ESTIMATING THE DEMAND IMPACTS OF NEW ROLLING STOCK

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Professor Mark Wardman

1. INTRODUCTION

To determine the impact of new rolling stock on passenger demand an innovative study was undertaken for the Passenger Demand Forecasting Council by Accent, Oxera and Mark Wardman using two research methods: ‘event analysis’ and market research. This paper intends to clearly describe the methodology and the research findings from this work, as well as explaining the reasons for recommendations for further research.

1.1. Background

The members of the Passenger Demand Forecasting Council, which includes representatives from the British Train Operating Companies, the Department for Transport’s Rail Division, Network Rail, and the Office of Rail Regulation, have a common interest in understanding the drivers of rail passenger demand.

As part of an on-going programme, the Council seeks to develop and procure research that will enhance and expand on the frameworks developed within the Passenger Demand Forecasting Handbook (PDFH). The Council wanted to develop an improved understanding of the effects of new and refurbished rolling stock on rail demand.

Much of the existing understanding is drawn from a series of stated preference studies, tempered by subsequent revealed preference studies, which between them suggest that the introduction of new rolling stock has a 3-4% effect on demand, on average.

The values for new and refurbished rolling stock provided in the PDFH were felt to need reviewing and potentially updating and hence this research was commissioned.

1.2. Objectives

The primary aims of the study were to gain a comprehensive demand forecasting methodology and recommendations relating to the introduction of new rolling stock. Significant recent investment in rolling stock has raised the need to assess the return on investment and to provide recommendations for future rolling stock investment.

1.3. Methodology

Two methods were used:
Event analysis
Market research.

The event analysis was designed to determine the demand impact associated with new or refurbished rolling stock based on revealed preference evidence from ticket sales data.

The market research was designed to collect direct evidence of any impact that new rolling stock has had on passenger demand.

2. MARKET RESEARCH

The method for the market research was the distribution and collection of self-completion questionnaires on train. The distribution of the questionnaires was on a random basis (ie 1 in n passengers). The questionnaires asked respondents to state why they were making the journey and to say whether the new rolling stock had had an impact on their use of the train.

Route maps

The route types that were selected for the research comprised InterCity, Suburban and Regional.

- InterCity (FGW) = London Paddington-Great Malvern route where ‘Adelantes’ replaced Class 165 ‘Turbos’ (and in some cases HSTs).
Suburban (Southern) = London Victoria-Worthing/Chichester where Class 377 ‘Electrostars’ replaced Mk 1 stock
Regional (Scotrail) = Glasgow-Hamilton where Class 334 ‘Junipers’ replaced Class 303 and Class 314 stock.

There were 1,335 completed questionnaires: 451 InterCity; 460 Suburban and 424 Regional.

Fieldwork took place between 8 and 17 September 2005.

3. MARKET RESEARCH FINDINGS

Key travel characteristics of the samples are shown below:

- Journey purpose:
  - Southern: 52% commuting and 35% leisure
  - Scotrail: 39% commuting, 29% leisure, fifth shopping
  - FGW: 43% leisure, 30% commuting

- Frequency of rail travel:
  - Southern: 38% 5+ days a week, 19% 1-4 days a week, 19% less often than once a month, 9% first time
  - Scotrail: 30% 5+ days a week, 27% 1-4 days a week, 16% less often than once a month, 2% first time
  - FGW: 7% 5+ days a week, 14% 1-4 days a week, 40% less often than once a month, 17% first time

- When first travelled on route:
  - Southern: 19% within last month, 34% over 5 years ago
  - Scotrail: 17% within last month, 38% over 5 years ago
  - FGW: 28% within last month, 23% over 5 years ago

3.1. Whether noticed that new trains had been introduced

Respondents who had travelled on the route more than once (ie excluding those who were travelling for the first time on the route) were asked whether they had noticed that new trains had been introduced.

Almost all on Southern (86%) had noticed the new trains but much smaller proportions on FGW (59%) and Scotrail (55%) had noticed the new trains.

As would be expected there was a relationship between when first travelled on the route and whether noticed the new trains with those who had travelled for longest most likely to have noticed the new trains. For example, 70% of Scotrail respondents who had travelled on the route for over five years had noticed the new trains compared to 44% of those who first travelled on the route within the last month.

There was no significant difference in whether respondents had noticed the new trains by class of travel, employment status, gender or distance travelled.
3.2. Which preferred: the new trains or the old trains

Those who had noticed the new trains were asked which they preferred more – the new train, the old trains or neither.

**FGW**

Adelante

Class 165 ‘Turbo.’

**Southern**

Class 377 ‘Electrostar’

Mk 1 stock

**Scotrail**

Class 334 ‘Juniper’

Class 303.

There was overwhelming preference for the new trains on all three routes. On Scotrail not one respondent preferred the old trains.
3.3. Whether aspects of rail travel have improved or worsened since introduction of the new trains

Those who had noticed the new trains were asked whether the following aspects of rail travel had improved or worsened since the introduction of the new trains:

- seat layout
- smoothness of ride
- reliability
- journey times
- seat comfort
- chance of getting a seat
- ambience
- toilets
- information/announcements.

On all three routes far more said that each aspect had improved than worsened.

4. BEHAVIOURAL RESPONSE TO NEW TRAINS

4.1. Whether changed class of travel as a result of the new trains

All respondents on FGW and Southern (which had First Class accommodation) except those who were travelling for the first time were asked whether they had changed class of travel as a result of the new trains.
On FGW there was a net increase in First Class usage of about 2%.

On Southern there was a net increase in First Class usage of about 1%.

4.2. Whether new trains led to change in number of journeys made by rail on route

All respondents were asked whether the new trains had led them to change the number of journeys they made by rail on the route.

About three quarters on each route said they hadn’t changed the number of journeys they made because of the new trains. On all three routes there was a notable stated impact in patronage caused by the new trains:

- FGW – 11% make new/more trips
- Southern – 11% make new/more trips
- Scotrail – 8% make new/more trips.

Of course the nature of such a survey is that it will not be able to report those who no longer travel. However, the very positive response to the new rolling stock indicates that there would very few who would stop travelling because of the new rolling stock.

4.3. Demand Impacts

The data on whether respondents had travelled more because of the new trains was converted into the impact on demand in the following way.

Those who thought that there was improved reliability or faster journey times because of the new trains were excluded from the analysis.

The frequency of travel on the route was analysed against the behavioural response to the new trains. The following weights were then applied to all trips:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>5+ days a week</td>
<td>5</td>
</tr>
<tr>
<td>3-4 days a week</td>
<td>3.5</td>
</tr>
<tr>
<td>1-2 days a week</td>
<td>1.5</td>
</tr>
<tr>
<td>Between once a fortnight and once a month</td>
<td>0.33</td>
</tr>
<tr>
<td>Less often</td>
<td>0.125</td>
</tr>
<tr>
<td>First time</td>
<td>0.04</td>
</tr>
</tbody>
</table>

For additional and fewer trips we took 10% of the total journeys for each individual who said that this was the case as an assumption of the proportion of trips that were additional or fewer.

The demand calculation was as follows:
\[
\frac{B + (C-D)}{A}
\]

Where:

A = all trips
B = new trips
C = additional trips
D = fewer trips.

The implied increases in demand for the three routes are:

- FGW 2.0%
- Southern 1.1%
- Scotrail 0.7%.

The demand impacts were also examined by main journey purpose and distance travelled.

On Southern the lowest impact on demand is from commuters and business travellers and the highest from leisure travellers. For Scotrail and FGW the commuting market shows the highest level of increased travel. For all three routes the lowest level of increase is from the business market.

For FGW we also examined the demand after excluding short distance travellers because of the large impact of the Reading-Paddington flow.

There is some indication that on longer distances there is less of a demand impact.

5. EVENT STUDIES

The following changes in rolling stock were examined:
Table 1: Information on rolling stock changes examined in the event studies

<table>
<thead>
<tr>
<th>TOC</th>
<th>Rolling stock change and date</th>
<th>Data</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Great Western</td>
<td>Adelante replacing Thames Turbos from 2005 P08</td>
<td>Five routes from 2002 P01 to 2006 P04; journeys, receipts, GJT and delay</td>
<td>Adelantes had been in service elsewhere for two years, so teething delays were overcome</td>
</tr>
<tr>
<td>Southern</td>
<td>Replacement of slam-door stock by 2005 P03</td>
<td>Four routes from 2002 P01 to 2006 P03; journeys, receipts, GJT and delay</td>
<td></td>
</tr>
<tr>
<td>Scotrail</td>
<td>Class 334s replacing class 305s</td>
<td>Six routes from 2002 P01 to 2006 P04; journeys, receipts and delay (PPM)</td>
<td></td>
</tr>
<tr>
<td>GNER</td>
<td>Refurbishment from 2004 P07</td>
<td>Five routes to and from London from 2002 P01 to 2006 P07; journeys, receipts and delay (% of late trains)</td>
<td>Refurbished stock – branded Mallard – was introduced gradually</td>
</tr>
<tr>
<td>Northern</td>
<td>Class 333s replacing class 308/1s from January 2001</td>
<td>Five routes from 2002 P01 to 2005 P13; journeys and receipts</td>
<td></td>
</tr>
</tbody>
</table>

Notes: All data was aligned with national GVA from the Office of National Statistics.

5.1. Methodology

To estimate the impact on demand of the introduction of new or refurbished rolling stock, a popular method was adopted from the finance literature. So-called ‘event studies’ are generally used to assess the impact on share prices of events eg, the announcement of takeovers, share buy-backs and changes to dividend policy.

For First Great Western, GNER, Southern and Scotrail, demand models were estimated before changes in rolling stock for first, full and total ticket types. Data for the explanatory variables after the change in stock, and the parameters from the demand models, were used to suggest what demand might have been in the absence of any change in the rolling stock (‘predictions from the demand model’). These predictions were then compared with actual demand, and the difference between the two, after controlling for changes in real fares, GJT, delay and real GVA, taken as attributable to changes in rolling stock.

No data before the change in rolling stock was available for the routes operated by Northern, and therefore, a demand model could not be estimated prior to the introduction of the new stock. This was resolved by developing an annual forecasting model, using PDFH4 elasticities for external environment factors and fares, and delay elasticities for regional services estimated by Oxera for a recent Rail Policy Group meeting. These were combined with data on national GVA, local employment growth, average fares from the LENNON data and PPM data for the TOC to produce annual forecasts of journeys for the full fare ticket category. Only results for the full fare ticket category are presented for the Northern flows, due to irregular and unexpected growth in other types of journeys during the period observed.

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5.2. The specification of the demand models

For First Great Western, GNER and Southern, current passenger journeys have been explained in a dynamic demand model using the following variables, which were expressed in logarithms.

- previous passenger journeys – the autoregressive element of the model
- current real fares, delays and GJT
- previous real fares, delays and GJT from one four-weekly period and one year (13 four-weekly periods) previously the lagged element of the model
- real GVA from one year (13 four-weekly periods) previously and
- dummies to control for any seasonal variation in demand

Equation 1

\[ v_{it} = \alpha + \beta_1 v_{it-1} + \beta_2 v_{it-13} + \beta_3 p_{it} + \beta_4 p_{it-1} + \beta_5 p_{it-13} + \beta_6 d_{it} + \beta_7 d_{it-1} + \beta_8 d_{it-13} + \beta_9 g_{it-13} + \beta_{10} g_{it-13} + s_{2,..,13} + \epsilon_{it} + \mu_i \]

Table 2: Description of the variables in the demand model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v_{it} )</td>
<td>Current passenger journeys</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>Constant</td>
</tr>
<tr>
<td>( v_{it-1} )</td>
<td>Passenger journeys in the previous four-weekly period</td>
</tr>
<tr>
<td>( v_{it-13} )</td>
<td>Passenger journeys one year (13 four-weekly periods) previously</td>
</tr>
<tr>
<td>( p_{it} )</td>
<td>Current average real fares</td>
</tr>
<tr>
<td>( p_{it-1} )</td>
<td>Average real fares in the previous four-weekly period</td>
</tr>
<tr>
<td>( p_{it-13} )</td>
<td>Average real fares one year (13 four-weekly periods) previously</td>
</tr>
<tr>
<td>( d_{it} )</td>
<td>Current delays</td>
</tr>
<tr>
<td>( d_{it-1} )</td>
<td>Delays in the previous four-weekly period</td>
</tr>
<tr>
<td>( d_{it-13} )</td>
<td>Delays one year (13 four-weekly periods) previously</td>
</tr>
<tr>
<td>( t_{it-13} )</td>
<td>GJT one year (13 four-weekly periods) previously</td>
</tr>
<tr>
<td>( g_{it-13} )</td>
<td>National real GVA one year (13 four-weekly periods) previously</td>
</tr>
<tr>
<td>( s_{2,13} )</td>
<td>Seasonal dummies for each four-weekly period</td>
</tr>
<tr>
<td>( \epsilon_{it} )</td>
<td>Error term</td>
</tr>
<tr>
<td>( \mu_i )</td>
<td>Unobservable effects, specific to each flow, which only vary across flows and not through time</td>
</tr>
</tbody>
</table>

Note: Data on journeys, fares, delays and GJT was obtained from the relevant TOC, whilst data on national GVA was obtained from the Office for National Statistics.

Due to limited data availability for this period, an alternative dynamic demand model was estimated for Scotrail before changes in its rolling stock. An autoregressive model was used to estimate Scotrail’s ‘general’ demand model, which explains current journeys through previous journeys, in the form of equation 2.

Equation 2

\[ v_{it} = \alpha + \beta_1 v_{it-1} + \beta_2 v_{it-2} + \beta_3 v_{it-3} + \beta_4 v_{it-5} + \beta_5 v_{it-6} + \beta_6 v_{it-7} + \beta_7 v_{it-7} + \epsilon_{it} + \mu_i \]

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Table 3: Description of the variables in the demand model for Scotrail

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_{it}$</td>
<td>Current passenger journeys by ticket type</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Constant</td>
</tr>
<tr>
<td>$v_{it-1}$</td>
<td>Passenger journeys in the previous four–weekly period</td>
</tr>
<tr>
<td>$v_{it-2}$</td>
<td>Passenger journeys two four-weekly periods previously</td>
</tr>
<tr>
<td>$v_{it-7}$</td>
<td>Passenger journeys seven four-weekly periods (just over half a year) previously</td>
</tr>
<tr>
<td>$\epsilon_{it}$</td>
<td>Error term</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Unobservable effects, specific to each flow, which only vary across flows and not through time</td>
</tr>
</tbody>
</table>

Note: The data was obtained from Scotrail.

5.3. General modelling procedure

To ensure the robustness of the demand models, and given that data for all flows is restricted to a period of approximately four years, the lag structure assumed in the models for all the TOCs was restricted to the specification of equations 1 and 2. Given the small sample size, there is likely to be a high level of correlation between the explanatory variables, causing the individual parameter estimates to be biased. In an attempt to minimise these problems, a panel data approach was followed to increase the potential explanatory power of the models, and the general models were also restricted to the specification of equation 2. In order to generate accurate predictions of demand in the absence of any changes in the rolling stock, models with the maximum within sample performance have been selected.

A general-to-specific approach was followed during the estimation of each model. Variables that were found not to be significant at the 10% level in the general models (shown in equations 1 and 2) were removed from the final ‘preferred’ model.

5.4. Limitations of the event study methodology

A number of caveats are worth mentioning:

- Evidence of heteroscedasticity was found for some routes using both modified Wald statistic and tests for cross-sectional dependence in the residuals. Techniques such as Feasible Generalised Least Squares could have been used to overcome this in a panel data context. However, such problems are quite common in regressions estimated on a limited panel dataset, and these issues did not occur in all the demand models, and therefore, this approach was not employed.
- The sensitivity of results to the form of the demand model selected was overcome by using comparative tests for overall significance for each regression.
- Limited data was available for the period after the introduction of rolling stock on routes operated by First Great Western and Southern.
- It was not possible to control for all external influences on demand, due to data limitations.

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These limitations, arising from the estimation of the demand models, suggests that the results presented should be interpreted as only indicative of the impact on demand from the change in rolling stock. As a result of the above limitations, the predictions of demand, in the absence of any change in rolling stock, may be under- or over-estimated. The results should therefore be interpreted in conjunction with other studies, and the market research carried out for this study.

5.5. Attributes analysis

As the final part of the analysis, aspects of the improvement in the rolling stock have been assessed, so as to highlight those attributes that have the greatest effect on demand. The same attributes from the market research have been used in this stage of the analysis, and are listed below:

- Seat layout
- Seat comfort
- Smoothness of ride
- Ambience
- Toilets
- Information and announcements
- Reliability
- Chance of getting a seat
- Journey times.

The information was examined to identify correlations between the uplift in demand, possibly occurring as a result of change in the rolling stock, and passengers' mean ratings of the above attributes, taken from the market research. As this analysis has been based on the event studies, these results should also be interpreted cautiously. A slight change in the magnitude of the estimated uplift in demand will affect the degree of correlation between the increase in demand and the passengers' ratings of the attributes. It is also worth noting that the results rely upon passengers adopting a rational approach when valuing the different aspects of the new rolling stock.

In order to maximise the size of the sample for the correlation analysis, the uplifts in demand for the first and full fare ticket categories have been used for First Great Western and Southern. Due to limited data, the uplift in demand for the total ticket category for Scotrail is used to calculate the correlations. No analysis can be undertaken for Northern and GNER, as these routes were not covered in the market research.

6. EVENT STUDIES RESULTS

This section reports the results from the event study analysis. These suggest that:

- The change in rolling stock has led to a small uplift in overall demand
The introduction of class 333 units on the Northern routes has the greatest influence on demand.  

6.1. Results

The changes in total demand, which may be a result of the change in rolling stock, are shown in Table 4. The percentage change in demand is calculated for the total ticket category, which includes first, full, reduced and season tickets for First Great Western, Southern, Scotrail and GNER. The uplift in demand for Northern is only presented for the full fare ticket type, due to difficulties explaining the high growth (168%) in reduced fare tickets over the period in question – meaning a comparable total ticket category is not available.

Table 4: Uplifts in demand as a result of the change in the rolling stock

<table>
<thead>
<tr>
<th></th>
<th>Number of post-introduction four-weekly periods</th>
<th>Percentage change in demand (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total ticket category</td>
<td>First Great Western</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Southern</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Scotrail</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>GNER</td>
<td>26</td>
</tr>
<tr>
<td>Full fares</td>
<td>Northern</td>
<td>39</td>
</tr>
</tbody>
</table>

Notes: The percentage change is calculated as [sum of actual journeys–sum of predicted journeys]/sum of predicted journeys.

It should be noted that the results in Table 4 are sensitive to the selected period of analysis and that, for some routes, not enough data is available post changes in the rolling stock to assess the full effect of new trains.

The event studies results for First Great Western, Southern and Scotrail all show increases in demand similar to those observed from the market research.

The GNER and Northern flows were not assessed as part of the market research, making it difficult to compare the results for these services, reported in Table 4, with market research analysis. The result reported for Northern should be interpreted with caution, in view of the difficulty in attributing demand increases on flows around Leeds to the introduction of new rolling stock. The GNER results may also have overestimated the increase in demand attributable to the rolling stock change, as GJT reductions over the period were not factored into the ‘before’ model.

Analysis of the profile of predicted versus actual demand has shown that it is difficult to draw conclusions as to whether the new rolling stock has led to a permanent step change in demand, a gradual increase, or a temporary uplift.
6.2. Attributes analysis

The results of the attributes analysis are discussed in this section. These results should be interpreted with caution, as the correlations are very sensitive to the magnitude and signs of uplift in demand. It is, however, worth noting that:

- The comfort and layout of the seats appears to have the greatest influence on demand
- The appearance of the interior of the train and the quality of the toilets may have a lesser influence on demand, relative to other attributes assessed in the market research

Table 5: Correlations between the uplift in demand and attributes assessed

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat comfort</td>
<td>0.96</td>
</tr>
<tr>
<td>Seat Layout</td>
<td>0.95</td>
</tr>
<tr>
<td>Ride smoothness</td>
<td>0.80</td>
</tr>
<tr>
<td>Announcements</td>
<td>0.54</td>
</tr>
<tr>
<td>Ambience</td>
<td>0.50</td>
</tr>
<tr>
<td>Air quality</td>
<td>0.43</td>
</tr>
<tr>
<td>Noise</td>
<td>0.36</td>
</tr>
<tr>
<td>Look of interior</td>
<td>0.31</td>
</tr>
<tr>
<td>Toilets</td>
<td>-0.11</td>
</tr>
</tbody>
</table>

Note: Figures should be taken as only indicative of the importance of the attributes, and should be interpreted in line with the market research and earlier studies.

The correlations reported in the above table illustrate the strength of the relationship between the uplift in demand and passengers’ valuations of the attributes. As correlations can lie between –1 and +1, a correlation nearer to unity, would suggest the existence of a strong relationship. Directly interpreting the correlation associated with toilets suggests that as passengers’ valuations of the quality of the toilets increases, the uplift in demand declines. This clearly appears counter-intuitive, and therefore suggests care should be taken in interpreting the values presented above, although the rankings might be afforded more weight.

7. CONCLUSIONS

The event study analysis has suggested that a change in rolling stock may lead to a small uplift in total demand, between 0.7% to 11%, depending on the TOC. However, given the limited availability of data since the change in rolling stock, it is likely that the full effect of the introduction of new rolling stock may not yet have occurred. The attributes analysis has suggested that the comfort of the seats and their layout may have the greatest ability to influence the magnitude of the uplift in demand. However, given the limitations outlined above, the results from this analysis should be interpreted in conjunction with the market research findings and the results of previous studies.

The market research findings themselves have provided sensible looking results that compare well with the revealed preference models. This type of
exercise could collect appropriate data very cost efficiently allowing demand impacts to be examined across a broader array of market segments.
Notes

1. The total ticket category has been calculated as the sum of first, full, reduced and season tickets.

2. The predictions from the demand model have been calculated on a rolling basis. For example, the predicted level of journeys in the first-period after the change in rolling stock is used to calculate the predicted level of demand for the second period (after the introduction of the new rolling stock).

3. To analyse the within-sample performance of the models, predictions from the models before the change in rolling stock have been compared with actual levels of demand before the change in rolling stock.

4. The coefficients that are significant at the 5% level have a 95% probability of being 'true' and only a 5% chance of being false.

5. As a result of having no data for the Northern flows before the change in rolling stock, the uplift in demand reported for Northern should be interpreted as only being indicative.