Modelling Land Use – Transport Dynamics:
The London to Ipswich Corridor in the United Kingdom

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This paper describes the use of an integrated land use and transport model in the development of a long-term strategy for sustainable transport in the London to Ipswich Corridor (LOIS) in the UK. The project is one of a number of larger scale corridor studies commissioned by the UK government as part of a major programme of Multi Modal Studies. The application of the model is reviewed in the dynamic interactions between land use and transport policies, and the choice behaviours of the households and travellers in the region. This helps to explain the ways in which policy initiatives may be assessed in terms of the effectiveness in achieving sustainability objectives for the corridor.

1. Introduction

The London to Ipswich Corridor Study (LOIS) is one of the UK Multi Modal Transport Studies, which were initiated following the publication of the Government's Transport White Paper (DETR, 1998). Of particular relevance, the White Paper has widened the brief of transport studies in order to acknowledge the relationships between transport, land use, environment and the economy. The approach laid down in the White Paper was subsequently taken forward and elaborated through the Multi Modal Transport Studies. The specific project objectives of a multi-modal study area were different for the particular local circumstances pertained to each corridor. A comparison of LOIS with, e.g. Simmonds (this issue) would give an indication of the similarities and differences that face the UK regions.
LOIS identified a number of project-specific objectives related to current transport problems and sub-regional growth and development issues. These aimed to assess the current and future demand for travel, and to identify current transport problems and the likelihood of further transport problems arising from natural growth and the effects of various planning strategies. The time horizon of the study was 2016 and 2031.

The policy measures under consideration included those to make better use of existing infrastructure, to give priority to public transport, pedestrians and cycling where appropriate, to provide new infrastructure and modal opportunities, and to charge urban and inter-urban roads. Transport developments outside the corridor would be considered where there is significant impact. The combinations of policy options would be tested in a consistent manner against the criteria identified in the Government's New Approach to Appraisal. The study was required to recommend one or more plans, which would meet national, regional and local objectives. It was also to identify from those plans a preferred strategy for inclusion in the Regional Planning Guidance, and to identify a range of measures needed to implement that preferred strategy.

The project objectives underlined the need for a theoretically well founded approach to forecasting changes in travel demand over a period of 15-30 years. Also, the study area cannot be analysed in isolation to the adjacent transport corridors. These considerations have dictated that the modelling tool would have to represent the land use and transport interactions not only in the study area, but also those in the wider region, of which the LOIS corridor is an integral part.

Section 2 below sets the scene for modelling through examining the role and influence of land use and planning policy in shaping travel demand in the corridor. This is followed by a description of the policy model that has been used to represent land use and transport interaction. The model results are considered next. The paper concludes with an assessment of the approach and the potential for enhancements in the future.

2. Land use, planning and travel demand

2.1 Geographic context

Although described as the London to Ipswich Corridor and focused on the A12 trunk route, the LOIS study area is closely integrated with the rest of London, the M11 corridor to the west, and the A13 corridor to the south. Transport hubs of national importance are found in the area: Stansted Airport lies on the western edge of the study area, the Ports of Harwich and Felixstowe on the East Coast are major Gateways to Continental Europe. The area is served by busy commuter rail services on the London Liverpool Street – Ipswich – Norwich line, which runs roughly in parallel to the trunk road A12 (Figure 1).

The corridor has been part of the East of England, the fastest growing region of the UK, and indeed one of the fastest and most dynamic regions in Europe. Between 1981 and 1991 the resident population in the area grew by 9.9 per cent, whilst between 1991 and 1997 the growth accelerated further to nearly 20 per cent (ONS, 1999). This is more than twice the figure for the UK as a whole, and just ahead of the more populous, neighbouring South East Region. During 1981-1997, the annual rate of net in-migration increased two and a half fold, underlining the attractions of the region.

The LOIS Corridor exhibits serious local imbalances between homes and jobs. For the past fifty years, the corridor has supplied a large number of homes for workers relocating from London. The growth in housing has not been matched by a corresponding increase in employment opportunities. The traditional manufacturing employment in the major towns in

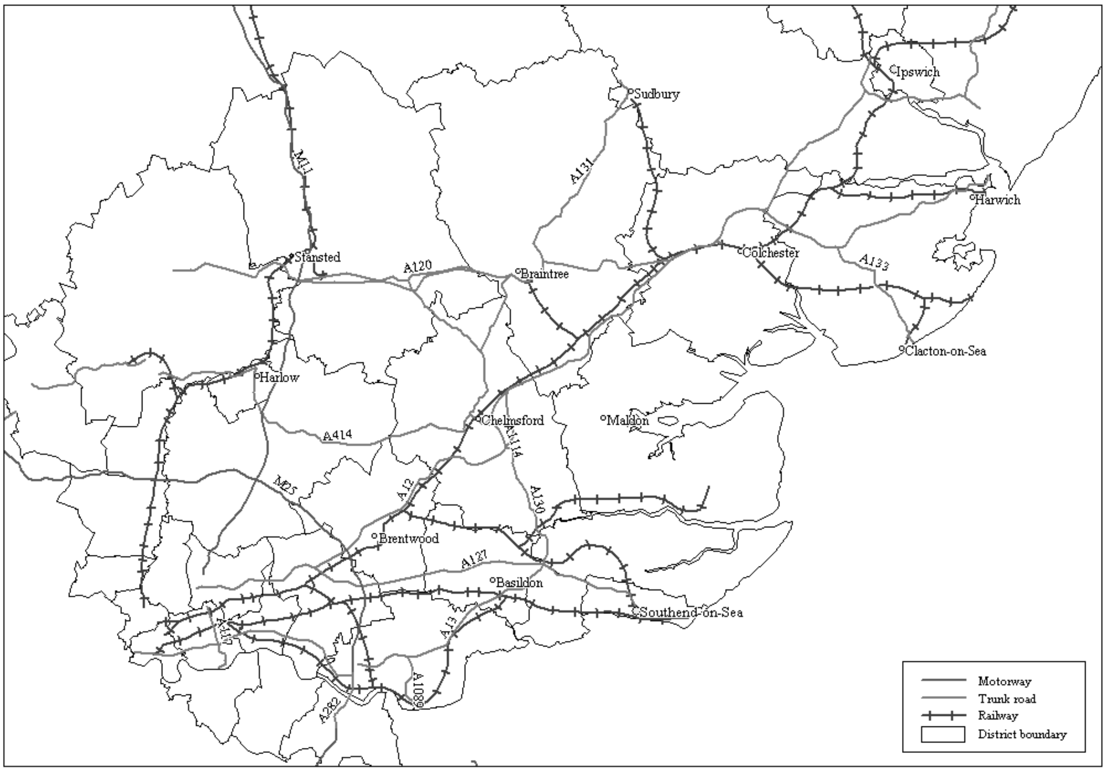

Figure 1. The London to Ipswich Corridor Multimodal Corridor

the A12 Corridor has declined. The imbalance had previously been confined to the locations close to London, but it has in recent years extended to the north and west of the corridor. Out-commuting has been growing as a result.

In terms of built form, there is a stark contrast between the densely built up towns and the rural areas. In most urban areas, property prices tend to be high and future land availability poor. On the coastal fringes and in the old industrial areas of northeast London, there is potential land supply, but these areas are disadvantaged by a combination of unattractive location and poor accessibility.

2.2 Current transport issues

The multi-modal study was commissioned mainly in response to the congestion on various sections of the A12 between its junction with the M25 South of Brentwood and the junction with the A14, South of Ipswich. The road is a mixture of dual 2-lane and dual 3-lane all-purpose carriageway with a combination of grade separated junctions and local accesses, not all of them designed to current safety standards. The traffic flow ranges from approximately 40,000 to 75,000 vehicles per day along the length. It is a multi-purpose road, acting as strategic route between the East Coast and London as well as being a local distributor road carrying commuter traffic to and from the major towns along its length (i.e. Ipswich, Colchester, Chelmsford and Brentwood), and providing a fast route access for many other small towns and villages. The existence of congestion on the A12 has widespread effects beyond the immediate corridor with traffic diverting onto alternative, sometimes unsuitable, routes through nearby communities.

The A12 is paralleled for much of its length by the Great Eastern railway line from the Liverpool Street Terminal in London to Ipswich and then Norwich. This line is mainly two tracks, though there are 4 tracks between Shenfield and London. It carries a mix of traffic with local stopping trains between London and Colchester mixed in with Inter City expresses to Norwich, and freight trains from the ports of Harwich and Felixstowe. The route is currently operating close to capacity in terms of train paths.

2.3 Land use and transport dynamics

Understanding the evolution of travel patterns is a prerequisite to an appreciation of current transport problems. Firstly, a better understanding of the socio-economic profile of an area and the way in which this has influenced travel demand helps to identify how future demand for transport is likely to develop and how demand will respond to changes in both economic conditions and policy. Secondly, an improved understanding of travel patterns and the underlying interactions between economic activity, land use and transport provides a guide to the likely sectoral and spatial impacts of future planning and transport policies. It also provides a starting point for the process of developing a spatial framework for analysis.

The existing pattern of settlement is dispersed, which means it is often difficult for public transport to serve efficiently. A significant proportion of the population live in the area between the A12 and the M11, away from the strategic transport network. East-West movements are dependent on the road A120, which leads from the East Coast to Stansted Airport. Opportunities for East-West movement by public transport are far more limited than radial movements to/from London.

Among the population groups, the elderly (over 64's) are more numerous away from the main urban centres - with particular clusters in peripheral areas including the seaside towns and less accessible parts of Babergh and Tendring, along the eastern and northern edge of the corridor. This elderly group suffers from mobility problems. The distribution of the unemployed shows a similar pattern with clusters on the periphery of the Corridor - Notably in central Ipswich, coastal parts of Tendring, and northeast London. The lower car ownership of this demographic group further compounds the accessibility problem.

The evolution of personal mobility is characterised by a stark contrast in *car ownership: m*ore than 1 in 3 households now owns 2 or more cars; however at the other end of the spectrum less than 1 in 4 has no car at all. The distribution of households with no car available is greatest in the urban areas and parts of the coastal fringe where incomes are generally lower and the proportion of one-adult households is higher. Multiple car-ownership is higher in the more affluent and less densely populated areas that are poorly served by public transport and more remote from the main employment centres.

The jobs are focused on the London boroughs/ main urban areas as might be expected (see Figure 2.) The residential location of the workers on the other hand, contrasts with the locations of the jobs thus highlighting the significant mismatch between incidence of job opportunities and the location of the workforce (see Figure 3).

Figure 2. Number of employees working in each Census Ward

As a result, large parts of the study area have exceptionally high levels of long-distance commuting. There is a widespread incidence of journeys to work of >20kms.

Figure 4 shows that the car mode has the largest mode share followed by walk and cycle. Bus is less popular but captures a relatively larger proportion of trips in large towns like Colchester and Ipswich. Rail captures a greater share closer to London but overall remains a minor proportion of all journeys to work.

Figure 3. Number of employees living in each Census Ward

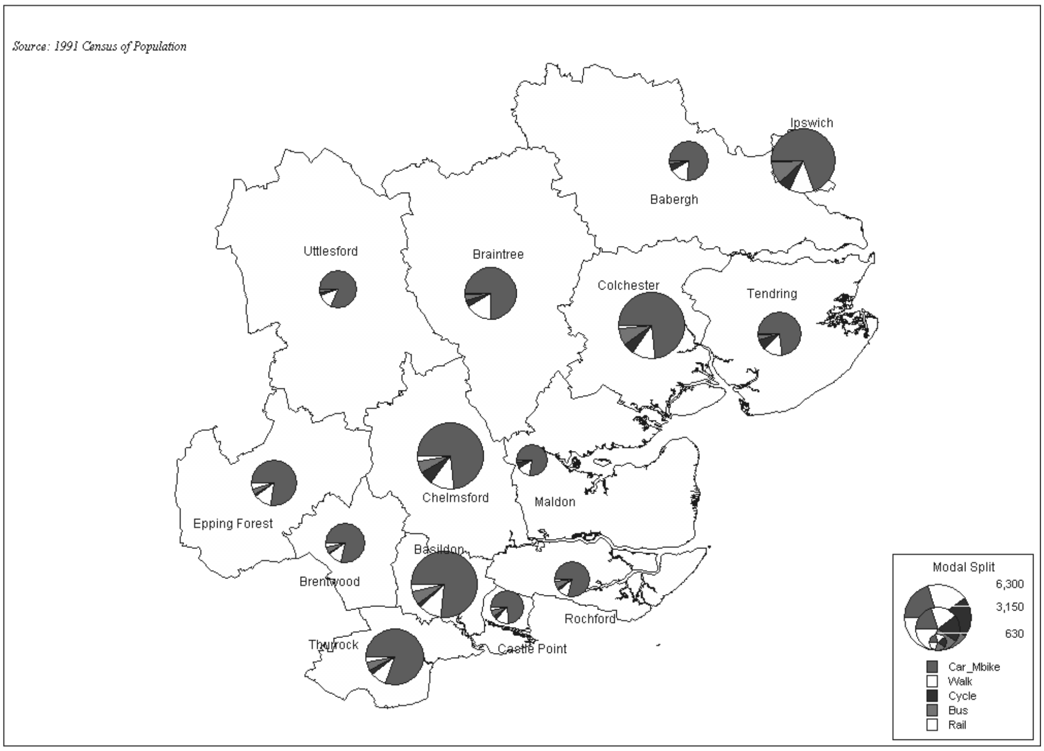

Figure 4. Main mode of transport for journeys to work (originating from each home district)

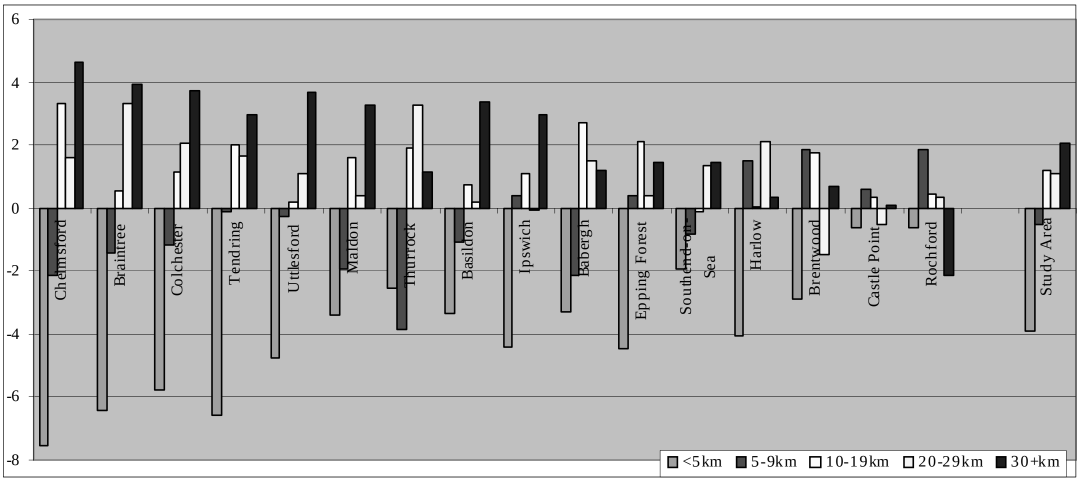

Figure 5. Percentage change in journey to work distances by town in the study area: 1981 - 1991

Figure 5 outlines the changes in travel during 1981-91, using the information from the Census. Across the corridor there has been a marked decrease in the number of shorter journeys to work (less than 5 kilometres). There has been an even more pronounced increase in the number of longer journeys (more than 30kms). This is in keeping with changes at the national level where similar trends are also observed for other journeys. Other information available at the national level shows that virtually all of the increase in travel distances is explained by growth in car travel. Distances travelled by other modes remained fairly constant.

3. Modelling approach

The LOIS Strategic Policy Model, which has been used to represent land use and transport interaction, is a derivative of LASER3.0, a land use and transport model that the Cambridge based Policy and Research Unit of WSP (formerly ME&P) has developed for the UK Department for Transport. An outline description of the model structure is provided below and further discussions of the model are found in Jin, Williams and Shahkarami (2002).
The interaction between land use and transport is modelled through information flows between the main steps as follows:

a **Initial activity generation by basic employment.** The model takes all exogenous employment (which is everything other than local retail and education services) in each zone as given, and segments the persons employed in the exogenous industries by socio-economic group and car ownership.

b **Spatial distribution of employed residents.** A logit-based discrete choice model is applied to simulate the probabilistic choice of residential location of the workers. The resulting flow of employed residents from the residential zones to the work zones become the underlying pattern for journeys to work.

c **Secondary activity generation**. Employed households (i.e. those containing at least one employed adult) are derived in each zone via employed residents estimated in (b). The model does not generate households that contain no employed adults, but allows external estimates to be input into the model by zone. Demand is generated by all households for local service employment, production of non-commuting trips, and housing. Local service employment then generates further demand for households, and the additional households in turn generate their demand for services, trips, housing, and so forth. The secondary activity generation is based on (a) and (b), and completes all activity and trip production in the model.

d **Spatial distribution for non-commuting trips**. The non-commuting trips are segmented by purpose into education, shopping and other personal business, leisure, and employer's business. Logit-based discrete choice models are applied to distribute the trips for each origin zone.

e **Modal split.** The commuting and non-commuting journeys are attributed to modes of transport that are available between each pair of origin and destination zones. Logit-based multi-level multinomial discrete choice models were calibrated for the travel demand segments on the London Area Transport Survey and National Travel Survey data.

f **Link assignment.** The journeys on each mode are assigned to the morning peak road and rail (including London Underground) networks, using a logit-based stochastic user equilibrium algorithm. Road and rail-service capacity restraints are incorporated.

Steps (a) to (d) above are regarded as the land use model, whereas (e) and (f) as the transport model. Travel demand is generated in the land use model and fed top-down to the transport model. The travel costs, times and time-based generalised travel costs are calculated in the transport model to be fed back to the land use model. It is apparent that the model needs successive iterations, not only between the land use and transport models, but also within each of them. Model calibration starts from step (f), and works its way back up to (a), following the order in which the costs and generalised costs are calculated.

One way of approaching the structure of the LASER3.0 model is to compare it with a standard four-stage transportation model. In LASER3.0, the generation and distribution stages are replaced by a Land Use Model, where the causal relationships leading to travel demand are explicitly defined. The modal split and assignment stages are similar to those of a four-stage model.

LASER3.0 is a computer simulation model for integrated planning and transport studies and is an implementation of the MEPLAN software. Changes in land use affect transport and vice versa. In particular the model shows how changes in employment affect the choice of residential location and commuting; how the future location of employment and households affects the demand for travel; how congestion and overcrowding affect travel and locational choices. How these choices impact on patterns of land use and how changes in land use in turn give rise to new patterns of travel.

Geographically, the model's study area is defined as the Wider South East of England, which includes Greater London and the Government Office Regions of the South East and the East of England. The LOIS area is one of the radial corridors emanating from London, that are covered by the model.

LASER3.0 has two components: a land use module based on administrative areas, and multi modal transport model based on networks. The main inputs are: future employment projections in each area, future demographic profile for the region as a whole, transport

infrastructure and service improvements, and levels of car operating costs and public transport fares.
The main model outputs are: household and local service employment by area, commuting, education, business and other journeys between zones, using all means of travel including walking and cycling, morning peak (7-10 am) travel costs, times, road traffic speeds and volume to capacity ratios (congestion), and rail crowding levels, traffic flows on individual links, for project screening purposes
Alternative employment growth patterns, demographic projections etc are simply treated as alternative model scenarios. Employees and households are classified into detailed categories to capture their behaviour under different transport network and housing supply conditions. Travel demand is allocated between car, bus, rail and walking/cycling based on travellers' perceptions of costs, travel times (including any congestion or overcrowding), and the convenience of using the mode for different trip purposes.
The road and rail traffic patterns output from the model represent a realistic estimation of what will happen given the land use and transport policy measures proposed
Nevertheless LASER3.0 is a strategic policy model. Its geographic resolution is not as detailed as local traffic models. But its particular strength lies in its estimation of long term travel demand responses under any given land use and transport scenario. It includes a large number of demographic and socio-economic variables. As a result, it is capable of representing a wide range of travel demand responses under a policy scenario.

4. Model results

In LOIS, the model has been used to forecast a reference case for 2016. Then a number of alternative policy packages are tested, and compared with the reference case. The model results provide insights into the economic, social and environmental benefits of the alternative investment and policy measures. As a result, some road schemes competing with new public transport services have been deleted from the list, a few rail schemes have been withdrawn for low patronage, and a considerable number of high quality bus/coach services have been introduced. As a result, the Preferred Strategy is shown to provide a better and more coherent package for the LOIS area as a whole, with a strong public transport focus.
Rather than detailing the specific projects, the discussion below are focused on the more generic results concerning land use and transport dynamics. Four aspects are discussed. They are

- Future land use changes are leading to strong travel demand growth
- Transport schemes alone do not have significant impact on overall modal shift
- The wider impacts are complex: the example of high quality bus services
- Impacts of distance based road charging vary by area and corridor

Future land use changes are leading to strong travel demand growth
In the reference case, the model suggests that the demographic structure of the LOIS area evolves broadly in line with the rest of the Wider South East of England. There is a noticeable increase in the number of economically inactive households, as the population ages. However, the area is expected to see very strong growth in the number of employed

households, as a result of the rise in employment opportunities in London as well as in the LOIS area itself. Although the percentage of the lower socio-economic groups of employed households would reduce, there will still be a substantial number of semi and non-skilled workers living and working in the corridor. Travel demand continues to grow, but the increase of average journey lengths is either in line with historic trends or slightly below it. Car and rail modes both gain traffic at the expense of bus/coach and slow modes, reflecting changes over time such as car ownership growth, the lengthening of average journey lengths, and the investment in rail as assumed in the reference case.

Both employment and housing are input to the model, which provide the context for the model forecasts of household location and travel demand. Over the period of 1997-2031, agriculture and manufacturing are to experience a substantial decline (19% reduction in the LOIS area as opposed to 24% for the Wider South East as a whole). This is particularly pronounced in London, where the rate is 34%. By contrast, service sector employment growth has grown rapidly, more than compensating the decline in the other sectors. The growth of employment is particularly strong in Central London (49%). In the LOIS area the overall growth is 12%. The LOIS area is also expected to have an overall increase of 25% in the supply of dwellings, on a par with the rest of the Wider South East outside London, but higher than Outer London.

Based on these assumptions, the model forecasts changes in the location of the employed households. The model estimates the distribution of employed households amongst zones whilst controlling the total number of households to the total of official projection for the region. The LOIS area is expected to have strong growth in professional and managerial workers (less than London but more than the other areas outside London), but most notably it has relatively high growth rates of clerical and skilled manual workers. The decline of semi and non skilled workers is less pronounced in this corridor than in the other areas. These reflect the slower decline of the non-service industries and milder increases in the service industries in the LOIS area.

The growth of economically inactive households (i.e. predominantly the retired, plus the unemployed) in the LOIS area is expected to be less strong than the rest of the Wider South East.

Passenger transport demand is derived as part of the processes of land use modelling, as discussed above. Travel demand is segmented by a combination of income group, purpose, and car ownership group. They are first generated as trips between each zone pair, and then split into trips on different modes through the modal choice procedure. Trips between zones on each mode are then assigned onto the respective modal networks.

Table 1 shows the modelled growth of average journey lengths by purpose. The average journey lengths are an important measure in gauging the magnitude of transport demand growth. The UK National Travel Survey (NTS) data provides observed trends of journey length growth over time. However, because NTS is a small sample survey, it is not possible to obtain data that is specific to the LOIS area. In the table, the modelled travel originating from the LOIS zones is compared with the observed NTS trends for the Wider South East as a whole. Because the NTS data includes London residents, whose journey lengths are known to have grown more slowly than those in the rest of the Wider South East, the modelled journey length growths are expected to be higher than the NTS figures. This is shown in the comparisons for 1991-1997, where in the LOIS area the average journey length for commuting grows 12%, as against the 8% for the Wider South East including London. The other purposes show a similar pattern. For 1997 to 2031, there is no observed data to compare with. However, an extrapolated trend based on the average NTS annual growth rates can be used as a yardstick for gauging the modelled growths. The comparisons for 1997-2016 and 2016-2031 show that the modelled journey length growths by purpose tend to either reflect the observed trend (i.e. in the case of commuting) or to be slower than the observed trends (i.e. for the other purposes). This means the model is likely to provide a slightly more conservative estimate of the passenger travel demand growth.

Table 1. Changes in journey length by purpose (AM peak period)

	1991	**1997**	**1991-97**	**2016**	**1997-2016**	**2031**	**2016-2031**
Modelled: LOIS area only	Km	km		km		km	
Commuting	14.8	16.6	12%	20.1	21%	25.4	26%
Education	2.7	2.9	6%	3.1	7%	3.2	3%
Other private	3.1	3.1	0%	3.3	8%	3.4	2%
Business	48.2	53.2	10%	56.8	7%	60.8	7%
NTS observed: The Wider South East as a whole			**NTS1991-96**		**Trend extrapolated for 1997-2016**		
Commuting			8%		19%		
Education			4%		9%		
Other private			-1%		?		
Business			5%		10%		

Table 1 provides a summary of the key indicators of travel demand statistics, such as the number of trips, modal share, and average trip lengths by mode for all trips originating from the LOIS zones. The total number of journeys grow by 10.7% for 1997-2016 because of the increased employment opportunities, labour participation, and increased population in the area. However, the average journey lengths grow more strongly, by 23% for 1997-2016. This pattern of passenger demand growth is consistent with the NTS observations over the recent decades. In terms of modal share, in the reference case car and rail both gain traffic at the expense of bus/coach and walking/cycling. The modal share changes reflect a number of effects, including car ownership growth, the lengthening of average journey lengths, and investment in substantial new rail infrastructure and services. These model share changes are in line with the NTS observed trends.

As a result, traffic grows on the road network, and the growth is noticeably stronger in those areas where there had been less traffic and hence less congestion. The reference case road projects, such as the A120 between Braintree and Stansted, and the A130 south of Chelmsford, is shown to have had a discernable impact on the road traffic. In the LOIS area, the most congested areas include the high capacity roads, such as the M25 end of the M11, and the southern sections of the A12 towards London. The links around Braintree are also put under pressure, partly because of increases of land use activities there, and partly for the increased traffic levels on the A120 to the west of Braintree.

Table 2. Indicators of travel demand statistics for reference case years

Total person trips to/from Study area			
Trips	**1997/98**	**2016 Reference Case**	**2031 Reference Case**
Work, Education, Business	1,611,738	1,789,754	1,940,716
Recreation, Shopping, Other	527,646	578,807	587,423
All purposes	2,139,383	2,368,561	2,528,139
Purpose		**2016 Reference Case**	**2031 Reference Case**
Work, Education, Business		11.0%	8.4%
Recreation, Shopping, Other		9.7%	1.5%
All purposes		10.7%	6.7%
Mode share			
Mode	**1997 Reference Case**	**2016 Reference Case**	**2031 Reference Case**
Car	59.0%	62.3%	63.4%
Bus	6.5%	5.7%	5.1%
Rail	6.2%	8.4%	11.0%
Slow	28.2%	23.5%	20.4%
All modes	100.0%	100.0%	100.0%
Trip lengths (km)			
Mode	**1997 Reference Case**	**2016 Reference Case**	**2031 Reference Case**
Car	13.6	15.4	19.6
Bus	6.5	6.5	6.4
Rail	39.7	43.2	46.1
Slow	1.4	1.4	1.4
All modes	11.3	13.9	18.1

Transport schemes alone do not have significant impact on overall modal shift

Four policy packages are tested under the reference case. They are the rail projects, road projects, combined rail and road packages, and the combined package without proposed rail services via Epping. From the perspective of the entire road and rail networks, these LOIS projects add only a very small amount of additional capacities. The model runs have shown that no major change occurred either in modal share or in the average journey lengths overall, although within the particular areas where the policy intervention is introduced the changes in modal share are more noticeable. It should be noted that these alternative scheme runs are carried out using fixed, reference case trip ends, in order for transport user benefits to be assessed on a consistent footing under the standard UK transport cost-benefit analysis framework TUBA. This however means that all trip origins and destinations are identical in all runs, and only the distribution, modal choice and network assignment are allowed to change in the 2016 runs. This, of course, limits the level of response the policy runs may have.

The main impact of the full rail project package is a significant relief of overcrowding on commuting services towards Central London. The new services to London do not save actual travel time on board the train, although a better quality of rail service is achieved. As a result, there is a small shift of traffic from road to rail. However, this shift occurs mainly on the existing routes where the rail is in a strong position to compete (i.e. towards Central London), rather than on the orbital routes or the outbound services from London.

The full road project package run shows that the proposed new road capacities will be well used. The increase of traffic on the new trunk links is substantial. This traffic increase is a result of redistribution of trips, as well as re-routeing on the road network. The overall modal shift to road appears small. Along the new road corridors many travellers are able to save travel time, although the reassignment of road traffic also produces increased congestion on those roads that feed into the proposed new or expanded road links.

The rail and road combined package show characteristics already seen in the two separate runs above. As road and rail projects are input at the same time, the modal shift effect is in between the rail and the rail runs. Rail gains a marginal share, but the average journey length on car also extends.

Taking out the rail services via Epping from the combined rail and road package makes rail services lose part of the share gained in the full combined run, as expected. Not having the Epping services (particularly the services towards London) means rail will lose approximately half of the modal share gains in terms of trips, and 80% of the trip kms gained by rail in the combined rail and road run.

The model results suggest that the cost and time savings generated by the road project package is significantly higher than those arising from the rail project package. Under the rail test, however, there are considerable benefits if the reduction of rail overcrowding is to be taken into account.

Table 3 provides a summary of the key transport demand statistics. The directions of movements in modal share and average journey lengths are in line with expectations in all policy runs. The magnitudes of the movements in terms of overall statistics are small in the LOIS area as a whole.

Table 3. Indicators of travel demand statistics for 2016 reference and policies

Total person trips to/from LOIS area					
Trips	**2016 Reference**	**2016 Rail**	**2016 Road**	**2016 Combined**	**2016 No Epping**
Work, Education, Business	1,789,754	1,790,717	1,789,633	1,790,662	1,790,012
Recreation, Shopping, Other	578,807	578,828	578,842	578,863	578,851
All purposes	2,368,561	2,369,545	2,368,474	2,369,525	2,368,863
Trips (% change)		**2016 Rail**	**2016 Road**	**2016 Combined**	**2016 No Epping**
Work, Education, Business		0.1%	0.0%	0.1%	0.0%
Recreation, Shopping, Other		0.0%	0.0%	0.0%	0.0%
All purposes		0.0%	0.0%	0.0%	0.0%
Mode share					
Mode	**2016 Reference**	**2016 Rail**	**2016 Road**	**2016 Combined**	**2016 No Epping**
Car	62.3%	62.1%	62.5%	62.3%	62.4%
Bus	5.7%	5.7%	5.7%	5.7%	5.7%
Rail	8.4%	8.7%	8.3%	8.6%	8.5%
Slow	23.5%	23.5%	23.5%	23.5%	23.5%
All modes	100.0%	100.0%	100.0%	100.0%	100.0%
Trip lengths (km)					
Mode	**2016 Reference**	**2016 Rail**	**2016 Road**	**2016 Combined**	**2016 No Epping**
Car	15.4	15.2	15.8	15.6	15.7
Bus	6.5	6.5	6.5	6.4	6.4
Rail	43.2	43.5	42.4	42.6	42.1
Slow	1.4	1.4	1.4	1.4	1.4
All modes	13.9	13.9	14.1	14.1	14.1

The wider impacts are complex: the example of high quality bus services

From the outset of the LOIS study it was acknowledged that the requirement for a more sustainable future transport strategy would require significant improvements in the provision of public transport throughout the sub-region. This posed a particular challenge in relation to the problems discussed earlier. In particular the dispersed, mis-matched pattern of homes and jobs, coupled with the overall poor East-West communications infrastructure and the relatively limited extent of the rail network demanded a flexible and spatially integrated approach.

A major plank of the recommended strategy was the proposed introduction of a series of high quality bus corridors (HQBC) based on a combination of existing / shared road space and dedicated bus lanes (Figure 6) These were designed to link the main urban centres and to connect the outer areas of the sub-region with the main employment centres in the core of the Corridor. The bus corridors provide a means of improving east-west communications and making better use of existing road infrastructure. Compared with the rail options, bus services also offers an important degree of flexibility in relation to the need to provide access to dispersed and peripheral communities. In order to supply the quality of service associated with a HQBC and provide an economically viable service however fares need to be set at levels that are closer to rail tariffs than to fares associated with traditional inter-urban coach services.

Of particular importance in the context of the sub-region this component of the policy package offered a means of linking areas of relatively high unemployment in the Priority Areas for Economic Regeneration (PAERS) on the East Coast via the A120 / A12 to employment areas in Colchester and Chelmsford. The long distance corridors also offer the prospect of a quality bus service across to Stansted Airport on the western periphery of the study area based on a dedicated bus lane on the A120 west of the A12. Stansted Airport is expanding quickly but currently is unable to satisfy the associated growth in demand for unskilled labour from the local population, which is characterised by a large proportion of white collar workers and London commuters.

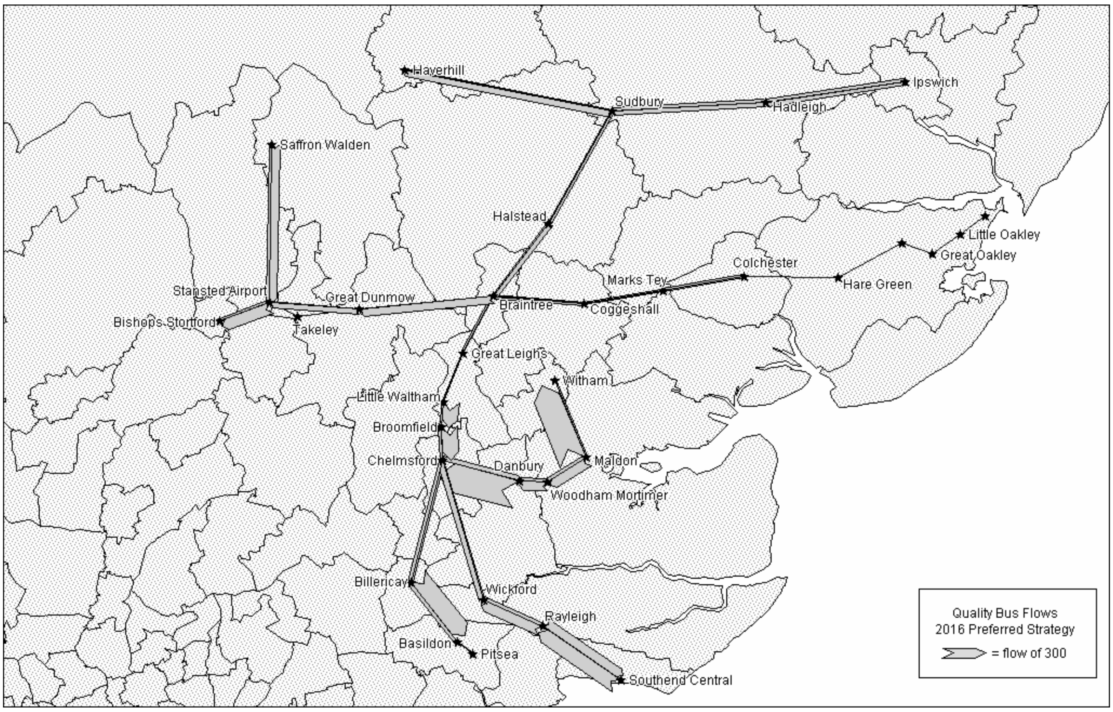

Figure 6. Passenger flows of the high quality bus/coach network

If the link can be made this would make the airport jobs accessible to the labour force resident within the PAERs thereby improving social inclusion of these areas and making a potentially important contribution to objectives for economic growth and regeneration.

The model results indicate that the HQBC services would indeed attract good levels of patronage and would be successful in terms of contributing to an improved modal shift in favour of public transport (Table 4). However close inspection of the results demonstrates a number of unexpected, underlying policy responses that demonstrate the value of incorporating a land use model in this type of study. Of particular interest in relation to the original aims of the HQBC policy further analysis of the bus patronage showed that the services were not well-used by the more disadvantaged groups. In fact the model forecasts suggest that the specified services are likely to be used most heavily by higher income group commuters (Table 5). Further analysis of the land use and transport model results reveals the explanation for this. This suggests that the buses will be used primarily as rail feeder services by commuters to London travelling from town centre and parkway stations in Essex. The services provide a solution to the current problem of limited car parking in the vicinity of railway stations and this in turn allows these groups of the population to move further from their place of work into the peripheral areas served by the High Quality Buses.

Table 4. Destination of commuters using high quality bus/coach services

Destination area	Total Passengers	Percentage share among all destinations
Central London	1,269	25%
Inner London	1,175	23%
Outer London	235	5%
LOIS area without HQ BUS	346	6%
LOIS area with HQ Bus	2,083	40%
Rest	43	1%
Total	5,151	100%

Table 5. Low income travellers using High Quality Bus/Coach

Zone Name	% Low income residents in zone	% travellers belonging to low income groups: Original Fares (75 percent of rail fares)	New fares (same as local bus)
Haverhill	22%	13%	16%
Ipswich	15%	12%	15%
Bishop Stortford	8%	7%	11%
Marks Tey	11%	10%	12%
Saffron Walden	11%	5%	6%
Billericay/Wickford	8%	2%	2%
Basildon	12%	9%	12%
Broomfield	12%	12%	14%
Chelmsford	8%	7%	10%
Danbury	9%	0%	1%
Halstead	16%	9%	11%
Witham	11%	9%	15%
Braintree	14%	13%	18%
Colchester	13%	12%	14%
Harwich	15%	5%	7%
Maldon	12%	1%	1%
Rayleigh	9%	4%	6%
Southend on Sea	9%	2%	3%
Sawston	9%	10%	13%
Sudbury	16%	9%	11%
Coggeshall	14%	11%	14%
Great Dunmow	14%	16%	19%
Great Leighs	11%	2%	2%

The previously unexpected relocation impact of this policy could be expected to bring benefits to the peripheral areas from increased consumer spending in the local economy. However it also implies increased competition in the local housing market with the prospect of higher income groups. Before implementation the policy will therefore need to be further analysed and refined in order to strike an acceptable balance between revenues/fares and access to opportunities for the more disadvantaged groups that constitute an important part of the target market for the buses.

Impacts of distance based road charging vary by area and corridor

A distance based road user charging scheme was tested as a potential measure for demand management. As the space in this paper is limited, the discussion below will be focused on the differences in the demand responses between geographic areas.

The analysis of model results first quantifies the overall demand responses in the entire Wider South East. The demand response here is defined as the percentage change in passenger kilometre of car travel divided by the percentage change of the perceived cost of car travel. These responses are uneven between different traveller types. Whilst the private passenger demand segments reduce their level of car use under charging, there appears a tendency for certain business journeys to switch back to car to take advantage of the increased road speeds. Also, the demand responses presented here depend on how the trips of a segment are distributed geographically, the lengths of the trips, and what part of a trip is charged by the road tolls.

Table 6 shows the overall car travel responsiveness is –0.085. It is clear that some are at the low (especially those segments of high income car owners, and of education trips i.e. school runs), whilst others are high (e.g. low income, non-car owners); the response from business travel is positive, indicating that there is a reverse mode switching. This appears to be low when compared with published demand elasticities. However, in the Wider South East of England, the average income for the travelers in the AM peak is close to the upper end of a typical UK income range (particularly if this is weighted by the passenger-km), and the proportion of travellers using rail/LU services, relative to bus, is high compared to the average UK situation. In addition, a fairly large proportion of the AM peak traffic in the study area is captive to certain PT modes (e.g. long distance commuting for Central London) or to car (in the rural areas where PT is not well provided for). These are obvious reasons why the elasticities in this study area are expected to be closer to the lower end of the benchmark ranges. However, because not all land use responses are modeled, and the model is AM peak only without time of day choice the responsiveness of the model is expected to be lower than in a fully specified model.

The road user charge was applied to the southern part of the LOIS area, whilst the roads in the rest of the corridor was not charged (i.e. apart from the trunk roads of the M11, A12 and A13). The tables below present the costs, passenger-km and demand responsiveness for the charged and non-charged areas.

Table 6. Responsiveness of car travel by purpose and traveller type: The Wider South East

Demand segment	Name	Responsiveness
1	Commuting trips, high income household, with no car.	-0.146
2	Commuting trips, high income household, with part car availability.	-0.077
3	Commuting trips, high income household, with full car availability.	-0.091
4	Commuting trips, low income household, with no car.	-0.371
5	Commuting trips, low income household, with part car availability.	-0.169
6	Commuting trips, low income household, with full car availability.	-0.302
7	School trips, high income, with no car.	-0.009
8	School trips, high income, with part car availability.	-0.023
9	School trips, high income, with full car availability.	-0.026
10	School trips, low income, with no car.	-0.092
11	School trips, low income, with part car availability.	-0.090
12	School trips, low income, with full car availability.	-0.082
13	Other trips, high income, with no car.	-0.114
14	Other trips, high income, with part car availability.	-0.024
15	Other trips, high income, with full car availability.	-0.167
16	Other trips, low income, with no car.	-0.142
17	Other trips, low income, with part car availability.	-0.227
18	Other trips, low income, with full car availability.	-0.340
20	Employers business trips, professional	0.016
	All demand segments combined	-0.085

Note: The responsiveness is calculated as the percentage change in car passenger kilometres divided by the percentage change in perceived car costs.

In the charged area, the demand responsiveness seem to be lower than the Wider South East area as a whole, whilst the relativities between the demand segments in terms of purpose, income and car ownership hold a similar pattern (Table 7). This is not surprising, given the lack of alternatives both for the Central London commuters (who already travel on trains by and large), and also to many other destinations not well served by public transport (where car is often the most convenient mode). The availability of public transport modes is less developed in this area as compared with Central and Inner London. As stated above, the modelled response may be inclined to underestimating rather than overestimating the demand response, for the lack of land use response and peak spreading. However, even assuming this area has the same responsiveness as the Wider South East as a whole (which it is thought will be more than compensating the model underestimation of demand responsiveness), the level of demand response can still be regarded low.

Table 8 provides the analysis for the non-charged area. The impacts of charging are very small in this area. Only the longer distance trips starting or ending in this area would be affected by charging. Moreover, the land use pattern in the non-charged area is more dispersed, resulting in a higher dependence on car travel.

Table 7. Car travel demand responsiveness: LOIS charged area

Demand Segment	Car cost p per km (Ref)	Car cost p per km (High)	Car cost p per km (Very high)	Car pax-km (Ref)	Car pax-km (High)	Car pax-km (Very High)	Respon-siveness (High)	Respon-siveness (Very High)
1	5.0	18.5	24.8	5,302	4,929	4,639	-0.026	-0.032
2	3.9	15.1	20.9	223,445	204,509	189,792	-0.031	-0.038
3	4.9	18.5	25.6	1,075,621	977,802	907,520	-0.034	-0.039
4	3.5	13.9	19.1	2,288	1,867	1,573	-0.068	-0.079
5	3.5	13.8	17.9	19,872	17,155	15,532	-0.050	-0.055
6	4.7	17.8	23.6	51,363	40,911	35,267	-0.075	-0.079
7	2.4	11.3	14.2	229	238	223	0.015	-0.006
8	2.3	10.5	13.4	35,603	34,344	33,382	-0.013	-0.016
9	2.4	10.2	13.2	187,488	182,160	178,406	-0.010	-0.012
10	2.4	10.8	13.5	751	719	679	-0.016	-0.024
11	2.5	10.6	13.4	9,949	9,108	8,741	-0.031	-0.031
12	2.4	10.3	13.2	18,002	16,886	16,340	-0.023	-0.023
13	3.6	15.3	19.1	167	155	150	-0.026	-0.026
14	3.1	13.0	16.8	45,023	43,827	42,449	-0.010	-0.014
15	4.3	17.2	22.2	29,576	26,148	24,932	-0.043	-0.040
16	2.9	11.5	14.3	1,210	1,074	1,033	-0.041	-0.037
17	2.9	11.6	14.4	3,872	3,182	2,970	-0.066	-0.059
18	3.8	15.0	19.2	8,871	7,595	7,161	-0.053	-0.049
20	11.3	23.6	30.1	111,613	110,414	109,469	-0.004	-0.005

Between 1997 and the 2016 Reference Case, areas within London grow more slowly than outside London in terms of passenger kilometres . This is also seen in the LOIS area: the area to be charged (closer to London) sees 16% growth in passenger kilometres whilst the growth in the non-charged outer area is 39%. Road travel demand grows respectively in the charged and non-charged areas by 11% and 34% under one charge scheme, and 8% and 33% under a higher charge scheme.

Under charging, the total amount of car passenger kms originating from the LOIS charged zones would remain at a similar level to that in 1997 or slightly decreasing depending on the charging scheme. This is achieved mainly through a reduction of car journey lengths, with limited transfer of the shorter journeys to slow modes, bus and rail. In the uncharged area, however, the impact has been limited. Note that the total passenger km in the charged area amounts to only 1/7 of the LOIS total for car travel.

At the network level, the motorways and other trunk roads have lost more traffic than the smaller roads, as car journeys generally become shorter. In the uncharged area, the charging of A12 has not caused a significant diversion of traffic to smaller roads. This has, however, more to do with the geometry of the network in the LOIS area (where there are no apparent alternatives to the A12), and cannot be taken as a rule for trunk roads in other areas.

Table 8. Car travel demand responsiveness: LOIS non-charged area

Demand Segment	Car cost p per km (Ref)	Car cost p per km (High)	Car cost p per km (Very high)	Car pax-km (Ref)	Car pax-km (High)	Car pax-km (Very High)	Respon-siveness (High)	Respon-siveness (Very High)
1	4.2	5.6	6.8	36,491	35,942	35,457	-0.006	-0.007
2	3.6	5.4	6.7	1,437,325	1,394,384	1,372,493	-0.011	-0.011
3	4.3	7.4	9.6	7,591,368	7,270,443	7,088,912	-0.016	-0.017
4	3.5	4.7	5.4	25,080	24,066	23,274	-0.015	-0.018
5	3.7	4.3	4.7	171,102	167,544	166,060	-0.008	-0.007
6	4.8	6.1	6.7	617,045	594,374	580,830	-0.014	-0.015
7	2.8	2.8	2.9	211	196	202	-0.026	-0.010
8	2.5	2.6	2.7	92,648	80,162	83,582	-0.050	-0.025
9	2.4	2.6	2.6	849,506	747,677	771,391	-0.044	-0.023
10	2.8	2.9	2.9	1,525	1,443	1,469	-0.020	-0.009
11	2.8	2.8	2.8	30,738	29,199	29,717	-0.018	-0.008
12	2.7	2.8	2.8	75,020	69,899	71,303	-0.025	-0.012
13	3.9	3.9	3.9	840	840	840	0.000	0.000
14	3.1	3.2	3.4	153,891	127,754	136,431	-0.063	-0.029
15	4.5	4.5	4.5	165,606	165,069	165,413	-0.001	0.000
16	2.9	2.9	2.9	7,757	7,757	7,757	0.000	0.000
17	2.9	2.9	2.9	27,867	27,863	27,866	0.000	0.000
18	4.2	4.2	4.2	50,257	49,853	50,084	-0.003	-0.001
20	8.5	12.4	15.8	1,077,505	1,066,596	1,067,050	-0.004	-0.002

From this analysis, it is not possible to say how the uncharged area would respond to road user charging if a comprehensive regime is applied, as in the charged area. The Outer areas of LOIS have even fewer alternatives to car than the charged area, with the exception of the rail corridors to London. The demand responses are expected to be low under charging, unless additional measures are implemented at the same time to promote a change from the expected patterns of car use.

5. Conclusions

The use of the LOIS Strategic Policy Model has contributed to the identification of a comprehensive package of schemes and measures, which aim to assist in improving movement for people and goods, seek to protect the environment, and assist in economic growth and regeneration. Underlying the Strategy is the need to support measures to reduce the demand for travel and make better use of the existing transport network. Policy measures such as road user charging and alternative land use scenarios have been tested along with road and rail infrastructure investment, and high quality bus/coach services between key residential and employment locations.

The model results show that if no major transport investment occurs in the LOIS study area there will be serious congestion problems on both the road and rail network in a decade's time, with progressive deterioration in travel conditions. It is important that a coherent transport strategy is formulated, which co-ordinates the development of all modes. However, the model indicates that the future travel patterns can never be separated from the underlying land use activity distribution. The significant interaction between the travel demands in the LOIS corridor and the surrounding areas means that the effects of transport and land use proposals both within and external to the LOIS area require a full consideration. The land use – transport dynamics that are examined in this paper help to illustrate just how important they are in formulating transport strategies for the future.

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