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Forecasting and Appraising the Impact of a Regular Interval Timetable[i]

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Abstract

The timetable is the prime and essential feature of the service offered to potential travellers by public transport. The *Taktfahrplan* concept is based on trains leaving stations at the same time past the hour throughout the operational day. The objective is to provide an attractive rail service, memorable and easy to market, with well planned connections. This paper presents an appraisal of the introduction of a *Taktfahrplan* timetable onto the UK's East Coast Mainline rail route. We find positive changes for user and non-user benefits and revenue on London and non-London based flows.

1. Introduction

This paper outlines results from a project examining the demand and benefit implications from the introduction of a regular interval timetable, or *Taktfahrplan*, onto the UK's East Coast Main Line (ECML) rail route.

The objective of a *Taktfahrplan* is to provide an attractive rail service at regular intervals with well planned connections. However, in the interests of the coherence of the overall timetable, certain stations may receive a slower or less frequent service, so there is a tradeoff between costs and benefits to be made.

The paper applies various methodologies and valuations developed in earlier papers. The timetable to be evaluated is based on the *Taktfahrplan* concept, outlined in detail in (Tyler, 2003a). To forecast demand changes following the new timetable, we adapted a cross section demand model (Lythgoe and Wardman (2004)), capable of modelling access and station choice to incorporate the results of a stated preference exercise (Wardman et al 2003) which estimated small, but statistically significant, values for the characteristics of a *Taktfahrplan*. The appraisal of the results is carried out using a process similar to that used by the Strategic Rail Authority (SRA, 2003).

Section 2 of this paper outlines the methodology adopted, whilst section 3 presents results. Section 4 summarises the results and concludes. An outline of the application of *Taktfahrplan* concept to the ECML is included in Appendix 1, but for more details see Tyler (2003b). Appendix 2 shows a netgraph of the *Taktfahrplan*.

2. Methodology

2.1 The Principles of a Taktfahrplan

2.1.1 The Theory

The timetable is the prime feature of the service offered to travellers by public transport. Other features are significant, but without a timetable whose characteristics make choosing the train or coach an option competitively relevant to sufficient customers the service will fail.

Every timetable is planned in one of three ways, as may be appropriate for the circumstances:

- each element can be organised individually to match the planner's judgment of market demands; or
- a repeating pattern that provides in broad terms for the demand can be determined and strictly maintained throughout the operating day; or
- a pattern can be a starting-point, with the detail varied as required.

Traditionally, most timetables were produced on a painstaking train-by-train basis, although patterning is almost as old as railways and many networks offer trains at regular intervals. System-wide coordinated timetabling based on clear rules and consistency is largely the product of discussions among visionary staff of the Swiss Federal Railways [SBB] and was first implemented in 1982. The name they used then, *Takt-fahr-plan* ['rhythm-journey-plan'], has become established in German and is used in the absence of a satisfactory phrase in English.

The advantages of a *Taktfahrplan* are derived from six characteristics:

1. the methodology delivers a coherent timetable across a network;
2. it articulates a well-defined hierarchy of services;
3. connectivity for a journey on any relation (place-pair) is optimised;
4. systematic planning and regularity together make the best use of capacity;
5. a repeating pattern is simple to market and memorable for customers; and
6. the service in one direction is the mirror-image of that in the reverse direction.

The first three characteristics provide the structural framework. Its merits are measured by asking whether more attractive journey opportunities would grow revenue, net of any extra costs, and afford the community the best benefit from its railway. Note that a region may choose to forgo improvements on one line for the sake of enhanced connectivity and hence environmental gains in a wider area.

Considering the fourth characteristic, a railway is a system comprising track, trains and control mechanisms. The number of trains that can pass along each section is determined by its specific features. On multi-purpose, multi-route railways trade-offs are unavoidable between the commercial requirement for different types of service and the obligation to obtain the best return on the cost of the infrastructure. The equations are complicated because it is not obvious what the objective function should be. Rather than search for a theoretically optimal solution it is usually more sensible to select one from a small number of feasible solutions as a 'standard hour'. Not being able to satisfy time-sensitive markets may impose rigidity and at worst a loss of business. On the other hand, even a small deviation from a pattern can spread consequential changes extensively, and confuse passengers. This ‘clean sheet’ exercise proposes regular patterns.

The fifth characteristic concerns customers' reading of the timetable. Self-evidently, a repeating pattern can be presented more simply in every medium than haphazard timings (eg. "10 and 40 minutes past every hour" compared with recourse to an information source because every hour differs from the next). Even so, preferred and offered timings are unlikely to coincide for every traveller, and forecasting procedures incorporate an equivalent time-value for the negative impact of the necessary adjustment. A rigorous *Taktfahrplan* with high connectivity may offset this by creating such a sense of the convenience of moving about an area that most travellers are content to adjust their lives to what is offered. The impression of clear purpose may strengthen this perception, while simplicity may of itself generate use of a system. Seeking to understand these factors is not, however, easy.

The last characteristic is the design of the two directions as mirror-images, the one of the other. This is intrinsic to the idea of structure, it is necessary arithmetically for good connectivity, it simplifies the planning process, and it aids memorability. Moreover, its absence often means a poorer service in one direction than the other, which matters because most travellers judge a timetable by the two directions taken together.

2.1.2 Terminology

‘Regular-interval’ is an adequate phrase for describing the ‘standard-hour’ approach to planning the timetables of a network, but there must not be any suggestion that 'regular' connotes 'even'. Evenness may be the ideal, but it is not the highest priority[iii]. In the context of this paper, the adjective ‘clockface’ describes regular-interval timings.

More importantly, a collection of services independently timed at regular intervals only qualifies as a *Taktfahrplan* if the rules outlined in section 2.1.3 are followed, and in particular if the emphasis is on optimising connectivity and if the mirror-image is exact. Mere regular operation would yield some benefits, but it is unlikely to have the impact of a comprehensive plan.

Some Train Operating Companies believe departures from principal stations at round-number times (eg. xx.00, xx.30) are commercially desirable. There is tentative evidence to support this (Wardman et al. (2003)), but since it can only be achieved at a few stations and since doing it usually precludes a mirror-image timetable for X ↔ Y, it was not an objective in the present exercise. Moreover, 'round-numbered-ness' is arithmetically incompatible with the ‘zero-minute’ rule, outlined in the next section.

2.1.3 Seeking perfection: goals and rules

The *Taktfahrplan* philosophy is realised through a number of goals and rules. If a train leaves station A at xx.02 and arrives at B at xx.58 and the service in the opposite direction leaves B at xx.02 and arrives at A at xx.58 they will pass at xx.30 (where *xx* stands for any hour of the operating day). If the A ↔ B trains call at a station, Z, located where they pass, then a local train that arrives at Z at xx.25 and departs at xx.35 will have an optimal outward and return connection with both A and B. Where the frequency is hourly the principal stations should ideally lie 26 or 56 minutes apart from each other (assuming 4-minute dwell-times) to maximise connectivity. If services run half-hourly then centres can lie at the quarter-hour crossings.

It will be noted that 2 + 58, 30 + 30 and 25 + 35 all sum to 60. By arranging timings around the ‘zero-minute’ and ensuring strict mirror-image working *every* pair of departure and arrival times at *every* station will sum to 60. The base does not have to be zero, but that convention ensures simplicity. Because damaging accumulative (and unintended) effects across the network arise from derogations from these rules the case-study maintains their integrity. Nonetheless, in reality places do not form a hypothetical perfect network with neat time-separation from each other. In these cases it will be necessary for secondary services to have longer dwell-times or to consider increases (or even reductions, where possible) in sectional running times (SRTs).

The distinguishing tenor of *Taktfahrplan*, unlike traditional practice in Britain, is its concern for connectivity. The significance of connections should not be exaggerated, but neglect of the network concept may harm the collective interests of the industry – and even of individual companies. Large numbers of journeys involve more than one operator, and poor connections draw widespread criticism. The Swiss philosophy is to bind the whole country together in a coordinated web of routes such that *any* I ↔ J journey can be made straightforwardly, on a repetitive basis every hour. The outcome seems to be a more positive perception of public transport than exists in Britain.

It is an unlikely proposition that Switzerland was blessed with a disposition of nodes that especially favoured *Taktfahrplan*. However, it is possible, over time, to adjust the network so that the arrangement of sectional running times approximates the ideal. The *Bahn 2000* project devised a timetable vision, tested what could be done by combinations of infrastructure enhancements and new rolling stock, iterated solutions and then committed to a programme of works that would deliver the best practicable timetable, including a new line and establishing Bern as the second principal ‘zero-minute’ hub after Zürich. This was implemented in a ‘big bang’ revision in December 2004, and further schemes will culminate in the opening of the two new Alpine Tunnels. The strategy was approved by referendum as being superior in net national benefit to dramatic high-speed improvements for selected corridors, and it illustrates the Swiss dictum “as fast as necessary, not as fast as possible” – in other words, use speed to obtain good nodal interchanges rather than pursue it for its own sake.

With such a timetable reliable operation is obviously and absolutely vital, and it is also essential to have firm rules about the holding, or not, of connections. Some dwell-times of secondary services may be extended, but the disadvantages appear to be outweighed by the (perhaps psychologically important) benefits of locking these routes into the wider network.

In building a *Taktfahrplan* the ideal is that major interchanges shall be ‘located’ at the zero-minute and all significant interchanges at the hour, quarter, half or three-quarter positions. Some will fall serendipitously in the right place, some can be adjusted, and some may present intractable difficulties. The challenge is to get the balance right between the ideal, the achievable, the cost, the benefits and the impossible (for now). And it does need to be right because the cost of misjudgment may be high.

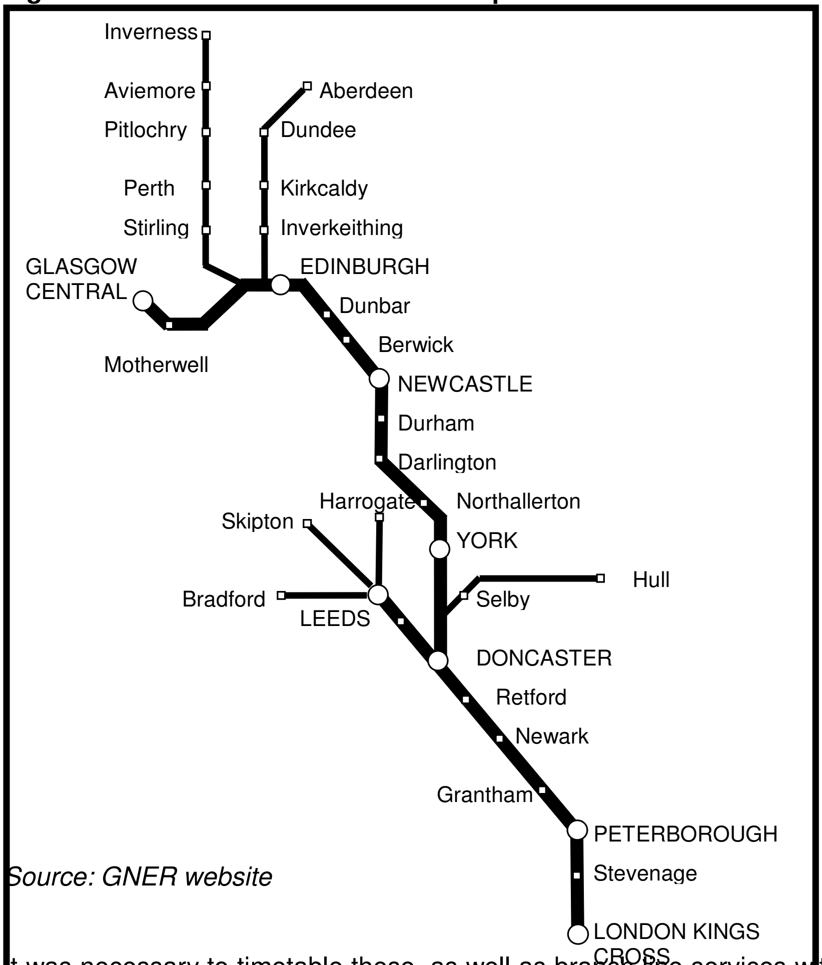
2.1.4 The East Coast Main Line, its current services and the case-study

The East Coast Main Line [ECML] is the principal rail artery on the east side of Britain, running from Edinburgh, through Newcastle upon Tyne, York and Peterborough, to London. Its electrification was completed in 1991. A line from Leeds, also electrified, joins the route at Doncaster, and the services between Edinburgh and London and Leeds and London form the core of the timetable on the route. Some of these are extended to serve Aberdeen, Inverness and Glasgow in Scotland, and Hull, Harrogate, Skipton and Bradford in Yorkshire.

North of York the route also serves as the northern end of two corridors connecting major provincial cities: across the Pennines to link with Manchester and Liverpool, and southwest toward Sheffield, Birmingham and Bristol. Apart from a limited number of through London trains and some cross-country trains via Birmingham, none of the extensive network of Scottish services runs beyond Edinburgh. In North East England regional and local routes serve Tyneside (Newcastle), Wearside (Sunderland) and Teesside (Middlesbrough), and a similar network serves East, West and South Yorkshire. Peterborough is an important junction with services to/from East Anglia, and south of Peterborough the line also carries outer- and inner-suburban traffic.

The route is illustrated in figure 1 below

Figure 1: East Coast Mainline Route Map



Source: GNER website

It was necessary to timetable these, as well as branch line services within the area. The focus of the original work was on long distance inter-city services, so London suburban services and those south of Doncaster were not considered in detail.

At the time of the study, services were operated by:

- Great North Eastern Railway [GNER] – all trains to and from London;
- Virgin CrossCountry [VXC] – all the through trains on the Birmingham route;
- Arriva Trains Northern [ATN] – all other services in the North East and Yorkshire;
- West Anglia Great Northern [WAGN] – the suburban services in the London area.

The rest of this Paper will not however refer to services by operator. It is essential to plan the best possible timetable first and to decide the best means of delivering it, as a secondary matter.

Appendix 1 provides a detailed discussion of the specific implementation of *Taktfahrplan* on the East Coast Main Line. It is not a definitive plan. It expresses judgments based on the evidence available at the time of the work, both from ticket sales[iv] and from an analysis of catchment areas to identify the potential importance of different nodes (described in more detail in Tyler, (2003b)) and on an understanding of then-current thinking in the industry. The work assumes some slight adjustments to the existing infrastructure and some redistribution of the rolling-stock fleet but otherwise reflects the broad outline of the 1999/2000 timetable that acted as the comparator for the evaluation. Thus we do not believe that the costs will be significantly different from those under the existing timetable.

The timetable encapsulating the objectives and aspirations was designed with the aid of the Swiss *Viriato* software that was conceived and developed for this type of strategic overview. Its essential components are a database describing the infrastructure, a file containing the running details of each path (including traction, and tracks used) and displays of the timetable both as conventional time x distance graphs for sections of route and in ‘netgraphs’. Two of these for the ECML *Taktfahrplan* form Appendix 2. This form of presentation is the distinctive feature of an absolutely-regular, truly mirror-image timetable, since those characteristics make it possible to display the essentials of the offer over an entire network in this elegantly simple manner. The rules for reading a netgraph are (a) that the times shown adjacent to the line for each service are on the same side as the running-line convention for the country and (b) that arrival times are adjacent to the station-box and departure times are set further from it.

It was agreed in establishing the Project that real railway data would be used. Railtrack therefore provided a copy of the Rules of the Plan, which sets out the practical arrangements for operating the railway safely and robustly, and a database of sectional running times, which lists the standard times to be applied between any pair of timing points for each direction and all relevant types of train. Information on track layouts is available in the ‘Quail’ maps that are privately published but with the assistance of Railtrack, now Network Rail. Every effort was made to apply this data rigorously. In a few cases where errors are apparent it was supplemented by personal observations of train performance[v].

On most of the British network the extra time needed in the event of temporary speed restrictions caused by engineering work is provided by inserting a stipulated number of minutes into the standard schedule over certain key sections. This usually has the effect of unbalancing intermediate times in a mirror-image scheme and is thus undesirable in a *Taktfahrplan*.

Three other allowances appear at specific locations in Working Timetables: “extra time for pathing requirements”, a “performance allowance”, and adjustments from working to advertised times. The first is almost always the result of paths simply not being compatible and should not be necessary in a clean-sheet, regularised timetable. The second has been introduced as a means of enhancing the performance statistics, and the third has become more generous for the same reason. Vastly better reliability is a *sine qua non* of *Taktfahrplan*, and its simplicity may aid the achievement of this end

It is impossible to operate a railway with precise accuracy for every train every day. Slight variations in the behaviour of apparently identical trains and in driving technique, minor equipment failures, weather and other environmental factors, fluctuating numbers of passengers, small incidents at stations, and the consequential interactions where paths conflict, all mean that minor perturbations are inevitable. It is therefore desirable and proper to allow for this in timetable planning, at some level that distinguishes between the everyday variation and the more random, larger disruptions which cannot be predicted.

We decided to replace the allowance system with a percentage addition to all SRTs – typically 4-5% – and slightly longer dwells[vi]. It should have the effect of promoting more reliable timekeeping when minor delays are fairly evenly distributed along a train's path.

On the basis of our research it was concluded that the long-term aim should be to establish the following categories of service:

- Long-distance inter-urban – fast and normally calling only at principal stations;
- Regional inter-urban – not as fast as the long-distance trains but brisk over shorter inter-station distances and not calling at minor stations, probably differentiated between routes connecting major cities and the generality of routes;
- Outer-suburban – the longer routes providing fast links between local centres and London and in some provincial territories;
- Suburban – stopping trains entirely within a conurbation; and
- Local and rural – branches, and the social lines in sparsely-populated areas.

Compromises would nevertheless be likely in certain circumstances. In practice the key services were:

- Hourly Edinburgh – London;
- Hourly Newcastle – London (combining with the above to give a half hourly service between principal stations);
- Hourly Edinburgh – Birmingham;
- Half hourly Leeds – London, alternatively fast and stopping;
- Hourly Doncaster – London stopping service, giving a half hourly service to and from intermediate points;
- A regional Edinburgh – Newcastle service serving intermediate points.

There would also be one additional morning peak service to London, and an evening peak service from London.

Other services are broadly as now but regularised. A full discussion, including rationale is given in Appendix A.

In paper-and-pencil days planning the utilisation of resources was typically undertaken after the timetabling was complete. With the advent of computer-based methods two schools of thought have emerged, one being to apply optimisation algorithms to pre-specified timetables and the other to bring the two tasks together so that the one influences the other from the outset. The bus industry has tended to pursue the first course in respect both of vehicles and staff, the railways – and this exercise – the second.

A *Taktfahrplan* makes combined analysis easier because of its repetitive scheme through the day, but its rules normally take precedence over the minimisation of resources. This can lead to a requirement for additional resources. It has been found in this case-study that a good pattern may deliver no significant extra call on resources compared with an irregular timetable (only train-sets were actually planned, but the point can be assumed to be similar for staff). Some will have brisk turnrounds, some will be longer than ideal, and some may justifiably be manipulated to work well.

2.2 Forecasting with the model

In order to carry out an evaluation of the benefits of Taktfahrplan on the ECML we needed to generate forecasts of the changes in demand and revenues for Origin Destination (OD) pairs on a selected part of the network.

To forecast demand changes following the new timetable, we used a cross section demand model (Lythgoe and Wardman, 2004) referred to here as the Lythgoe model, capable of modelling access, station choice and timetable characteristics. This was adapted to incorporate the results of a stated preference exercise (Wardman et al, 2003) which estimated small, but statistically significant, values for all these characteristics.

The model is calibrated and generates predicted volumes for flows based on the following data:

- Origin destination pairs specifying the flows for which forecasted volumes will be generated;
- A set of GJTs, 1 for each OD pair;
- A set of TAKT indices, quantifying the characteristics of the timetable for each OD pair;
- Average fares for each origin destination pair;
- Access times and distances from origin zones to origin stations.

Because the model is based on station choice, the above data is also required for each of the competing origin station to destination pairs.

For each flow, both as now and post-*Taktfahrplan*, we measured the characteristics of the timetable, or TAKT indices, which included the following:

<u>*Clockfaceness*</u>
This measures the degree to which trains run at the same minutes past each hour. Clockfaceness was quantified using indices based on the average number of departures/arrivals per hour as a proportion of the total number of actual different departure/arrival times throughout the day[vii].

There were two variants of this measure to allow for a degree of flexibility over the definition of perfectly clockfaced, with index A being a pure measure and index B allowing for one extra peak service.

<u>*Even intervalness.*</u>
This measures the degree to which intervals between trains are even. A single index measured the total number of different intervals between departure times as a proportion of the total number of departures over the operating day[viii].

<u>*Round numberedness (memorability).*</u>
This measures the degree to which trains depart at 'memorable' times past the hour. These measures were based on the total number of 'memorable' departures as a proportion of the total number of departures. Three of these indices were included, capturing different interpretations of 'memorability', based on round 5 minute, 15 minute and 30 minute departure times[ix].

This measure does not form part of the philosophy behind the *Taktfahrplan*, which may in fact lead to less round numberedness. However, as the stated preference exercise (Wardman et al, 2003) attributed values to these measures, it was decided to keep them in as a potential explanatory variable.

Forecasts are generated by applying the changes to variables including generalised journey times (GJTs) and TAKT indices arising from the *Taktfahrplan* to the calibrated parameters in the model.

2.3 Calibration of the model

The Lythgoe model is calibrated on the top 10% of flows on the British rail network. This cut-off point yields 12,253 flows based on 438 stations.

In order to incorporate TAKT indices for the existing timetable into the Lythgoe model, we needed the complete set of opportunities to travel (OTTs) for the existing timetable. AEAT provided data on OTTs between 178,727 OD pairs based on 538 stations. The common set of stations between the Lythgoe data and the AEAT data was 358, so these were the basis of the final calibration. The OTTs were converted to TAKT indices using some bespoke software, known as *AutoTAKT*[x].

In total, eight TAKT measures, and combinations thereof, were tested as to their significance in the Lythgoe model.

1. Departure clockfaceness: INDEX-A[xi]
2. Departure clockfaceness: INDEX-B[xii]
3. Departure and Arrival clockfaceness INDEX-A
4. Arrival: INDEX-A
5. Even interval measure
6. 0,5,10 round numbered ness
7. 15,30,45,00 round numberedness
8. 30,00 round numberedness

After various sensitivity tests, it was found that continuous versions (ie not simply 0/1 dummies based on a threshold level), of the 0, 5, 10 round numberedness and departure clockfaceness index A were the most significant determinants of demand, so were included in the variables for the calibration of the model. These two indices could also be used in conjunction with results from the stated preference study (Wardman et al, 2003) which gave values to clockfaceness and memorability in terms of minutes, which could then be included in the calculation of generalised cost.

2.4 Forecasting for the East Coast Main Line Case Study

In our East Coast Main Line case study, the introduction of the *Taktfahrplan* produces a new timetable which generates changes in GJTs (whilst maintaining broadly the current service level) and TAKT indices. The new values of GJTs and TAKT associated with the new timetable are then used to generate forecasts of predicted demand between each of the significant OD pairs on the ECML network. The base and predicted forecasts generated form the basis of the subsequent evaluation exercise.

The 31 stations for which forecasts were prepared are shown in Table 1. Forecasts were prepared for each possible combination of origins and destinations from this set of stations which were large enough to form part of the Lythgoe dataset. This resulted in 46 London based and 314 non-London based flows.

Table 1: Stations Used in the Flow Estimation

Station Name	Station Name
Berwick- upon-Tweed	MetroCentre
Beverley	Middlesbrough
Bishop Auckland	Morpeth
Bridlington	Newark
Carlisle	Newcastle
Chester-le-Street	Northallerton
Darlington	Peterborough
Doncaster	Redcar
Durham	Retford
Edinburgh Waverley	Scarborough
Grantham	Selby
Hartlepool	Stevenage
Hexham	Sunderland
Hull	Wakefield Westgate
Leeds	York
London Kings Cross	

2.5 Appraisal

The appraisal framework that has been developed is largely based upon the SRA's Appraisal Framework (SRA, 2003). We have concentrated on quantification of the three elements of revenue, user benefits and non-user benefits (from changes in external costs of competing modes).

All the factors used for the calculation of external costs for road and rail have been taken directly from a report carried out by ITS for the DETR which examined surface transport costs and charges for Great Britain for 1998 (Sansom et al, 2001). For long distance flows from London to Edinburgh and Newcastle we have considered competition from air as these have their own airports and are of a long enough distance for consideration of air as an alternative mode. Air external costs were more difficult to implement, but values were derived from the UNITE study (Bickel et al (2003) and Doll et al (2003)) which provides a comprehensive set of marginal cost estimates for different transport contexts across Europe.

2.5.1 External costs

Given that rail train kilometres are more or less constant, the sole change in external cost is related to changes in road traffic and air, where appropriate. In order to estimate the impact on the road system, we first need to forecast the extent to which changes in rail patronage will lead to changes in numbers of vehicles on the road system. The change in rail passenger trips can be used to calculate the modal shift between rail, car, coach, air and not travel or new journeys. An integral part of these calculations are the application of diversion factors shown in table 2 to the change in passenger trips. These factors show the proportion of any change in rail demand that is diverted to or from the mode in question.

Table 2: Diversion Factors & Sources of New Rail Journeys

Diversion factors	No air competition	Air competition
Car	68%	59%
Coach	24%	20%
Air	-	6%
Generated	8%	14%

Source:Train Operating Company Figures (1998), and Demand for Public Transport (2004), based on 2000 data.

To calculate the modal shift in terms of car and coach vehicle kms requires the average loadings of car, coach and air vehicles to be taken into account, alongside the length of the trips made by both modes. In the case of car a loading factor of 1.6 has been used and in the case of coach a loading factor of 12.1 has been used (both loading factors are taken from TEN, DfT, 2003). For air we have assumed an occupancy of 130 per plane, as used in the UNITE case studies. These assumptions ~~is~~ allow~~s~~ the change in the number of car, ~~and~~ coach and air journeys to be calculated.

To estimate the total number of car, coach and air vehicle kms that have been switched the total distance of the trip needs to be calculated. For our appraisal this process has been taken a step further for road and the total distance has been disaggregated into two road types:

- Motorways;
- Trunk and Principal Roads

For each flow, distances were calculated for each of the road types outlined above, which were calculated using the Automobile Association (AA) route finder software located on the AA's website (www.theaa.co.uk). These figures are factored by the number of journeys for each mode to calculate the total modal switch in terms of vehicle kms. This information can be taken forward and used to calculate the external cost changes on other modes.

In order to estimate changes in external costs resulting from ~~these~~ changes in road traffic, all flows were examined in detail to identify the types of road from which traffic would be diverted and the external costs for these road types from Sansom et al (2001) applied. This involved calculating a non-use value per passenger km based upon the road types. This figure has then been used to calculate the non-user impacts and added to the change in user benefits (change in rail consumer surplus) and the change in financial impacts (change in rail revenue) to complete the appraisal. The values ~~used are~~ shown in Table 3~~; they are in~~have been uplifted from 1998 to 2004 prices using the retail price index~~, whereas in the final appraisal they have been uplifted to 2004 prices using the retail price index.~~. We have not allowed for the fact that the benefits of reduced congestion will be over-estimated because of subsequent generation of additional road traffic. For air, valuations were taken from a UNITE case study (Bickel et al, 2003) of a flight from Berlin to London, providing values per flight, which we have converted into an amount per km.

Table 3: Values of Environmental Factors per vkm (£s in ~~1998~~ 2004 Prices and Values)

	Coach		Car		Air
	Motorway	Trunk and principal	Motorway	Trunk and principal	
Noise	0.0001	0.0023	0.0000	0.0002	0.064
Air Quality (LAQ):					
Average	0.0087	0.0447	0.0013		0.090
From London				0.0034	
To London				0.0023	
Regional				0.0034	
Greenhouse Gases	0.0048	0.0069	0.0015	0.0011	0.274
Safety	0.0137	0.0046	0.0001	0.0195	

The values for car and coach presented in Table 3 are the combined values which are used in the appraisal. In most cases the values for the peak and off-peak and by region were the same. When this is not the case we have had to calculate three values to reflect the peak and off-peak splits of train journeys that are coming from London, are going to London or that are regional in nature.

The change in rail passenger trips is shown in the results tables, and in most circumstances we would expect an increase in rail passengers to bring about a positive appraisal value (and vice versa) since the costs of externalities will decrease due to modal switch and train revenue will increase. However the reverse is possible if the increase is due to the worsening of the service from a competing station, and vice versa in the case of a reduced flow. When interpreting the impacts it should be remembered that benefits are represented as positive and costs as negative.

2.5.2 User Benefits

For rail the change in user benefits is the change in the consumer surplus. The model outlined in section 2.2 calculates the change in generalised cost and this has been subjected to the rule of a half to obtain the change in user benefits for rail users.

For car, coach and air travellers the change in user benefits is the change in congestion costs incurred and the change in the Mohring effect. The costs of congestion and Mohring benefits for coach and car are taken from Sansom et al (2001) and are outlined in Table 4. In most cases the values for the peak and off-peak are the same. When this is not the case we have had to calculate three values to reflect the peak and off-peak splits of different types of flows, as with the environmental factors.

Table 4: Disaggregated Values of Congestion and Mohring Effect per vkm (£s in ~~1998~~ 2005 Prices and Values)

Impact Type –	Coach		Car		Air
	Rural Motorways	Trunk & Principal	Rural Motorways	Trunk & Principal	
Congestion:					
Average					1.3187
From London	0.0718	0.2386	0.0046	0.1595	
To London	0.0710	0.2203	0.0046	0.1469	
Regional	0.0716	0.2352	0.0046	0.1572	
Mohring Effect	0.147				-0.1593

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The Air Mohring values were based on the evaluation of changes in travel times and schedule adjustment times, resulting from variations observed in European airlines' schedules between 1990 and 1998 based on a sample of 469 intra-European routes connecting the main European airports undertaken as part of the UNITE study (Doll et al 2003). Per vehicle km figures were derived by taking per passenger values for a medium density route of 525km and the loading of 130.

Air congestion values were based on flight delays at Madrid airport, using data on programmed and actual arrival/departure times for passenger flights. Again per passenger values were multiplied by an assumed load of 130

2.5.3 Private Transport Providers

We have estimated that train kilometres and the number of train sets required have not changed significantly following the introduction of the new rail timetable. Rail costs are therefore assumed to have remained constant Coach operating costs on the other hand are assumed to change by the factor of £0.738 per vehicle km (Sansom et al, 2001).

In terms of rail revenue change, the Lythgoe model predicts the change in rail revenue following the introduction of the new timetable. In order to calculate the average revenue for coach operators we took two samples comprising the largest ten London and non-London flows and calculated the average fare per km from the National Express website (www.nationalexpress.com). Using this information we conducted a regression for each route type to relate average fare per km with distance. The resulting coefficients were then applied to all London and non-London based flows. The fares used are outlined in Table 5.

Table 5: National Express Standard Fares (£s – 2003)

Journey	Standard Return Fare	Journey	Standard Return Fare
Non-London Routes		*London Routes*	
York-Edinburgh	29.50	Doncaster-London	22.50
Hull-Leeds	8.00	Darlington-London	33.50
Scarborough-York	8.50	London-York	29.50
Doncaster-Leeds	8.00	Edinburgh-London	36.00
Edinburgh-Newcastle	22.00	York-London	29.50
Darlington-Newcastle	7.00	London-Newcastle	33.50
Newcastle-York	17.50	London-Leeds	22.50
Newcastle-Edinburgh	22.00	London-Edinburgh	36.00
Leeds-York	7.00	Newcastle-London	33.50
York-Leeds	7.00	Leeds-London	22.50

Profits for the Air industry were taken from the accounts of a major British airline company, and converted into an average profit figure per plane kilometre using the figures on total passenger kilometres and an assumed loading factor of 130. This was computed to be £0.65 per plane km.

2.5.4 Government Impacts

The impact of indirect tax directly affects government revenues. Where expenditure is diverted to rail, in general there is a loss of tax revenue from fuel duty and Vehicle Excise Duty (VED). For expenditure diverted from car or generated from other non-transport sources, there is a loss of Value Added Tax (VAT) as coach, rail and air fares are tax exempt. However, where the expenditure is diverted from coach and air fares, there is no loss of VAT since these are, like rail fares, exempt. Values per average UK vehicle kms have been taken from Sansom et al (2001) and are presented in Table 6.

Table 6: UK Average Values for Indirect Taxes Per Vehicle Kms (£s-1998)

Mode	VED	Fuel Duty	VAT on Fuel Duty
Car	0.0103	0.0386	0.0068
Coach	0.0061	0.0526	0.0092

During the lifetime of the current franchises subsidy will not be affected, although ultimately any increase in rail revenue may reduce the level of subsidy at the next refranchising, passing the benefit on to the taxpayer.

Air passenger duty is levied at £5 per passenger for European flights, but operators do not pay fuel duty.

3. Results

In this section the results of the appraisals are outlined. For illustrative purposes, we report the results individually for the largest 10 London and non-London flows, and then aggregated over all 46 London and 314 non-London flows. We have only included air competition for flows between London and Edinburgh and Newcastle.

3.1 Appraisal Values

We can see from tables 7 and 8 that in terms of the change in rail passenger trips the move towards a Taktfahrplan timetable appears to be very beneficial for the largest non-London flows (9 of the 10 largest flows experience an increase in passenger trips). There is an overall increase in demand of 23% for non-London flows. This may reflect the greater variability of the existing timetables for the non-London flows. The results appear less beneficial for the ten largest London flows (6 of the 10 routes experience a reduction in passenger trips). In particular the long distance London based flows seem to be particularly adversely affected (Edinburgh and Newcastle) compared to those under 200 miles (Leeds, Doncaster and Peterborough). This is because on average, trains on these very long distance routes have more stops than in the current timetable. There is an overall increase in demand of 4% for non-London flows.

Over all the flows, the introduction of a *Taktfahrplan* timetable has resulted in an increase in passenger flows in 76% of London and 77% of non-London routes. There is a positive welfare outcome for 85% of the London flows and 82% of the non-London flows. The reason for the higher incidence of positive welfare impacts is that in a number of cases the reductions in generalised cost off-set a reduction in passenger numbers. The paradox of falling generalised costs and falling passenger numbers reflects the service competition aspect of the demand model, in that passengers will choose to switch to other services if those services offer a larger reduction in generalised cost than the service they currently use.

We also found that flows that did suffer from negative welfare impacts were, on average, over longer distances than those with a positive impact, emphasising the point made for the largest London based flows, that long-distance services may become slower with more stops.

The final column of tables 7 and 8 show that the introduction of a *Taktfahrplan* timetable would result in overall benefits of £6.5 million per annum for London services and £16.2 million pounds for non-London based services. In each case positive changes were found for user benefits, revenue and non-user benefits. The increase in revenue was 6% and 17% of current base revenue for London and non-London flows respectively.

Table 7 Appraisal Results for Non-London Flows (Annual figures)

Top 10 Non-London Flows	York Edinburgh	Hull Leeds	Scarbrgh York	Doncster Leeds	Edinbrgh Newcstle	Darlngton Newcastle	Newcstle York	Newcstle Edinbrgh	Leeds York	York Leeds	**ALL FLOWS**
Change in Rail Trips	-1,870	17,221	12,440	21,724	12,432	23,953	16,501	20,221	70,518	76,992	**845,687**
Percentage change	-3	25	16	24	13	23	12	14	39	29	**23**
The Environment											
Noise	-76	50	108	59	276	59	212	449	389	425	**9,927**
LAQ	-1,219	1,655	1,737	1,365	4,446	1,556	3,924	7,232	6,317	6,897	**171,076**
Green house	-432	1,184	616	783	1,575	984	1,751	2,562	2,272	2,480	**68,521**
Safety	-4,738	3,381	6,756	3,778	17,288	3,841	13,415	28,120	24,393	26,633	**624,788**
Modal shift & economy											
Rail - change in GC	114,772	167,534	69,942	183,875	148,633	194,933	189,869	345,949	321,377	388,929	**9,097,335**
Car Congestion	-38,183	26,427	54,443	30,036	139,315	30,360	107,609	226,604	196,529	214,572	**5,024,050**
Coach Congestion	-2,726	3,521	3,887	2,963	9,945	3,350	8,668	16,177	14,121	15,418	**380,279**
Coach Mohring	2,123	-4,520	-3,027	-3,198	-7,745	-3,896	-7,824	-12,598	-11,097	-12,116	**-319,695**
Air Congestion	0	0	0	0	0	0	0	0	0	0	**0**
Air Mohring	0	0	0	0	0	0	0	0	0	0	**0**
Transport operators											
Rail Profits	-23,212	54,988	28,736	37,759	98,488	46,924	72,158	144,787	135,947	145,133	**3,548,372**
Coach Profits	-3,111	2,012	574	392	5,675	677	5,181	9,231	763	833	**242,487**
Air Profits											
Government											
Car Tax	13,629	-38,315	-19,433	-25,195	-49,728	-31,748	-55,849	-80,885	-71,770	-78,359	**-2,175,596**
Coach Tax	779	-2,189	-1,110	-1,440	-2,842	-1,814	-3,191	-4,622	-4,101	-4,478	**-124,321**
VAT	2,893	-5,157	-2,685	-3,508	-11,975	-4,337	-6,511	-16,781	-14,899	-15,690	**-389,799**
Air Tax											
Overall Total £s	**60,499**	**210,571**	**140,542**	**227,669**	**353,351**	**240,889**	**329,412**	**666,224**	**600,242**	**690,677**	**16,157,424**

Table 8 Appraisal Results for London Flows (Annual figures) [1]

Top 10 London Flows	Doncaster London	Darlngton London	London York	Edinbrgh London	York London	London Newcstle	London Leeds	London Edinbrgh	Newcstle London	Leeds London	**ALL FLOWS**
Change in Rail Trips	34,794	11,067	-3,592	-29,874	-5,370	-13,923	55,319	-49,096	-4,456	72,463	**204,570**
Percentage change	17	6	-1	-10	-2	-4	14	-11	-1	14	**4**
The Environment											
Noise	126	406	-112	-750	-167	-633	169	-1,233	-202	222	**-119**
LAQ	7,996	7,380	-2,015	-16,008	-3,012	-9,277	13,888	-26,308	-2,969	18,193	**33,499**
Green house	7,067	3,214	-867	-14,287	-1,297	-4,562	12,835	-23,480	-1,460	16,813	**19,016**
Safety	9,458	25,632	-7,049	-24,556	-10,540	-32,312	13,565	-40,355	-10,341	17,769	**73,368**
Modal shift & economy											
Rail - change in GC	551,767	266,219	-81,420	-769,844	278,115	-381,178	1,357,368	-1,600,782	179,293	1,345,585	**3,959,814**
Car Congestion	66,936	192,867	-57,303	-179,782	-85,679	-262,974	99,297	-315,884	-77,923	123,201	**535,744**
Coach Congestion	16,247	15,393	-4,512	-30,225	-6,746	-19,632	28,773	-51,387	-5,857	36,878	**76,947**
Coach Mohring	-25,526	-14,499	3,931	44,138	5,877	17,239	-45,873	72,538	5,517	-60,090	**-100,548**
Air Congestion	0	0	0	-8,202	0	-2,612	0	-13,480	-836	0	**-25,131**
Air Mohring	0	0	0	991	0	316	0	1,628	101	0	**3,036**
Transport operators											
Rail Profits	530,410	184,891	-60,939	-452,405	-94,782	-242,853	1,022,542	-780,754	-71,005	1,244,293	**3,226,451**
Coach Profits	46,980	30,363	-6,693	-186,089	-10,007	-32,099	99,123	-305,824	-10,273	129,844	**-82,200**
Air Profits	0	0	0	4,047	0	1,289	0	6,651	412	0	**10,807**
Government											
Car Tax	-229,768	-102,420	27,627	411,617	41,308	129,335	-417,674	676,464	41,392	-547,121	**-773,744**
Coach Tax	-13,130	-5,853	1,579	22,148	2,360	6,959	-23,867	36,399	2,227	-31,264	**-48,414**
VAT	-72,148	-24,789	8,361	62,994	13,143	32,801	-143,765	110,046	9,322	-171,668	**-443,696**
Air Tax	0	0	0	10,283	0	4,792	0	16,899	1,534	0	**29,205**
Overall Total £s	**867,958**	**548,458**	**-169,513**	**-1,108,585**	**122,001**	**-755,077**	**1,945,414**	**-2,187,781**	**54,456**	**2,058,201**	**6,494,035**

[1] Because of the lack of UK specific data on Air traffic external cost valuations, and on the effect of air competition on long distance rail, we also re-computed the results for the London flows without Air competition. We found this made very little difference to the overall evaluation, giving a value of £6,352,204 compared to £6,255,174 when Air competition was included.

3.2 Demand Effects Without TAKT Effects

In order to see what the effect on rail demand would be, simply from generalised journey time changes, following the introduction of a *Taktfahrplan*, the demand model was re-run but with the TAKT indices set to zero (ie no value was placed on attributes such as even intervalness etc.). In Table 9 the demand and revenue for the 'with TAKT' and 'no TAKT' models are presented for the largest ten London and non-London flows, along with totals for each route type. It can be seen that with the TAKT indices set to zero the changes in demand and revenues are reduced vis a vis when the indices are not set to 0. The change in demand for non-London services falls by 24% whilst revenues are reduced by 23% suggesting most of the increase is attributable to changes in GJTs. For London services the equivalent falls are considerably larger at 48% for both demand and revenue. However, overall the introduction of the *Taktfahrplan* still results in positive revenue and passenger growth for both London and non-London flows.

Table 9: London and Non-London Flows With and Without TAKT Values

Non-London Services	'With TAKT Values' A Change In		'Without TAKT Values' A Change In		Difference With TAKT–Without TAKT	
	Demand	Revenue	Demand	Revenue	Demand	Revenue
York-Edinburgh	-1,870	-21,961	-3,423	-40,208	1,553	18,247
Hull-Leeds	17,221	52,026	15,585	47,082	1,636	4,944
Scarborough-York	12,440	27,188	6,270	13,703	6,170	13,485
Doncaster-Leeds	21,724	35,725	30,223	49,701	-8,499	-13,976
Edinburgh-Newcastle	12,432	93,183	10,292	77,142	2,140	16,041
Darlington-Newcastle	23,953	44,397	21,207	39,308	2,746	5,089
Newcastle-York	16,501	68,271	3,501	14,485	13,000	53,786
Newcastle-Edinburgh	20,221	136,989	7,240	49,050	12,981	87,939
Leeds-York	70,518	128,625	27,905	50,898	42,613	77,727
York-Leeds	76,992	137,315	34,421	61,391	42,571	75,924
Totals	845,687	3,357,246	641,367	2,637,316	204,320	719,930
London Services	Demand	Revenue	Demand	Revenue	Demand	Revenue
Darlington – York	34,794	501,840	22,553	325,277	12,241	176,563
Doncaster – York	11,067	174,932	4,756	75,183	6,311	99,749
London – York	-3,592	-57,657	-1,177	-18,889	-2,415	-38,768
Edinburgh – London	-29,874	-428,037	-31,735	-454,694	1,861	26,657
York- London	-5,370	-89,676	-17,241	-287,917	11,871	198,241
London-Newcastle	-13,923	-229,772	-11,565	-190,852	-2,358	-38,920
Edinburgh-London	55,319	967,465	45,730	799,766	9,589	167,699
London-Edinburgh	-49,096	-738,700	-50,685	-762,605	1,589	23,905
Newcastle-London	-4,456	-67,180	-24,103	-363,395	19,647	296,215
Leeds-London	72,463	1,177,272	60,147	977,171	12,316	200,101
Totals	204,570	3,052,665	107,005	1,591,794	97,565	1,460,871

4. Conclusions

This project has forecast the change in patronage for the 360 O/D pairs for which CAPRI data was available following the introduction of a *Taktfahrplan* timetable. We find that in the vast majority of cases the introduction of a *Taktfahrplan* timetable has resulted in an increase in passenger flows for 76% and 77% of London and non-London flows respectively. This is reflected in the aggregate appraisal results which finds a positive outcome for 85% of the London flows and 82% of the non-London flows.

Changes in revenue and user benefit for all flows were calculated directly from the model output. The appraisal results found that the introduction of a *Taktfahrplan* timetable would result in overall annual benefits of £16.2 million for non-London services and £6.5 million pounds for London based services. In each case positive changes were found for user benefits, revenue and non-user benefits, with an improvement of revenue of the order of £3m p.a. for each type of flow corresponding to an increase in the existing revenue of 6% and 17% respectively for London and non-London flows. Given that train frequencies are comparable to the present it was assumed that operating costs would be unchanged.

It would thus appear that the introduction of a *Taktfahrplan* timetable is very beneficial overall for both non-London and London based flows. For some long-distance flows the evidence would suggest that the benefits of a *Taktfahrplan* timetable will be outweighed by the increase in generalised costs if an increase in the number of stops leads to slower journeys. The major non-London based flows tend to be over shorter distances and have more variable timetables so more of these flows would appear to benefit from the operation of a *Taktfahrplan*.

Given the low market share that rail presently holds on non-London routes, our findings could have important implications for the relative priority of projects in the context of the Government's environmental and social objectives.

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Appendix 1: An outline of the Taktfahrplan for ECML.

A1.1 Long-distance services

The natural heart of the plan is the service between Edinburgh Waverley and London Kings Cross. It cannot hope to attract those for whom speed is paramount between Edinburgh and London, and it is difficult to match the allure of cheap flights. There is, though, a strong market for travellers wanting a reasonably fast facility with a quality of journey-experience rarely obtained by flying. Moreover, the route also serves important relations between major provincial centres and London where air competition is more limited. Many non-London flows are significant too.

The Edinburgh ↔ London trains should therefore stop sufficiently often to secure good frequencies and speeds to capture the intermediate business but not so often as to degrade the end-to-end journey. The two indubitable calls are at Newcastle upon Tyne and York. The next three were considered to be Darlington, Doncaster and Peterborough, all significant urban centres in their own right but also important junctions for connectional purposes, as described below. The reason for adding Berwick-upon-Tweed is given in a wider context below, and Durham was judged best served by alternating this direct service with a connection, described below. York was chosen to be the key 'zero-minute' node.

It was assumed that some trains would run through Edinburgh to serve other Scottish centres. Those for Aberdeen and Inverness involve non-electrified routes and must use diesel trains. Given the *Taktfahrplan* emphasis on consistency the choice of a diesel base for the timings almost made itself.

This all gave an end-to-end time of 4 hours 38 minutes, 6 minutes slower than the 1999 mean time, which was deemed satisfactory. The southbound and northbound trains are planned to call at York simultaneously at xx.58½ – xx.01½, or xx.59 – xx.01 in the public timetable. Departure from Edinburgh is at xx.26 and hence arrival at xx.34, not quite perfect but a good approximation. Intermediate (up/down) times are 08/52 at Berwick (to simplify the description a single mid dwell-time is quoted), 56/04 at Newcastle, 11/49 at Durham and 30/29 at Darlington.

South of York the running times are not so conducive to ideal patterns. The station times are 24½/35½ at Doncaster and 15/44½ at Peterborough. Since 15 minutes cannot be cut from the York ↔ Peterborough SRTs it is probably best to accept the connectional outcome at Doncaster and to leave Peterborough on the quarter-hour. Arrival in London is at xx.04 and departure at xx.56.

The two directions (up/down, south-/north-bound) have been described as an entity, because of the strict application of the mirror-image rule. The rest of the text has been further simplified by discussing only the one, specified direction- what applies in that direction, whether of timings or of connections, will work in the opposite case, give or take some minor variation.

Between Edinburgh and London the basic service will be hourly. As far down as York it shares the ECML with the cross-country route, which also has a strong case to operate hourly.

We have chosen to arrange the two paths as nearly as possible at even intervals. Whereas the London leaves Edinburgh at xx.26 and arrives at Newcastle at xx.54 the cross-country is timed at xx.57, arrive xx.22. Both timings depend on the decision about intermediate stations. The ECML passes through sparsely populated territory north of Newcastle upon Tyne. Even Berwick-upon-Tweed did not register strongly in an analysis of population and urban hierarchy, although plainly it serves as a railhead for a huge area. Dunbar and Alnmouth qualify as minor centres, large enough not to be ignored but too small to justify inclusion in the upper-tier network unless that is the only means of serving them.

Immediately north of Newcastle a sizeable population in the Morpeth / Ashington / Blyth area has been poorly served for many years. The chosen solution is to operate a 'regional' service between Edinburgh, Drem (for connections with North Berwick), Dunbar, Berwick, Alnmouth, Pegswood, Morpeth, Cramlington and Newcastle. By leaving Edinburgh after the London and preceding the cross-country into Newcastle it would secure for these intermediate towns extensive connections every hour – but with the loss of direct services.

For the purposes of this case-study the cross-country trains serve Edinburgh, Berwick, Newcastle, Darlington, York and Leeds. It is assumed that they will continue to Sheffield, Derby, Birmingham, Cheltenham, Bristol, Taunton, Exeter, Newton Abbot and Plymouth, and provisional timings suggest that the SRTs and this calling pattern will fit quite closely into the ideal *Taktfahrplan* scheme.

To complement the Edinburgh ↔ London service trains run hourly between Newcastle upon Tyne and London. These are timed to depart at xx.30, thereby affording a connection out of the Edinburgh → Plymouth (arrive xx.22) and thus a half-hourly pattern between Edinburgh and principal ECML stations, alternately through and by changing.

Services within Scotland were not included in this study, except in the sense that their probable future shape was borne in mind in planning operations at Edinburgh Waverley. Some consideration was given to the through workings. These present problems that could not be properly settled without further debate.

Edinburgh and Newcastle London bound trains represent one part of the ECML offer, the other, equally important, is the Leeds ↔ London service. This was increased to close to a day-long half-hourly frequency during the course of the study. A sharper differentiation than GNER apply between the alternating trains was adopted. One hourly service calls only at Wakefield and Peterborough and completes the journey in 129 minutes. The other calls also at Doncaster and Stevenage and provides the main London service for the three places between Doncaster and Peterborough, namely Retford, Newark and Grantham.

The main reasoning behind this arrangement was as follows:

- these three centres and their wider catchments are undoubtedly important enough to be served at least hourly by a fast train to/from London;
- the flows between any pair of these three plus Doncaster and Peterborough are not large but if they are to be cultivated, the timetable must be patterned (and preferably half-hourly; and
- the relations between the three and West Yorkshire are numerically more important than the relations with places north of Doncaster.

This was deemed to be a more coherent scheme than the erratic distribution of stops that now obtains. Leeds → London customers would be offered this timetable, with a choice of changing at Doncaster from the slow train for an earlier arrival in London:

Leeds	dep	00.33	00.49	00.49
Doncaster	arr		01.20½	(*01.20½*)
Doncaster	dep		01.26	(*01.30½*)
London KX	arr	02.42	03.04	03.27

It does not give Leeds a near-even half-hourly fast pattern for London trips (which it does not have now), but unless and until that can be justified the disposition of the slower train 16 minutes behind on departure and 15 minutes ahead into London seems a good compromise when taken with the Doncaster option.

The remaining question is 'the fifth path' on the ECML south of Doncaster. It did not appear that there is a need throughout the day for a third service between either Northern England or Leeds and London. Another contender is Hull and Lincolnshire.

A second 'stopping' path has been included in each hour, with calls at all stations from Doncaster to Peterborough, then non-stop to London. Departures from Doncaster are at xx.30 for the Leeds train and xx.08 for this service, but arrival in London is near-even in spacing (xx.27 / xx.59) because only the Leeds stops at Stevenage. The intermediate stations gain a more regular and more frequent pattern, as is desirable. It would probably make sense to run through from Hull every other hour (assuming good connections at the alternate hour and into the fast train at the other half-hours).[2]

[2] Other possibilities might be considered for this path. They include a Leeds ↔ Cambridge ↔ Stansted Airport; a through South Humberside ↔ Lincoln ↔ Newark ↔ London service alternating with the Hull working; and stopping the Doncaster train at Huntingdon, which is otherwise left only with an outer-suburban service.

Two other matters should be mentioned in conclusion. Regularisation excludes the acceleration of selected trains by omitting stops or running exceptionally fast under special pathing arrangements, but it may be possible to provide for *extra* trains. One such case, for which a path could possibly be found, is an up-morning / down-evening working calling at all the mainline stations between Edinburgh and Newcastle, plus York (the up timings appear in the netgraph in appendix 2). At the southern end of the ECML, where the long-distance trains share the route with a frequent and well-structured regional and local service, two acute operating problems arise, namely the conflicts at Cambridge Junction, Hitchin and the reduction from four to two tracks over Welwyn Viaduct. The draft plan has merely been checked for basic operability in the area. This led to the provisional decision to stop only one long-distance service at Stevenage. The netgraph in appendix 2 shows provisional timings for the Cambridge and outer-suburban services.

A 1.2 Services within Scotland

Reference has been made above to trunk services within Scotland and their arrangement vis-à-vis Anglo-Scottish services. Beyond that no detailed timetabling of Scottish routes in general was undertaken for the case-study. So far as the lines around Edinburgh are concerned it is expected that their frequencies will fit well with the principal ECML departures at xx.26 and xx.57. Two routes however did need full planning because they interact with ECML trains east of Waverley, namely the North Berwick service and the Newcraighall Park & Ride service.

A 1.3 Services in North East England

In North East England, Yorkshire and Humberside regional and local routes perform vital functions within the area as well as complementing the north ↔ south long-distance routes. The principal regional corridors in the North East are Carlisle … Newcastle via the Tyne Valley and Newcastle … Middlesbrough via the coastal route. It is convenient to serve these two by through trains in order to facilitate journeys across Newcastle. An hourly Carlisle ↔ Middlesbrough service was therefore timed, using 145 km/h Class 158 units; it calls at Haltwhistle, Hexham, MetroCentre, Newcastle, Heworth (for Metro interchange), Sunderland, Seaham, Hartlepool, Stockton-on-Tees, Billingham and Thornaby. This gives both corridors a quality core service. It is timed into Newcastle from the west at xx.21 to feed neatly into Plymouth and London trains.

Hexham justifies a second service to Newcastle each hour, MetroCentre needs frequent trains and the intermediate stations appear to be worth serving hourly[3]. A similar logic applies on the other side of Newcastle, at least as far as Hartlepool. These considerations lead to a Hexham ↔ Hartlepool local

[3] With the exceptions of Riding Mill and the barely-used inner-urban Blaydon and Dunston.

train being timed at the other half-hour at Newcastle (connecting with the Edinburgh ↔ London)[4].

In a proper attempt to keep public transport relevant for people travelling to the MetroCentre the station has always had a frequent service, at present every 15 minutes with some variations. This practice has been replicated but with exact patterns by supplementing the Carlisle and Hexham trains with a regularisation and extension of the Morpeth ↔ Newcastle service and a MetroCentre ↔ Newcastle shuttle.

The Tyneside ↔ Teesside service via the Coast is currently matched at some hours by trains running via the ECML and Darlington, most of which are extended beyond Middlesbrough to Saltburn. The benefit is sometimes lost because trains by the two routes are timed close together and also fail to offer useful connections at Darlington. It was decided that the ECML route should have a regular hourly service, carefully timed to alternate with the Coast trains. Respective departures from Newcastle are at xx.07 and xx.26, with arrivals in Middlesbrough at xx.10 and xx.39 (ie. running times are 63 min and 73 min). This scheme does several other things:

- it adds a third train to the Newcastle ↔ Durham timetable at reasonably even intervals;
- it feeds Durham passengers into the Plymouth and Newcastle → London trains at Darlington, thus enabling them to omit a Durham stop;
- it covers the need for a decent frequency of calls at Chester-le-Street, so ensuring its links with the national network;
- it forms one half of the Darlington ↔ Teesside service; and
- it provides a connection at Darlington from the northbound Edinburgh train for passengers between London, intermediate stations and Teesside.

Since this plan was drafted the SRA has expressed its intention to remove these trains in the course of its Route Utilisation Strategy and re-letting of the ECML and new Northern franchises. If this is the only means of securing adequate freight paths it may be unavoidable, but the evidence for that has not yet been published.

East of Middlesbrough there are two lines. One provides a local service for Redcar and Saltburn, the other is the Whitby branch. The former has sufficient traffic to justify two trains/hour on present assessments of social benefit, and running the ECML local through and alternating it with a

[4] This service is shown as being extended to Billingham, on the basis of using time otherwise spare in the diagram, and preferably it should run through to Middlesbrough, albeit at the cost of an extra unit. The drawback is that this is an area where *per-capita* demand seems to be exceptionally low (or very localised) and buses notably frequent.

Darlington ↔ Saltburn service has maintained that[5]. The timings are arranged to give good connections out of the Carlisle ↔ Middlesbrough regional and a trans-Pennine service (respectively).

The Whitby branch has not been timed, since on the evidence from demographic studies and ticket sales data its future must be in serious doubt.

Finally in the North East there is the equally problematic Bishop Auckland branch. This runs for 19 km to a junction with the ECML at Darlington. It is the last remnant of a once-extensive network in County Durham west of the main line, and it has suffered the characteristic spiral of decline as attempts to economise in the face of large losses and an arguable social case have led to poorer services and very few users.

In the absence of a full investigation we chose to indicate a short-term compromise, pending a clearer policy regarding such lines. This is a one-unit hourly shuttle that brings a higher frequency and regularity, although it cannot be a mirror-image service and hence offers timings that differ by direction for through journeys.

A 1.4 Trans-Pennine services

Trans-Pennine services are one of the success stories of British Rail's management of regional routes. On the central corridor between Leeds and Manchester via Huddersfield and Standedge Tunnel the frequency was built up to 4 trains/hour (though with some irregularities). In parallel with this the Bradford … Halifax … Burnley … Preston route, which had had few trains, moved in stages toward an hourly timetable. Although passenger numbers still fall well short of securing profitability they have grown considerably.

East of the Pennines the routes to be served are those from Newcastle upon Tyne, Middlesbrough, Scarborough and Hull. West of the Pennines the routes serve Preston, Liverpool via Manchester, and Manchester Airport. A further service runs between Sheffield and Manchester via the Hope Valley Line and Stockport, with many trains being extended along part or all of the Cleethorpes ↔ Airport or Norwich ↔ Liverpool axes[6]. The permutation of east and west places has varied from time to time, but in recent years the normal scheme has settled down to

- Newcastle ↔ York ↔ Leeds ↔ Manchester Piccadilly ↔ Liverpool
- Middlesbrough ↔ York ↔ Leeds ↔ Manchester Piccadilly ↔ Manchester Airport
- Scarborough ↔ York ↔ Leeds ↔ Bradford ↔ Preston ↔ Blackpool
- Hull ↔ Leeds ↔ Manchester Piccadilly ↔ Manchester Airport
- Leeds ↔ Manchester Piccadilly.

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[5] The plan assumes closure of the poorly-used stations of Dinsdale, Tees-side Airport and Allens West .

[6] This has not been included in the present exercise, although pairing the Hope Valley Liverpool trains west of Manchester half an hour apart from the trans-Pennine trains would effectively impose timings on routes across a swathe of country [see ¶2.2.17].

During the day there are some variations. Some of the supporting local services have also been included in the case-study and are described below. Although no deep analysis was undertaken this seems intuitively sound and accords with the messages from the demographic studies.

The chosen scheme therefore replicates the current general pattern while regularising its detail. It has only been timetabled fully east of the Pennines, but the framework is broadly consistent with arrangements on the west side, including provision for sensible turnrounds. The Newcastle ↔ Liverpool trains serve Durham, Darlington, York and Leeds. They start back from Sunderland but stand for 12 minutes at Newcastle: the purpose of this arrangement is to offer a good connection from Sunderland into the Plymouth and Newcastle → London trains.

The Middlesbrough ↔ Manchester Airport trains serve Thornaby, Yarm, Northallerton, Thirsk, York and Leeds. Yarm and Thirsk are small places but this is probably a case where a longer-distance service must cover their needs in the absence of any credible alternative. Timings at York allow a feed into the Edinburgh → London in order to secure a fast connection between Teesside and London. The connection via Darlington requires departure from Middlesbrough 10 minutes earlier, although it is necessarily via Darlington at the other half-hour.

The Scarborough ↔ Blackpool trains call at Seamer, Malton, York, Garforth and Leeds. They too have an extended dwell, at York. It uses what would otherwise be idle time at Scarborough, where instead the turnround is brief. The steps of the argument here were

1. departure for Leeds must be at xx.36 after a feed out of the Newcastle → London;
2. latest arrival at York must be at about xx.25, between the Plymouth and the Newcastle, which provides the connection toward London;
3. if the arrival is moved back to xx.17 there can also be a feed into the Plymouth;
4. the majority of passengers using the Scarborough trains join or leave at York; and
5. passengers for Leeds have the option of a change into the Plymouth train.

This type of situation is not unique to *Taktfahrplan*, but under that regime, unlike a context of different permutations for every train, the issues are made clearer because by definition the pattern will be applied across the day – though that makes the right choice very important.

Each of these pathing decisions was made primarily with respect to connections and conflicts on the ECML and its associated lines north of York. However, equally important considerations affect the schemes between York and Leeds and west of Leeds. The section between York and Leeds carries a substantial through traffic, but in addition York ↔ Leeds is the busiest inter-urban relation of its kind outside London. Unfortunately the need also to serve the intermediate stations introduces a restriction.

The local service consists of an hourly train from York to Leeds calling at Church Fenton (sometimes), Micklefield and three further stations to Leeds, and an hourly train from Selby to Leeds calling at South Milford, Micklefield (the junction) and the three others into Leeds. Between Micklefield and Leeds the timetable is regular for much of the day, and the trains are extended west of Leeds in an equally regular pattern as the all-stations service to Manchester Victoria via Bradford, Halifax, the Calder Valley and Rochdale. The problem is that faster trains from York cannot overtake before Leeds (except at Church Fenton, which is not a useful point to do it, and then only southbound). For the present there is a severe timing dilemma.

A *Voyager* unit is allowed 23 minutes between York and Leeds, a Class 158 on the Newcastle and Middlesbrough services 26 and the Scarborough, with the Garforth stop, 28 minutes. The local requires 40 minutes. This has the effect that there must be about a 24-minute gap between the pair of fasts either side of the stopper and hence about 12 minutes between the other pairs. This and the ECML pattern therefore together determined the following timetable:

		MDBR	local	X-country	HULL	SCRB	local	NCLT
York	arr	54		20		17	-	43
York	dep	57	02	23		36		49
Selby	dep				34		38	
Leeds	arr	23	42	46	56	04	12	15
Leeds	dep	31	(45)	01			19	
	dep		46	53		07	16	

It will be noticed that the Hull feeds into the local at Selby and then takes the place of the Scarborough on the Standedge route as the latter heads toward Blackpool via Bradford. Similarly, a Leeds → Manchester Piccadilly service starts up at xx.45 to take the place of the Plymouth train as it turns toward Wakefield (but does not connect out of it). This secures the 4 trains/h frequency between Leeds and Manchester, and by holding the Middlesbrough for 8 minutes departures from Leeds are at nearly-even intervals. The distribution is in fact so designed (provisionally) that, taking into account differing intermediate stops, arrivals in Piccadilly form an exact 15-minute sequence and hence eastbound departures do the same.

A 1.5 Other services in Yorkshire

One other service was prepared in detail, that between Scarborough and Hull. This route is typical of a number in Britain's railway network where it can be argued that a useful link between towns is not offering the service it could do because it is slowed down by calls at minor stations. The aim therefore, within the *Taktfahrplan* framework, was to propose a step-change in the offer on this route.

Three stations – Bempton, Arram and Hunmanby – are assumed closed due to light usage. Several others serve small communities, but no operating benefit other than acceleration would be obtained.

It is desirable (but rarely found in the present timetable) that passengers from the York direction should have a good connection at Seamer (the junction between the Scarborough … York and Scarborough … Hull lines, and also a useful station for the southern part of Scarborough) toward Filey and Bridlington *and* that passengers from the Leeds and Doncaster directions should be able to connect quickly at Hull for Beverley and beyond. This largely determined the paths, but it does require tight working for access to the single line between Seamer and Bridlington (the intermediate double section between Filey and Hunmanby is not used for crossing in this plan) and an extended dwell-time at Bridlington, which does not affect the majority of users but does offset the gain in end-to-end time from the station closures.

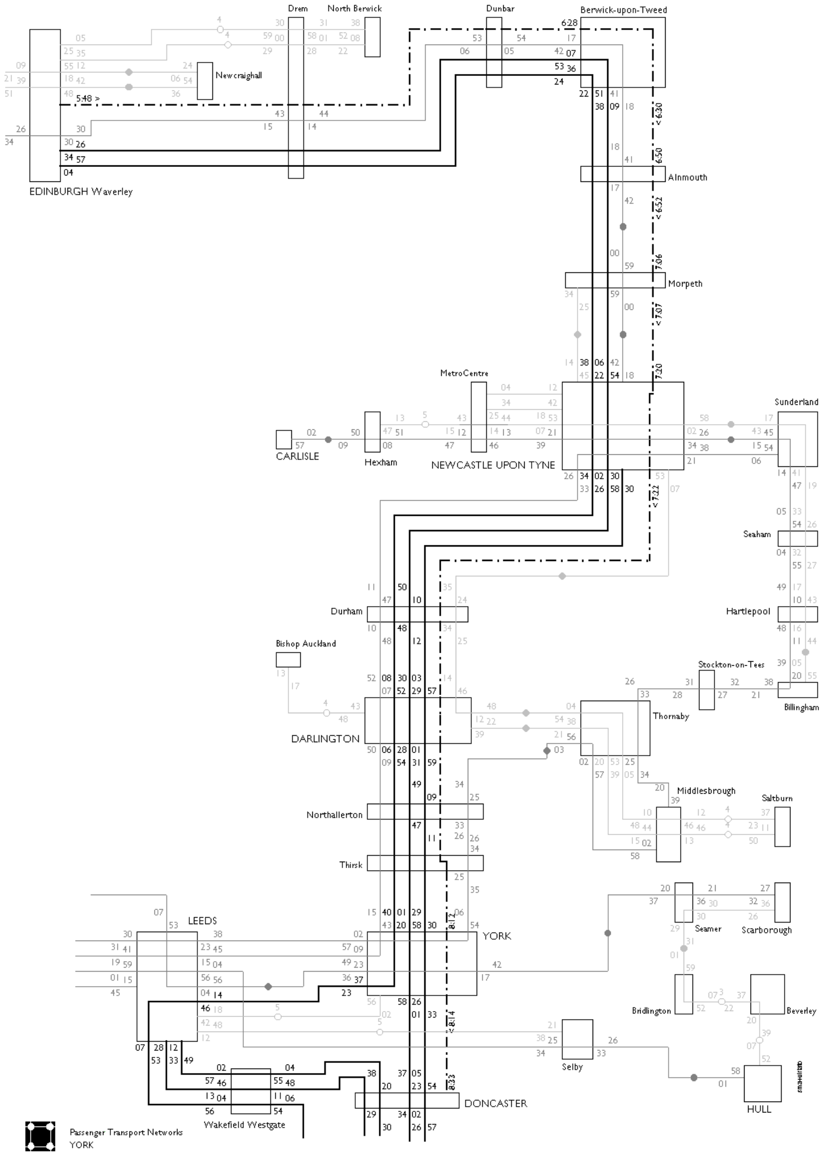
The present nine trains/day are replaced by an hourly service with good links with the wider network. The timings are such that units could be diagrammed to run Manchester Airport → Hull → Scarborough and return: this would obviate either an un-robust or an over-long turnround for the trans-Pennine service at Hull and afford the additional benefit of through services. A dwell-time of 9 minutes would cushion the local service against most perturbations. Finally, though not timed in detail, the Scarborough service will be complemented as now by a Beverley ↔ Hull shuttle at an even 30-minute interval to cater for a surprisingly strong flow.

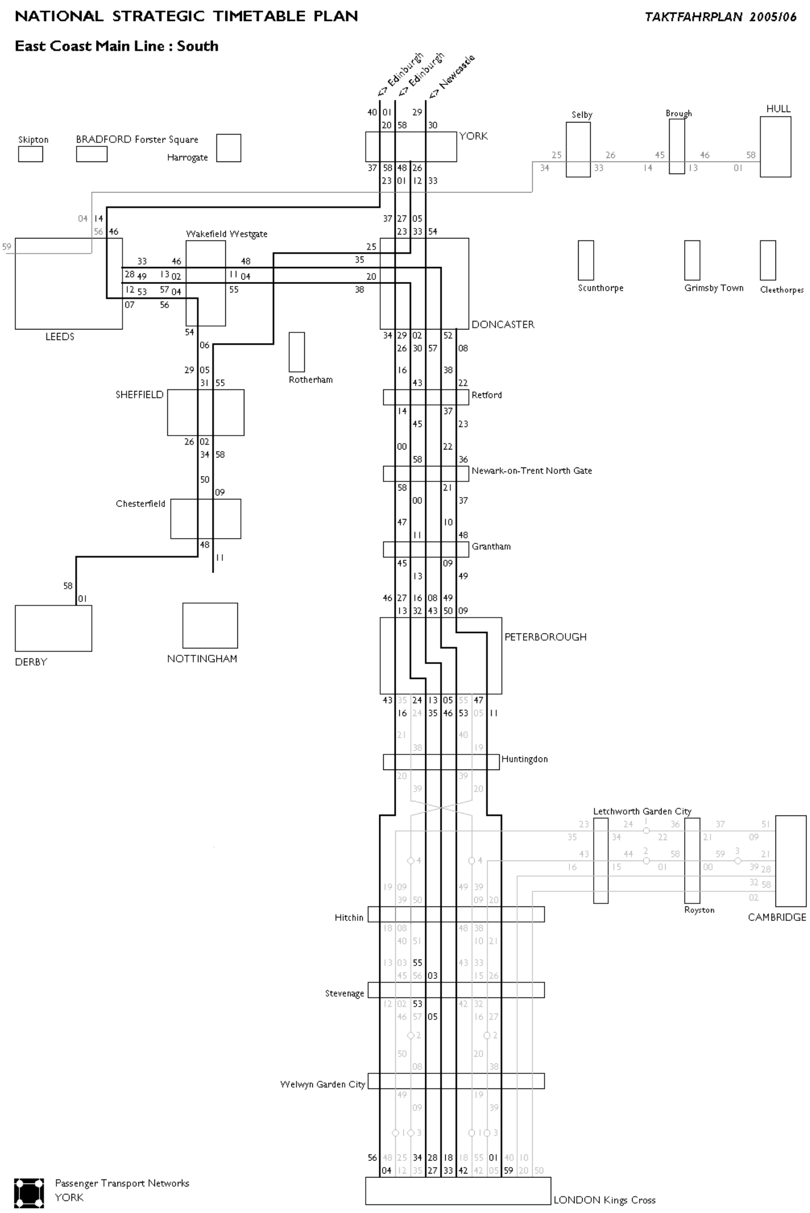
That completes the description of the services which were included in the *Taktfahrplan* and thus in the evaluation. Others have been borne in mind (and have been detailed in Tyler, 2003b).

Appendix 2: Netgraphs of the East Coast Main Line Taktfahrplan

NATIONAL STRATEGIC TIMETABLE PLAN *TAKTFAHRPLAN 2005/06*

East Coast Main Line : North





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ii Corresponding author. Tel: +44 0113 3436607. E-mail address: djohnson@its.leeds.ac.uk
iii Of the three features of a timetable that were evaluated it has the weakest percentage effect on demand.

[iv] As part of the railway industry's support for the Project we were provided with a complete database, drawn from the CAPRI accounting system, of station x station ticket sales for the year 1999/2000, disaggregated by ticket-type and route. Access to the industry-standard forecasting model MOIRA and its built-in ticket data was also arranged. We are extremely grateful to the Passenger Demand Forecasting Council for facilitating these arrangements.

[v] We are equally grateful to the Operations Planning staff of Network Rail for their assistance with this material.

[vi] The percentage method is found on the former Southern Region (in lieu of engineering margins) and on some mainland European railways.

[vii] The theoretical minimum value of these indices would be 0.042,derived from having 60 services throughout the day each at different departure times,and the maximum value, 1, from having the same number of departing trains per hour as different departure times over the day.

[viii] The theoretical minimum value of this index would be 0, from having no repeated intervals, and the maximum value, would be 0.996 from a service every five minutes over 24 hours.

[ix] Here the maximum value is 1 for a service with all its departure times being 'memorable' and 0 for a service with no 'memorable' departure times.

[x] Written by Peter Wightman at ITS.

[xi] Index A has no adjustment for peak extra services.

[xii] Index B incorporates an adjustment for one peak extra service.