INTEGRATION OF TRANSPORT AND LAND USE PLANNING IN CHINA'S CITY REGIONS: THE CONTRIBUTION OF EVIDENCE-BASED RESEARCH AND MODEL SIMULATION

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ABSTRACT

Passenger transport and freight logistics are gaining a high profile in the planning of China's city regions. Their roles in shaping the built form are also being examined more closely. The master planners have been calling for co-ordination between transport and land use development. However, international experience has shown that rapid growth may make it difficult to integrate the concerns of the transport and land use planners. Whilst transport is focused on short term, quantifiable demands that appear to have apparent, technical solutions, land use planning is about long term, qualitative, political outlook with multiple objectives. Yet short term transport decisions often lead to irreversible land use change, and land use changes may create bottlenecks that lead to rapid escalation of cost in providing transport solutions.

The authors review the data sources, planning research and modelling in Europe (particularly in the United Kingdom), and argue that the current evidence base in China's city regions can start to support quantitative models that help master planners co-ordinate transport development in a practical manner, as well as address the key weaknesses of the existing urban traffic models. They outline how the practical experience gained internationally may be adapted to the policy making context in these city regions, concerning the economic and sustainability appraisal of the planning and transport strategies. Three practical modeling examples are used to illustrate the use and potential in major policy applications. They also identify the need for better dissemination of best practice, as policy applications have largely remained in grey literature such as study reports, which at present are only accessible to specialists in the field.

INTRODUCTION

Passenger transport and freight logistics are gaining a high profile in the planning of China's city regions, as the high rate of economic growth continues. Their roles in shaping the built form are starting to be examined more closely by planners, investors, and the environmental lobby. The master planners have been calling for co-ordination between transport and land use development.

However, international experience has shown that rapid growth may make it difficult to integrate the concerns of the transport and land use planners. Whilst transport is focused on short term, quantifiable demands that appear to have apparent, technical solutions, land use planning is about long term, qualitative, political outlook with multiple objectives. Yet short term transport decisions often lead to irreversible land use change, and land use changes may create bottlenecks that lead to rapid escalation of cost in providing transport solutions.

The authors review the data sources, planning research and modeling that they have an in-depth knowledge respectively in Europe and in China, and argue that the current evidence base in China's city regions can start to support quantitative models that help master planners co-ordinate transport development in a practical manner, as well as building on the achievements in urban traffic modelling. They outline how the practical experience gained internationally may be adapted to the policy making context in these city regions, to address the needs for the economic and sustainability appraisal of the planning and transport strategies. Three practical modeling examples in the UK and the European Union are used to illustrate the use in policy applications.

CHINA'S CITY REGIONS: TRANSPORT DEVELOPMENT AS AN OPPORTUNITY AS WELL AS A CHALLENGE

Over the last thirty years, China has undergone reform, opening up, and a rapid acceleration of urbanization across the country. The papers of this conference will have shown an amazing array of achievements at an unprecedented scale. However, economic and social development has also imposed severe pressure on infrastructure. Transport as a key support system has become a central issue to resolving the conflicts between economic development, sustainability, and social equality.

High speed of urbanization has resulted not only rapid growth of city size, but also an ad hoc coalescence of existing settlements (Mao, 2004). Most of the urban construction projects concentrate in the central area of the cities and in close proximity to arterial roads and this worsens congestion and pollution impacts. The quality of the natural environment surrounding the city regions are deteriorating. Low-income areas start to appear at the urban fringe as well as within some built-up areas, posing new questions for equality in transport accessibility for the economically disadvantaged communities. Transport at the urban and regional scale poses serious challenges for China's Master Planners. Tsinghua University (2006) provides an extensive review of the current situations in transport, urban planning and other related areas.

Firstly, traffic congestion in China’s city regions have been rising, so much so that there are now serious concerns that it may constrain the prospects of further economic and social development. In recent years, although most cities have speeded up the expansion of the urban road system, transport supply still lags behind. In many cases the situation is becoming worse. The vehicle speed in central urban areas of big cities is slow by international standards, and both the duration and areal coverage of traffic jams are extending. According to the investigation in Beijing, the reduction of average bus operating speed by one kilometer per hour could equal to the loss of operation capacity of 200 buses and RMB 100 million yuan. Traffic jams reduce efficiency and increase operating costs, which impacts on a health economic and social development.

Secondly, imbalanced development of the transport system has led to conflicts and problems in the utilization of infrastructure. Currently, travel demand growth often out-pace traffic planning. At the same time, private car ownership and usage are rising rapidly. As private cars and taxies gain modal share, less road space is available for bus and bicycle traffic, which in turn encourage those who can afford to transfer to car use. This reduces the efficiency of road space use, and leads to more traffic congestion and more tail gas and noise pollution. Moreover, along with the increase of private motorization, the conflict of bicycle, bus and car traffic flows become intense. It severely reduces traffic capacity at road crossings and around bus stops.

Thirdly, the supply and demand conflict on parking facilities worsens. Along with the increase of automotive vehicles, it becomes more and more difficult for drivers to find parking place in the dense built-up areas. The number of designated parking spaces are far less than the number of cars, and that is the reason why many vehicles are parked on the roadside without permission. During a survey in 10 big cities, it was found that the parking space in most downtown areas was far from enough and could only satisfy about half of the actual demand. In some cities, only 1/4-1/6 of the demand could be met. In Beijing, the number of automotive vehicles is more than 2.4 million, while the number of designated parking spaces is no more than 700,000. In Guangzhou, the number of vehicle is 800,000, but there are only 180,000 parking spaces available. Moreover, among these parking spaces, about 1/3 are on the roadside. This greatly affects the traffic and the general urban environment.

Fourthly, the development of mass rail transit systems lags behind urban development. Most cities in China are focused on one centre and feature compact land utilization. Both population and city functions are highly concentrated and there is very limited scope for providing car traffic and parking space. This constraint, however, can be turned into an advantage if the urban mass rail transit systems can be developed to support compact city development. This will require sufficient number of lines to be built so as to achieve a critical mass and become an effective alternative for those who can afford to travel by car.

Fifthly, the land resource in the cities is limited and the construction of traffic facilities is therefore constrained. According to the planning regulations in China, the land used for construction in the big cities is restricted within 100 square meters for each resident; therefore, the land resource for road facilities is extremely tight. In 2004, the average road space for urban population in China is 10.3 square metres, increasing by only 1 square meters since 2003. By comparison, the average road space area in US cities with more than 250,000 residents is 25 square metres per resident, and in Berlin, 22 square metres.

In the centre of metropolitan areas of Beijing, Shanghai, and Guangzhou, the population density is more than 20,000 residents per square kilometer. The high density can contribute to the economical use of land and other resources, so long as the needs for travel in these areas are effectively managed. The Master planners have come to realize that urban and regional transport is not only a matter of passive supply to meet the burgeoning demand, but also a tool to guide the long term development proactively. The ultimate goal of urban planning is to develop a better human settlement for all of people. Transport should be treated as an integral component of it. It is to be jointed up with policy concerns for the environment, energy, housing, employment, transient population and disadvantaged groups. Nevertheless, planners will require tools that may have them to integrate the planning of these diverse policy areas. The experience of integrated transport and land use planning in the European cities would be of relevance in this respect.

WHAT ANALYTICAL PLANNING TOOLS ARE APPROPRIATE FOR THIS PURPOSE?

The Master Planners in China have always been working towards integrating the many aspects of land use and transport planning. The need to do so has been growing as the scale of development expands. The technical opportunities to assist this integration have also been growing, as computer, database and geographical information systems (GIS) improve. Although the extent of integration and coordination that can be achieved is ultimately an institutional issue, having appropriate analytical tools will help the Master Planners to progress this with their colleagues in other government departments and facilitate consensus building on the key urban and regional development priorities.

Naturally, there are many analytical tools that can contribute to this purpose. These tools arise in response to the particular needs of policy analysis. Most of them tend to be examining a few aspects of the city region. Their values are not diminished by the partial nature. In many cases, the partial tools are fit for purpose, and can respond very quickly to policy needs.

However, in order to maximize the value of these partial tools, it is important to establish a comprehensive framework. This framework provides an overview of the system, and the context in which the partial tools can operate. The ideal form of this framework would need to embrace all complex relationships that are at play in urban and regional development, and it will remain a Master Planner's dream. The closest, practical form to such a framework that has been developed in Europe and the US for quantified planning analysis would seem to be computer simulation models for land use and transport interaction, which aim to represent the regional economy (i.e. production and employment), the use of land by different types of production and residential activities, and the interaction between travel demand and transport capacity.

The integrated land use and transport models were first developed half a century ago in the US and then in Europe in response to the large growth in development and car ownership. They were first developed as transport and traffic models that contain some forecast capability for travel demand. The forecasting of the travel demand are then extended into increasingly sophisticated simulation of the interaction between production, consumption, trade, and residential activities between different locations.

The history has certainly been one that is mixed with successes and failures. Looking at the circumstances in which they succeed and fail is instructive to what roles they can be expected to play. Betty (1994) has reviewed the Anglo-American experience, whilst Wegener (1994) has chronicled the renaissance of land use and transport modeling since the 1980s, which have learnt from the earlier failures and developed a much wider range of methods. Klosterman and Pettit (2005) classified these tools in terms planning support systems in terms of the approach such as

- Large scale urban
- Rule based
- State-change
- Cellular automata

And also in terms of the tasks they perform,

- Land use/land cover change
- Comprehensive projection
- 3D visualization
- Impact assessment

Betty (2004) provides an insightful review of the developments and the strengths and weaknesses of the different approaches.

It is clear that the more recent models have benefited significantly from the advances in computer technology, data provision and the growing community of model-literacy among the decision makers and their support staff. Whilst Flyvbjorg et al (2005) identified some serious problems that can occur transport and traffic modeling, they have come to the conclusion that the cure for them was in fact to have better modeling, rather than abandoning the approach. What they have called for is modeling that is transparent, accountable and based on newer, better methods.

Because of the complex relationships that are to be represented, it is extremely unlikely that any one model can embrace all the key relationships. It is necessary to develop both theoretical models that explore the conceptual and technical possibilities, and practical policy models that make practical use of the theory and can cope with current data availability.

However, whilst the theoretical models are fairly accessible in the academic literature, the practical models tend to reside primarily in the grey literature (i.e. study reports that are published by individual clients which are usually international organisations, Central and regional governments). Even studies that are published by major national governments and international bodies tend not to be accessible outside a restricted circle of specialists. Whilst during the policy studies peer-reviewing and sometimes heated debate do take place, such studies would certainly benefit from the feedback from a wider audience. In turn, the practical modeling technology can also be learnt by an extended group of decision makers and the research community.

Below we review three such policy models that have been developed in the United Kingdom and European Union. They belong to the 'large-scale', 'land use' and 'comprehensive projection' categories in the Klosterman and Pettit classification (2005). In fact, these models are the more recent developments from one of the traditions in the SPATACUS group of models (Lautso, 2003), as reviewed by Klosterman and Pettit. The particular reasons for selecting these models are

1) we have more direct experience of the models

2) they respectively cover passenger transport in a large city region (London and its wider commuting area), freight and logistics (in the north of England which saw its hey day in the Industrial Revolution) and a multinational area (the 25 member countries of the European Union)

3) the data requirements of these models are fairly modest, when compared with other models. These data requirements, as will become apparent below, are likely to be met by the recent developments in China's city regions

Two of these models (London and European Union) have been already extensively used for recent policy analysis on urban, regional and national developments, and the remaining one on freight and logistics in the north of England has attracted attention from the research community in several countries in Europe.

MODELLING A LARGE CITY REGION: LONDON AND THE SOUTH EAST OF ENGLAND

The London and South East Region Model (LASER) version 3.0 is an integrated land use and transport model for a study area that covers Greater London, and 2 UK Government Office Regions around London (the *South East* and the *East of England,* see Figure 1). The area as a whole, often referred to as the 'South East' in the UK, has around 20 million inhabitants and 10 million employed and self-employed workers. The prominence of London, as a world financial centre, and the concentration of the wider service sector skills, has made the region attractive to business activities world-wide. The evolution of the regional demography and the peaks and troughs of the regional economy have left their imprint on the land use patterns and on the organisation of transport. This LASER model is an attempt to depict the basic land use and transport processes of the region, and is intended to be used as a platform for assessing a range of policy measures that aim to transform land use and transport.

Figure 1. LASER3.0 MODEL ZONES: THE SOUTH EAST AND THE EASTERN REGIONS
Source: Author

The LASER study area is faced with a number of land use and transport issues that have significant long term implications. The service sector is expected to grow strongly in the next two decades, both in the financial centres of Central and Inner London, and farther afield. The demand on labour supply is such that no single change is capable of meeting the demand for employment. Increases of labour participation, of in-commuting, and of inward migration are all likely consequences of this demand. As a result, there is to be strong rise in the demand for business and residential space, and in commuting and business travel.

The regional demography is undergoing its own transformation. Although the number of inhabitants is expected to increase relatively slowly, the number of households is to rise many times faster, exacerbating the demand for dwelling units. The demographic profiles of urban, suburban and rural areas within the region are markedly different, thus exerting distinct impacts on land use and transport.

A significant proportion of households are to become full car owning (i.e. each adult having access to a car for own use). Since full car owning adults make more trips and travel a great deal longer, this change in car ownership may lead to a potentially strong rise in travel.

Furthermore, as the business markets develop, the inhabitants become more affluent, and more leisure time is available, there is potentially a strong demand for international travel. Hubs for international travel, such as airports, ferry ports and rail termini, are themselves a focal point of employment and traffic growth. Their impact on local communities in the vicinity and their long term influence on regional land use change are profound yet complex to predict.

Economic development and demographic change are currently exerting apparent pressure on land – greenfields and brownfields alike – in those locations perceived to be favourable for business or residential purposes. In contrast, in the region which has the highest average per capita income in the UK, there also exist a number of pockets which are among socially and economically the most deprived. How the growth and change will affect these areas is an interesting policy question which is required to be answered, if the policy measures are to be effective in promoting social inclusion.

In recent years policy makers have been conscious in promoting the management of travel demand. Pricing and non-pricing measures have been put forward for discussion, with an aim to facilitate a reduction in the need for travel, and to encourage a shift from private car to public transport modes. Advances in technology are to an increasing extent redefining the need for travel, for example through tele-commuting and tele-sales. The link between land use activities and travel demand has started to be carefully re-examined in the policy context.

Modeling Approach

The role for a land use and transport model is best understood in the context of the region and of the policy concerns. Land use implies a multitude of relationships and feedbacks, which are nearly as complex as the world itself. There is little chance, or indeed little to be gained, to introduce all the complexities of land use into transport modelling. LASER3.0 has abstracted a limited range of the key relationships of land use and transport, based on the concerns and policy applications on the current agenda. As it has made use of all datasets of employment, demography, housing, and transport networks that were available at the time of model development in 2001, it has perhaps the most comprehensive coverage of land use and transport interactions as currently feasible for London and its surrounding regions.

The geography of the study area is represented with 312 zones. These zones, together with 22 zones for the rest of Great Britain, define the spatial resolution of the model. 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.** Employment in the model is defined, in terms of exogenous and endogenous 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. The car ownership segmentation is a new development, which was absent from the previous LASER. More importantly, the segmentation coefficients can now be modified for each zone as land use and transport conditions change from one year to another, or indeed for each major policy scenario.

(b) **Spatial distribution of employed residents.** Given the location of the demand for employed workers, 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. The cost of living, a monetised non-pecuniary attractiveness at a residential zone, and the generalised commuting cost between the residential zone and a work zone, were the influences of the probabilistic choice in the previous LASER. The new LASER model improves this formulation by adding a new influence to the residential location choice model: this is a spatial impedance that is not explained by the costs of living, zonal attractiveness, and generalised travel cost. A matrix of constants that represent such impedance are derived by comparing the pattern of commuting as estimated with the previous formulation with what was observed in the Census journey to work matrices. This significantly improves the goodness of fit of the model in the calibration year, whilst retaining the explanatory power of the explicit model variables of the costs of living and commuting.

(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. The new LASER model segments households by socio-economic group and car ownership, and generate non-commuting trip production for three age groups (children, adult and elderly) and three employment status (full time employed, part time employed and non-employed) for the adult group. Car ownership and the person-based trip generation were not included in the previous LASER.

(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. They are attracted to either service employment or the households as appropriate. Logit-based discrete choice models are applied to distribute the trips for each origin zone. This part of the model remain similar to the previous LASER.

(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, according to the modal choice behaviour of each socio-economic and car ownership group, for each travel purpose. 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. Compared with the previous version, the new modal split models differentiate the income and car ownership groups, and thus represent more fully the behavioural variations.

(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. Light and heavy goods vehicles are input externally to be assigned together with road passenger traffic. Structurally, this part of LASER remain the same as the previous version, although the road and rail networks now come from, respectively, the NAOMI highway model and the PLANET rail model, with much more detailed network coding than what was used previously.

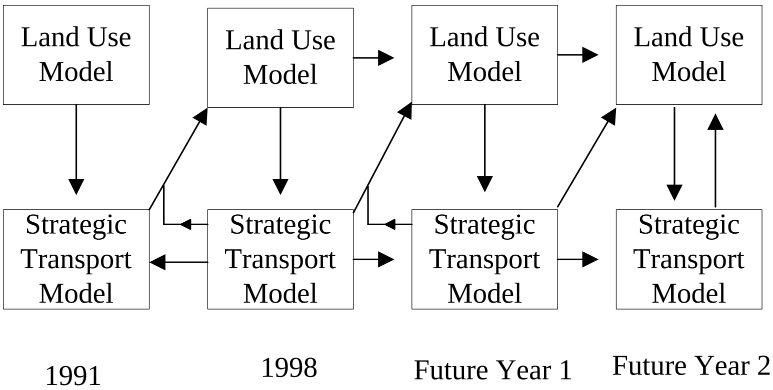
Steps (a) to (d) above are regarded as the land use model, whereas (e) and (f) as the transport model. Travel demand is generated in the land use model and fed top-down to the transport model. The travel costs, times and time-based generalised travel costs are calculated in the transport model to be 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. The iterations between modal split and assignment are required so that modal choice and network assignment are in equilibrium. Within the land use model the iterative procedure solves the demand for service industry employment, and makes sure housing demand is in balance with housing supply constraints. This allows an extensive interaction between land use and transport, for the causal relationships represented in the model. 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.

The LASER model is a morning peak only model for modal split and assignment. Only journeys arriving within the morning peak of a typical weekday (0700-0959 hours) are modelled. The model calibration year is 1991, and the validation year is 1997.

The way in which LASER is run through time is outlined in Figure 2. The 1991 calibration of the land use and transport models provides the key model parameters for 1997 and later years. The 1991 transport model network, however, is derived by modifying those sections of the networks which have been changed between 1991 and 1997, which is indicated by a horizontal arrow pointing to the left. In 1991, the land use and transport models are run iteratively until a stable solution is reached. The land use model for 1997 does not directly use the transport cost matrices generated by the 1997 transport model. To do so would mean that land use activities would have reacted instantaneously to transport costs of the current year. In fact there is usually a time lag between a change in transport cost and a change in land use decisions, and only some proportion of the travellers can react to changes in transport at any one time. It is assumed that half of the travellers make their land use decisions on the current year transport costs (e.g. 1997), and the other half do on the historic transport costs of the previous model period (e.g. 1991). This is indicated by the two merging arrows pointing from the 1991 and 1997 transport models towards the 1997 land use model.

For a future policy year, there are two ways in which the land use/transport interaction can be represented. First, a future policy year can be run with inter-temporal cost averaging as in 1997, as shown for 'Future Year 1'; model outputs from such a run indicate the most likely land use pattern based on time-lagged land use decisions. Secondly, the land use and transport models can be run iteratively till a stable solution is reached for a future year, as shown for 'Future Year 2'; this is applicable, for example, where the long term equilibrium solution is of policy interest.

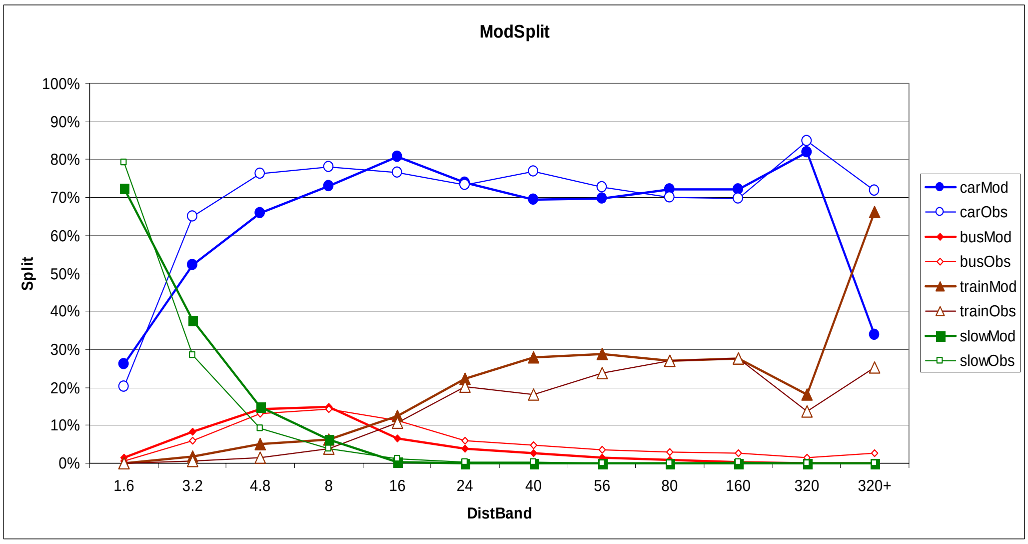
Figure 2. RUNNING LASER3.0 THROUGH TIME
Source: Author



Model performance

Model performance has been closely monitored in the simulation runs for 1991, 1997, and the future policy years of 2016 and 2031. The purpose of verification and validation is to confirm how well the model reproduces the observed calibration year data, and how capable it is of forecasting trends in land use and transport over a period of time.

Figure 3. MODELLED 1997 MODAL SPLIT VERSUS OBSERVED NATIONAL TRAVEL SURVEY (1988-1996 AVERAGE) - ALL PASSENGER TRAVEL
Source: Author



For 1991, the model has reproduced the geographical distribution of industries, employment, households, and individuals within the households as recorded in the Census. The patterns of trip making and modal choice for individual demand segments compare well with the UK National Travel Survey, London Area Transport Survey and Census Journey to Work Matrices. Traffic loads are comparable with the observed over road and rail cordons and screenlines, indicating the synthesised modal matrices are of good quality. However, traffic loads on individual road and rail service links do not always compare well with the observed, as it is often difficult to tune the loading to the network from the zone centroids where zones are large.

Model validation was carried out for 1997. This applies to both the land use model and the transport model, although observed data is more readily available for the transport model. In particular, the UK National Travel Survey, which serves as the main source for modal choice data for the study area as a whole, is a three-year rolling sample survey with a small sample size in each year for Great Britain The summary comparison is shown in Figure 3 for frequency distribution by distance band. They confirm that the patterns of modal choice by purpose and by car ownership are well captured by the model, similar to those in the calibration year 1991. The goodness of fit has been examined at the demand segment level, which shows good comparisons are achieved for most demand segments, especially those of commuting.

Short and long term travel demand elasticities

LASER3.0 is being applied to multi-modal transport corridor studies in the region. There is a strong policy interest in how mode choice is affected by pricing and non-pricing measures as well as by wider socio-economic change over the next 20 years. For this reason, it is important to assess the parameterisation of the model in terms of its short and long term demand elasticities. These elasticities are implied by the calibration of the modal choice models of travel and the spatial distribution models of land use activities, based on criteria of goodness of fit; they are not an input to the model in calibration. The demand elasticities are necessary rather than sufficient conditions for a good performance of the model; they do not substitute other aspects of validation. Nevertheless, for policy analysis they are probably the best indicators of model performance. Only own elasticities are discussed below.

The short term own elasticities are calculated between two model runs with a change in perceived user cost, with no change in the overall travel demand between each zone pair. In other words, they detect only mode switching, without any changes in trip ends or trip distribution.

For the long term own elasticities, a run of the transport model is first carried out with the changed costs. The revised cost and generalised cost matrices are fed into the land use model to re-estimate activity location and trip distribution. The transport model is run again with the revised demand matrices and the changed costs. The results are then compared with the base run. The percentage change of modal passenger km in this case includes not only mode shift, but also trip end and distribution change.

The tests are carried out on the model for 1997. The cost changes are tested for both an increase in passenger car fuel prices and an simultaneous increase of bus, coach, London Underground and surface rail fares. The model elasticities are found to be consistent with theoretical expectations and sensible for the LASER area. For further details, see Jin et al (2002).

LASER3.0 have been applied in a series of practical policy studies since its calibration in 2002. The recent examples include UK Department for Transport's Road Pricing Feasibility Study (WSP, 2004) and the Wider South East Research Study (WSP, 2005). Further academic research in on going using the LASER model in studying the planning and design of London's sub-urban areas (University of Cambridge, 2006).

LASER3.0 is an ambitious and wide-ranging model which covers all modes of passenger travel in the study area and a variety of land use and transport responses. It is designed to be a strategic model that is comprehensive in its potential to address policy initiatives. The key strength lies in the wide range of short and longer term behavioural responses that it represents. To achieve this while retaining computational feasibility, it sacrifices some spatial detail and so only has a limited ability to test small scale local network improvements with precision. In this manner it is complementary to spatially detailed assignment models.

The overall performance of the model based on the verification and validation work, has proved in general to be satisfactory. The enhancements that have been introduced to the model are working as intended and it has been applied in practice to test a variety of policy initiatives.

MODELLING FREIGHT AND LOGISTICS IN THE NORTH OF ENGLAND

The second model to be discussed here is a freight and logistic research model called EUNET2.0, which was recently completed for the north of England, where manufacturing and logistical activities form an important part of the regional economy.

The research considers economic and trade growth, evolution of manufacturing and service industries, and a series of logistics developments that have evolved in the last two decades. It is designed to examine

- The economy, including the sectoral growth, industrial restructuring, and the development of foreign trade in different commodity groups
- Land use change, regarding their impacts upon the volume and pattern of freight movement, and the associated location of handling and warehousing facilities
- Consumer and retail sector behaviour, and the changing trends in household expenditure, e.g. in shopping and in tele-shopping/mail-ordering
- Logistical evolution, i.e. the key trends in logistics and supply chain management
- Changes in transport operations, particularly in terms of road haulage, rail freight and inter-modal operations

The model represents a new methodology in freight forecasting that

- adopts detailed commodity categories and input-output modelling that are consistent with economic and trade forecasting at the national level
- represents main logistic stages and their choices of mode and lorry type
- forecasts future freight demand transparently, based on structural changes in production, trade, logistics, user charges and investment
- realistic user behaviour on location, distribution, mode and route choices, including redistribution of freight between intermodal terminals
- can interface with passenger and local traffic models.

The economic transactions (i.e. production, consumption and trade) between suppliers and consumers, and the logistics operations that actually deliver the goods, are the two main drivers behind the rapidly evolving patterns of freight movements. Logically, it is difficult to model future freight demand satisfactorily without due regard to the supply chains of the distribution system.

EUNET2.0 divides the flow of products from the initial producer to the ultimate consumer into a number of logistic stages, as appropriate for each category of commodity. The model thus estimates a large number of O-D matrices that are segmented by commodity type and type of distribution stage, including those handled by product consolidation centres, national/regional distribution centres, major ports, down to local depots. In doing so, it is capable of simulating influences on freight demand that come from logistical operations as well as from the wider regional and national economy.

The explicit representation of logistical stages distinguishes large, regular movements between producers and distribution centres (for which rail can potentially compete) from dispersed, time-sensitive movements to individual final consumers (for which road has clear advantage). The road/rail choice modelling has in fact been made simpler as the logistics representation is introduced in EUNET2.0.

Furthermore, it improves the simulation of the use of road goods vehicles of different sizes. Shipments from factories to distribution centres are typically single drop, large consignments moved on large vehicles, whereas the local distribution shipments are usually spread as part loads with more use of the smaller vehicle sizes, depending on the particular combination of the size and urgency of the consignment and on the access time windows for the pick up and drop.

Results from EUNET2.0 are assessed for both its Calibration Year (2001) and its Future Policy Year (2016). The sensitivity tests include road tolling and changes in average vehicle load factor. The performance of the model is discussed, particularly in relation to its responsiveness to changes in inputs that represent regional economic and freight logistics variables.

Innovation

This study addresses two key areas of innovation in freight demand modelling:

- First, it connects the pattern of freight demand to the underlying spatial pattern of economic transactions of the UK, thus providing a transparent interrelationship between the growth of freight and the patterns of economic activity. This makes it possible to explore opportunities for de-coupling freight growth from economic growth.

- Secondly, it represents the main logistical stages of freight transport explicitly.[1] By representing the main logistical stages explicitly, the model is better able to capture the choice between road and rail, and between the use of different sizes of lorries.

The main innovative features of EUNET2.0 are the representation of logistic movements, and the integration of this representation in a SIO model. These features make it possible to forecast changes in freight demand that result from future transport and logistics policy options, whilst taking into account of the growth and change in the spatial economy.

Model Structure

The many strands of the supply and demand components of the freight transport model are summarised in Figure 4 and Figure 5, respectively for the Base Year (2001) model calibration, and for application in a Forecasting Year (2016). Both charts when read from the top downwards illustrate the manner in which the demand for transport is estimated successively through a number of connected modules of the simulation model based on the MEPLAN software (WSP, 2004). Throughout, the input data to the model is divided into raw data (i.e. that is collected from existing sources) and processed data (i.e. derivations and estimations carried out within this study).

The core of the model is the set of iterations of the SIO model that represent the production and distribution chains within the second and third modules. At convergence of these two modules, an O-D matrix is output by freight type in units of the monetary value of goods transported. This value matrix is then converted into tonnes, and in turn the tonnes of weight by origin and destination are used to estimate empty returning lorries in the reverse direction of the trade[2]. Next, having been split by mode and lorry size, the matrix is converted into vehicles, which are assigned to the road and the rail freight networks[3].

The transport costs are fed back up the model as shown by the dotted lines. This feedback of costs ensures that the mode choice and the distribution pattern of goods movements are influenced by the actual door-to-door costs that they face on the networks.

[1] For example, the movements of food and manufactured consumer products are separated into a sequence of separate logistics legs: i) freight from the producer to a consolidation depot, ii) from the depot to a regional distribution centre, iii) from the regional distribution centre to supermarkets and shops, and iv) from supermarkets/shops to the consumers' homes.

[2] A simple approach to modelling empty return lorries has been adopted for EUNET2.0, as appropriate for a strategic freight model. The number of empty return lorries is worked out as a proportion of the total loaded lorries for each origin-destination pair, based on average proportions of empty running for each category of product (such proportions are observed to be stable over time). An empty lorries origin-destination matrix is then created, and the empties are assumed to travel in the reverse direction to the trade. This approach may be inaccurate in some cases where the lorry has a triangular itinerary. However, the simulation of complex itineraries is beyond the scope of the current study.

[3] The road network has congested travel times that take account of the existence of passenger traffic on its links.

Figure 4. THE STRUCTURE OF THE EUNET2.0 FREIGHT AND LOGISTICS MODEL: CALIBRATION YEAR (2001)
Source: Author

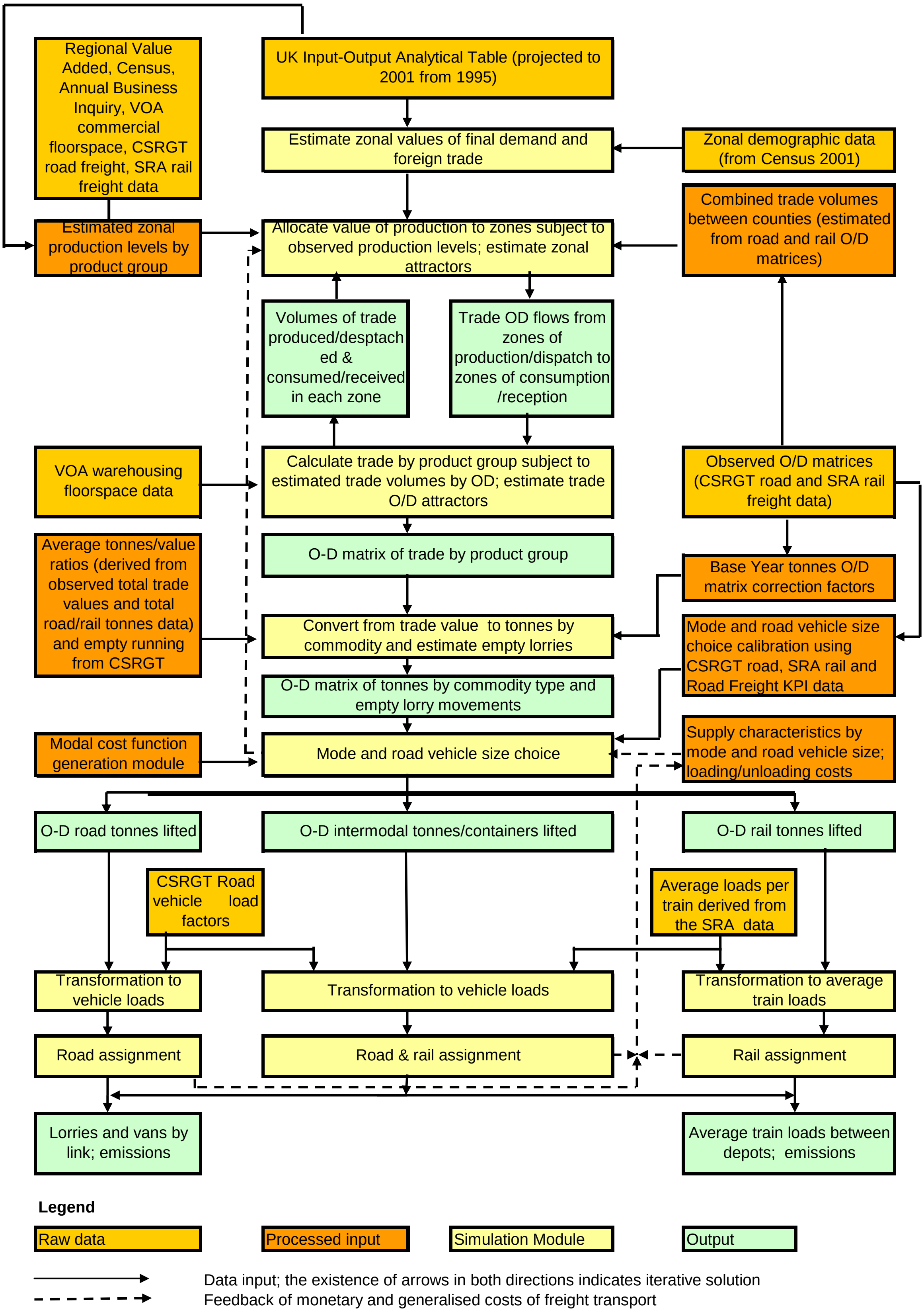
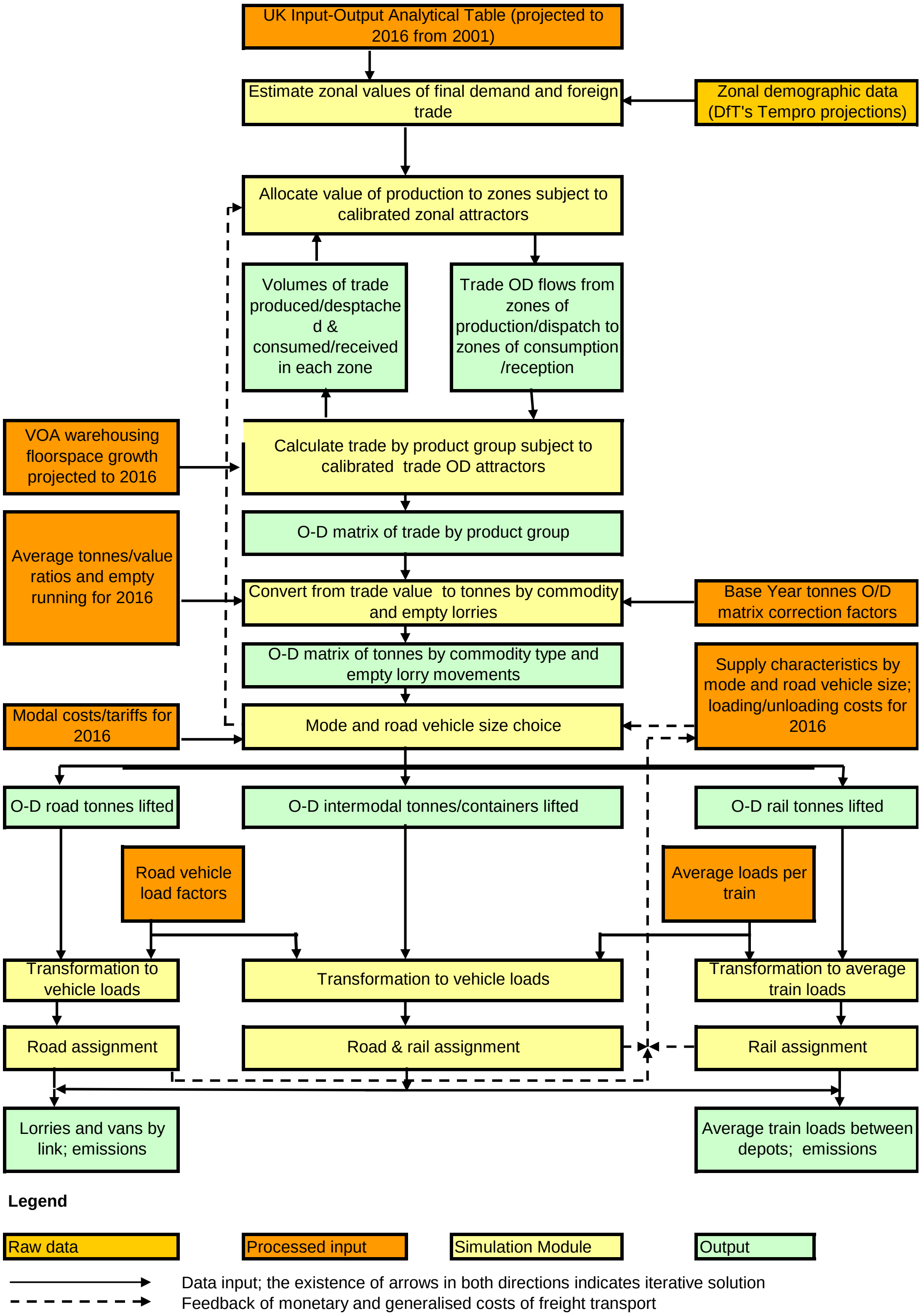


Figure 5. THE STRUCTURE OF THE EUNET2.0 FREIGHT AND LOGISTICS MODEL: FORECASTING YEAR (2016)
Source: Author



DEFINITION OF DISTRIBUTION STAGES

The most innovative component is the structure that is used to represent the movements of goods subdivided into their individual distribution stages, both for domestic movements within the UK, and for imports and exports.

The freight market is divided into 22 groups of products, excluding crude petroleum[1]. Five types of logistics chains have been set up for each product category, depending upon the initial origin of the products. These are:

- goods produced in the UK destined for consumer retail market in the UK,
- goods produced in the UK destined for use by firms and institutions,
- goods produced in the UK for exports,
- goods produced outside the UK for consumer retail market in the UK, and
- goods produced outside the UK for use by firms and institutions.

The complexities of these logistic chains differ from commodity to commodity, because the number of times the goods are lifted between production and consumption (or in short, the **handling factor**) varies considerably between product groups. The design of these logistics chains has made use of knowledge on the average handling factors for Great Britain, calculated using a number of data sources by Campbell and McKinnon (1997) in the REDEFINE project (REDEFINE, 1999).

A simple example of the distribution chain is shown in Figure 6 for manufactured goods and components used as inputs to industrial production, to illustrate the relationships between production/consumption links, and the distribution chains and distribution channels modelled in EUNET2.0. The product groups that adopt this chain structure include goods at the higher end of the value density spectrum, such as textile products, machines, instruments, vehicle parts and the like.

The various logistic stages that may arise in the course of moving such manufactured goods from the zone of production to the zone of consumption are illustrated in the three diagrams shown in Figure 6

- The left hand diagram shows a single link between production (i.e. supplier of the goods) and consumption (the industrial user of the goods), in other words, from the factory/farm where the good is produced to another factory/farm where it is used as an input to the production of some other goods.
- The middle diagram shows the various distribution legs within the distribution chain for this single production-consumption relationship. The goods are first moved to a depot to be consolidated so that they can be moved on large vehicles; some to a distribution centre A and others to another nearby depot for use in adjacent factories. Some of the goods at the distribution centre A will be moved to another distribution centre B if they are being shipped to distant locations, others will be moved straight to depots for transfer to the factories where they are consumed. Each type of distribution leg is assigned a distinct commodity type number as shown in the diagram. This code is used to distinguish the type of entity at its start and end point, the level of costs faced, and the mode/vehicle type mix used on that type of distribution leg.
- The diagram on the right shows how these combinations of distribution legs, when set up in the model, generate a variety of distribution channels. Each sequence of distribution legs connecting from the producer through to the consumer is a separate *distribution channel* - the model is calibrated on the basis of average handling factors to represent the relative weights of the distribution channels for each product group. For example, products that have a high average handling factor put through a larger proportion of goods via the multi-legged channels.

[1] Crude petroleum is excluded on the basis that its transport planning is generally separate from other freight traffic and crude petroleum traffic has little impact on road congestion.

Sensitivity Tests in Forecasting Mode

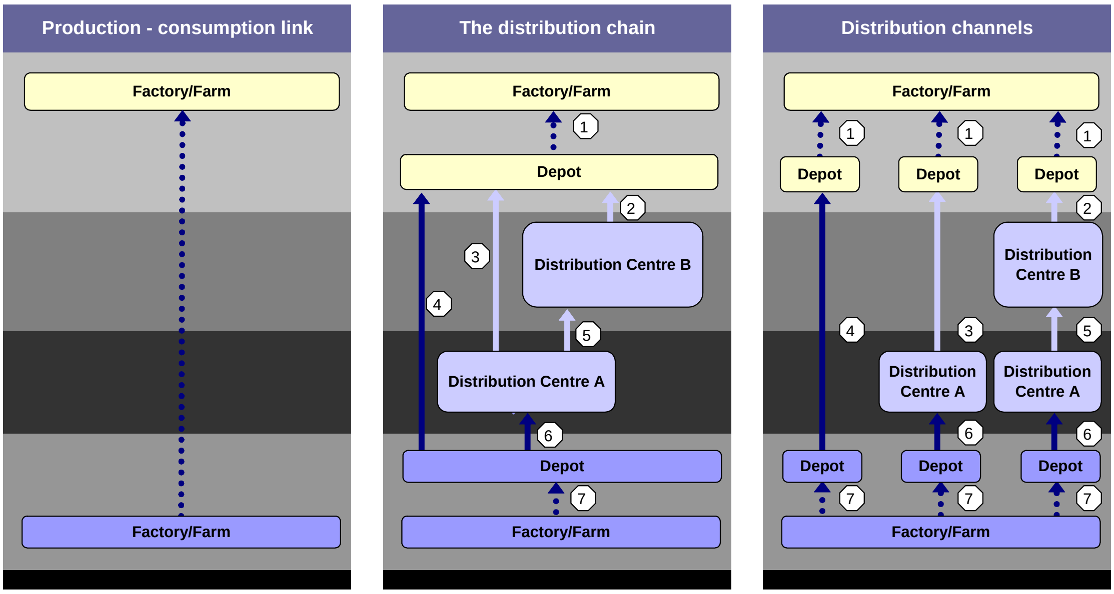
The EUNET2.0 model has been run to 2016 for demonstration purposes. It makes use of the economic and demographic assumptions that are derived from the GDP forecast of HM Treasury (2005) and employment and demographic projections from UK Department for Transport. A number of other assumptions are also made regarding future developments of road and rail freight costs, warehousing location and logistic operations.

Although this Base run compares well with the trend of slow growth on road and significant rail freight growth in the last few years, it should be noted that the model results are highly contingent upon the input assumptions. The model is capable of representing e.g. the continuing evolution of the logistics operations such as those currently taking place with the third party pallet logistic networks, and potentially further reduction of labour costs in the road haulage industry. Alternative input assumptions, such as significant logistics re-structuring, improvements in road speeds, and a fall in real road haulage costs, may lead to higher forecasts of road freight demand.

Two further sensitivity tests have been carried out to give insights into the responsiveness of the model. This form of sensitivity test is particularly useful for analysing those input variables whose future development trajectory is highly uncertain, and for which little consensus exists. The first test introduces a road pricing scheme with the tolls set at a level that differentiates tolls by time of day. Such tolling schemes will have a different impact on traffic that travels during the normal working hours, from that travelling by night. A second sensitivity test increases the average payload factor by 10%. This change is applied to all road goods vehicle types, including the articulated trucks, rigids and vans, for all non-bulk flows that are on either the primary or secondary stage, which accounts for 74% of all tonne-kms and 68% of all tonnes under the 2016 Base case. Such changes in payload factor can arise due to a variety of future changes in vehicle capacity (in terms of either loading weight or volume capacity), product mix, handling equipment, and goods packaging.

Whilst projecting the model to 2016 demonstrates that the model is versatile in implementing a wide range of future year assumptions in a transparent manner, the sensitivity tests show that the model's underlying demand elasticities with respect to price changes are consistent with those published in the literature. They also show that the model is capable of producing a wide range of demand responses, from trade distribution, modal choice, to route choice. For details of this model, see Jin et al (2005). There is still room for fine tuning some of the more detailed aspects of the model. However, the research methodology has now been applied in the policy studies in the UK.

Figure 6. PRODUCTION/CONSUMPTION LINK, DISTRIBUTION CHAIN AND DISTRIBUTION CHANNELS FOR MANUFACTURED GOODS AND COMPONENTS FOR INDUSTRIAL PRODUCTION
Source: Author



MODELLING FOR 25 MEMBER COUNTRIES OF THE EUROPEAN UNION

The third model, SCENES is a European-wide multi-modal integrated passenger and freight transport model. It was developed through the European Commission's Fourth Framework Research Programme and has since been extensively used in research and policy studies of DG-TREN and other Commission services.

SCENES uses standard European nomenclature and NUTS2003 GIS data to define the geographic areas (which are called model zones; see definition of the zones later in this Section). For the EU25, it operates at the NUTS2 level for passenger and freight demand modelling, and at the NUTS 3 level for road traffic analysis. All EU10 New Member States are incorporated within the SCENES model as internal zones, including Cyprus and Malta. The SCENES model also covers Switzerland and Norway at a NUTS2-equivalent level, although the extent of transport demand modelling is limited. The Candidate Countries are included as external zones of the model at the country level. Other countries in Europe and in the rest of the world are covered in broad geographic areas that reflect the main trade routes by land and sea.

For the purpose of this project, the Base Year of the SCENES has been updated from 1995 to 2000. This means that all main input data underpinning the Base Year modelling have been updated, including the national accounts, population size and profiles, and transport supply. The model provides forecast for both 2010 and 2020.

The freight demand model is based on a sophisticated regional economic model (REM) using input-output techniques for EU15, and trade-based matrices of goods movements for EU10 that are estimated using data from a recent DG-TREN project, TEN-STAC (2004), and from the European foreign trade database COMEXT. The passenger demand model uses a uniform trip generation and distribution mechanism for all EU25, based on the age, employment and car ownership profiles of the population in each model zone; it also covers all short and long passenger trips, including car/motor-cycle, bus/coach, train/metro/tram, air, and walking/cycling.

Transport networks are coded in the model for highways, rail, inland waterways, ferries and short sea shipping. The model uses a detailed European road and rail networks for assignment.

Vehicle operating cost and tariff functions are coded for each type of travel. Travel costs, times and generalised costs are output from the transport model and fed into the demand model. Any change in the transport model, be it through transport cost or infrastructure change, or any change in the travel speeds, has a bearing on the demand for travel. This feedback affects the distribution and hence the average length of trips, and thus passenger- and tonne-kilometres.

The model is calibrated in the Base Year (2000) on observed national totals of travel by mode, and known international patterns of passenger and freight transport. The sub-national pattern of passenger and freight traffic is generated by the model, based on typical travel behaviour for each freight and passenger demand segment defined in the model.

The model is designed, in the first instance, to produce European-level transport forecasts. But, comprising as it does a wide range of demographic, economic, socio-economic and transport factors, and being built as a ‘bottom up’ model from the zonal level, a greater level of detail is possible, and indeed many country and sector specific results have been reported.

The most recent forecasts for 2010 and 2020 were carried out for the Directorate General for Energy and Transport of the European Commission in the ASSESS project (TML et al, 2005) which provided policy research for the European Commission's mid term review of the transport white paper (European Commission, 2001). The policy inputs are defined through

- road and rail networks, and network variations for alternative scenarios;
- defining the transport cost and tariff functions, particularly for road vehicles based on fuel price assumptions
- demographic projections, including population size and the profile of age, employment and car ownership
- macro-economic projections on GDP foreign trade growth

The model results are cross-checked with the recent observed rates of demand growth by mode in the member states, and the freight and passenger demand elasticity with respect to price changes conform to the observed values in published transport demand literature. In this sense the results are robust and they reflect well the differences in inputs between the alternative scenarios.

Because of the sheer spatial scale of the model which covers all EU25 and beyond, the network details and spatial interaction at the local level may not all be accurate. Consistent observed data is lacking at this level to check the model outputs. As a result, spatially detailed results will need to be examined with care and only used where there is corroborating evidence at the local level.

Although there is a substantial body of research on demand elasticities with respect to price changes, the actual impact of price changes on demand may still be affected by new adaptations the transport users may make in freight logistics and in daily activity patterns of passenger travel. Although the model is consistent with the known demand elasticities, the results will need to be continuously examined as new evidence emerge (such as from the road charging schemes for trucks that have been implemented recently in some European countries). This is especially so given the Social Marginal Cost Pricing measures may be implemented in very different ways from previous cost measures, and they may evolve in different directions through time. Further details of the research and model results are published in Jin, Deane, Zhu, Jakimovska, Martino and Fiorello (2005).

CONCLUSIONS

This paper has discussed the need for and availability of practical modelling methods for integrating transport and land use planning. Land use planning here is defined in its wider sense embracing economic development, urban and rural construction, logistics, demographic changes and consumer behaviour. Two practical models that have already found extensive policy use in the UK regional and European policy studies, and a further one that is being examined by the research community have been discussed.

It would appear that the data sources that these models use, such as the employment and population census, and travel behaviour surveys are starting to become available in China's city regions. The current development in transport and traffic modelling in the city regions provides natural platforms for building more comprehensive models that integrate economic and land use analysis. The need for policy integration has also been growing. However, as the policy models tend to remain as grey literature such as study reports (albeit published by the national government and the European Commission), further exchange and debate would be useful to disseminate what has been learnt, a knowledge at present are only accessible to specialists in the field.

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