dummy variables for all but one of the p origin stations and all but one of the q destination stations respectively, and GC_{ij} denotes the generalised cost of rail travel between i and j. Whilst this model tells us little of the factors which generate and attract trips and it is not readily transferable to forecast demand at stations for which generation and attraction terms have not been specified, these are not problems if we are concerned primarily with the elasticities to the other elements of the demand model such as timetable features.

A composite generalised cost (GC) is specified because of the high correlation between generalised journey time (GJT) as defined in equation 1 and fare (F). GC is here defined as:

$$GC_{ij} = F_{ij} + \upsilon(GJT_{ij} - \varphi CI_{ij} - \phi MI_{ij}) \qquad (6)$$

GJT has here effectively been extended to cover the timetable related factors of clockfacedness and memorability, each weighted by their time valuation obtained from the SP exercise. The parameter υ is the value of time and converts the service quality elements which are expressed in units of time into equivalent monetary amounts.

5.2 Demand Model Results

GJT for each flow was obtained from the MOIRA computer model and provided to us by the Association of Train Operating Companies. The values of time used were obtained from a large scale review reported in Wardman (2001) with appropriate weighting on London and Non-London flows to allow for the different mixes of business and leisure travel. The same purpose weightings were applied to the values of clockfacedness and memorability estimated for business and leisure travel. These were taken from Model I of Table 3 for business travel and Model I of Table 4 for leisure travel. We have not included any additional benefits for even interval timetables over and above that which would be attributed by GJT.

The estimated models with and without the timetable feature indices are reported in Table 5. The inclusion of CI and MI reduces the GC elasticity (ω) although only slightly. The impact is slight because the proportion of GC accounted for by CI and MI is very small, on average less than 1%. The GC elasticity is around -1.6 which is reasonable given fare and GJT elasticities are both typically found to be around -0.9 on these routes (ATOC, 2002). The model that includes CI and MI provides a slightly better fit than the model that does not. Although the improvement in fit is very small, this is hardly surprising given that the CI and MI terms form such a small proportion of GC, whilst any improvement in fit is certainly preferable to a deterioration.

TABLE 5

Some experimentation with free estimation of elasticities to CI and MI has also been undertaken. This revealed, as with the SP analysis, that the best definition of memorability was that where departure times were divisible by 5 minutes. We also experimented with different specifications of clockfacedness, including the creation of dummy variables to denote whether a timetable was clockfaced or not depending upon threshold values of CI of 0.5 or 0.95, but the use of the continuous variable provided the best fit.

The situation on London flows is not straightforward, since these are the largest flows and also tend to have clockfaced and memorable departures. Analysis was therefore conducted on Non London flows. This obtained a coefficient for CI which was not far removed from significant (t=1.8) and which marginally improved the fit. It estimated that a perfect clockfaced timetable would increase demand by around 12% compared to an essentially random set of departures. Whilst this figure is on the high side, these initial results indicate that further analysis might prove fruitful.

6. ILLUSTRATIVE DEMAND IMPACTS

Table 6 uses the results of the model reported in Table 5 to illustrate the demand increases that would be forecast to result from various timetable improvements. These improvements are based around the scenarios contained in Table 1 which were used in the SP exercise. For one, two and four trains per hour, the incremental impacts of clockfaced, even interval and memorable timetables are forecast. The clockfaced and memorability benefits are those estimated by our SP models whilst the benefits of even interval timetables are those which are attributed by GJT. We have not used any of the SP evidence relating to even interval timetables.

Forecasts are produced for a range of different journeys since, given the inclusion of the benefits of regular timetables within a broader GC measure, the impact of the timetable improvement will depend on the proportion it forms of GC. For one and two trains an hour, the journey times are one, two and three hours. For four trains per hour, the journey times are half an hour and an hour since it is only usually on shorter distance flows where frequencies are so high.

The initial scenario is where there is no particular pattern to the timetable. This determines a base level of GC given the headway penalty (GJT-H) outlined in Table 1, the time and fare specified, and the value of time. Thus for an hourly service and 60 minute journey time, the 60 minutes of journey time and 31.2

minutes of headway penalty are added together and multiplied by the value of time of 15 pence per minute. To this is added the single fare of 1000 pence to yield a GC of 2368 pence. These hourly departures have no fixed pattern. The initial improvement is to provide a clockfaced timetable, followed by an even interval clockfaced timetable and finally adding memorability.

TABLE 6

Clockfaced departures do not impact on GJT-H but have been found to be valued in the SP exercises. The value of clockfaced departures for hourly services is 5 minutes amongst business travellers and 3 minutes amongst leisure travellers. Applying the assumed 30:70 split of business and leisure travel gives a value of 3.6 minutes which when multiplied by the value of time is valued at 54 pence. This reduces GC to 2314 pence which, given a GC elasticity of -1.6, would imply a 3.8% increase in the volume of rail demand.

An even interval timetable is the same as a clockfaced timetable for hourly services so brings no additional benefits. In the case of an half hourly service, departures at 08 and 38 would be attributed a GJT-H of 22.6 minutes by the standard demand forecasting procedure set out in section 2.2 whereas departures at 08 and 23 would be valued at 23.9 minutes. The even interval departure pattern would here reduce GC by 20 pence to 2119 on a 60 minute journey, implying a demand increase of 1.5%. Returning to the initial example of an hourly journey time and hourly service, introducing a memorable departure time of 00 would be valued at 2 minutes by business travellers although not at all by leisure travellers. Given the business travel proportion and a value of time of 15 pence per minute, this would reduce GC by 9 pence to 2305 pence, implying a 0.6% increase in rail demand.

The impact on the demand forecasts of the proportion that the change in GC forms of the level of GC is quite clear. In general, the timetable improvements have relatively small impacts on demand, but they can be large where the fare and journey time are low. However, should the benefits of regular timetables be included in evaluation, particularly those associated with clockfacedness, they would provide worthwhile additional benefits.

The impact of clockfaced departures far exceeds that of memorability. This is to be expected given the differences in the valuations of these two aspects of timetables. However, what is noticeable is the small impact from even interval timetables, somewhat smaller even than memorability. This raises the question of whether the results in Tables 3 and 4 for even interval are in fact discerning a benefit that is not being covered by GJT.

7. CONCLUSIONS

Although the research reported here was ambitious in nature, and has dealt with quality improvements that are inherently difficult to represent and value, some interesting results have emerged from a novel application of SP methods. The valuations of clockfacedness and memorability produced by the SP exercise seem reasonable, whilst the results obtained for even interval timetables suggest that the current procedure used in Britain may be underestimating this benefit.

There are obviously many different degrees of non-clockfacedness and ideally more detail on the precise timetable involved would have been given when the timetable varies across the day. However, the survey process, strongly influenced by resource constraints, meant that the latter was not a practical option. Additionally, a range of other timetables with specific features could have been examined. For example, we could have specified: clockfacedness for varying parts of the day or as a subset of all departures; bunching of services, which might be attractive to risk averse travellers; more extensive forms of memorability; the inclusion of prima donna services and peak supplements; different frequencies by time of day and varying running times across departures. Our view was that it was sufficiently challenging within the survey method to be used to examine the range of relatively straightforward timetables set out in Table 1, and that examination of these would in any event constitute a substantial contribution to understanding in this area. The area would also benefit from the conduct of a series of focus groups to reveal how individuals conceptualise timetables and the best means of presenting them within an SP context, their preferences between different patterns of departures and how they acquire and process information.

The SP values have been used to enhance the conventional form of rail demand model used in Britain and in turn this has been used to forecast the effect on demand of more regular timetables for a range of situations. Not surprisingly, the demand impacts are generally relatively small, although they would be welcome additional benefits in the evaluation of a regular timetable. Details of a far more extensive evaluation of a regular interval timetable for the East Coast route in Britain and the additional benefits to be obtained from clockfacedness and memorability are reported in Shires et al. (2003). However, there remains an urgent need to determine through closely controlled monitoring the effect on demand of the actual introduction of regular timetables. Regular timetables could also provide a basis for the more effective promotion of rail services amongst non-users and this potential needs to be explored.

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Table 1: Timetable Scenarios Used In SP Exercise

Scenario	Timetable	Clock	Mem	Design	GJT-H
TT1	4 per hour, even interval, 00 15 30 45	Yes	Yes	1	14.2
TT2	4 per hour, uneven interval, 00 05 30 35	Yes	Maybe	1	18.0
TT3	4 per hour, even interval, 08 23 38 53	Yes	No	2	14.2
TT4	4 per hour, uneven interval, 08 16 40 51	Yes	No	2	15.5
TT5	4 per hour, varies across day	No	No	2	15.2
TT6	2 per hour, even interval, 00 30	Yes	Yes	1	22.6
TT7	2 per hour, uneven interval, 00 10	Yes	Maybe	2	25.4
TT8	2 per hour, even interval, 08 38	Yes	No	1	22.6
TT9	2 per hour, uneven interval, 08 23	Yes	No	2	23.9
TT10	2 per hour, varies across day	No	No	1	22.9
TT11	1 per hour, 08	Yes	No	Both	31.2
TT12	1 per hour, 00	Yes	Yes	Both	31.2
TT13	1 per hour, varies across day	No	No	Both	31.2
TT14	Timetable as now				

Note: GJT-H is the average value across full fare and reduced fare tickets.

Table 2: Survey Response Rates

	GNER		Virgin	
	Out	In	Out	In
Distributed	708	1032	444	306
Returned in Total	676 (95%)	1004 (97%)	422 (95%)	282 (92%)
Returned with Some Information	634 (90%)	941 (91%)	390 (88%)	258 (84%)
Returned with Some SP Response	511 (72%)	609 (59%)	113 (25%)	135 (44%)
Returned with Complete SP Responses	434 (61%)	500 (48%)	108 (24%)	126 (41%)

Table 3: Business Models

	Model I		Model II	
	Coeff (t)	Value (t)	Coeff (t)	Value (t)
GJT-H	-0.073 (9.3)	1.35 (8.5)	-0.082 (10.8)	1.52 (9.6)
Time	-0.054 (21.1)	38.6 (3.3)	-0.054 (21.4)	38.57 (3.6)
EVEN2_4	0.416 (6.9)	7.70 (6.6)	-	-
CLOCK1	0.268 (3.5)	4.96 (3.5)	0.291 (3.7)	5.39 (3.6)
CLOCK2	0.373 (7.0)	6.91 (6.6)	0.538 (12.1)	9.96 (10.5)
CLOCK4	0.555 (9.5)	10.28 (8.7)	0.634 (11.3)	11.74 (10.0)
MEM1	0.109 (2.2)	2.02 (2.2)	0.109 (2.2)	2.02 (2.2)
MEM2_4	0.357 (6.0)	6.61 (5.8)	0.309 (5.3)	5.72 (5.1)
Cost	-0.0014 (3.5)	-	-0.0014 (3.6)	-
Cost-In	0.0010 (1.9)	-	0.0010 (2.0)	-
Initial Log-Lik	-19029		-19029	
Final Log-Lik	-17528		-17575	
ρ^2	0.113		0.111	

Note: Values are in equivalent units of time, except for time which is a monetary value

Table 4: Leisure Models

	Model I		Model II		Model III	
	Coeff (t)	Value (t)	Coeff (t)	Value (t)	Coeff (t)	Value (t)
GJT-H	-0.047 (7.5)	0.96 (7.1)	-0.019 (1.5)	0.39 (1.5)	-0.052 (9.3)	1.06 (8.6)
Time	-0.049 (21.7)	9.07 (10.4)	-0.049 (22.0)	9.07 (10.3)	-0.049 (21.8)	9.07 (10.1)
EVEN2	0.227 (3.2)	4.63 (3.2)	0.294 (3.5)	6.00 (3.5)	-	-
EVEN4	0.422 (6.4)	8.61 (6.1)	0.478 (6.4)	9.76 (6.1)	-	-
CLOCK1	0.145 (3.2)	2.96 (3.2)	0.146 (2.9)	2.97 (2.9)	0.168 (3.7)	3.43 (3.6)
CLOCK2_4	0.339 (5.9)	6.92 (5.7)	0.275 (4.2)	5.61 (4.1)	0.438 (9.1)	8.94 (8.4)
MEM2_4	0.127 (2.4)	2.59 (2.4)	0.097 (2.0)	1.98 (2.0)	0.107 (2.2)	2.18 (2.2)
FREQ2	-	-	0.246 (2.5)	5.02 (2.5)	-	
FREQ4	-	-	0.499 (2.6)	10.18 (2.6)	-	
Cost	-0.0054 (11.3)	-	-0.0054 (11.6)	-	-0.0054 (11.4)	
Cost-In	0.0022 (3.6)	-	0.0021 (3.6)	-	0.0022 (3.6)	
Initial Log-Lik	-18450		-18450		-18450	
Final Log-Lik	-17476		-17469		-17504	
ρ^2	0.099		0.099		0.097	

Note: Values are in equivalent units of time, except for time which is a monetary value

Table 5: Ticket Sales Demand Models

	Without CI/MI	With CI/MI
GC (ω)	-1.615 (145.3)	-1.605 (145.4)
Adj R^2	0.7992	0.7993

Table 6: Illustrative Demand Forecasts

Base					Introduce Clockfaced Timetable			Introduce Even Interval Timetable			Introduce Memorable Timetable		
	Time	Head	Fare	GC	Clock	GC	%ΔV	Even	GC	%ΔV	Mem	GC	%ΔV
Hourly Service	60	31.2	1000	2368	08	2314	3.8%	08	2314	0.0%	00	2305	0.6%
	120	31.2	2000	4570		4509	2.2%		4509	0.0%		4499	0.4%
	180	31.2	3000	7013		6945	1.6%		6945	0.0%		6933	0.3%
½ Hourly Service	60	22.9	1000	2243	08 23	2139	7.8%	08 38	2119	1.5%	00 30	2062	4.5%
	120	22.9	2000	4429		4311	4.4%		4289	0.8%		4224	2.5%
	180	22.9	3000	6855		6704	3.6%		6680	0.6%		6607	1.8%
¼ Hourly Service	30	15.2	500	1133	08 16	1022	18.0%	08 23	1003	3.1%	00 15	949	9.2%
	60	15.2	1000	2128	40 51	2009	9.7%	38 53	1989	1.6%	30 45	1932	4.8%

Note: The value of time used to create GC depends on distance (Wardman, 2001) and values corresponding reasonably closely to the journey time have here been used. The values of time are averages across business and leisure travel and are around 14, 15, 17 and 19 pence per minute for the four journey times used of 30, 60, 120 and 180 minutes. A split of 30% business travel and 70% leisure travel was assumed.