ABCD

GREENGAUGE 21

High Speed Rail

Consequences for employment and economic growth

Technical report

KPMG LLP

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This report contains 30 pages

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GREENGAUGE21

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A1 Modelling overview

This report describes the methodology deployed by KPMG when assessing the employment and wider economic impacts of a national high speed rail network for Greengauge 21.

A1.1 Overview of methodology and sources

The objective of the study was to estimate whether High Speed Rail (HSR) could affect the wider economy, including impacts it could have on employment, productivity and the geographical pattern of business activity. The methodology therefore begins with the hypothesis that changing transport supply could change the way businesses work, influence their location decisions, how productive they are and how they shrink or grow, and sets out to test this hypothesis. The central theoretical underpinning of the analysis is that connectivity can be a driver of specialisation. This can affect the way that companies experience economies of scale and hence affect the productivity and competitiveness of different areas and of the country as a whole.

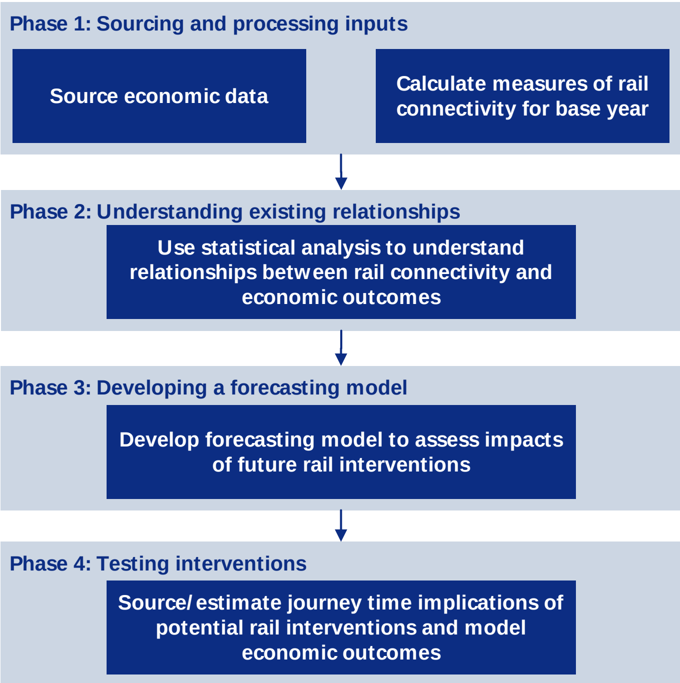
The Department for Transport does not provide appraisal guidance on how to assess these impacts and requires core transport business cases to assume no changes in land use or business behaviour except travel behaviour, although this can be presented as a sensitivity test[1]. The Department has published guidance on estimating the GDP impacts of transport schemes in 2006[2], although this guidance is also based on the assumptions of fixed land use and business behaviour and so did not capture impacts that may occur as the structure, size and geographic pattern of economic activity changes in response to transport.

It was therefore necessary to employ a methodology that was not supported by DfT guidance which was based on observing whether relationships exist between rail connectivity and business behaviour, and using these to develop a forecasting model to assess the likely implications of future changes in rail connectivity.

The process is described in Figure 1 below.

[1] Department for Transport Web Transport Appraisal Guidance Unit 3.5.14, Chapter 7
[2] Transport, wider economic benefits and impacts on GDP, DfT, 2006

Figure 1: Overview of methodology



Source: KPMG

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We have not verified the reliability or accuracy of any information obtained in the course of our work. We have checked information provided to us for consistency but have otherwise taken information at face value. In particular, we have not carried out any kind of audit of information received.

A1.2 Structure of report

This report is split into four further sections:

A2 describes the model geography and input data used and how this was used by KPMG to calculate measures of rail connectivity.

A3 describes how KPMG has undertaken statistical analysis to identify the existing relationships between rail connectivity and economic outcomes.

A4 describes how KPMG has used information about how rail connectivity is related to economic outcomes to develop a forecasting model to assess future implications of changes in rail connectivity on productivity, jobs and GVA.

A5 describes how KPMG has used this model and the assumptions made to test HSR interventions (shown as Phase 4 in Figure 1 above).

A2 Model specification

A2.1 Model geography

The model geography was developed to enable analysis of the impacts of rail connectivity at a national level. The model geography was developed to cover all of Great Britain at district level.

The zoning was based upon local authority districts to be consistent with available socio-economic data. Specifically this was pre-2009 local authorities (District / Unitary) of which there are a total of 408 for Great Britain. These are shown in Table 1 below.

Table 1: Districts within the model study area

Country	Local Government Authorities	Total
England	the City of London Corporation, London boroughs, metropolitan districts and unitary authorities (all providing single-tier local government) and county districts (lower-tier in areas of two-tier local government);	354
Wales	single-tier unitary authorities	22
Scotland	single-tier unitary authorities	32
Total		**408**

Source: National Statistics and KPMG

A2.2 Base case rail service data

All rail generalised journey time data for the base case was sourced from the national version of the MOIRA rail network model. The journey times were supplied by DfT (via Delta Rail) from the 'top skim' of the National MOIRA model. This consists of generalised journey time data for flows between 376 stations.

To create a matrix of district to district journey times to populate the model, each district was allocated a representative station. Stations were assigned to districts on the basis of the closest station to the population weighted centroid of each district. The closest station was defined as the one with the shortest crow flies distance to the district population weighted centroid. As only major stations are represented in this version of the MOIRA model, the danger of choosing a minor or unrepresentative station is limited but not ruled out completely. In addition, the MOIRA model uses generic 'BR station zones' in some cases where there are multiple major stations within a city or town (such as Manchester BR which represents Manchester Piccadilly, Manchester Victoria and Manchester Oxford Road stations). This limits the danger of choosing a station with a limited set of services.

Population weighted centroids were calculated from data sourced from the Office for National statistics (ONS) Neighbourhood Statistics at Middle layer Super Outer Area (MSOA) level. ONS grid references for all stations were sourced from Network Rail.

A2.2.1 Calculating rail generalised journey times

Generalised journey time data inputs capture in-vehicle time, additional time penalties to represent the inconvenience of waiting for services, and additional time penalties to represent the inconvenience of having to interchange. MOIRA automatically calculates the combined impact of these different aspects of journey inconvenience based on rules and parameters set out in the Passenger Demand Forecasting Handbook (PDFH) and expresses them as a rail 'generalised journey time'. However, MOIRA generalised journey times omit the inconvenience of overcrowding, fares and access to the rail network. Fares and access to the network have been considered separately, while incorporating an analysis of overcrowding within base rail service levels is beyond the scope of this project.

The analysis used the generalised costs including fare faced by commuters to capture measures of access to labour markets and the generalised costs including fare faced by business passengers to capture measures of access to other businesses.

Data were supplied for:

- Full price ticket holders;
- Reduced price ticket holders; and
- Season ticket holders.

Generalised journey time data varies slightly between these groups because evidence suggests that they have slightly different attitudes to the inconvenience of waiting and interchanging. We have constructed rail generalised journey times for business and commuter trips by using different weightings of generalised journey time for different ticket types.

Business trips are assumed to include a higher proportion of the full fare tickets due to the nature of business travel as often short notice and inelastic to price. Commuting trips are assumed to include a higher element of the lower seasonal fares as commuters with a set pattern will tend to take advantage of discounted season tickets. As the modelled generalised journey times only differ slightly by ticket type the construction of this has little impact on the model results. For reference, the weighting was applied as follows:

Table 2: Generalised journey time make-up by market segment

Market segment	GJTF	GJTR	GJTS
Business trips	80%	20%	0%
Commuting trips	20%	0%	80%

Source: KPMG assumptions

Rail generalised journey times for each pair of stations were sourced from the MOIRA data and applied to flows between model zones.

A2.2.2 Access/Egress time

An access time was calculated for each model zone to represent the time taken for the average rail traveller to reach the station within each zone. The access time is assumed to be the time taken to travel the crow flies distance from the population weighted centroid to the corresponding station at a speed of 30 kph. Where journey time data is to or from BR stations KPMG calculated the geographic midpoint of these stations and used this as the station location. The egress time was similarly calculated for the destination zone. Both are added to the rail generalised journey time to create an aggregate generalised journey time.

A2.2.3 Fares

Detailed geographical data on rail fares was unavailable due to its confidential nature. Publicly available data is available on a national basis. KPMG therefore made a number of assumptions in order to incorporate an element of fares within the modelling.

National data is published annually for rail passenger journeys, rail passenger kilometres and rail revenues earned. For the base year (2007) this was source at an aggregate level from TAS. This is shown in Figure 2 below.

Figure 2: National rail passenger kilometres and revenue, 2007

	2007
Passenger kilometres (billion)	
London and Southeast	23.4
All outside London	25.0
Passenger revenue (£ million)	
London and Southeast	2,726.2
All outside London	2,726.1
Revenue per passenger kilometre (p/km)	
London and Southeast	11.65
All outside London	10.90

Source: TAS [http://taspublications.co.uk/blog/?p=35, accessed 22/07/2009]

Passenger revenue is divided by passenger kilometres to give a measure of revenue per kilometre differentiating between higher fares in London and the South of England.

The distance by rail for each pair of stations was supplied by DfT (through Delta Rail). A proxy for journey fare was then calculated by multiplying the overall rail journey distance by a standard 10.9p per kilometre. To reflect higher fares in London any journey with a London station as an origin or destination was ascribed the higher fare of 11.65p per kilometre. Business fares were assumed to be twice as high as commuting fares.

These simplified assumptions about fares do not capture the pattern of local variations and variations along different routes.

This monetary cost was converted into a generalised time cost by using a value of time. For this standard DfT Webtag values of time were taken. These are shown in Table 3 below.

Table 3: Generalised journey time make up by market segment, 2007, pence per minute, 2006 prices

Market segment	Value of time
B2B rail trips	75.1345
Rail commute trips	9.989

Source: WebTAG

The fare (measured in minutes) was then added to the generalised journey time to create the final generalised cost of rail travel which has been used in the analysis.

A2.3 Socio-economic data

KPMG collected socio-economic data for each model zone to represent or proxy for:

- Workplace employment by business sector
- Working age population; and
- Productivity.

Data for number of employees by district by business sector was sourced from the Annual Business Inquiry for 2007, the latest year for which data is available. District areas (as at 31st December 2007) were sourced from National Statistics and used to derive employment density measured in workplace employees per square kilometre.

Mid year total and working age population estimates were sourced by district from NOMIS for 2007.

Productivity data is not available at a district level by business sector. Instead KPMG has constructed district level measures of wage income by business sector as a proxy for the contribution of labour to GVA. Throughout this report, average wage is referred to as productivity for convenience. Although this measure of wage income is not the same as labour productivity, it is intended to reflect the contribution that labour makes to GVA and we henceforward describe it as a measure of productivity for ease of reference. However, it is important to bear this in mind when interpreting the outputs of the model.

Wage data available by sector, but only at a regional level, was combined with wage data that is available at a district level, but not split by sector. It was estimated from the following data sources:

- Total wage income by business sector for 2007 from the Annual Business Inquiry (available at a regional level);

- Employment by sector for 2007 from the Annual Business Inquiry (available at a district level); and

- Mean total pay including incentives (aggregate for all sectors) from the Annual Survey of Hours and Earnings (available at a district level).

To estimate wage income by business sector at a local level, KPMG first constructed a measure of total wage income within each district by multiplying district level average wages (not split by sector) and employment (call this A). This was used to control total district level wage income. Second, wage income by district by sectors was estimated by multiplying district level employment by sector by regional average wages by business sector. This does not take account of different wage levels within different districts within the region, so wages in all sectors were factored equally to control this measure of total wage income to the first measure (A). The resulting measure of wage income is therefore a way of capturing the regional pattern of wage differentials within business sectors and the local pattern of differences in average wages within business sectors.

Section A3 below describes how workplace employment and productivity were used as dependent variables in KPMG's analysis to determine whether rail connectivity is related to economic outcomes. Attempts were made to assess the strength of these relationships by business sector. However, this was made difficult because of data quality issues at this level of sectoral and geographic disaggregation.

KPMG has therefore constructed two further aggregate measures of productivity across sectors to help understand how rail connectivity and productivity are linked in more detail. These control the aggregate productivity measures for differences in sectoral mix and for geographic variations in productivity within sectors. The measures have been constructed as follows:

- **Productivity controlled for differences in the sectoral mix of employment:** This measure was created by fixing the sectoral mix of employment at the national average so that variations in aggregate productivity between locations are based only on local variations in productivity within business sectors.

- **Productivity differences driven only by changes in the sectoral mix**: Differences in the sectoral mix of employment are one reason why, on average, firms in different locations exhibit different levels of productivity. To assess how this affects the productivity of different locations, KPMG constructed a measure of productivity for each area that assumes that productivity within each business sector is equal to the national average for that sector. Hence differences in aggregate productivity are only driven by changes in the sectoral split of employment within that location.

A forecast year of 2040 has been used in the analysis. This reflects a balance between projecting socioeconomic data into the future in a meaningful way and ensuring that sufficient time is given for the development of a national HSR network. The selection of 2040 does not imply that an HS network could necessarily be in place by then as phasing and timing issues have not yet been resolved. Rather, it represents a suitable future year in which to assess the economic outcomes of such a network if it had come about by then.

Employment and population data for 2040 was constructed using growth rates derived from data sourced from SYSTRA-MVA. This was done to ensure that the socioeconomic scenario that underpins KPMG's work was consistent with the other work for Greengauge 21. Table 4 represents these changes in population and workplace employment.

Table 4: Exogenous employment forecasts used in KPMG's modelling

Region	Base employment, 2007	Employment growth rate to 2040 in base case with no HSR	Base employment, 2040
Source	Annual Business Enquiry	SYSTRA-MVA	*[calculated]*
East	2,380,000	0.76%	3,052,000
East Midlands	1,910,000	0.71%	2,414,000
London	4,080,000	0.95%	5,579,000
North East	1,030,000	0.12%	1,071,000
North West	3,040,000	0.46%	3,532,000
Scotland	2,410,000	0.38%	2,726,000
South East	3,730,000	0.89%	5,006,000
South West	2,240,000	0.83%	2,937,000
Wales	1,170,000	0.22%	1,260,000
West Midlands	2,360,000	0.35%	2,645,000
Yorkshire and The Humber	2,240,000	0.39%	2,550,000
Total	**26,580,000**	**0.636%**	**32,771,000**

Source: SYSTRA-MVA, KPMG analysis

Productivity data for 2040 was constructed using the Treasury's long run productivity growth assumptions of 2.25% per annum real productivity growth.

A2.4 Measuring connectivity

The next stage in the modelling consisted in calculating the connectivity that rail provides to other businesses and to labour markets. These connectivity measures were then compared with economic outcomes including productivity, sectoral mix and employment density.

In this section, we describe how measures of connectivity were developed by KPMG to be used as inputs for this analysis.

There are many ways of measuring accessibility and connectivity, from simple metrics such as the distance from a rail station to more complex measures reflecting connections to 'opportunities' such as other businesses, employees or customers that these stations provide. KPMG has focussed on how rail provides opportunities to connect businesses to labour and to other businesses. The analysis therefore does not consider the contribution that can be made to economic outcomes by the provision of rail freight services.

The rail generalised journey time data and the socio-economic data are brought together in the models to construct measures of rail connectivity. These can be thought of as the 'effective rail labour market catchment' and the 'effective rail business to business market catchment' of each district.

For a particular workplace destination, the number of potential employees within the catchment of a workplace is governed by:

- The generalised cost of the rail commuting journey from the origin zone to the workplace;
- The number of potential employees in the origin zone; and
- The willingness of potential employees to accept the generalised cost of commuting.

Similarly, for a workplace, the importance of access to other businesses in another zone is governed by: the generalised cost of the rail business trip between the zones; the number of workplaces in the other zones; and willingness to accept the generalised cost of business trips to them.

A2.4.1 Willingness to travel and generalised time decay curves

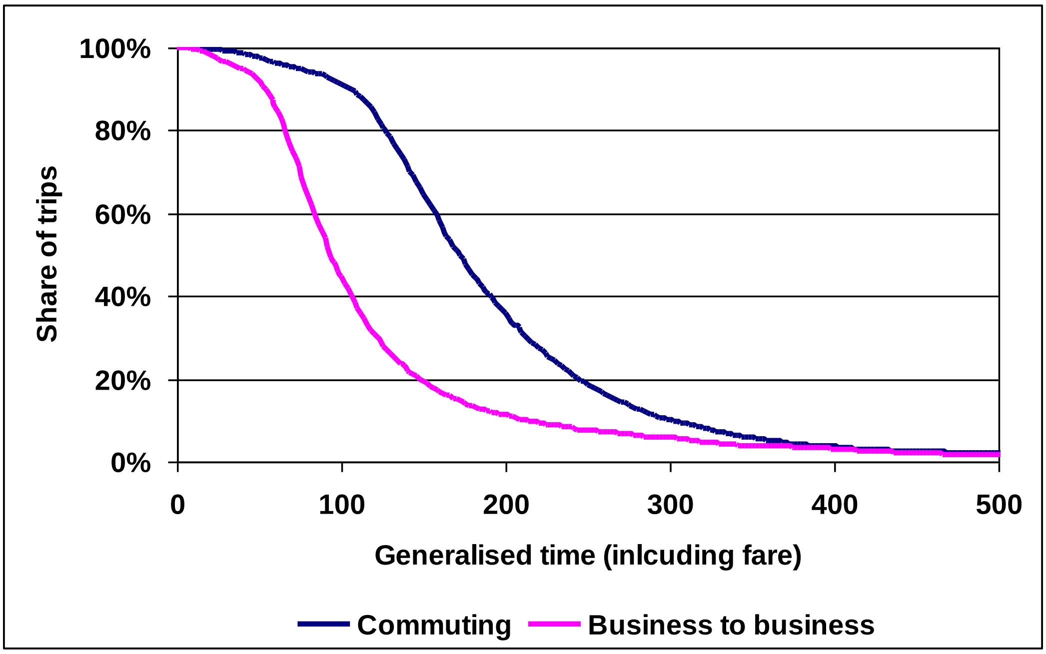
As generalised cost increases, the share of people willing to accept that cost to make a commuting or a business trip declines. There are a number of options available for representing this relationship including, for example:

- a simple boundary (e.g. how many people with one hour?);
- a simple linear decay function; or
- a mathematically defined decay function such as an exponential decay function.

KPMG has chosen instead to base the analysis of willingness to travel on observed travel patterns using a trip 'length'[3] distribution. Using demand data, KPMG calculated the share of people that accept different levels of generalised costs when making commuting and business trips. This reflects how far (in terms of generalised cost) people currently travel given prevailing conditions such as wage rates and the geographic dispersal of people and businesses.

[3] Instead of distance, KPMG's analysis is based on a generalised cost distribution.

Figure 3: Share of business trips over different generalised time (including fare) thresholds, 2006



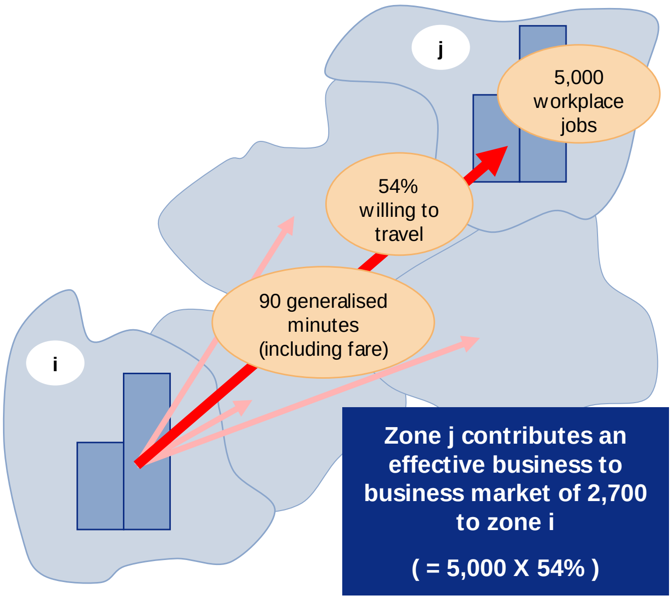
Source: KPMG analysis

The decay curves shown above capture existing trip length distributions. It appears counter intuitive that commuting trips are, in general, longer in terms of generalised time. However, this is because commuters have a much lower value of time so the fare component of commuting trips can make up a large share of the generalised costs. Conversely for businesses travellers who have higher values of time, the impact of fares on generalised time is much smaller, although average physical journey lengths are longer.

A2.4.2 Calculating overall effective market sizes

The decay curves were then applied to the generalised cost data to estimate the share of people willing to commute or make business trips between different zone pairs. Socio economic data covering working age population and workplace based employment is then used to estimate the total effective business and labour market size for each location.

Figure 4: Illustrative example of contribution of destination zone j to business to business market catchment of origin zone i



Source: KPMG

Summing across all destination zones for outbound business to business trips, KPMG calculated the total business to business market catchment of each district. Similarly, summing across all origins, KPMG calculated the labour market catchment of each district.

These catchments were used in the analysis that follows to describe the rail connectivity offered to businesses in each district.

The 10 zones in the model with the largest rail connectivity catchments are all in London ranging from the City of London and Southwark with commuting catchments of over 4 million and business to business catchments of around 3.5 million to boroughs such as Croydon and Newham with commuter rail catchments of around 2.5 million and business to business catchments of over 2 million. The top ten areas with the largest rail connectivity scores outside London are shown in Table 5.

Table 5: Effective market catchments for top ten model zones (outside London), 2007

Business to business connectivity			Labour market connectivity		
Rank	**Location**	**Catchment**	**Rank**	**Location**	**Catchment**
1	Birmingham	1,595,119	1	Manchester	1,927,596
2	Manchester	1,438,519	2	Birmingham	1,915,543
3	Reading	1,257,188	3	Epsom and Ewell	1,635,997
4	Woking	1,234,172	4	Leeds	1,552,588
5	Watford	1,229,371	5	Spelthorne	1,542,607
6	Solihull	1,178,605	6	Runnymede	1,507,900
7	Leeds	1,171,149	7	Woking	1,398,833
8	Wolverhampton	1,157,380	8	Salford	1,389,116
9	Three Rivers	1,153,704	9	Wolverhampton	1,381,932
10	Stockport	1,129,843	10	Bolton	1,357,578

Source: KPMG analysis

A3 Estimating relationships between rail connectivity and economic outcomes

This chapter describes the approach deployed by KPMG to establish links between rail connectivity and business behaviour.

The methodology takes as its starting point the hypothesis that transport could affect different aspects of business behaviour including productivity but also where businesses choose to locate, how many jobs they create and how many people enter the workforce. That is not to say that rail connectivity is the only determinant of these economic outcomes, but that it may contribute to them and that the size of this contribution, if any, can be measured. This is shown in Figure 5 below.

Figure 5: Dependent and explanatory variables

A log linear model of the form:

$$\ln(y) = \alpha + \beta \ln(\text{business market catchment}) + \gamma \ln(\text{labour market catchment})$$

allows the business to business market parameter (β) and the labour market parameter (γ) to be separately estimated. It also enables the resulting coefficients to be interpreted as partial elasticities, which is useful when developing model parameters.

However, the measures of business market catchments and labour market catchments are serially correlated. This is because the matrices of rail journey times are very similar and there is also similarity in the pattern of residential and employment density. KPMG also estimated two other equations in order to inform parameterisation of the forecasting model. This analysis takes the form:

$$\ln(y) = \alpha + \beta \ln(\text{business market catchment}); \text{ and}$$

$$\ln(y) = \gamma + \delta \ln(\text{labour market catchment})$$

Results are presented below for all formulations.

A3.1 Business productivity

A3.1.1 Overall impacts on productivity

Areas with higher levels of rail connectivity also have higher levels of productivity. Evidence from the model suggests that, other things being equal, an area with 10% higher business to business rail connectivity will tend to have overall productivity which is 1.1% higher. The analysis excluded Scotland where productivity data could not be sourced on a consistent basis.

Table 6 shows the relationships observed between rail connectivity and productivity by business sector. It shows the results of testing the hypothesis that the productivity of an area may be related to the rail connectivity characteristics of that area.

Table 6: Influence of rail connectivity on total productivity

	Effective rail based labour market catchment			Effective rail based business to business market catchment			Combined effect of labour and business to business market catchments				
Sectors	Coefficient	T Stat	R2	Coefficient	T Stat	R2	Labour market Coefficient	T Stat	B2B Coefficient	T Stat	R2
Agriculture/fishing	- 0.01	-1.10	0.3%	- 0.00	- 0.49	0.1%	- 0.07	- 2.21	0.07	1.97	1.2%
Energy & Water	0.05	4.96	5.8%	0.06	5.41	6.8%	- 0.02	- 0.64	0.08	2.18	6.9%
Manufacturing	0.05	7.76	12.9%	0.06	8.44	14.9%	- 0.02	- 0.78	0.08	3.19	15.1%
Construction	0.06	8.80	16.0%	0.06	9.20	17.2%	0.00	0.20	0.06	2.46	17.2%
Distribution, hotels, restaurants	0.08	10.12	20.2%	0.10	12.76	28.6%	- 0.13	- 5.40	0.24	8.99	33.4%
Transport & Comms	0.05	6.49	9.4%	0.06	7.81	13.0%	- 0.07	- 2.94	0.13	5.10	14.9%
Business services and finance	0.10	10.81	22.3%	0.12	11.32	24.0%	0.01	0.31	0.11	2.98	24.0%
Public Admin, Edu, Health	0.05	8.06	13.8%	0.05	7.76	12.9%	0.04	2.03	0.01	0.31	13.8%
Other	0.09	11.10	23.3%	0.11	11.38	24.2%	0.03	0.96	0.08	2.37	24.3%
UK total	**0.09**	**12.92**	**29.1%**	**0.11**	**13.99**	**32.5%**	**- 0.01**	**- 0.54**	**0.13**	**4.56**	**32.6%**

Source: KPMG analysis

Table 7 shows how the results at a national level break down by region. While there are 376 districts in the model outside Scotland, this translates into an average of only around 42 per region so sample sizes are relatively small at a regional level.

Table 7: Influence of rail connectivity on total productivity by region

	Effective rail based labour market catchment			Effective rail based business to business market catchment			Combined effect of labour and business to business market catchments				
Sectors	Coefficient	T Stat	R2	Coefficient	T Stat	R2	Labour market Coefficient	T Stat	B2B Coefficient	T Stat	R2
London	0.20	3.21	24.9%	0.23	3.92	33.2%	- 0.08	- 0.55	0.30	2.01	33.9%
South East	0.18	6.10	36.4%	0.26	7.03	43.2%	- 0.04	- 0.50	0.31	2.82	43.4%
South West	0.13	9.13	66.0%	0.10	8.13	60.6%	0.11	2.62	0.02	0.43	66.1%
East Midlands	0.09	5.55	44.8%	0.12	5.87	47.5%	- 0.02	- 0.20	0.14	1.41	47.6%
West Midlands	0.05	1.83	9.5%	0.09	2.55	16.9%	- 0.21	- 2.09	0.35	2.74	27.1%
Yorkshire & Humber	0.04	2.07	18.4%	0.05	2.09	18.6%	0.01	0.16	0.04	0.28	18.7%
Northwest	-0.01	- 0.47	0.5%	- 0.01	- 0.20	0.1%	- 0.08	- 0.95	0.09	0.85	2.3%
Northeast	0.05	1.10	5.4%	0.07	1.58	10.7%	- 0.18	- 1.28	0.25	1.71	17.4%
Wales	0.05	2.43	22.9%	0.05	2.34	21.6%	0.04	0.57	0.00	0.03	22.9%

Source: KPMG analysis

The coefficients measure the elasticity of productivity to changes in rail connectivity. The overall UK coefficients of 0.09 for labour market connectivity and 0.11 for business to business connectivity imply that an area with 10% higher rail business to business connectivity is consistent with 1.1% higher productivity while an area with 10% higher rail labour market connectivity is consistent with 0.9% higher productivity.

The R^2 value is a measure of the ability of the explanatory variables (in this case rail connectivity measures) to explain the variation in the dependent data (in this case productivity). In a full analysis of the determinants of productivity one would hope to achieve an R^2 value of close to 100%. However, this is intended to be a partial analysis which only investigates the contribution that rail connectivity makes to explaining variations in productivity.

The R^2 values vary between 66.1% and 0.1%. When considering one connectivity measure at a time (i.e. in the first seven columns of the table), the best fit is found when all sectors are considered together when the business to business connectivity equation shows an R^2 value of 32.5%. This indicates that 32.5% of the variability in productivity between districts can be explained by rail connectivity to other businesses. Hence, more that two thirds of the variation in productivity between districts is left unexplained by this analysis. Productivity is statistically significantly correlated to Rail business to business connectivity in all business sectors except agriculture, forestry and fishing and in all regions except the Northeast and Northwest, although care must be taken here due to small sample sizes.

The T-statistic is a measure of how much confidence one can have that the parameter is statistically significant. A value of more than 1.96 indicates that the coefficient is positive at the 95% level of confidence. Most of the T-statistics are above 1.96 indicating a reasonable (95%) degree of confidence in the findings. The national elasticity of productivity with respect to labour market rail connectivity is found to be 0.094 and has a T-Statistic of 12.92. This implies that we can be 95% confident that the elasticity is between 0.079 and 0.108. Similarly, we can be 95% confident that the elasticity of productivity with respect to business to business rail connectivity is between 0.096 and 0.127 at a national level.

Some T-Statistics are not above 1.96 indicating that we cannot have the same level of confidence in the results. For example, the T-Statistic for the elasticity of productivity of firms in the Northwest with respect to labour market connectivity by rail is -0.47, indicating that we cannot be confident in the findings across the smaller sample of districts within the Northwest.

In general, it can be seen from Table 6 that the coefficients tend to be slightly higher for business to business connectivity than for labour market connectivity. This implies that business to business rail connectivity exerts a slightly stronger influence on productivity that access to labour by rail. This may also be because the district level model is relatively aggregate and therefore does not pick out some aspects of variations in local access to labour by rail.

The results of the equations combining measures of both access to labour and access to other businesses are shown in the five right hand columns of Table 6. In general these find that the business to business coefficient is positive and the T-Statistic indicates a statistically significant relationship. However, the labour market coefficient and T-Statistic is highly variable. The behaviour of the labour market variable in this combined equation suggests that it is not independent of the business to business connectivity measure. This is not surprising given that rail journey time data is a key input into both measures. It appears that the business to business connectivity measure is dominating and that the regression model is essentially using this to drive the model while the labour market connectivity measure is reduced to explaining the residuals. The result of this is variable and counterintuitive elasticities, which are different in different model formulations. This is important when devising a forecasting model and is discussed further in section A4 on page 25.

The impacts across different business sectors show that productivity of the business services and finance is most sensitive to levels of rail connectivity. This is followed by the 'other' sector which includes other community, social and personal services, and by the distribution, hotels and restaurants sector.

The coefficients in Table 6 are in many cases substantially higher than the agglomeration elasticities identified by the DfT and used in appraisal guidance. This is to be expected and there are several reasons for it:

- First, this analysis will also tend to capture business time savings that are usually captured in appraisal as user benefits;

- Second, this analysis captures both productivity within business sectors (including for example, business travel time savings and agglomeration) and changes in the sectoral mix which are usually excluded from fixed land use appraisals; and

- It may also be that other aspects of areas with good rail service are captured within this analysis that are currently not captured in DfT guidance. An example of this may be that, in areas well served by rail, many business trips are made by rail where time can be used more productively than when travelling by car.

A3.1.2 Impact on productivity through changing productivity within sectors

KPMG has attempted to break down the impacts on productivity into two separate impacts. The first is the impact on productivity that occurs within sectors. The second is the impact on productivity through influencing the sectoral mix of employment.

The results of this analysis are presented in Table 8 and Table 9. The analysis presented in these tables is the same as that presented in Table 6. However in Table 8 the dependent variable is productivity controlled for changes in the sectoral mix of employment, while in Table 9 the dependent variable is productivity calculated with productivity within each sector held at national average levels so that the only variation is due to variations in the sectoral mix of employment.

Table 8: Influence of rail connectivity on productivity through changing productivity within sectors

	Effective rail based labour market size			Effective rail based business to business market catchment			Combined impact of ELM and B2B market size				
Sectors	Coefficient	T Stat	R2	Coefficient	T Stat	R2	ELM Coefficient	T Stat	B2B Coefficient	T Stat	R2
UK total	**0.07**	**10.84**	**22%**	**0.09**	**11.73**	**25%**	**- 0.01**	**- 0.63**	**0.10**	**4.00**	**25%**
Regions											
London	0.07	2.05	9%	0.08	2.59	15%	-0.06	-0.68	0.14	1.62	14%
South East	0.15	5.50	31%	0.21	6.18	36%	-0.02	-0.29	0.23	2.33	35%
South West	0.08	6.02	44%	0.07	5.38	39%	0.08	2.06	-0.00	-0.08	43%
East Midlands	0.07	4.66	35%	0.10	4.91	37%	-0.02	-0.23	0.12	1.24	36%
West Midlands	0.04	1.33	2%	0.08	2.08	9%	-0.24	-2.46	0.37	2.98	22%
Yorkshire & Humber	0.03	1.60	7%	0.05	1.66	8%	-0.01	-0.09	0.06	0.44	3%
Northwest	0.03	0.78	-2%	0.05	1.20	2%	-0.16	-1.17	0.21	1.48	4%
Northeast	-0.02	-0.84	-1%	-0.01	-0.46	-2%	-0.10	-1.35	0.12	1.15	0%
Wales	0.03	1.63	7%	0.03	1.63	7%	0.01	0.18	0.02	0.23	3%

Source: KPMG analysis

The coefficients of productivity controlled for sectoral mix are 0.07 for labour market connectivity and 0.09 for business to business connectivity. These are smaller than the results for overall productivity found in Table 6. The T-Statistics for the labour connectivity and business to business UK results in Table 7 are 10.84 and 11.73 respectively. This implies a high degree of confidence in this statistical relationship and that, nationally, around three quarters of the productivity impacts due to rail connectivity are due to influencing productivity within sectors.

A3.1.3 Impact on productivity through influencing sectoral mix

KPMG has found evidence from the UK model that by influencing the sectoral mix, rail can have an impact on the average productivity of an area. This suggests that areas with 10% higher rail access to labour have a sectoral mix which will tend to increase productivity by around 0.2%. The findings are set out for the different measures of rail connectivity and by region in Table 9.

Table 9: Influence of rail connectivity on productivity through supporting a different industry mix

	Effective rail based labour market size			Effective rail based business to business market catchment			Combined impact of ELM and B2B market size				
Sectors	**Coefficient**	**T Stat**	**R2**	**Coefficient**	**T Stat**	**R2**	**ELM Coefficient**	**T Stat**	**B2B Coefficient**	**T Stat**	**R2**
UK total	**0.03**	**14.84**	**35%**	**0.03**	**16.35**	**40%**	**-0.01**	**-0.91**	**0.04**	**5.59**	**40%**
Regions											
London	0.06	2.84	18%	0.07	3.55	27%	0.04	0.68	0.11	1.99	25%
South East	0.04	5.47	33%	0.06	6.13	38%	-0.00	-0.23	0.07	2.24	37%
South West	0.05	10.18	70%	0.04	9.79	68%	0.03	2.12	0.02	1.41	71%
East Midlands	0.02	4.50	33%	0.03	4.95	38%	-0.02	-0.85	0.06	1.86	37%
West Midlands	0.02	2.09	9%	0.02	2.00	8%	0.02	0.58	-0.00	-0.02	6%
Yorkshire & Humber	0.02	2.34	18%	0.03	2.19	16%	0.03	0.77	-0.02	-0.29	14%
Northwest	0.01	2.60	12%	0.02	2.66	13%	0.00	0.23	0.01	0.56	11%
Northeast	0.03	2.48	19%	0.03	2.80	24%	-0.01	-0.38	0.05	1.19	20%
Wales	0.02	3.07	29%	0.02	3.23	31%	-0.00	-0.01	0.02	0.81	27%

Source: KPMG analysis

The coefficients are 0.03 for labour market connectivity and 0.03 for business to business connectivity. These are smaller than the results for overall productivity found in Table 6. The T-Statistics for the labour connectivity and business to business UK results in Table 8 are 14.84 and 16.35 respectively. Again, this implies a high degree of confidence in the existence of this kind of statistical relationship. This implies that, nationally, around one quarter of the productivity impacts due to rail connectivity are due to influencing the sectoral mix of employment.

Both business to business connectivity and labour market connectivity are statistically significant for all regions. This implies that the impact of rail connectivity on productivity within business sectors is more consistent across the country than the impact of influencing sectoral mix.

A3.1.4 Summary of productivity results

The modelling finds that around a quarter of the impact of rail connectivity on productivity comes from changes in the sectoral mix. This cannot be captured or analysed if land use is assumed to be fixed. The impact on productivity within sectors is around three quarters of the total productivity effect. We find an elasticity of productivity controlled for sectoral mix of between 0.7 and 0.9 depending on whether labour market or business to business connectivity is the explanatory variable, and an elasticity of 0.03 for the sectoral mix component of productivity impacts.

It has not been possible to disentangle the individual effects of connectivity to labour and connectivity to other businesses. Although they differ in many respects, the two measures of rail connectivity constructed by KPMG are closely related to each other. Areas with a good service connecting to households with attractive commuting journey times also tend to have good rail access to other businesses via longer distance routes that are attractive to business. There are not enough locations which have good access to business areas and poor access to labour and vice versa to disentangle fully the two relationships. There are, however, some clues in the statistical analysis that suggest that business to business access tends to dominate access to labour.

A3.2 Employment density

KPMG has adopted a similar analytical technique to examine the relationship between employment density and connectivity. This analysis assesses how rail can influence business location decisions and employment density in different locations. This analysis follows a similar structure to the analysis presented in previous sections describing links with productivity. Table 10 and Table 11 show the results of applying this log linear analysis to data for different sectors and regions. They show the results of testing the hypothesis that the density of jobs within that area is related to the rail connectivity characteristics of that location.

Table 10: Influence of rail connectivity on employment density by sector

	Effective rail based labour market size			Effective rail based business to business market catchment			Combined impact of ELM and B2B market size				
Sectors	**Coefficient**	**T Stat**	**R2**	**Coefficient**	**T Stat**	**R2**	**ELM Coefficient**	**T Stat**	**B2B Coefficient**	**T Stat**	**R2**
Agriculture/ fishing	0.2	3.3	3%	0.2	4.0	4%	- 0.3	- 1.9	0.6	3.0	5%
Energy & Water											
Manufacturing	1.1	18.7	46%	1.2	17.4	43%	1.1	5.1	0.1	0.3	46%
Construction	1.2	21.0	52%	1.2	18.8	47%	1.3	6.9	- 0.2	- 0.9	52%
Distribution, hotels, restaurants	1.2	19.9	49%	1.3	18.3	45%	1.2	5.7	0.0	0.0	49%
Transport & Comms	1.3	19.3	48%	1.4	18.0	44%	1.2	5.2	0.1	0.4	48%
Business services and finance	1.5	22.6	56%	1.7	21.6	53%	1.1	4.9	0.5	1.7	56%
Public Admin, Edu, Health	1.2	18.4	45%	1.3	16.5	40%	1.4	6.3	- 0.3	- 1.0	46%
Other	1.3	20.9	52%	1.4	18.9	47%	1.4	6.6	- 0.1	- 0.6	52%
UK total	**1.3**	**20.5**	**51%**	**1.4**	**18.8**	**47%**	**1.3**	**5.9**	**0.0**	**0.0**	**51%**

Source: KPMG analysis

Table 11: Influence of rail connectivity on employment density by region

	Effective rail based labour market size			Effective rail based business to business market catchment			Combined impact of ELM and B2B market size				
Regions	**Coefficient**	**T Stat**	**R2**	**Coefficient**	**T Stat**	**R2**	**ELM Coefficient**	**T Stat**	**B2B Coefficient**	**T Stat**	**R2**
London	1.7	5.2	46%	1.8	5.6	51%	0.4	0.5	1.4	1.7	51%
South East	1.0	4.0	20%	1.2	3.6	16%	1.2	1.7	- 0.3	- 0.3	20%
South West	0.8	2.7	15%	0.6	2.4	12%	1.1	1.3	- 0.3	- 0.4	15%
East Midlands	1.1	4.2	32%	1.4	4.1	30%	1.2	1.0	- 0.2	- 0.1	32%
West Midlands	1.7	4.6	40%	1.9	3.9	32%	3.3	2.5	- 2.1	- 1.3	43%
Yorkshire & Humber	1.1	3.3	37%	1.7	3.7	42%	- 1.0	- 0.7	3.1	1.5	44%
Northwest	1.0	6.1	48%	1.3	5.0	38%	1.7	3.1	- 1.0	- 1.3	50%
Northeast	2.4	5.5	59%	2.5	5.2	56%	1.9	1.3	0.6	0.4	60%
Wales	1.0	5.4	60%	1.1	5.3	59%	0.6	0.8	0.4	0.5	60%

Source: KPMG analysis

The model generates elasticities of 1.3 for access to labour and 1.4 for access to other businesses. The equation fit is slightly better for access to labour than access to other businesses as evidenced by the higher R^2 and T Statistics.

The analysis shows that the relationships are statistically significant across all sectors and regions for both rail connectivity to labour and rail connectivity to other businesses. The elasticities are highest for business services and finance and strongest in the Northeast, although there is a small sample size in this region.

A4 Developing a forecasting model

A4.1 Summary of existing relationships between rail connectivity and economic outcomes

KPMG's statistical analysis demonstrated a number of relationships between effective market catchments and socio-economic measures. This is broadly consistent with findings from other studies including work by the Department for Transport to estimate links between connectivity and productivity.

The key findings and limitations for developing a forecasting model are:

- **Rail connectivity is statistically significantly related to productivity within sectors**: There is a relationship between productivity controlled for differences in sectoral mix and the rail connectivity that an area can offer. While rail access only explains a small part of variations in productivity between locations, it is a statistically significant relationship at the national level.

- **Rail connectivity is statistically significantly related to productivity by influencing the sectoral mix of employment**: Findings suggest that rail connectivity affects productivity by influencing the industry mix of sectors present in areas with good rail connectivity.

- **Rail connectivity is statistically significantly related to employment density**: KPMG finds a relationship between employment density and rail, strongest in the business services and finance sector.

- **The statistical analysis is insufficient to distinguish between rail connectivity to labour and to other businesses.**

The statistical analysis is cross-sectional and so provides evidence of the relative impact on different places, but on its own is insufficient to provide evidence of absolute net impacts on employment or sectoral mix, which must also take account of factors such as redistribution of activity and competition between areas for mobile jobs. How KPMG has dealt with issues of redistribution and changes in net levels of economic activity are dealt with separately in section A4.3.

A4.2 Model parameters

This section describes the parameters used in the forecasting model. KPMG has derived these from the statistical analysis before assessing the extent to which modelled impacts are redistributive or whether they change net economic outcomes across the study area.

A4.2.1 Productivity impacts

KPMG has made some assumptions to disentangle the effects of business to business rail connectivity and labour market rail connectivity. Business to business trips appear to dominate the regression findings for productivity but both are statistically significant and have similar parameters. KPMG has selected the higher of the two elasticities and allocated 60% to business to business connectivity and the remaining 40% to labour market connectivity. This is a practical solution to dealing with the fact that the two variables are not independent of each other. KPMG has only used the parameters reflecting productivity impacts within business sectors in the forecasting model. This reflects the difficulties in distinguishing net national change in the sectoral mix of businesses from changes in the distribution of business sectors. This is described in more detail below.

A4.2.2 Employment

A similar approach has been followed where rail labour market connectivity appears to dominate business to business connectivity in the analysis. This occurred when estimating employment density in terms of workplace jobs per square kilometre. Here the parameter values to be used in the modelling have been based on the elasticity of employment density to labour market connectivity (an elasticity of 1.3). This has then been split so that 60% of this elasticity is applied to changes in rail based labour markets and 40% is applied to rail based business to business markets.

A4.3 Modelling redistribution and growth

KPMG's statistical analysis has considered cross sectional data across different locations. This provides for estimates of how changes in rail connectivity will affect relative impacts in different areas and gives some guide to how economic activity, business sectors and productivity may be redistributed as rail connectivity changes. However, it does not explain how rail connectivity changes may affect absolute levels of productivity, sectoral mix or overall levels of employment.

A4.3.1 Productivity

In arriving at national level impacts, it is assumed that productivity gains within sectors captures the net national gain in productivity which comes from business time savings and other, now familiar, elements of Wider Impact appraisals such as agglomeration.

In terms of productivity gains from changes in the sectoral mix, much of the impacts measured are likely to arise as business sectors redistribute themselves from other parts of the UK; in which case the impact on GVA at a national level is likely to be modest. Reflecting this, and (as far as KPMG is aware) the limited evidence to help quantify potential net national changes in sectoral mix, impacts of sectoral mix changes on net national GVA have been excluded from the analysis.

A4.3.2 Employment

KPMG has made the deliberately cautious assumption that all modelled employment changes using the employment density elasticity derived in section A3 actually reflect redistribution of employment between areas. The employment redistribution impact arising from changes in connectivity was derived by:

- Determining the proportion of businesses that are mobile at district and regional level;
- Constraining modelled employment changes in each region based on the share of employment deemed to be mobile between regions;
- Constraining redistribution in employment between districts based on the share of employment deemed to be mobile between districts; and
- Controlling total national employment change from this process to zero. In effect this approach assumes that jobs are not mobile at the national level.

Business mobility was assessed by analysing the geographic distribution of different employment sectors by region and district. It was assumed that businesses that are tied to local markets (such as newsagents, hairdressers, or car mechanics) will tend to be relatively evenly spread throughout the country, while more footloose businesses will tend to congregate in the areas that offer them the best business environment.

To measure the degree of business mobility, KPMG estimated the minimum number of jobs per resident by business sector across different regions and districts. This minimum was assumed to serve local markets; the remainder, which differs between districts and regions, was assumed to be footloose. On average, at a regional level, mobile employment constituted 25.1% of all employment. At a district level mobile employment constituted 76.5% of all employment.

A4.4 Net national changes in employment

The methodology assumes that net national changes in employment due to transport only occur if people are attracted into the labour market as the net returns from working (or employing people) change. This could happen in three ways:

- Improving business productivity and the wages that they offer so that people are attracted into the labour market and businesses seek more labour;
- Improving commuting journey options so that people are attracted into the labour market as commuting costs fall and the net returns from working thereby increase and employers are better able to match people to jobs; and
- Attracting foreign businesses and workers into the country.

KPMG has not calculated how changes in commuting costs could affect the net financial returns from working, so have not taken account of this process in the analysis. Nor in the time available for this study has also not been possible to establish robust relationships between transport supply and international migration or international business mobility. These relationships have therefore also been excluded this from the analysis.

The impact on net national employment is therefore based on changes in wages (calculated from the model parameters described above). These are translated into net changes in national employment by using an elasticity of 0.1. This is the elasticity recommended by the DfT for estimating the employment impacts of changes in the net returns from working. It was originally derived from an analysis of labour model runs by DWP and national labour market statistics taken from ONS.

Little quantitative evidence is available describing how the quality and coverage of transport services might affect foreign direct investment or international migration. Some evidence is available about how businesses make international location decisions and what share of changes in the business stock is due to the behaviour of international businesses. Other studies have estimated positive employment impacts from job redistribution from overseas. For example, Oxford Economic Forecasting estimated that that 17% of the employment benefits of Crossrail would come from international sources. In 2006 around 30% of the migrant inflow to the UK regions was international with the remaining 70% being domestic. Although this analysis is indicative of a positive relationship between connectivity and the ability of the UK to attract internationally mobile business activity, it does not provide readily useable quantitative relationships of the type this study has sought to rely on. KPMG therefore excluded these impacts from its analysis.

A4.5 Areas for further analysis

Data constraints and inadequate statistical results mean that KPMG has not been able to construct a forecasting model that separately assesses changes in the size and location of businesses, and wages offered by different business sectors. Instead, KPMG modelled the aggregate changes in wages offered in different areas and the pattern of overall employment as a result of introducing HSR services.

A second important data constraint was the difficulty of collecting local data for each model zone relating to other variables that can affect economic outcomes. When used for forecasting, KPMG's analysis therefore makes some implicit assumptions:

1. First, that there is a causal relationship between rail connectivity and business behaviour. Although there are reasons to believe that causation runs in this direction, it is an important assumption, and different assumptions would produce significantly different results; and
2. Second, that rail connectivity is not sufficiently correlated to other factors that may drive business productivity to undermine the results. This particularly applies to connectivity provided by other modes of transport such as bus or the road network.

The budget and timescales available for the study mean that it has not been possible to take into consideration is the feedback effect from relocation of businesses to denser urban areas which will tend to reinforce agglomeration or disagglomeration impacts.

Other things being equal, excluding this agglomeration multiplier effect will understate productivity impacts as a result of land use change that promotes accelerated growth in economically dense places.

The model assumes that other factors such as the planning system and the location and use of other public infrastructure continue to influence economic outcomes as they have in the past. It may be that planning policy either supports or frustrates some of the modelled changes. For example, planning policy may change to encourage denser development in the core city centres when HSR is implemented. Conversely, modelled growth in economic activity could lead to congestion on other transport and public services (e.g. public open spaces) in the core cities. Investigating these feedback effects through congestion is beyond the scope of this study but could benefit from further work.

A5 Modelling economic changes due to a National HSR network

A5.1 Overview of the forecasting process

KPMG has constructed a forecasting model to assess the impacts of changes in rail connectivity arising from investment in HSR based on the model parameters described in A2.

First, the future base case connectivity measures were calculated for business to business connectivity and labour market connectivity for 2040. This assumed that the existing rail timetable persists into the future with no changes. This is a simplification and does not capture known committed schemes. However, given the scale of the changes that could be brought about by the development of a future HSR network, the impacts of this on the findings will be limited. However, forecast exogenous changes in the size and distribution of population and employment do affect the future pattern of connectivity measures for the different districts.

Second, a 2040 scenario case was constructed based on input generalised journey time data from SYSTRA-MVA. The data provided were adapted to fit the model geography and expressed as generalised journey time changes between districts due to the implementation of HSR. The model then calculates the 2040 connectivity measures for this scenario and compares them with the 2040 base case.

Finally, the changes in connectivity are converted into changes in productivity, changes in net national employment and changes in the pattern of national employment due to employment redistribution. The overall consequences of these processes on employment and connectivity are then calculated (for example, as changes in employment location can have further impacts on productivity as jobs move to more or less productive locations).

A5.2 Scenario rail service data

Changes in generalised journey times (including fares) were sourced from SYSTRA-MVA for the base case and for the national HSR network scenario that was tested. These costs were collected for five modes: car; bus; HS rail; classic rail; and air. Composite costs were also sourced for combined HS rail and classic rail services.

The timetable input data was based on the following key journey time savings from HSR.

Table 12: Changes in key journey times

Origin	Destination	Journey time saving
Central London	Birmingham	0h 40
Central London	Manchester	0h 55
Central London	Leeds	1h 00
Central London	Sheffield	0h 50
Central London	Newcastle	1h 10
Central London	Glasgow	1h 50
Central London	Edinburgh	1h 50
Central London	Cardiff	0h 20
Central London	Bristol	0h 20
Birmingham	Paris	1h 30
Manchester	Newcastle	1h 00

Source: Fast Forward, Greengauge 21, 2009

Each district in KPMG's model was allocated to a SYSTRA-MVA zone. The composite rail journey time change between SYSTRA-MVA's base case and scenario was imported into KPMG's model and applied to the 2040 base case generalised costs to create the 2040 scenario case.

As KPMG's model is a rail based model only, it does not seek to capture the contribution that air services make to connectivity. Many of the journey opportunities provided by HSR would compete with domestic air services. To adjust for this, KPMG only incorporated journey time changes from HSR where HSR ended up dominating the competition with air services. To do this, demand matrices were sourced from SYSTRA-MVA and journey time improvements only implemented when rail's market share rose to above 90% of rail and air passengers.