DEVELOPMENT AND APPLICATION OF THE GREATER MANCHESTER STRATEGY PLANNING MODEL

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1. INTRODUCTION

Greater Manchester is a large conurbation in the North West of England with a population of approximately 2.6 million. It is a polycentric urban area, with ten district councils. Manchester City Centre, as the largest urban centre, acts as the Regional Centre and is the primary focus of the public transport network. However, the presence of many other important urban centres in the conurbation leads to a very complex pattern of travel demand.

The conurbation has an extensive motorway network and the orbital motorway (M60) is due to be completed in the near future. Other than for travel to the Regional Centre, bus is the main mode of public transport. The suburban heavy rail network, which terminates at the periphery of Manchester City Centre, is operated mostly by short two or three car trains at typical frequencies of 15 to 30 minutes, and its usage is accordingly rather low. The first line of the Metrolink LRT system opened from Manchester to Bury and Altrincham in 1992 and a major programme of extensions to the system has gained government support.

In Greater Manchester, as in other metropolitan areas, recent years have seen a rapid growth in car ownership, leading to a dominance of car travel, with accompanying reductions in public transport services. Over the same period, there has been a dispersal of economic activity, so that many journeys are only feasible by car, stimulating further car ownership and reduced public transport, in the classic vicious circle. This has led to worsening traffic congestion and reduced accessibility for people without access to a car.

To counter the adverse impacts of these changes, the Greater Manchester local authorities (which comprise the ten district councils and Greater Manchester Passenger Transport Authority) have been pursuing policies which seek to reinforce the existing urban pattern. In addition, they have sought to revive areas that have declined as a result of the major industrial and commercial restructuring of the late twentieth century. The provision of high quality public transport is regarded as critical to achieving these objectives. In order to plan measures to tackle these transport issues the Greater Manchester Authorities commissioned a model that would enable...
them to examine the consequences of alternative transport strategies\(^1\) and scenarios\(^2\) in a comprehensive manner.

The Greater Manchester Modelling System (GMMS) is a two-tier modelling system, comprising strategic transport and land-use models at the upper level, with detailed traffic and public transport assignment models at the lower level. The Innovative part of GMMS is the Greater Manchester Strategy Planning Model (GMSPM) which is based on MVA’s strategic transport model START \((1)\) and the DELTA \((2)\) land-use model of the David Simmonds Consultancy. In this paper we outline the concept and structure of GMSPM, but concentrate on results from the model, some of which have been used to support the Local Transport Plan submission for Greater Manchester.

2. Model Objectives

With increased government emphasis on multi-modal approaches and demonstrable appraisal, the model was designed to aid the authorities in the development and appraisal of strategies across modes throughout the conurbation. Strategies intended to achieve this change in behaviour typically consist of a range of policies and measures, including:

- land-use policies that seek to reduce the need to travel;
- measures to discourage the inappropriate use of private transport, and thus encourage a transfer to other more sustainable modes (bus, rail, walk, cycle); and
- measures to improve the image and performance of public transport.

The model had to be able to reflect the interaction over time between transport demand and supply, and the manner in which the two elements move towards equilibrium. The model must also reflect the policy of introducing combinations of transport and land-use measures, representing any synergy between them. This requires the consideration of both land-use effects on transport demand and the effects of transport supply on land-use, in a dynamic land-use/transport interaction model.

3. Model Overview

The objectives require the model to be capable of representing considerably more effects than a conventional transport model, in particular choice of destination, choice of time and frequency of travel, car ownership decisions, and land-use choices, in addition to the more conventional mode and route choices. The model had to reflect these effects in a way that would permit comprehensive evaluation of the social, economic and environmental effects, whilst being capable of run-times that would enable it to be run many times during strategy development.
Realistic modelling of travel behaviour requires highly disaggregate travel demand data, reflecting the differences between different person types and between different trip purposes, in conjunction with detailed transport supply data. This combination of detail in an equilibrium model is not compatible with the required run-times. Consequently, a two-tiered approach was adopted, with travel demand and land-use dealt with at the higher level, using large geographical zones and numerous person categories. Route choice issues are dealt with in a strategic manner at the higher level but, in principle, can be modelled in more detail at the lower level.

The transport element of GMSPM is a development of MVA's START model, which has two main components: the demand model and the supply model. The demand model calculates the changes in travel patterns - from change of route up to generation and suppression of trips (in a nested hierarchy) – due to changes in generalised costs of travel. The supply model deals with both 'system effects', such as the effects of highway congestion upon vehicle speeds or of overcrowding upon passenger behaviour; and with 'operator effects', such as decreasing public transport frequencies as a response to decreasing demand. The strategic transport model is iterated until aspects of the demand and supply processes are in equilibrium. The convergence routine within the transport model ensures that the outputs from successive iterations are equivalent. Figure 1 shows the basic structure of the strategic transport model.

The structure of the non-transport elements of the strategic model falls into two separate parts. The first part is the DELTA land-use model, which deals with changes in land-use, household structure, employment and car ownership. The second part consists of the external forecasting model, which provides the link between the land-use and transport models.

The results from the transport model are passed both to the evaluation module and to the calculation of land-use effects. The evaluation module provides full analysis on travel statistics, economics, environmental indicators and accessibilities.

3.1 Strategic Transport Model: Demand Model

With the exception of the generation/suppression effect, the demand model is constructed entirely as a set of incremental nested logit choice models. It starts from a fully detailed set of base year matrices, and - given the specification of the models and all the necessary coefficients - calculates the changes at all levels in response to changes in generalised cost at the most detailed level.

The different levels of the nesting hierarchy correspond with any or all of destination choice (including specific treatment of intra-zonal movements), mode choice, sub-mode and/or route choice, and time-of-day choice. Route
choice is available for car and public transport travel. The order in which these choices are implemented within the hierarchy was selected for each traveller category on the basis of the available evidence. Figure 2 shows an example of a choice hierarchy within the demand model.

3.2 Strategic Transport Model: Supply Modelling

The future year travel demand estimates are transferred to the supply model and grouped into the required categories. These categories include vehicle and passenger link flows, origin/destination person flows and demand for parking. Some important features of the supply model are listed below.

- **Highway capacity** is represented by a mixture of 'implicit' and 'real' networks, rather than a conventional network representation. The implicit network is measured in terms of the road capacity within each geographic zone for the main directions of travel and includes radial inward and outward, and orbital clockwise and anti-clockwise. The real network represents major links such as motorways, bridges and tunnels.

- **Highway and Public Transport routes** are defined in terms of the distance travelled on implicit and real networks, determined directly from the detailed models. Thus, realistic infrastructure changes can be made in the detailed model and properly represented in the strategic model.

- **Speeds on links** are adjusted in accordance with the change in total flow, which can include the assigned flows of cars and goods vehicles; bus flows; traffic searching for parking spaces; and exogenous flows such as through (external-to-external) traffic. Highway public transport speeds are related to car speeds and allowance is made for bus lanes, time at stops and passengers boarding and alighting.

- **Parking supply** capacity affects both the time spent searching for a space and the egress (walk) time. This includes splits between short- and long-term parking, the use of private non-residential spaces (PNR) and of public parking, and consideration for residential parking or not to park at all (setting down passengers, delivering light goods).

- **Bus waiting times** are a function of frequencies plus the likelihood that the first bus will be full.

- Crowding **penalties**, determined from the ratio of passengers to the number of seats, can be applied to public transport journey times.
Public transport fares and service levels input can be adjusted between two opposite strategies: maintaining constant service levels and fares, regardless of changes in demand, or adjusting service levels and fares in proportion to demand.

3.3 Strategic Land-Use and External Forecasting Model

The theoretical structure of the land-use model is based on the view that there is no single process of urban change, but a variety of different processes, each having its own dynamics, which interact in certain ways. The land-use model therefore consists of a database and a number of sub-models each representing one or more process of urban change. Some, though not all, of these respond, usually with time lags, to the results of other processes.

The land-use model consists of six sub-models. These estimate: the development of buildings on land; demographic transitions and economic growth; levels of car ownership; location and relocation of households and jobs; employment status changes; and changes in quality of urban areas. The first and last deal with changes in the quantity and quality, respectively, of the buildings available for households and firms to occupy. The other four models deal with changes in activities.

The transport and land-use models are combined such that the demand for transport at any time is based upon the estimated land-uses at that time. The land-use model calculates changes in the location of activities and in the physical development of land over time, with explicit time lags representing the time that such changes take, for example, from the decision to build until the new building is available for occupation. In GMSPM the land-use model is run for every year and the transport model is run every fifth year. Figure 3 shows a simplified example of this transport/land-use interaction process.

The development of a dynamic, time series, land-use/transport interaction model permits the representation of self-reinforcing trends in transport usage. The best understood of these is the 'public transport spiral of decline' where rising incomes cause more cars to be purchased. This results in less use of public transport and hence higher fares and reduced services, leading to greater use of existing cars and back to increased incentive to purchase cars. The dynamic model is also able to represent how investment in highway facilities could lead to development pressure in outer urban areas, or how public transport investment, combined with a general increase in the cost of car usage, could support central area regeneration.

The external forecasting model converts the base and future year zonal land-use planning data to origin/destination travel demand that is not constrained to future congestion (that is the purpose of the transport model). Essentially, the external forecasting model uses land-use data to estimate, separately, the future production of trips from origins and the future attraction of trips to
destinations. These two forecasts are then combined to provide future year trips that are solely based on changes in land-use.

4. The Reference Case

The first strategy and scenario developed for Greater Manchester was for minimum change, against which the results for other model tests could be judged. There are two key elements to the philosophy behind the Reference Case: transport supply changes other than those already committed should be minimal; and land-use change should not be too tightly constrained by planning policy but should be able to respond to the effects of alternative transport strategies. The Reference Case assumed no investment in new transport infrastructure beyond 1996, other than the completion of the remaining sections of the M60 Manchester Motorway Box. Metrolink from Bury to Altrincham via Manchester City Centre was treated as opening in 1991, although the opening date was in fact 1992.

4.1 The Reference Case 1991 to 1996 Changes

The key changes in transport supply between 1991 and 1996 have been estimated from observed data and are common to all the test runs. Those changes are:

- bus fares increased by 13% in real terms and rail fares by 7%;
- in the am peak period Metrolink fares declined by 9% and increased by 3% at other times of day;
- car ownership grew by 11%, with some decentralisation of the population from the older urban areas to the periphery of the study area.

4.2 The Reference Case 1996 to 2021

It was assumed that the final link (Denton to Middleton) of the M60 Manchester Motorway Box would be completed, and that the Trafford Centre retail development would be opened between 1996 and 2001.

Other key forecasting assumptions between 1996 and 2021 were:

- incomes (and values of time) increase by 2% per annum in real terms;
- the fuel price duty escalator is set at 5% from 1996 to 2001 and 2.5% from 2001 to 2006;
park and ride capacity at Metrolink and rail stations was set at 120% of the 1991 parking demand; and,

bus frequencies and fares are assumed to be adjusted by operators in response to demand levels; train or Metrolink frequencies (but not fares) were adjusted downwards (with time lags) if demand fell below 1991 levels; if train or Metrolink demand increased above 1991 levels, train length was increased, reflecting limited opportunities for increasing frequencies without investment in new infrastructure.

4.3 The Reference Case Demographic and Economic Scenario

The main features are that over the period 1991-2021:

- the population of the Study Area remains stable;
- the number of households in the Study Area increases by 21%;
- the number of jobs in the Study Area remains stable; and
- the income of a household of any one type increases by 94% (2.24% pa), whilst the reference price of "Other goods and services" (i.e. everything except housing and transport) remains constant.

4.4 The Reference Case Planning Policy Assumptions

The key features of the reference case planning scenario are listed below.

- The planning scenario is based upon entering planning permissions (i.e. creating available space for development) for the space categories of residential, retail, office and industrial. Note that no demolition was entered (other than that known to have occurred before 1996). All planning permissions for the period 1996 to 2011 were estimated, and were then applied on an annual 'drip feed' basis, with the same rate used for 2011 to 2021.

- All development within the land-use model occur in either brown field or green field sites. The difference is in the costs of development, which are higher for brown field than for green field.

- Allocations of land for housing were based upon the Greater Manchester Planning Framework, and converted into the amounts of housing floor space that could be built in each zone.
For the non-residential sectors, TEMPRO employment projections were used to provide a guide to the total amount of commercial floor space required.

For the retail allocations of planning permissions, an additional 10% of 1991 stock was allowed in the various central area zones, and 5% in all other zones. The exception was the Trafford Centre edge-of-town shopping mall, which was added exogenously in 1997;

Growth at the airport was added exogenously, related to forecasts of expected passenger growth.

The permitted increase in office space was set at 6% of the 1991 stock.

Industrial space was treated the most simply, with a permitted increase of 5% of the 1991 stock, given the lack of any other sources for estimates.

4.5 Reference Case Findings

The 1991 base mode shares are shown for each of three different areas (the Regional centre, Other centres and whole Study Area) in Figure 4. Of the three areas, car mode share is, not surprisingly, lowest to the Regional Centre, at 42%, where walking and cycling trips are also at their lowest. Rail and LRT have greatest influence on the Regional Centre, where together they account for 18% of trips. Bus use is highest to the other centres.

Car ownership is forecast to grow from 0.35 cars per person in 1996 to 0.5 cars per person in 2021.

From 1991 to 2021, the reference case shows an overall increase in travel (trip kilometres) of 13% across the study area, with a growth of 27% in car travel. This will be at least partly due to the growth in incomes and car ownership. Bus travel is predicted to decline to 39% of its 1991 value, and rail travel to 82% of the 1991 value. Walking and cycling are predicted to fall to 55% of the 1991 levels. Only LRT is able to withstand this decline in public transport, showing an increase of 52% over the base level. These changes are accompanied by a growth of employment in the Regional centre of 4% and of population growth in Other centres, implying a degree of centralisation. Overall, public transport patronage in 2021 is predicted to be 62% of its 1996 level.

Peak period highway travel speeds are estimated to decline over the forecast period to 2021 to 75% of their 1991 level, with average speeds of 23 kilometres per hour across the study area.
Clearly, such high levels of car use and congestion are not desirable, and the remaining tests demonstrate approaches that could be considered to reduce this dependence on the car.

5. Public Transport Investment Test

The public transport investment test was based on the reference case infrastructure strategies, and land-use scenario and planning policy assumptions. The purpose of the test was to examine the extent to which investment in Metrolink and Bus, combined with some loss of highway capacity for car travel, could help contain the growth of car travel. For the sake of simplicity in the test, all improvements were added in 2001.

There was assumed to be a very substantial increase in the coverage and capacity of the Metrolink network. This included extensions of the Metrolink network with new lines to the Airport, Stockport, Ashton-under-Lyne, Rochdale (via Oldham), Eccles and the Trafford Centre, in addition to the existing service to Bury and Altrincham.

Other aspects of the test were:

- introduction of bus lanes on major radial roads, with commensurate 15% loss of highway capacity for general traffic;
- 20% reduction in bus waiting times; and
- 10% increases in bus speeds, reflecting improved fare collection systems.

5.1 Results from the Public Transport Investment Test

The assumed investment in 2001 is forecast to cause a slowing down of the car travel growth for the years 2001 and 2006, but the trend then continues for later years, resulting in car travel in 2021 being only 3 percentage points below the reference case. (Car ownership, which is linked to accessibility, is also forecast to be approximately 2% lower than the reference case.) However, this corresponds with LRT usage in 2021 about twice that for the reference case, rail usage almost 30% higher and bus usage 12% higher. Overall public transport usage in 2021 is predicted to be 77% of the 1996 level. There is some increased concentration of activity in the Regional and other centres, with increased employment in the Regional centre and increased population and workforce in the other centres.

The forecasts suggest that a policy of public transport infrastructure improvements alone has a useful but modest effect on containing the growth of car ownership and use.
6. Public Transport Quality Improvements

A feature of the incremental modelling approach is that the base conditions, perceptions and attitudes, can be assumed to be carried forward into the future (as implicit mode constants, etc.). In 1991, five years after bus deregulation and prior to the rail franchises, neither bus nor rail services (nor even Metrolink) were as attractive to users and potential users as they could have been. There is believed to be considerable scope for improvement in such areas as vehicle quality, reliability, and information. It is believed that some of these improvements have already taken place and the improvements are expected to continue in the future.

Research undertaken as part of the Metrolink Monitoring Study, and as part of the appraisal of individual Metrolink lines, has shown a modal constant between bus and Metrolink of approximately 20 minutes for car-available individuals. After discussion between consultant and client, we concluded that improvements of 5 minutes for each of bus and rail and 2.5 minutes for Metrolink were the most appropriate representations of the expected quality improvements, which were being undertaken as part of the GMPTE Integrate initiative. These changes were introduced at 2001, in addition to the investments assumed by the previous test, and applied to all individuals regardless of car availability.

6.1 Results from the Public Transport Quality Improvements Test

As for the public transport investment test, the quality improvements had a substantial effect on public transport patronage, but a more limited effect on car use. Growth in car use slowed over the 2001 and 2006 period, but reverted back to the reference case growth profile thereafter. Nevertheless, the combined effect of the public transport investments and the quality improvements limited the 2021 growth in car travel over 1991 to 21% as opposed to 27% in the reference case. This corresponds with bus usage having declined by 27% from the 1991 level, and increases in rail usage of 30% and LRT usage of 164% on the 1991 level. (This can be compared with declines of 61% and 18% for bus and rail and an increase of 52% for LRT between n11991 and 2001 in the reference case). In fact, bus and rail appear to attract patronage away from Metrolink, compared with the public transport investment test. Overall, public transport travel in 2021 is predicted to be equal to the 1996 level.

7. Road User Charging Test

This test investigated the effect of a hypothetical road user charge of 10 pence per vehicle mile, applied in the peak periods only, across the whole conurbation. The road user charges were introduced as an addition to the public transport improvements referred to above.
7.1 Results of the Road User Charging Test

The road user charging test again slowed down car ownership growth over the 2001 and 2006 period, resulting in a 2021 forecast of 18% growth in car travel over 1991 as opposed to the reference case forecast of 27%. Car ownership in 2021 is forecast to be 0.47 cars per head (6% below the reference case). Bus, rail and LRT patronage all increase, with the most substantial proportional increase going to rail, which shows a growth of 30% over its 1991 value, as opposed to a decline of 23% in the reference case. Bus patronage in 2021 is now 77% of its 1991 level, as opposed to 42% in the reference case. Overall public transport usage in 2021 is forecast to be 115% of its 1996 level.

The increases in public transport usage support and are supported by increased centralisation of employment in the Regional centre and in other centres. In the other centres, particularly, the employment level is forecast to be 93% of its 1991 level, as opposed to the forecast of 86% of the 1991 level in the reference case.

8. Conclusions

The dynamic land-use and transport model as defined and used in this analysis is one of the most advanced models which has been developed. However, the model is still a simplified representation of the many complex relationships in the land-use/transport system, and it may be that this limits its ability to forecast the self-reinforcing effects, which we expect to see in land-use/transport interaction. Nevertheless, there is evidence from the model that, as represented, the policy of investment in public transport can encourage a centralisation of activities such that public transport patronage on modes such as LRT can benefit.

It is rather more worrying to find that, as represented, the growth in incomes and car ownership will fuel continued increase in car use. This increase in personal mobility may encourage the dispersal of activities, and the proposed improvements in public transport are forecast to have an important, but limited, effect on this trend. Again, it is possible that some of this continued growth is due to limitations in the model specification. However, in this case we believe the modelling limitations are small compared to the inevitable consequence of a growing economy where the use of the car is not constrained. Even the hypothetical road user charging test has relatively little effect on the anticipated growth in car use, although it certainly has an effect on public transport patronage (and implies a substantial revenue stream which could be used to provide further improvements in public transport).
It is quite clear that road traffic reduction will not be achieved readily, and will require a combined approach of land use controls, public transport investment and restraint of private transport. The use of a dynamic, strategic, land-use/transport model, such as that described in this paper, can help in identifying the appropriate mix of policies and measures to contain future traffic growth.

Use of the model has enabled a range of issues to be addressed and investigated and policy directions to be considered. It must be recognised, however, that the use of the model requires considerable commitment and strong interpretative skills, since the interactions within the model can lead to some apparently counter-intuitive results. As a stand-alone tool, the dynamic strategic model is most suited for use in the overall identification of policy direction and strategy. It will generally need to be supplemented by other, more spatially detailed models or analysis for detailed scheme and policy testing and appraisal.

Bibliography


Figure 1 GMSPM Strategic Transport Model
Figure 2 Example of a Choice Hierarchy Available Within the Strategic Demand Model
Figure 3 The Dynamic Transport/Land-Use Modelling Process
1991 Regional Centre Mode Split

1991 Other Centre Mode Split

1991 Study Area Mode Split

Figure 4: Base Year Mode Shares
Notes

1 Strategies are combinations of transport infrastructure measures, other transport policies and land-use policies.
2 Scenarios are changes over time in the size and composition of the population, in the number and types of jobs, in incomes etc.