APPRAISING SUB-REGIONAL AND LOCAL GROWTH STRATEGIES IN THE NOTTINGHAM-LEICESTER-DERBY AREA, UK: POLICY APPLICATIONS OF A NEW MODEL OF TRANSPORT AND LAND USE ACTIVITIES

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1 INTRODUCTION

We report a new, quantitative approach to integrated land use and transport planning studies at the sub-regional level in the UK, using case studies that have been completed within the past year. Our case study area has a total resident population of 2 million, consisting of the cities of Nottingham, Leicester and Derby, and their main commuting hinterlands. This area is situated in the English Midlands, and its income, demographic and travel profiles are fairly close to the UK average.

The basic concept of integrated land use and transport analysis has been around since the 1950s and is not at all new (see e.g. Mitchell and Rapkin, 1954). Over the years the concept has become gradually accepted by an ever increasing group of researchers and practitioners[1]. There have been remarkable attempts to break down the disciplinary and institutional barriers that hamper the integration of land use and transport decision-making. However, in practice, it is still relatively rare to find examples of integrated transport and land use analysis for practical policy analysis. This is as much due to the relative infrequency of public sector client groups which combine their efforts to implement integrated land use and transport policy analysis, as to the technical complexities in dealing with the land use-transport interactions in forecasting and appraisal.

The new approach we report in this paper has been made possible through an active partnership arrangement of the UK Highways Agency and the regional and local authorities with responsibilities for planning, transport and economic development of the area[2], which aims to develop a joined-up approach to transport and development issues. The decision-support tool underlying this approach is a new computer simulation model of transport and land use activities which was given the name 'PTOLEMY'[3]. Because this simulation model has been calibrated to represent realistically how households and industries behave in making travel and location choices, and how travel costs and times impacts on land use activities and vice versa, it can be used to test a wide range of land use and transport strategies, i.e. to compare the policy

[1] The expanding sessions on integrated land use and transport planning and modelling at the European Transport Conference since the 1990s have been a good testimony of this trend.
[2] These included the UK East Midlands Regional Assembly (EMRA), UK East Midlands Development Agency (emda), the East Midlands Airport (EMA), and the six transport authorities in the area.
[3] The acronym PTOLEMY was derived from "**P**lanning, **T**ranspo**o**rt and **L**and-use for the **E**ast **M**idlands' Economy"

options quantitatively in the assessment of their economic, social and environmental impacts. This model has built upon previous work that has been presented to the European Transport Conference (e.g. Jin, Williams and Shahkarami, 2002), and has contained within it a number of innovative features (for details see below).

This paper will provide a brief summary of the PTOLEMY model, and then focuse on three policy studies that have been undertaken using this new approach. These cover very different policy scenarios and geographic scales:

- **Case Study 1**. Regional planning policy assessment, concerning the implications of different economic forecasts and housing development strategies.
- **Case Study 2**. Regional transport assessment, concerning the effects of a wide spectrum of transport measures, including investment, regulation, road user pricing, and demand management through individualised travel marketing campaigns.
- **Case Study 3**. Local housing policy assessment, concerning the effects of local housing development options on travel demand and congestion under specific transport scenarios.

2 THE PTOLEMY MODEL

2.1 A simulation model for transport and land use activities

PTOLEMY is a strategic, integrated transport and land use activity model. Figure 1 illustrates the Nottingham-Leicester-Derby sub-region which is the model's main study area.

The primary purpose of PTOLEMY is to support the development of sub-regional spatial, economic and transport policies and Local Development Frameworks in the area. The development of PTOLEMY has benefited from significant support and advice from the Client Group, the local modelling teams, and the local planners. This support has made it possible to gather the necessary data sources across the different institutions responsible for transport and land use planning, and to test jointly transport and land use policy measures in appropriate combination scenarios.

Figure 1 **PTOLEMY: the main study area**

2.2 Modelling Approach

Conceptually the PTOLEMY model consists of four sub-models.

Regional Economic model - This has a representation of regional production, consumption, trade, land and building construction, and demographic profiles. Growth and change in these aspects define the trends in land use activities.

Land Use Activity model - This predicts business location, housing demand, and car ownership by zone, from which travel is generated as a derived demand.

Travel Demand model- This estimates the out and return journeys from where travel is produced to where it is attracted, the split of journeys between

different time periods of the day, passengers' choice among all means of travel including mechanised modes, walking and cycling, and trips made by vans and lorries.

Multi-modal Network Traffic model - This model loads the travel demand matrices onto the multi-modal network, with a feedback from the road capacity restraint function ensuring that the additional costs and times arising from congestion are fed back to the travel demand model. It produces the movements of cars, vans and lorries on road, passenger traffic on rail, bus and tram, travel costs including user charges using the network and parking, and travel times including road congestion.

Within the model, whilst travel demand is generated by regional economic and land use activities, the costs and times incurred on the multi-modal transport network is fed back into the travel demand, land use and regional economic models. The travel demand and network models are solved iteratively until a simultaneously converged equilibrium solution is achieved for travel demand and congestion estimation.

The travel costs from the equilibrated travel demand-network model are fed into land use activity modelling, with a lagged response where appropriate (e.g. some decisions regarding business and household location were made many years before, and it takes time for firms and households to respond to the current network improvements).

The main linkages between these sub-models are summarised in Figure 2

The model structure builds on the previously developed proposals for the transport component of the model for the area, and has made important improvements to the methodology of the land-use activity and travel demand components. These land use model improvements have been influenced by experience gained through working with similar strategic models in other parts of the UK and Europe, most recently through the Multi Modal Studies, the Road Pricing Feasibility Study and the National Transport Model.

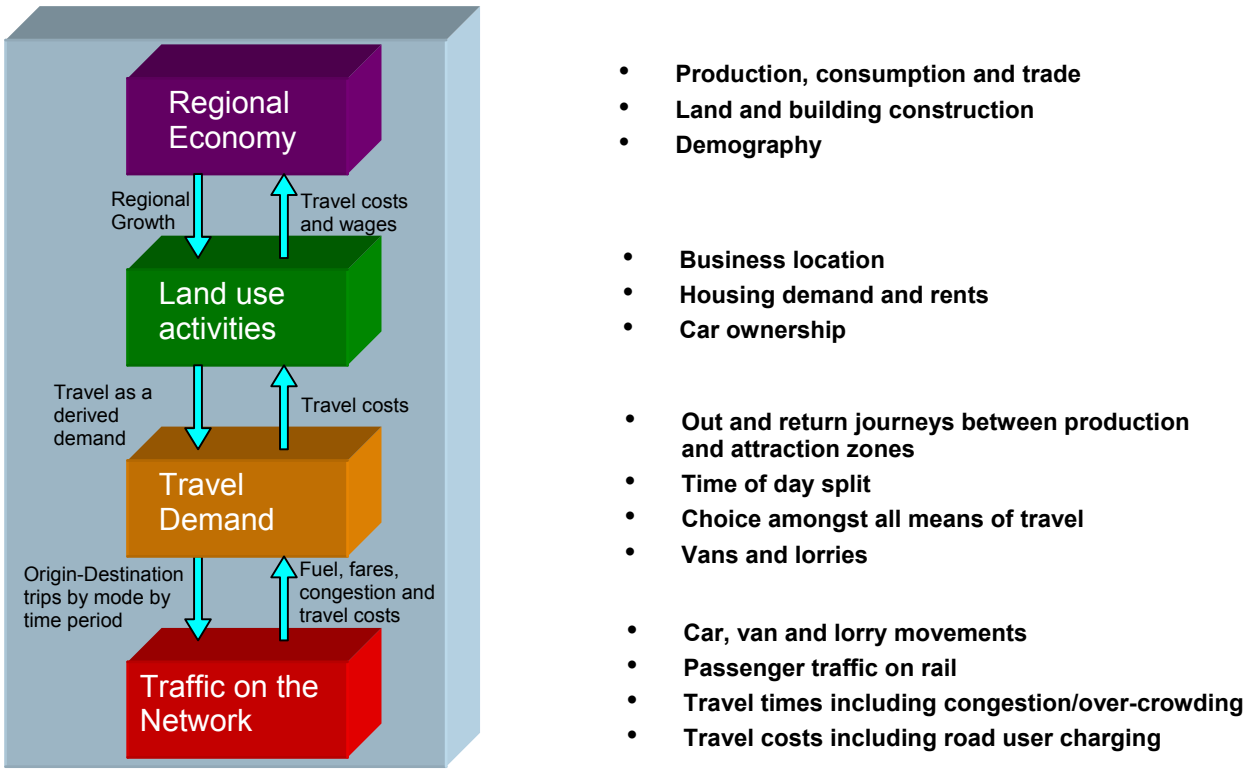

Figure 2 Main components of the PTOLEMY model

The design of the model structure reflects the requirements to:

- represent an increasingly complex range of behavioural responses to policy.
- retain sufficient spatial detail.
- avoid imposing an unacceptable computational burden during policy tests.

WSP Policy & Research (2006) provides further technical details of the model.

2.3 Model design features

The PTOLEMY model is designed to test future land-use planning and transport policy initiatives in the sub-region. This aims to take account of:

- The impacts of economic, demographic and land-use change on the spatial and modal pattern of passenger travel demand and traffic.
- The impacts of transport costs and services on the location of employment and households.
- The interaction between economic growth and transport in the sub-region.
- The growth in lorries, vans, and through-traffic by car traversing the motorways and trunk roads, including impacts of surface access to the East Midlands Airport.

Compared with the existing local models that have been developed for specific scheme or policy assessments, PTOLEMY is focused primarily at the strategic level. It covers the entire geographic area consistently, and represents in particular land use activity and multi-modal transport choices throughout the sub-region. It can thus be used to explore the impacts of both major development schemes, and the accumulated effects of small scale developments (e.g. infill, densification, windfall sties). The model contains sufficient spatial and socio-economic detail to facilitate the analysis of:

- the impacts of changes in land-use and economic activity on travel behaviour and traffic patterns, and
- the impact of transport on development and regeneration.

Through extensive segmentation of the industries, employee types, and household socio-economic classification within the model, PTOLEMY represents well the distinct economic, demographic and social composition of work and home locations and the associated travel demand patterns. This detailed level of segmentation also enables that model to differentiate patterns of change over time.

2.4 Role of the PTOLEMY model vs local traffic models

PTOLEMY and the existing transport models in the sub-region play complementary roles in forecasting and appraisal.

Geographic coverage

First of all, PTOLEMY and the local models have somewhat different geographic coverage

PTOLEMY is a strategic model that covers the entire sub-region whilst the local models, on the other hand, are focused on the respective cities or scheme for which they have been developed; the level of spatial detail in these models falls away rapidly outside the urban boundary.

Strengths of the models

The strengths and weaknesses of the models are also different:

PTOLEMY is designed to be a strategic model that is uniform and comprehensive in its potential to address policy initiatives.

- Its key strength is in the representation of the wide range of short and longer term behavioural responses that it represents, in both the land use and transport markets.
- It models the changes in the locations of households, the changes in matrices of trips and in average trip lengths at a detailed level of segmentation of households by socio-economic classification, household size and car ownership.
- To achieve this while retaining computational feasibility, it sacrifices some spatial detail and so, relative to the local models, it may be less precise for testing small scale local network improvements.
- In this manner it is complementary to the spatially more detailed local models.
- PTOLEMY is uniquely placed to test strategic land use and transport policy issues, because of its wide geographic coverage and comprehensive representation of the land use and transport responses to policy intervention.

The local models, by contrast, have their strength in providing detailed simulation of local network effects, including junction movements and congestion within hourly traffic assignment periods. For scheme appraisals that require this local level of precision, the local model results should be used in preference to the PTOLEMY outputs.

Consequently, PTOLEMY and the Local models should be used to support each other, rather than in isolation.

3 CASE STUDY 1: TESTING REGIONAL HOUSING POLICY OPTIONS

This test highlights the capability of using PTOLEMY to determine the sub-region wide implications of differing policy options (WSP Policy & Research. 2007).

The test consisted of two different housing options and two economic forecasts that are combined to produce four policy scenarios. The housing options and economic forecasts are shown in Table 1 and Table 2

Table 1: Dwelling test options

Dwelling test options	
D1: Dwelling Option 1	Trend based growth assumptions from the Department for Communities and Local Government projections of households.
D2: Dwelling Option 2	Policy based growth determined from the East Midlands draft-RSS (Regional Spatial Strategy).
These two options produce similar levels of growth over the period 2006 to 2026, but with alternative patterns of distribution, the draft-RSS concentrating growth within the main urban areas of Nottingham, Leicester and Derby.	

Table 2: Employment test options

Employment test forecasts	
E1: Employment Forecast 1	Employment forecast based upon TEMPRO 5.3, producing 5.9% growth over the period 2006 to 2016 and 3.4% growth over the period 2016 to 2026.
E2: Employment Forecast 2	Alternative employment forecast with 0.49% from 2001 to 2016, this resulted in -3.4% growth over the period 2006 to 2016, and was extrapolated to produce 1.3% growth over the period 2016 to 2026.
The two options have significant differences in economic growth over the two time period 2006-2016 and 2016-2026, with economic growth much higher in the Employment 1 test option.	

The results from the model show that balanced growth between employment and housing is important. Whilst the availability of housing attracts more workers to live in the PTOLEMY area, the level of employment growth also influences the pattern of in- and out-commuting from outside the study area

Table 3 shows the levels of total employment (i.e. total number of employed persons at the workplace), employed residents living in the study area, and in and out commuting of the study area by scenario. The results highlight the large increase in commuting out of the sub-region in the period 2006-2016 as employment opportunities drop by 4% in the E2 test whilst the dwelling growth encourages the growth in employed residents by between 9% and 12% for the two housing options.

Table 3: The change in the number of employed residents for the four scenario, and the implications of in and out commuting from the sub-regions

	2001-2006	2006 -2016				2016 – 2026			
		E1-D1	E1-D2	E2-D1	E2-D2	E1-D1	E1-D2	E2-D1	E2-D2
Total employment in study area	4%	6%	6%	-4%	-4%	3%	3%	1%	1%
Total employed residents in study area	4%	12%	9%	12%	9%	6%	10%	6%	10%
Total in-commuters	21%	6%	6%	-4%	-4%	4%	4%	1%	2%
Total out-commuters	15%	57%	36%	132%	112%	21%	51%	23%	41%

The transport impacts have been tested on the AM peak network, which is expected to have the highest level of congestion during a working day.

The results in Table 4 show that:

- There is a significant growth in travel demand and traffic in all scenarios, ranging from +15% under the E1-D2 scenario to +31% under the E2-D1 one in terms of passenger-km for 2006-2016.
- Lower employment growth does not necessarily lead to low traffic growth. For example, under the E2 employment assumptions which sees a low level of employment growth, travel demand still grows markedly because of a) the restructuring of the economy – service industries and white-collar workers replacing primary/manufacturing and blue-collar workers, and b) a marked increase in out-commuting owing to the imbalance between relatively low growth in jobs and relatively high growth in housing.
- Building more dwellings within the Cities has generally reduced the average length of trips by residents there, and hence overall travel demand, particularly for commuting. For example, the E1-D2 scenario is likely to have the lowest overall travel demand within the AM peak (15% increase 2006-16, as opposed to 31% under E2-D1. The E1-D2 scenario also has a slightly lower growth of car travel, owing to the fact that more new housing is built in urban areas with a relatively good level of PT provision.

Table 4: Changes in travel characteristics from 2016 to 2026 by trip purpose for the four scenarios

		Travel by all people living and working in the PTOLEMY area (AM peak period)			Growth 2006 -2026		
		Passenger trips (000)	Passenger-km (000)	Average journey length (km)	Passenger trips	Passenger-km	Average journey length
2016 E1-D1	Commuting	678	14,607	21.5	4%	25%	20%
	Education	559	2,427	4.3	7%	9%	2%
	Other private trips	299	4,425	14.8	11%	12%	1%
	Employer's Business	33	1,098	33.2	22%	18%	-4%
	All	1,569	22,557	14.4	7%	20%	13%
2016 E1-D2	Commuting	666	13,792	20.7	2%	18%	16%
	Education	552	2,384	4.3	5%	7%	2%
	Other private trips	293	4,318	14.8	9%	10%	1%
	Employer's Business	33	1,086	33.4	20%	16%	-3%
	All	1,543	21,580	14.0	5%	15%	10%
2016 E2-D1	Commuting	672	16,597	24.7	3%	43%	38%
	Education	560	2,434	4.3	7%	10%	2%
	Other private trips	298	4,448	14.9	11%	13%	2%
	Employer's Business	33	1,111	33.9	21%	19%	-2%
	All	1,563	24,590	15.7	6%	31%	23%
2016 E2-D2	Commuting	660	15,777	23.9	1%	35%	34%
	Education	553	2,394	4.3	6%	8%	2%
	Other private trips	292	4,346	14.9	9%	10%	2%
	Employer's Business	32	1,100	34.1	19%	18%	-1%
	All	1,537	23,617	15.4	5%	26%	21%

The implications on road traffic speed are shown for the E1-D2 scenario in Figure 3 This shows the worsening highway congestion in 2016 compared to 2006, particularly in suburban and rural networks. It also shows the improvements in road speeds that occur once road schemes have been implemented, in particular improvements on the M1 J21-J28, the A46 and A453.

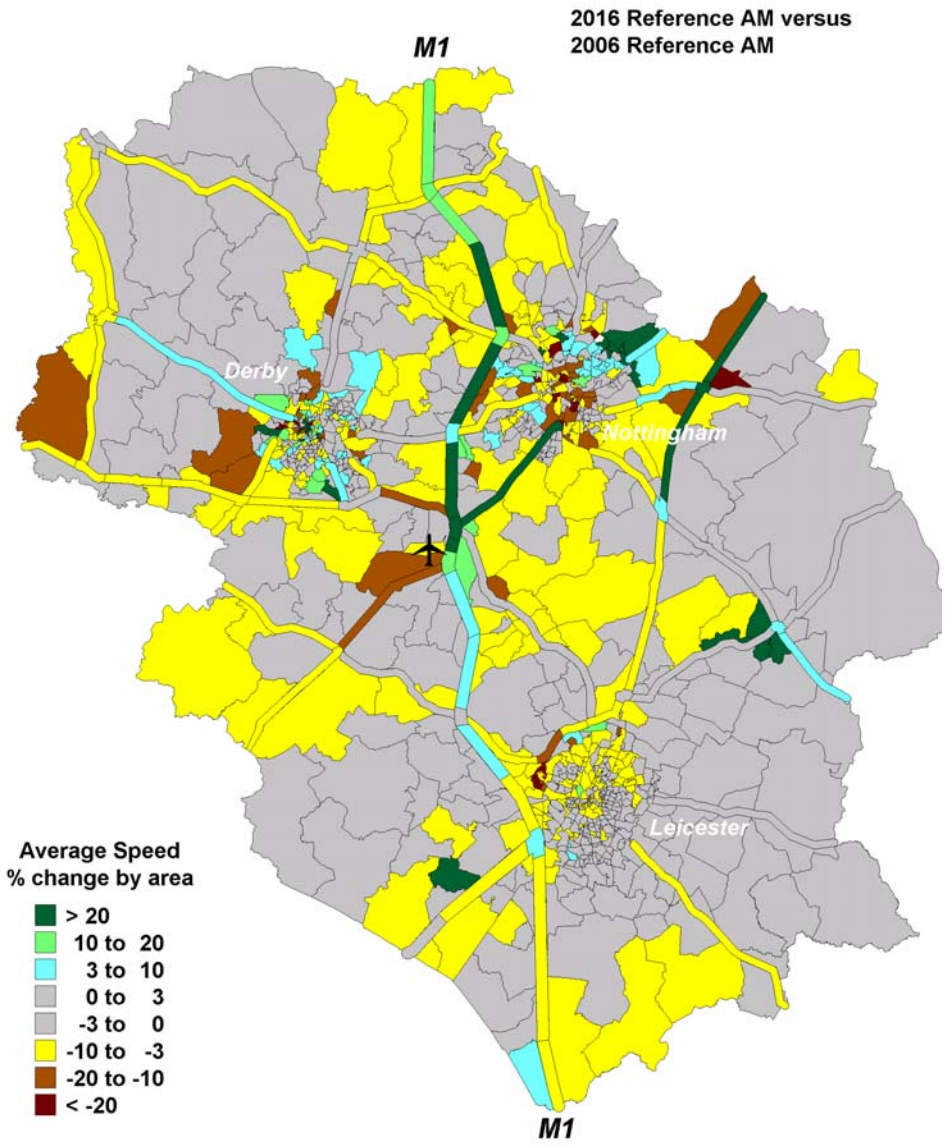

Figure 3: Percentage Change in AM peak Average Road Speeds 2006-2016: E1-D1 Scenario

Note: The average road speeds are an output of the model and analysed here by model zone and trunk road sections (i.e. the average speeds are weighted by the traffic on all road links contained within each land parcel shown in the figure above). This is an effective way to indicate the level of congestion for a given time period.

4 CASE STUDY 2: TESTING REGIONAL TRANSPORT POLICY OPTIONS

As part of the UK governments aim of finding new and innovate ways of reducing congestion, the 6C's, as they are known, (Derby City Council, Derbyshire County Council, Leicester City Council, Leicestershire County Council, Nottingham City Council, Nottinghamshire County Council - ie 6 Councils) were awarded funds to undertake an initial round of investigative work looking at congestion, and congestion reduction measures within the area. (The Six Authorities (6C's) Congestion Management Study. 2008)

A modelling task was undertaken which involved using PTOLEMY to provide a strategic level assessment of changes in travel behaviour, mode shift, as well as congestion levels.

The investigative work into congestion reduction lead to a package of measures being proposed that included:

- Implementing a congestion-charge cordon around Nottingham, Leicester and Derby involving a charge of around £1.75 on inbound traffic movements in the morning peak and outbound traffic movements in the evening peak. No charge was incurred outside the peak periods.
- Measures that would allow or encourage travellers to change from using the car to making use of alternative transport modes:
    - **Core measures**: primarily concerned with significantly improving bus and 'park and ride' services and mass transit schemes.
    - **Public transport fare reduction**: implementation of a 30% reduction of peak period bus, tram and park and ride fares.
    - **Smarter choices**: Involving the implementation of a high intensity programme of interventions to encourage and enable people to make better informed travel choices that did not involve the car. This involves personalised travel planning, workplace and school travel plans.

Results from the package of measures showed that compared to strategy based on a continuation of current policy:

- the number of car trips reduced by 15% although the passenger-km reduced by only 7% suggesting that shorter journeys were transferring from the car to alternative modes.
- The average monetary cost of the car journeys increased by 31% highlighting the impact of the congestion charge.
- Park and Ride use increased significantly with travellers closer to the park and ride sites making more use of the facilities.
- Bus use increased by 70% to 207,000 passenger trips in the AM peak period with the average journey length increasing by 6%.
- The impact of the bus-fare reduction was seen as the average fare reduced by 25% (the 30% fare reduction being diluted by the increased distance travelled).
- Train use which did not see a fare reduction still saw an increase in use, whilst the tram in Nottingham saw a 67% increase in patronage with the introduction of new routes.
- Walking and cycling saw a 8% increase.

The results from the test did show that the results would be successful in reducing car use with the car modal share reducing by 8.2% as travellers move to increase the use of the bus (4.9% increase) and walking (2.1% increase)

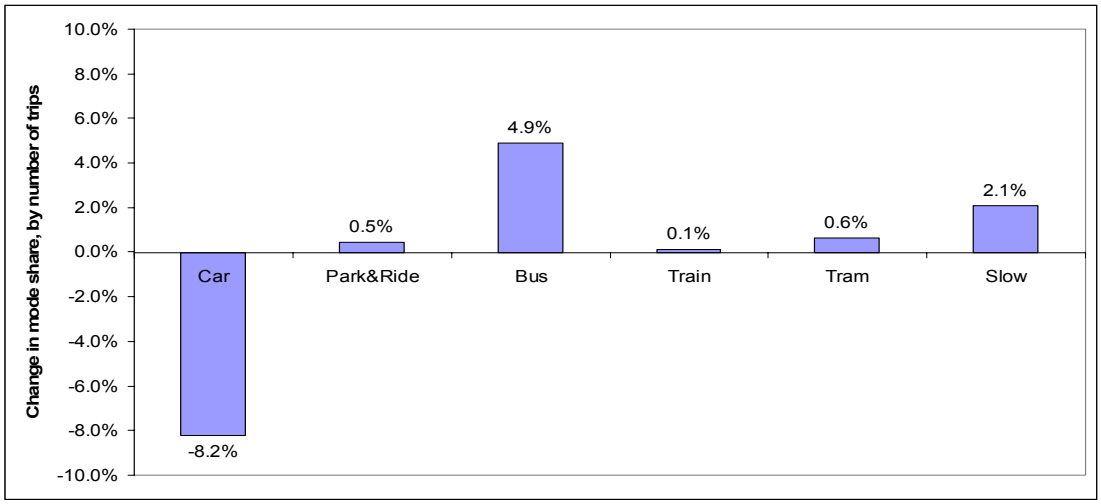

Figure 4: Change in modal share Full TIF package compared to the 2016 Reference Case

5 CASE STUDY 3: TESTING LOCAL HOUSING GROWTH OPTIONS

As part of the local planning process the local authorities wish to test the strategic impacts of housing options within Leicestershire The testing of housing options provides Leicestershire County Council, as strategic planning authority and highway authority, with initial feedback on possible options for the location of new housing in the County, the likely employment catchment areas as well as information on the congestion effects from the development. (WSP Policy & Research. 2008).

For these local tests the model was first checked for its ability to match observed traffic flows, and where necessary the model was enhanced to provide an improved match. This ensures that congestion levels modelled in the 2006 network broadly match what was observed. Figure 5 and Figure 6 show the results of the traffic validation showing PTOLEMY can provide a good match to observed traffic flows.

A test was undertaken which involved assessing the impact of locating 15,000 houses in Coalville, Leicestershire. It is important to note that this scale was specified by the client for testing purposes only; they were not intended to imply any site allocation proposals (which are a matter for district councils).

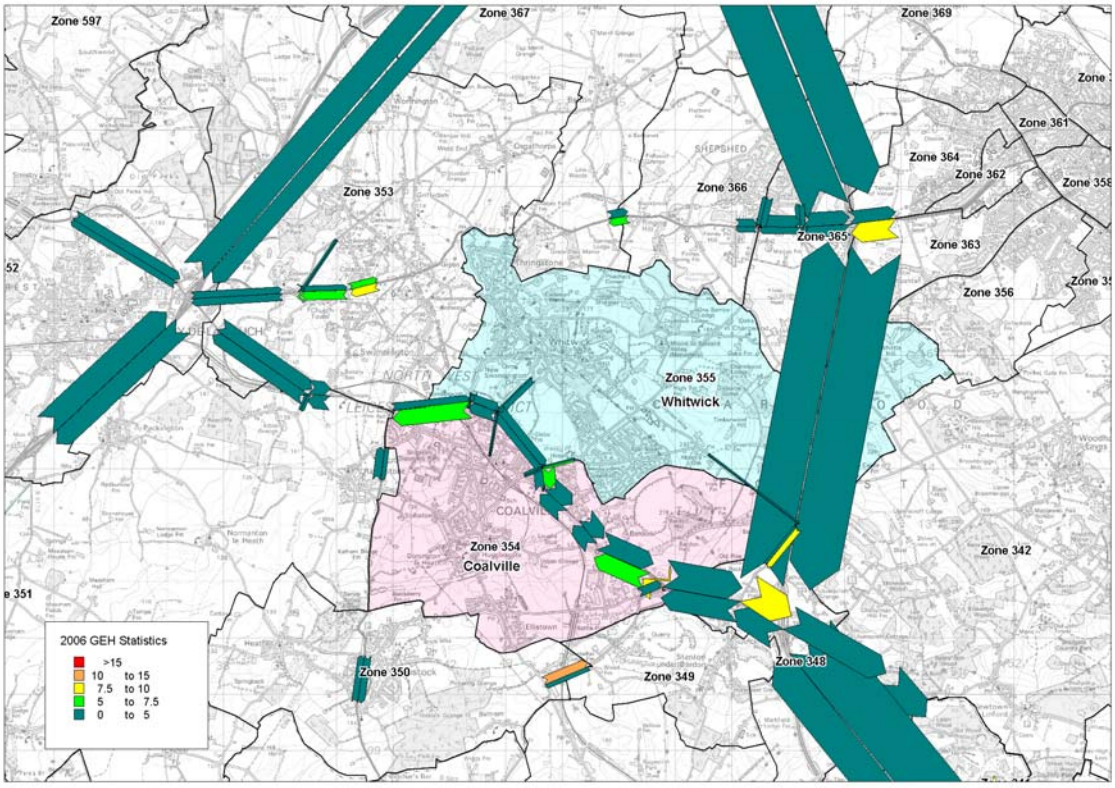

Figure 5: Comparison between the observed traffic counts (total PCU) and the modelled flows in the morning peak. The difference is shown as the GEH statistic

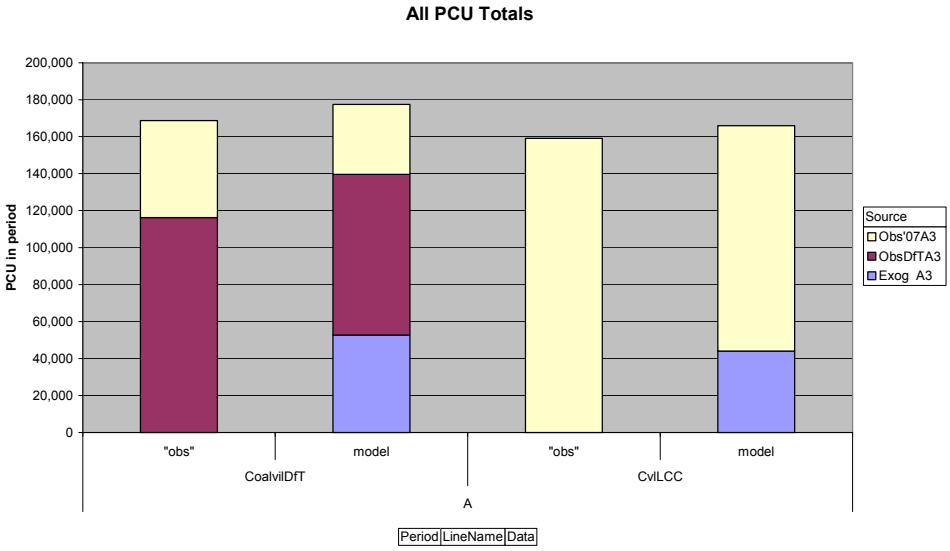

Figure 6 Modelled traffic flows compared to DfT monitoring sites or Leicester County Council monitoring sites.

Note that where a DfT and LCC count site monitor the same stretch of road, then LCC count is used in preference to the counts obtained from the DfT's traffic database.

In understanding the implications of this allocation the housing rent indicator is used which provides a useful insight into the role of supply and demand in the desirability of household location. The main purpose of the housing rent indicator (HRI) is to analyse the variations in the supply-/demand balance in the housing market of the 3 Cities sub-region in a given year. This indicator is defined as the average monthly outlay in the household expenditure that is spent to cover the mortgage costs (capital plus interest payments) in the case of an owner-occupier, or the rentals in the case of a renter. It is a zonal average, which masks a wide range of variations in the actual payments made by households. It is a function of

- Housing supply, as assumed in the test scenarios.
- Housing demand, which in turn is a function of job opportunities, ease of travel and residential attractiveness of the area.

The housing rent indicator (HRI) thus reflects the balance of housing supply and demand in each model zone within the 3 Cities sub-region, and provides a summary of the impacts of new housing on the housing market.

It should be noted that the HRI does not represent the effects arising from the macro-economic factors, such as prevailing interest changes, or the ease of credit. Thus it should not be used as a general indicator of house price changes over time. Figure 7 shows the effects in which a substantial amount of housing supply has been added, particularly in Coalville. The effects of increased supply on HRI can be seen clearly not only in Coalville, but also in a number of zones of similar socio-economic characteristics in the 3 Cities sub-region.

- Coalville would see the largest reduction with a 5% to 10% reduction in the HRI.
- HRI's in Loughborough and Leicester are also significantly affected with reductions in HRI of around 2% to 5%.
- In the wider area a slightly reduced effect (1%-2%) can be observed in the Coalville-Ashby-Burton corridor, also on the main route towards Hinckley, and along the M1 Motorway, as well as within Derby and Nottingham.

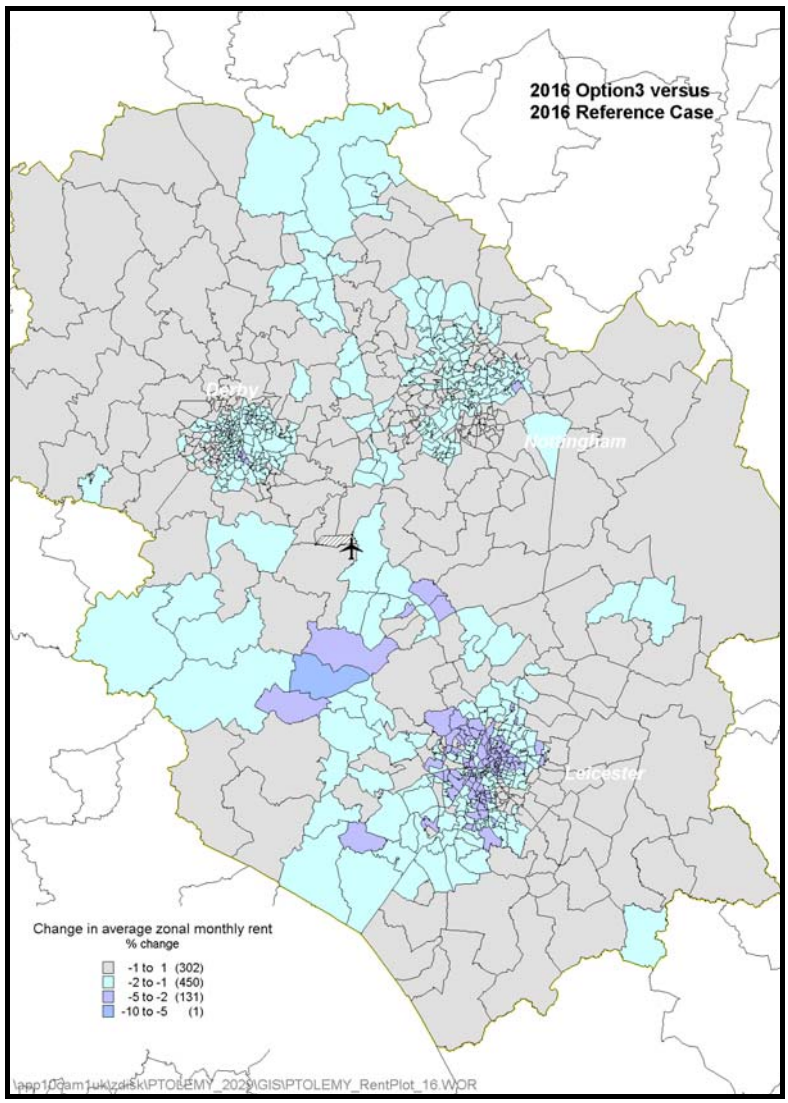

Figure 7: Housing rent indicator: % change Option 3 test vs 2016 Reference Case

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Commuting patterns can be observed in Figure 8, the plot showing the scale of the commuting journeys from Coalville.

Finally Figure 9 shows changes in average traffic speeds. This shows that the traffic speeds towards the M1 reduce by between 10 and 20% relative to the Reference Case. The additional housing to the west of Coalville causes the road speed to drop on the A447 by between 2% and 5%. There is also addition traffic on the B591 towards Loughborough where car speeds become slower by 2% to 5%.

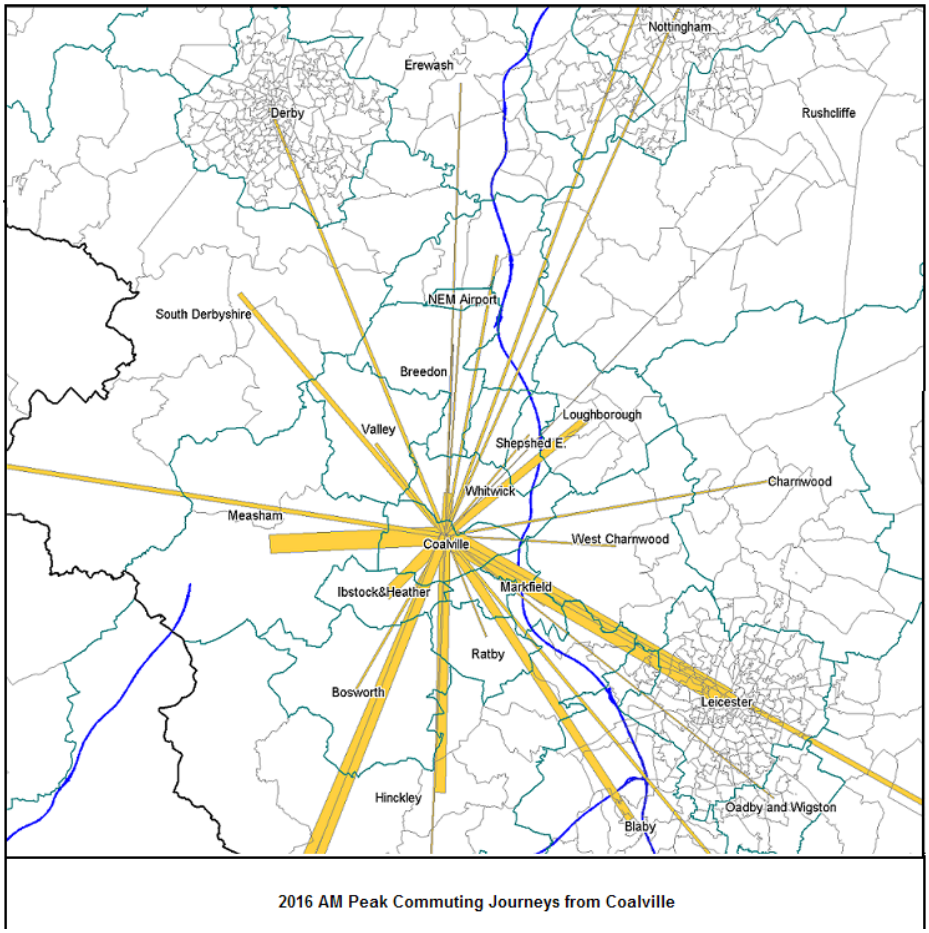

Figure 8 2016 Travel to Work Pattern from Coalville: Labour catchment area under the Reference Case (upper chart)

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Table 5: Summary travel statistics for the housing option test in 2016

Journey Origin	Passenger trips in 2016 ref case (x1000)	Passenger trip-kms in 2016 ref case (million)	% change of passenger trips vs ref case	% change of passenger trip-kms vs ref case
Coalville	16	0.20	36%	39%
Whitwick	11	0.15	13%	15%
Leicestershire	599	6.75	0%	0%
Nottinghamshire	465	4.30	0%	0%
Derbyshire	433	4.80	0%	0%
external zones	72	5.03	-4%	-4%
All	1594	21.26	0%	-1%

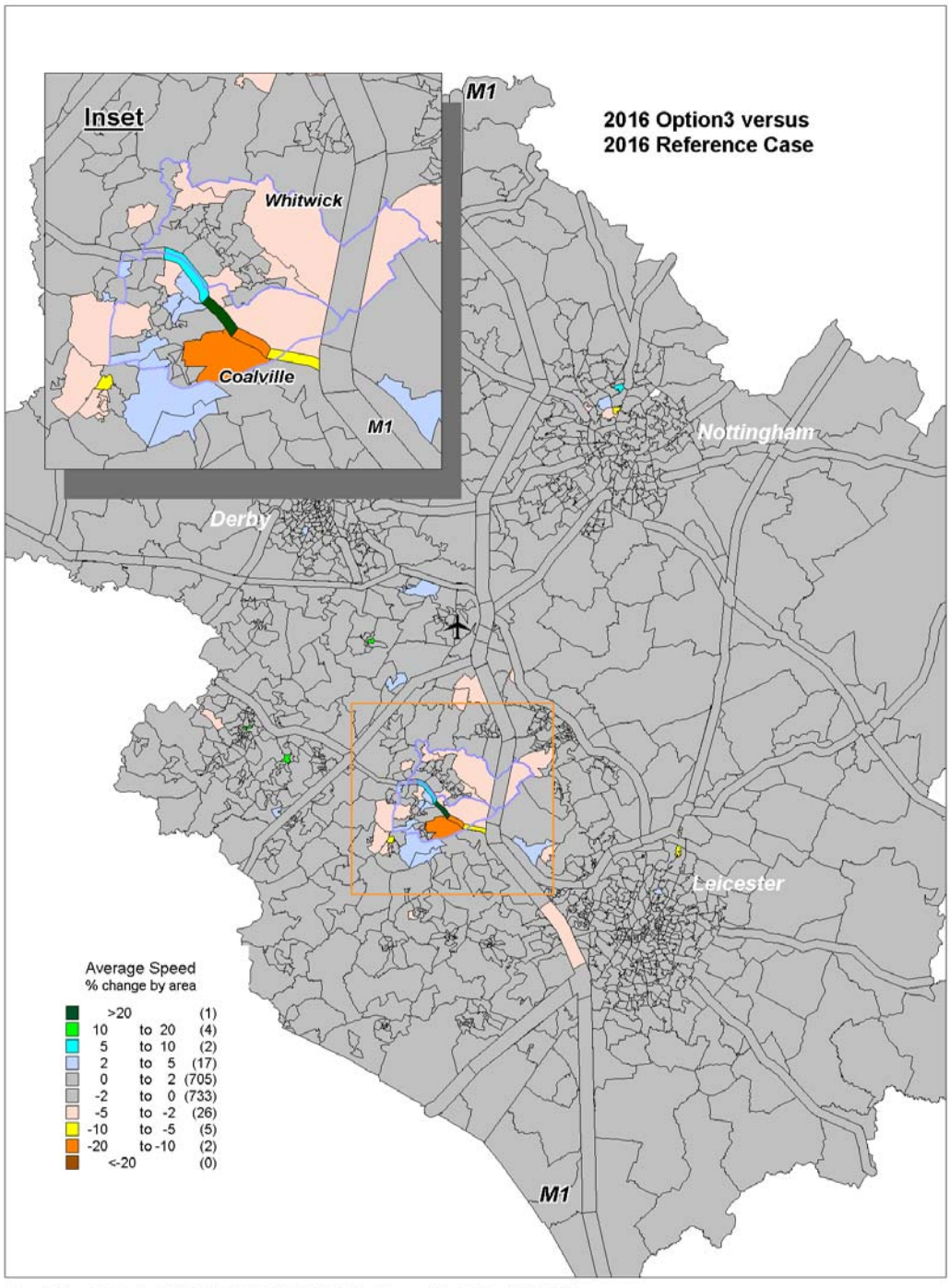

Figure 9 Changes in average car speeds for the AM peak period (7am to 10am) in 2016: Option 3 vs 2016 Reference Case

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6 CONCLUSIONS

PTOLEMY has been developed to undertake a range of policy test within the 3-cities sub region of the East Midlands. The strategic nature of the model allows insights to be gained from complex policy interventions for both regional and local tests involving both transport and land use.

- Case Study 1. Demonstrates the importance between the balance of employment and housing.
- Case Study 2. Shows that a package of transport measures would be successful in reducing car traffic to support the economic development ambitions of the sub-region.
- In Case Study 3: Shows the likely impacts to the local housing market, probable commuting patterns and the impact of development on the highway network.

The model is now being extensively used by both public and private bodies within the region, in a number of new policy applications including eco-town proposals, Housing Market Area proposals, strategic rail freight interchange schemes, and local housing and transport mitigation strategies under the UK Local Development Framework.

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