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SOME GUIDELINES FOR EVALUATING NEW LOCAL RAIL STATIONS

J.M. Preston and C.A. Nash

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Abstract

This paper, based on work undertaken as part of a Ph.D. studentship on new local rail stations in West Yorkshire, seeks to offer guidelines for identifying and appraising new local rail station sites, and recommendations for further work on the subject. It outlines three methods of forecasting demand at such stations - a simple method based on mean trip rates at certain distance bands for similar existing new stations, an aggregate regression model, and a combination of a disaggregate mode split model for the journey to work with an aggregate non-work journey model. Whilst the latter models do provide greater accuracy, it is suggested that a simple trip-rate model may be adequate for one-off low-cost stations, although packages of stations and train service alterations need more thorough investigation. On this basis, it is suggested that for new stations with the characteristics of those in West Yorkshire (i.e. suburban stations in residential areas a few miles from major employment centres), sites which are free of significant engineering problems, with good road access, close to an existing bridge or crossing and with a population of at least 2,000 within 800 metres of the site, should be sought. On single track rural branch lines, new stations may be justified at much lower population levels.

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Some Guidelines For Evaluating New Local Rail Stations

1.1 Foreword

This paper is based on work carried out between 1982 and 1985 as part of a Ph.D. Research Studentship on "The Evaluation of New Rail Stations in West Yorkshire". It attempts to bring together the practical implications of that work. In the rest of this section we shall examine, briefly, the recent history of new station development. In a second section we shall examine ways in which potential new station sites may be identified. Then we shall show how a simple trip rate model might be applied to produce crude forecasts of demand. The fourth section gives details of an aggregate model that attempts to overcome some of the weaknesses of the trip rate approach. In a fifth section we go on to outline what we have called a disaggregate approach (based in fact on a disaggregate work model and an aggregate non-work model) which it was thought would provide the most accurate forecasts. In a sixth section we look at the type of evaluation measures and issues that are relevant. Finally, the three forecasting methods will be compared and their possible applications discussed. Some guidelines for new station evaluation will be outlined along with recommendations for future work on the subject.

1.2 Recent History of New Station Development

Between 1976 and 1985 approximately 100 station openings or reopenings have occurred on publicly owned passenger railways in Great Britain, compared to just 28 closures. This indicates that:

i) station numbers are a lot more dynamic than many people perceive;

ii) there is an overall trend, in recent years, towards more stations on the rail network.

There is evidence that the trend towards new stations may be escalating as there are some 57 stations under construction or at the planning stage, with up to a further 105 proposed by Local Authorities (Roberts, a and b, 1985 and 1986). Major changes in bus networks following deregulation in October, 1986 may offer more opportunities both to fill gaps left in the commercial network and to offer an attractive alternative to Local Authorities compared with a subsidised bus route.

The stations opened in Britain over recent years may be placed into a number of categories:

1. Stations related to a "new" transport system, such as the stations on the Tyne and Wear Metro.

2. Stations related to a new or upgraded rail service such as

the Cross City Line - South in the West Midlands, the Garston branch in Merseyside or the Sinfin branch in Derby.

3. Inter City Parkway stations such as Birmingham International (opened 1976) or Sandwell and Dudley (1984).

4. Stations related to New Town development such as Newton Aycliffe (1979) and Milton Keynes Central (1982).

5. Stations related to improved central area rail links, for example those opened on the Argylle line (Glasgow) or on the Link and Loop schemes (Merseyside).

6. Stations on existing services serving local transport needs. These may be:

   a) Trip attractors, usually related to major employment centres for example BSC Redcar, IBM Halt (both opened 1978) or Cathays (opened 1982). Other possible attractors are sites close to schools, shopping centres or recreational facilities.

   b) Trip generators, related to mainly residential areas.

   In most of this discussion we are only considering stations of the type 6(b).

2. Identification of sites

In identifying potential sites, the obvious starting point is to identify routes on which a suitable provincial (or London and the South East) service already operates. (Where there is no such service, then the provision of a totally new service probably with a 'package' of new stations must be evaluated; obviously this requires a much higher traffic level to be justified). A search procedure might then be developed as follows:

1. Exclude sections within a specified distance of existing stations. Given our findings that most local rail station usage comes from within a straight line distance of 800m, this might be initially set at 1.6 km (≃ 1 mile). Where access distances are greater than average (for example for main line stations) this distance may be much higher, whilst where local geography results in distinct settlements or travel is mainly in one direction (and hence catchment areas are likely to be asymmetrical) this distance may be lower.

2. Exclude sections where engineering constraints, such as tunnels, deep cuttings or viaducts, or lack of adequate access, make the location of a new station impossible or excessively costly. In addition some sections, for example, on main lines, may be precluded due to pathing problems. If it is considered unacceptable for passengers to cross the

tracks on the level, then proximity to an existing bridge or level crossing is an advantage.

3. Exclude sections passing through non built up areas. From the models developed in later sections we shall attempt to give a precise definition of the population necessary to make a site worth considering.

In practice, examination of O.S. maps (updated by local knowledge where recent house building has taken place) should enable a common sense definition of sites worth further consideration to be made. Use might also be made of studies by pressure groups. For example Transport 2000 (1983) proposed 100 new stations as part of the Option T alternative to Serpell, whilst the Railway Development Society (1984) has put forward 410 possible new station sites.

3. Simple Trip Rate Models

In evaluating a potential new station the first question that needs to be asked is: "How many people will use the station after it is opened?"

The simplest way to answer this question may be by using a trip rate model. In this section such a model is developed for the 6 new stations opened in West Yorkshire between 1982 and 84 (Bramley, Crossflatts, Deighton, Fitzwilliam, Saltaire and Slaithwaite). This approach makes use of market research at these 6 stations which showed that 800m and 2km are 2 important thresholds in terms of access distance and access mode. Trip rates (defined as rail usage in zone i / population in zone i) were then calculated for the 0 to 800m and 801m to 2km distance bands from new stations. This required the following information:

a) 'Average' weekday and Saturday usage, derived from the Passenger Train Survey (PTS).
b) Information on the straight line access distance travelled and hence the proportion of travellers originating within various distance bands. This was derived from information on origin addresses collected by our market research at all 6 stations.
c) Data on the population in the 2 distance bands. This was derived from the 1981 Census Small Area Statistics, accessed via the University of Manchester Regional Computing Centre using the SASPAC package. As Figure 1 shows, zones were defined by aggregating whole, or part, of Enumeration Districts. An alternative source of this data might be provided by commercial organisations (Tyler, 1986).

The results of such an approach are shown by Table 1. If it is assumed that Sunday traffic is negligible these results imply, for the 0 to 800m distance band, a mean weekly trip rate of 126 ons and offs per thousand population, with a standard deviation of 38. For the 801m to 2 km band the mean weekly trip rate declines to 26 trips per thousand population, with a standard deviation of 14. In addition account should be taken of the fact that on average around 13% of demand comes from beyond 2 km (and thus results should be weighted by a factor of 1/0.87 = 1.15).

Furthermore it should be noted that the usage figure given by Table 1 was an initial usage figure and for 4 out of the 5 stations where later usage figures were available demand had increased. This meant that the mean weekly trip rate for the 0 to 800m band increased to 156 trips per thousand population (standard deviation 36), whilst the weekly trip rate for the 801m to 2km band increased to 31 trips per thousand population (standard deviation 14).

Clearly the use of such trip rates is very crude. It fails to take into account factors such as the socio-economic characteristics of the catchment area population, the attractiveness of destinations, the level of rail service and competition from other modes (principally bus and car). An attempt was made to take into account the effect of bus competition by excluding the catchment area of bus stops, but this failed to reduce the variability of trip rates between stations.

Following a request from BR London Midland Region, the simple trip rate approach was used to examine the relative merits of Langley Mill and Ilkeston. It may be applied, as there, by using the West Yorkshire rates or by developing new rates relevant to the area being studied (as would obviously be necessary, for example, in London and the South East). This latter approach would require information on the precise origin of travellers at nearby stations to the potential site being considered, which exists for London and the South East, but is unlikely to be available without fresh survey work elsewhere.

4. Aggregate Approach

In order to take into account some of the important factors that were ignored by the trip rate approach, a multiple regression equation of the following form was developed: (t- statistics in brackets)

$$\underset{(3.025)}{LFLOW = 5.496} + \underset{(2.617)}{0.380\ LOPOP} + \underset{(1.733)}{0.164\ LOPOP3} + \underset{(2.034)}{0.246\ LRSOC} + \underset{(6.678)}{0.269\ LDRX}$$

$$- \underset{(-2.269)}{1.341\ LGCOTH} - \underset{(-4.307)}{1.239\ LGCRA} \qquad R = 0.539 \quad \bar{R} = 0.509 \qquad \text{Equation 1}$$

This model was calibrated for 99 flows of over 25 per day for 36 small town, suburban and rural stations in West Yorkshire in 1981. Variable definitions and data availability are given by Table 2.

One of the main problems was in obtaining OD information, as ticket sales data for local services is very limited (although with the advent of APTIS and PORTIS this may change). However OD information may be derived from the PTS on/off counts by using a probabilistic approach similar to that used by Savage (1983) for bus revenue estimation. This would take the form

$$T_{i,j} = A_i \cdot \left[\frac{B_j}{\sum_{i}^{j-1} A - \sum_{i+1}^{j-1} B} \right] \qquad \text{Equation 2}$$

Where

$T_{i,j}$ = the number of rail trips between i and j

A_i = the number of people getting on a station i and still on train prior to reaching j

B_j = the number of people getting off at station j

$\sum_{i}^{j-1} A - \sum_{i+1}^{j-1} B$ = the number of passengers on the train prior to stopping at j

The part of the equation in square brackets is the probability of alighting and will be unity where a service terminates. Where a train is empty at any point and thus the divisor is zero, the probability is obviously set to zero.

More sophisticated methods of estimation may be used where additional information - such as an out-of-date O/D matrix - is available.

The resultant O/D matrix was produced by a FORTRAN program, which also gave the number of passengers on the train between any pair of adjacent stations, which may be used to evaluate the time penalty to existing users.

The other main data problems are related to reliable information on workplaces within the destination station catchment area (which may be available from the 1981 Census Special Workplace Statistics through SASPAC-W or through commercial organisations) and on the access/egress time to Public Transport modes. The model given by equation 1 was used by Hockenhull (1984) to estimate patronage at 5 sites around Leicester and by Alderson (1984) to estimate patronage at Dunston, Tyne and Wear. In addition, at the request of BR Eastern Region, the model was used to evaluate several sites in North Yorkshire and, at the request of West Yorkshire PTE, to estimate the effects of rerouteing the Leeds-Goole service. However it is suspected that a model of this type lacks spatial transferability (and is only applicable to provincial PTE-type areas) and temporal transferability (equation 1 rerun on a different set of O/D information produced from a West Yorkshire County Council self completion survey in 1984 gave significantly different parameter values). It would, though, be relatively straightforward to recalibrate such a model, given reliable O/D information (or even a recent PTS count) although the 1981 Census is becoming somewhat out of date.

5. Disaggregate Approach

A number of weaknesses were apparent with the aggregate approach, in particular that it fails to establish the importance of factors that exhibit greater intra zonal variations than inter zonal variation, for example walk and wait time which are critical in the choice of Public Transport mode. It also fails to use evidence on existing work-places of the residents of the area. These shortcomings may be overcome by making use of individual data on times and costs of the mode actually used and at least one alternative (or preferably a full choice set of alternatives) in order to calibrate a mode split model. A data set was provided by the 1981 West Yorkshire Corridor study, which collected information on the journey to work as part of the value of time study (MVA et al, 1985). The model form chosen was the hierarchical (or nested or tree) logit (HL), mainly so as to overcome the property of independence from irrelevant alternatives, that affects the more widely used multinomial logit model (MNL), whereby the cross elasticity with respect to any particular mode is assumed uniform across all other modes. We know from our surveys that new station users are more likely to be drawn from former bus users, all other things being equal, than car users. The models were estimated indirectly using the BLOGIT package (Crittle and Johnson, 1980) with the composite cost term (EMU) being calculated with FORTRAN programs. Previous work (for example by Small and Brownstone, 1982) has shown that direct estimation (or full information Maximum Likelihood) is preferable to indirect estimation but we did not have the requisite software readily available.

In fact our initially preferred model was market segmented and consisted of an MNL model for non car owning households and an HL model for car owning households. The structure of this model is shown by Table 3. However, a model of this form proved very data intensive and for West Yorkshire sufficient data only existed to validate this model for 5 new stations and make predictions for a further 3 potential sites (see section 7.1).

A simpler formulation, although arguably less powerful, may be provided by the single market model, shown by Table 4. A model of this form was used to predict the number of work trips by making use of aggregate data on the number of work trips from new station catchment areas to rail served destinations provided by the 1981 Census Special Workplace Statistics, Section C. In theory this data should be available from the Regional Computing Centres via the MATPAC package. In fact the data we used was obtained via West Yorkshire County Council.

In order to apply a model of the type shown in Table 4 use was made of the incremental logit model (IL). This might be experessed as (after Kumar, 1980):

$$P'_T = \frac{P_T . \exp (S'_T - S_T)}{\sum_M P_M . \exp (S'_M - S_M)}$$ Equation 3

Where P'_T = proportion choosing train in after situation
P_T = proportion choosing train in before situation
S'_T = utility of train in after situation
S_T = utility of train in before situation
$_M$ = any mode in choice set (train, bus, car driver, car passenger)

There are however two problems here:

1. Equation 3 is suitable for a MNL model but not an HL model.

2. In the case of new stations P_T is likely to equal 0.

In order to get round these problems Koppelman (1983) proposed the Extended Incremental Logit. For a simple HL model of the type shown in Table 4 this would take the form:

$$P'_{PT} = \frac{P_{PT} . \{\exp (S'_{NT} - S_{XT}) + \exp (S'_{XT} - S_{XT})\}^{\gamma}}{P_{PT} . \{\exp (S'_{NT} - S_{XT}) + \exp (S'_{XT} - S_{XT})\}^{\gamma} + \{1 - P_{PT}\}}$$ Equation 4

where P'_{PT} (P_{PT}) = Proportion choosing Public Transport in the after (before) situation.

S' (S) = Utility measure in the after (before) situation

XT = old Public Transport mode (bus); NT = new Public Transport mode (rail)

γ = EMU parameter

The lower split shares would then be:

$$P'_{NT} = \frac{\exp (S'_{NT} - S_{XT})}{\exp (S'_{NT} - S_{XT}) + \exp (S'_{XT} - S_{XT})} \cdot P'_{PT}$$ Equation 5

and

$$P'_{XT} = \frac{\exp (S'_{XT} - S_{XT})}{\exp (S'_{NT} - S_{XT}) + \exp (S'_{XT} - S_{XT})} \cdot P'_{PT}$$ Equation 6

As, in most cases, we would assume no change in the utility of the existing Public Transport mode $\exp (S'_{XT} - S_{XT})$ simplifies to 1.

For completeness private transport's share in the after situation may be defined as:

$$P'_M = \frac{P_M}{P_{PT} \cdot \left\{\exp(S'_{NT} - S_{XT}) + \exp(S'_{XT} - S_{XT})\right\}^{\delta} + \left\{1 - P_{PT}\right\}}$$ Equation 7

which is equivalent to:

$$P'_M = P_M \cdot \frac{1 - P'_{PT}}{1 - P_{PT}}$$ Equation 8

The approach given by Equations 4 to 8 would need to be modified in cases where rail has a significant market share in the before situation (i.e. $P_{NT} > 0$). However in such cases the simple IL model of Equation 3 might suffice.

The incremental logit approach has advantages in that it reduces the data requirements of a disaggregate approach, as we typically only need to know about modal shares, P_M and P_{PT} (which in Equations 4 to 8 = P_{XT}) and the utilities S_{XT} and S'_{NT}. In our study S_{XT} and S'_{NT} were calculated using engineering times and costs and predictions made for the 6 new stations already opened and 28 potential stations in West Yorkshire.

Our work has shown that whilst a disaggregate approach has a number of theoretical advantages there are a number of practical problems related to data availability and resources required. Moreover we have reason to doubt the transferability of our disaggregate models, despite the claims of Atherton and Ben Akiva (1976) or Ou and Yu (1983). To recalibrate a disaggregate model would require a major research effort, although a pragmatic approach might be based on using IL/EIL models with parameters from existing disaggregate studies (for example Koppelman, op cit, p 555 quotes a number of American studies).

Our disaggregate approach has at least 2 shortcomings:

1. It is based on a mode split model only, and thus can only consider abstracted trips. It is argued that, at least in the short run, few work trips are generated, although in the medium run onwards a generation component might be required.

2. Due to data limitations we have only been able to model work trips in this way. In any event, mode switching - as opposed to changes in destination and frequency - may be less significant for non-work journeys. This suggests that this approach may be limited to London and the South East and the major conurbations, where work trips are the main journey purpose.

In order to determine the number of non work journeys, an aggregate model was developed, calibrated for 64 non work flows of over 10 per day identified from the West Yorkshire County Council 1984 Survey. This took the following form (t-statistics in brackets)

$$
\begin{aligned}
LFLOW = & -3.580 + 0.562\ LOPOP + 0.252\ LREMP + 0.574\ LRS - 0.250 \\
& \ \ (-2.321) \quad (3.230) \qquad\quad (4.051) \qquad\quad (3.315) \quad (-2.408) \\
& LBS + 0.996\ IC - 1.247\ INTOPP \quad R = 0.709 \qquad \text{Equation 9} \\
& \ (4.634) \qquad (-8.077) \qquad\quad \bar{R} = 0.678
\end{aligned}
$$

Variable definitions and data availability are given by Table 5. It should be noted that school trips are not explicitly modelled, as Local Education Authorities should be able to provide the most reliable information. Data on retail employment provides some problems, although more reliable data might be obtained from commercial organisations or the Census SWS.

6. EVALUATION ISSUES AND MEASURES

In a financial analysis the following variables may be considered:

1. Capital costs. If stations similar to those in West Yorkshire are built (i.e. unmanned, wooden platforms) they may be costed at around £100,000 for double track, £60,000 for single track, although access problems due to location on an embankment or in a cutting may increase costs of a double platform station by an average £50,000.

2. There will be some recurrent costs associated with maintenance, administration, etc. This was estimated by West Yorkshire PTE to be around £1700 pa (£1500 for single platform stations).

3. In what follows, it is assumed that new stations can be opened without increasing train service operating costs; if this is not the situation then these must be evaluated, and the case for a new station will be correspondingly weakened.

4. Net revenue to BR. This needs to take into account
(a) Mean fare paid, which is largely a function of mean distance travelled and
(b) Abstraction from existing BR services. In West Yorkshire this only accounted for 13.4% of demand on weekdays (ranging from 0 at Fitzwilliam to 27.3% at Crossflatts). This figure may be higher for stations located close to an existing station; a 1985 Cleveland County Council survey at Longbeck indicated that 71% of passengers had been abstracted from Marske station (which is less than 1 km away).

Where one body finances both bus and rail (as is currently the position in the PTEs) account may have to be taken of abstraction from bus (which in West Yorkshire accounted for 55.8% of demand on weekdays).

5. The inclusion of an additional stop involves a time penalty of at least 1 minute for passengers already on the train. Assuming a journey time elasticity of - 0.418

(implied by the aggregate all trips model) and that travellers react to such a small time change this will lead to some loss of revenue. This will be significant where there are a large number of people already on the train travelling relatively short distances (especially if the fare scale is tapered).

A social analysis would include the same costs as above and the net revenue to Public Transport operators as a whole. In addition consideration should be made of:

1. Time savings to new station users. These will be at their greatest where mean distances travelled are long and existing Public Transport provision is poor.

2. Time penalties to existing users. These will be greatest where a train is heavily loaded prior to stopping at a new station. Consideration of this variable weakens the case for stations at the destination end of the main direction of travel (i.e. inner city sites) and strengthens the case for stations on lightly used sections, typically at same distance from the main destination (e.g. sites on the periphery of a rail network). Where frequency allows, experimentation with different stopping patterns might reduce the effect of this variable.

3. A number of additional variables might be taken into account, but these are more difficult to quantify. For the 6 new stations in West Yorkshire consideration of road user time savings (due to reduced congestion) and accident reductions were shown to strengthen the case for new stations, although only 17% of passengers on weekdays had diverted from car. We were unable to measure the effects of secondary changes (on activity patterns), tertiary changes (on land use) and environmental impacts, but these are likely to be small but positive.

An assumption is necessary concerning the growth (or decline) of traffic following the first year. From experience at existing new stations, the most appropriate seemed to be that traffic would build up to its forecast level at 15% p.a. over the first 5 years and then remain constant, other things being equal.

A Net Present Value (NPV) may then be estimated as:

$$NPV = \sum_{n=0}^{30} \frac{B_n - C_n}{(1 + r)^n} \qquad \text{Equation 10}$$

where B_n = Benefits in year n, C_n = Costs in year n, n = project life (assumed to be 30 years) and r = interest rate (0.07).

A new station is justified when the NPV $\geq$ 0.

7. CONCLUSIONS

In this section we firstly compare the predictive powers of the different forecasting methods. Secondly we develop some simple evaluation guidelines and thirdly we shall make some recommendations with regard to further work.

7.1 COMPARISON OF FORECASTING METHODS

A number of forecasting methods may be compared:

1. The trip rate model described in section 3 and outlined in Table 1. This will make use of the mean weekday trip rates.

2. The aggregate model described in section 4 and outlined by Equation 1. This model may be used to model flows to main destinations and is then factored to a total usage figure by making use of information on destination choice at nearby stations.

3. The market segmented HL/MNL models of work trips, outlined by Table 3, which were used with household interview data on journey to work times and costs collected as part of the West Yorkshire 1981 Transportation Study update. This may be referred to as a sample enumeration aggregation method. In order to factor up into a total usage for work trips figure data is required on the proportion of work trips originating within a pre-defined catchment area (defined as 800m radius). The total number of non work trips was estimated by the non work aggregate model shown by Equation 9.

4. The single market HL model of work trips, outlined by Table 4. This was used with zonal census data on journey to work flows and with engineered times and costs, in conjunction with an incremental logit formulation shown by equations 4 to 8. This may be referred to as a naive aggregation method. Again the total number of non work trips was estimated by the non work aggregate model of Equation 9.

5. PTE forecasts, which were based on a simple regression model that included only the number of households within 800m and the number of weekday trains.

These 5 approaches are compared by Table 6. In the case of the trip rate model, it is assumed that data would be available for the 5 stations other than the one being evaluated. Obviously this is not the case except for the last station built, and information relating to similar existing stations would have been used for the earlier forecasts. The forecasts show no obvious bias, but are only within ± 42% initial usage with a root mean square error (RMSE) of 71 trips. It is interesting to note that this method fails to replicate the correct ranking of new stations on the basis of initial usage, and in this respect performs worse than the aggregate and disaggregate approaches.

Of the four remaining approaches the most accurate, at least initially, is the market segmented HL/MNL approach which, however, can only be used to make predictons for 5 of the stations. This method may be shown to give predictions on average around 34% above the initial usage with an RMSE of around 77 trips. It should be noted, though, that the work model alone was very accurate, being within ± 15% of work trips. It is thus the aggregate non-work model which accounts for the biggest part of the forecasting error. By contrast the single market HL model gives predictions some 54% above initial usage, with an RMSE of around 97 trips. This deterioration of accuracy may be attributed to the use of a naive aggregation method based on engineered zonal times and costs. The aggregate all trips model is slightly more inaccurate than the single market HL model, giving predictions some 63% above initial trips with an RMSE of around 108 trips.

All three methods discussed in the preceding paragraph over predict usage. They may, however, be seen as an improvement to the simple PTE forecasts which overpredicted usage by around 193% with an RMSE of 336 trips. If new station demand builds up over time, and there is some evidence in West Yorkshire that this may be so, then one would expect our models to be initially over predicting demand. It is interesting to note that for those stations where a later usage figure is available (and for 4 out 5 stations this represents an increase in usage) the accuracy of the two latter methods is improved, and is broadly comparable to the market segmented approach. (However the forecasts should be adjusted upwards slightly in order to take into account reductions in real fares over the period). It is interesting to note that the disaggregate approaches both underestimate Deighton usage, whilst the market segmented MNL/HL model also underestimates usage at Crossflatts. This may reflect the inability of a disaggregate mode split model to take into account the effect of generated trips.

7.2 EVALUATION GUIDELINES

In this section we consider three new station scenarios:

1. A single platform station costing £60,000 with recurrent costs of £1500 p.a. In order for a financial NPV of the type shown in Equation 11 to be > 0 this would require net revenue to BR of £6,339 p.a.

2. A double platform station costing £100,000 with recurrent costs of £1,700 p.a. In order for a financial NPV to be positive this would require net revenue to BR of around £9,765 p.a.

3. A double platform station costing £150,000 with

recurrent costs of £1700 p.a. For a positive financial NPV this would require net revenue to BR of around £13,798 p.a.

For each of these scenarios a low (30 pence), medium (60 pence) and high (£1) mean fare were considered. In order to determine daily patronge required it was assumed, from our own market research, that only 13.4% of revenue was abstracted from existing BR services. No consideration was made of the effect of a 1 minute time penalty on existing revenue. From Table 7 it can be seen that between 25 and 177 weekday ons and offs are required in order to break even. For a typical West Yorkshire station (capital cost £100,000, mean fare 60 pence) this figure would be 63.

The population within 800 metres of a station that would be required in order to achieve the break even number of on/offs is also shown by Table 7. This was calculated by assuming 63% of usage originates within 800 m of a station and that the mean weekday trip rate in the 0 to 800 band was 20.17 per thousand (from Table 1). This assumes that the main access mode is walk (which in our market research accounted for 83% of trips), and is unlikey to hold if extensive use was made of feeder bus, park and ride or kiss and ride. The figures in Table 7 suggest our minimum definition of a built up area might be based on a population of 800 within 800 m of a railway line. For a typical West Yorkshire station this figure might be close to 2000 population.

7.3. FINAL CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

As a result of this project, we would offer the following advice to anyone involved in evaluation of new station sites:

1. The simplest approach to forecasting demand at a new local rail station is to look at the trip rates obtained per 1,000 population within a given distance band for similar stations elsewhere. For stations similar to those in West Yorkshire (i.e.stations in residential areas close to large towns), appropriate assumptions may be a trip rate of the order of 156 ons and offs per week per thousand population within 800 metres of the station, and 31 ons and offs per thousand population within the 801 to 2km band.

2. Obviously, this is a very crude approach, ignoring a host of important factors, but for such low-cost investments it may be deemed adequate. For instance, patronage at a new station will obviously be higher, the larger the existing number of commuters to nearby towns from the area and the poorer the roads and the bus service. A reasonably simple way of taking account of such factors is provided by the aggregate model described above, although we suspect that it would need recalibrating were it to be applied to areas other than West Yorkshire or very similar areas elsewhere.

3. The most accurate forecasts will be obtained by using the disaggregate approach, preferably extended to allow for long term generation of work trips. However, this is clearly a task for specialists (the Board's OR unit, or outside consultants including ourselves) and could probably only be justified where substantial investments (e.g. packages of new stations accompanied by significant restructuring of services) were involved.

4. In considering the number of passengers necessary for a new station to be financially viable, many more considerations are important, such as

- the ease of construction and number of platforms required

- the mean fare paid by newly attracted passengers

- whether the traffic can be handled without the need for additional rolling stock and train crew

- how heavily loaded the train already is, and the extent to which additional stop or stops might lose existing patronage.

Our calculations suggest that a single platform station combined with long mean trip lengths in favourable circumstances might break even with as few as 25 ons and offs per day; within West Yorkshire, of the order of 70 would suffice. This suggests a minimum population within 800 metres of roughly 2,000 in a suburban situation, falling to 800 on a single-track rural branch line. Where the local authority is paying for the station, it may of course be worth BR co-operating at even lower levels of population.

We would recommend the following further work:

1. A comparison of the trip rate achieved at new local stations in West Yorkshire with those obtained elsewhere, together with such further survey work as is necessary to establish new station catchment areas and mode previously used. It is possible that this might be undertaken by Masters degree students at a minimal cost (out of pocket expenses only) to BR.

2. A systematic search for potential sites for new stations, either nationwide or in selected areas considered to hold potential. Clearly such a study would depend heavily on the availability of a fast and convenient way of matching up census data to potential locations, and it is recommended that this work be considered in the light of the conclusions reached by the study of this issue commissioned by the Policy Unit from J. Tyler.

3. Further work on both aggregate and disaggregate models to examine their transferability and to extend the latter to allow for generation effects. This is a major task, and should probably be undertaken in the context of major proposals for station re-openings associated with service revisions requiring a more thorough investigation than is provided for by the simpler approaches.

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	Usage	% Originating within 0-800m	% Originating within 801m-2km	Population 0-800m	Population 801m-2hm	Trip rate 0-800m	Trip rate 801-2hm
Slaithwaite	130	52.5	27.0	2817	5450	24.23	6.44
Crossflatts	120	49.9	29.8	2989	5764	20.03	6.20
Deighton	87	66.7	25.1	4017	9990	14.45	2.19
Fitzwilliam	75	80.3	0.0	3594	2914	16.75	0.0
Bramley	226	65.9	25.0	10072	16554	14.79	3.41
Saltaire	254	63.1	27.7	5206	9134	30.78	7.70
					Mean	20.17	4.32
					Standard Deviation	5.81	2.69
(A) WEEKDAY							
Slaithwaite	179	52.8	31.9	As		33.55	10.48
Crossflatts	116	53.6	23.0	Above		20.80	4.63
Deighton	132	78.2	17.4			25.70	2.30
Fitzwilliam	103	40.0	20.0			11.46	7.07
Bramley	288	65.3	12.0			18.67	2.09
Saltaire	236	91.3	8.7			41.39	2.25
				Mean		25.26	4.80
				Standard Deviation		9.86	3.99
(B) SATURDAY							

TABLE 1 WEEKDAY AND SATURDAY TRIP RATES FOR 6 NEW STATIONS IN WEST YORKSHIRE

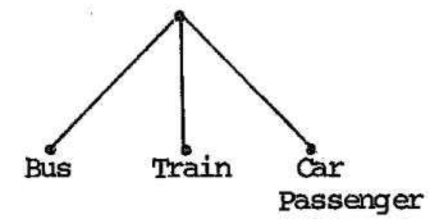
Variable	Definition
FLOW	Number of trips from i to j and j to i per average weekday. Calculated from the PTS (see text).
OPOP	Usually resident population within a straight line distance of 800 m of a station. Derived from 1981 Census using SASPAC.
OPOP3	Usually resident population between 800 m and 2 km of a station. Derived from 1981 Census using SASPAC. Where catchment areas overlap population should be allocated to the nearest station.
RSOC	Number of residents in Social class 1 or 2 (Professional and Managerial) within 800m of a station (derived from 1981 Census, 10% sample using SASPAC) divided by OPOP.
DRX	Number of workplaces within 800m of destination station (from Local Authority planning estimates) minus economically active population within 800m of a station (from 1981 Census).
GCRA	Generalised Cost of Rail = 2 (Walk + Wait time) + In Vehicle time + Fare/VOT where:
Walk	Access and Egress time calculated from the West Yorkshire Transportation Study
Wait	Calculated as a function of headway = 3.0 + 0.185 Service Interval (WYTS, 1976)
VOT	Department of Transport value of behavioural non-working in vehicle time (Department of Transport, 1980) = 74.4 pence per hour at November 1981 prices.
GCOTH	Index of competition = GCRA/(GCRA + GCBU + GCCA) where
GCBU	Generalised Cost of Bus = 2 (Walk + Wait time) + In Vehicle time + Fare/VOT where:
Walk	Calculated as rail walk time divided by the number of bus stop pairs on competing bus routes within 800m of a station
Wait	Calculated as a function of headway = 1.46 + 0.26 Service interval (Travers, Morgan and Partners, 1974)
GCCA	Generalised Cost of Car = In Vehicle time + Operating Costs/VOT + Parking charge/VOT where:
Operating Costs	Fuel costs only, assuming fuel consumption of 44km per gallon for urban conditions, 62km per gallon for rural conditions. (Automobile Association, 1981).
In Vehicle time	Based on following link-flow speeds: rural congested 77km/hr, rural uncongested 86km/hr,

urban congested 30km/hr (WYTS, 1975).

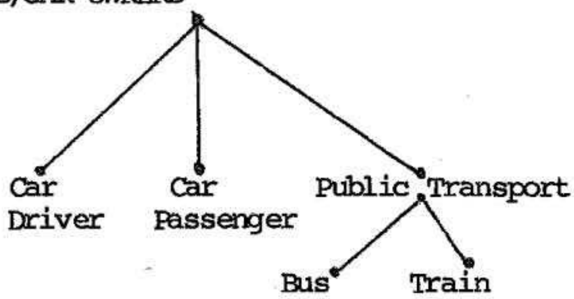
L Denotes a logarithm has been taken.

TABLE 2 VARIABLES USED IN AGGREGATE MODEL OF ALL TRIPS

(A) NON CAR OWNERS



(B) CAR OWNERS



	Parameter value	(t-stat)
ASC-Passenger	-0.844	(-1.305)
ASC-Bus	0.427	(1.004)
Wait time	-0.090	(-2.630)
Walk time	-0.071	(-2.335)
In vehicle time	-0.029	(1.339)
Availabilty-Passenger	-3.012	(-4.643)
No.of observations	173	
% right	72.4	

	Parameter value	(t-stat)
(i) Upper split		
ASC-Passenger	-0.339	(-0.596)
ASC-Driver	1.597	(2.789)
In vehicle time	-0.064	(-3.178)
Out of vehicle time	-0.059	(-1.481)
Total Cost	-0.013	(-4.176)
EMV-Public Transport	0.377	(4.996)
No. of observations	721	
% right	90.3	
(ii) Lower split		
IVT - Train	-0.111	(-1.785)
IVT - Bus	-0.118	(-2.605)
Walk time	-0.191	(-3.998)
Wait time	-0.276	(-2.565)
Total cost	-0.067	(2.196)
No. of observations	97	
% right	82.0	

NOTES Based on $P_i = \exp(V_i) / \sum_{j=1}^{J} \exp(V_j)$

where $V_j = \sum_{k=1}^{K} B_{jk} X_{jk}$ (i.e. utility)

ASC = Alternative Specific Constant

EMU = Expected Maximum Utility i.e. Public Transport Composite cost defined as:

$\ln \sum_j \exp(V_j)$

TABLE 3 SEGMENTED MARKET HL AND MNL MODELS

(A) LOWER SPLIT

Wait time	-0.132	(-3.025)
Walk time	-0.184	(-5.221)
In Vehicle time-Bus	-0.092	(-3.024)
In Vehicle time-Train	-0.080	(-2.295)
Total Cost	-0.044	(-2.490)
Number of observations	179	
% right	77	

(B) UPPER SPLIT

ASC-Car Driver	2.742	(5.867)
ASC-Passenger	0.804	(1.962)
EMV-Public Transport	0.205	(2.763)
Out of Vehicle time	-0.067	(-2.698)
In Vehicle time	-0.011	(-0.743)
Total Cost	-0.014	(-6.252)
Number of observations	907	
% right	87	

TABLE 4 SINGLE MARKET HL MODEL

Variable	Definition
FLOW	Number of non work trips (excluding education) from i to j and j to i per average weekday given by WYCC 1984 survey
REMP	Retail employment within central area shopping zone. Provided by 1971 Census of Distribution updated by Local Authority planning estimates
OPOP	As in Table 2.
RS	Rail service frequency during off peak periods (0930-1500 hours and 18.00 hours and beyond)
BS	Bus Service frequency during off peak periods
IC	Dummy variable = 1 where flows on to the inter city network exist. Limited to medium size towns. For most new stations = 0.
INTOPP	Proxy variable to take into account the number of competing or intervening opportunities.

TABLE 5 VARIABLES USED IN AGGREGATE MODEL OF NON WORK TRIPS

	Initial usage *	Next year usage	Trip rate model	Aggregate model	Hybrid approach: Market segmented model	Hybrid approach: Single market model	PTE model
Bramley	226	(235)	333	305	387	396	800
Crossflatts	120	(188)	96	278	178	244	400
Deighton	87	(177)	153	237	111	172	400
Fitzwilliam	75	(121)	104	98	-	138	169
Saltaire	254	-	147	378	286	281	650
Slaithwaite	130	(102)	87	158	136	120	200
Root mean square error 1:			71.32	108.3 (63.7)	78.6 (84.7)	96.9 (77.1)	335.8 (291.8)
Absolute deviation measure 2 :			0.422	0.630 (0.363)	0.343 (0.373)	0.540 (0.312)	1.936 (1.392)

1 Defined as $\sqrt{\frac{\sum_n (F - A)^2}{n}}$

2 Defined as $\frac{\sum_n |F - A|}{\sum_n A}$

where F = Forecasted usage, A= "Actual" usage, n = number of observations

TABLE 6 COMPARISON OF FORECASTING METHODS

*Number of ons and offs per average weekday

Mean fare (pence)	Scenario	Number of weekday on/offs required	Population within 800m required (to nearest 50)
	1	81	2550
30	2	125	3900
	3	177	5550
	1	41	1300
60	2	63	1950
	3	89	2800
	1	25	800
100	2	38	1200
	3	54	1700

TABLE 7 SOME EVALUATION GUIDELINES Scenarios 1: Capital cost £60,000 2: Capital cost £100,000 3: Capital cost £150,000

FIGURE 1 EXAMPLE OF A NEW STATION CATCHMENT AREA - SHOWING ENUMERATION DISTRICT BOUNDARIES.