Transport Modelling - A General Introduction for Non-Technical Readers

This introduction to modelling arose out of a request to add a less technical introduction to my chapter on modelling in the 2003 edition of Traffic Engineering and Management published by Monash University. Unfortunately, I could not respond within the page budget.

What is a Model?

Models, both physical and mathematical, are developed for similar reasons. It saves money and time to investigate the lift and drag characteristics of an aircraft by placing a scale model in a wind tunnel rather than building a full size version. Predictions of guided missile performance against a wide range of targets can be made using computer-based mathematical simulations of the missile systems and aerodynamics, information which would be very difficult to obtain otherwise.

Transport planning models are computerised mathematical models which are intended to provide answers to questions like: How many cars will use a proposed new motorway in 20 years time? Would it be better to provide a rail link in this corridor or improved bus services? Looking ahead 20-30 years, what transport infrastructure will be needed in this city and what transport policies should be applied to minimise congestion, pollution etc? What is the optimal re-design of this intersection to alleviate congestion for the next 5 years?

In all of these examples, both in the non-transport and transport contexts, experienced professionals may be able to suggest the likely answer - the most efficient wing profile or an efficient intersection layout - and opinionated commentators may feel quite sure that they too have the answers (quite common in transport planning!). Consequently decisions are made without modelling in many countries/states, but it is reasonable to ask how good these decisions really are.

It is equally unreasonable to presume that transport models alone can provide all of the answers. Transport plans should serve the objectives of the community, which cover a wide range of consequences of transport infrastructure and policy, not just a faster or cheaper journey, and not all of these are appropriately dealt with by models. But, while models are not the complete answer, they do provide information to help in reaching a decision.

Transport Decisions

Governments have many competing claims on their budgets and insufficient funds to meet all of them. Treasuries typically advocate directing limited financial resources to projects which will have the greatest impact on the economic performance of the country or state. Many require the use of cost benefit analysis to quantify the economic return on project investment.

This remains an important aspect of transport planning - determining the benefits of transport investment (in a new road, a better rail service or an improved intersection) and comparing these with the financial cost. Within a limited expenditure budget, transport projects whose costs are high relative to the benefits may not proceed if there are better performing projects available. It has been common for governments to rank transport projects by their economic return and choose to build only those top-performing projects which can be afforded within the annual budget.

For the purpose of forecasting the benefits, the role of transport models is to forecast how many people will benefit from a transport plan, new infrastructure or other transport

improvements and by how much they will benefit (for example, the time saving for their journey, the reduction in traffic queues).

There are wider consequences to be considered, not just economic, but also social and environmental (in recent times often referred to as 'triple bottom line appraisal'). Modelling also makes a contribution to determining some of these outcomes.

Governments may set targets - on the growth of traffic or the role of public transport - and again modelling can assist in evaluating the likely success of government policies designed to achieve these targets.

Transport infrastructure designers need to know how many people or vehicles will be using a proposed new facility in order to scale it efficiently, so as to avoid empty trains or congested new roads. Again, this is forecast by transport models.

How Does a Transport Model Work?

Suppose that we count 100,000 vehicles using an existing motorway every day on average, and we have records going back 5 years which show that the vehicle numbers are increasing 5% each year (ie each year the average daily traffic level increases by about 5,000 vehicles). Then, if this growth continues, the number of vehicles will increase by half as much again in the next 10 years (10 years times 5,000 vehicles increase each year gives a further 50,000 vehicles per day on top of the current 100,000 vehicle flow).

This is too much traffic for our existing road and will lead to heavy congestion, but we have the opportunity to build a new road which might provide an alternative for some of the motorway traffic. A survey of the existing traffic suggests that about one third of the vehicles could potentially use the alternative - in 10 years this would affect 50,000 of the forecast 150,000 vehicles per day and, if they all diverted to the new route, would enable the existing motorway to continue to operate without undue congestion.

For this group of road users, we calculate that if we build the new road to a very high standard then it will provide a quicker journey than the existing motorway for the majority of them. We forecast that 40,000 of the 50,000 potential users will divert to the proposed high standard new road.

These are the calculations that a mathematical model makes. The process needs to be computerised because the calculations are actually done in much greater detail than my example above. For example:

- the future growth of traffic on the motorway will probably need to be related to the specific changes in the residential population and in commercial and industrial activity along the corridor;
- the types of journeys on an existing road are very diverse and it is a demanding task to work out which particular journeys could benefit from the new road and how many of each there are;
- working out whether people will save time if they use the new route, and how much time they could save, depends on the time taken on the motorway, alternative road and on all other roads used for their journeys; it also depends how congested each route is 10 years in the future.

It is not just the detail that requires computer models. There may be a range of other issues which will need to be allowed for. For example, other road or rail plans or government transport policies concerning, say, the price of fuel or parking may affect the traffic on the

motorway. In many situations, the ageing of the population, reductions in the number of children in future, smaller family sizes or changes in working conditions may be seen as significant factors in future.

What are the Key Features of a Transport Model?

There are many different types of model, each type being designed to deal with a particular range of transport issues - some cover transport strategies for cities, others road projects or public transport projects, yet others look at very localised issues like individual road intersections. It goes without saying that it is important to choose the most appropriate model to address a particular problem.

Nonetheless, the majority of models share some common features.

All include data on the amount of current travel in the area of interest, the volume of people or vehicles on the roads or on public transport. Because transport projects are designed to serve particular types of journey (orbital, radial, to/from a particular suburb etc), the data is usually geographically detailed. For example, the number of persons travelling between different parts of the study area will be known (or have been estimated).

Given this knowledge of current travel patterns, there is often some process for forecasting how the amount of travel will change in future.

Models usually include a computerised representation of a transport network - the road system, public transport services or both. The models can work out the best route for people to take through the network, depending on where they start their journey and where it ends. By allocating all the expected future journeys to individual routes, the network models can estimate the traffic flows on each link in the road network or on each bus or rail service.

The heart of these models is the processes which they use to predict how people will change their travel behaviour in response to a new policy or new transport infrastructure - the route they use to go to work, their mode of transport or where they do their shopping. Generally this is based on the economic theory of consumer choice, and this relies on measures of the "cost" of travel and how this changes - where I have used quotation marks because cost refers not only to the financial costs but other aspects of journey convenience like the journey time.

How is a Transport Model Set Up?

There are computerised transport programs available through a number of international companies, in much the same way as office software such as word processors and spreadsheets can be acquired.

These are then set up for a particular study area and this involves assembling all relevant information: descriptions of the transport networks, information on the distribution of population and employment, data on travel patterns etc etc. Much of this data is available from public sources, but this is not usually the case for travel patterns, and this will often require specific travel surveys.

Most of the relationships in the models need to be tuned for the context, usually a complex process of statistical model estimation or calibration using specifically collected travel data.

Are Models Accurate?

Transport models are generally used to predict what transport and travel decisions people will make some time in the future, when the transport networks and policies will differ from

today. Obviously, forecasting how people will behave in future is challenging and the predictions of models are subject to uncertainty. For the better transport models, the developers will offer demonstrations of the soundness of the model, perhaps how well it replicates today's travel, how comprehensive is the information on which it is based, how consistent it is with the best international modelling experience, and how consistent its forecasts are with past experience in the area. It is also usual to offer sensitivity tests of key issues to illustrate the range of uncertainty which it is appropriate to attribute to the model forecasts - so that those who use the forecasts may allow for this in any decisions which they take.

History of Transport Models

Transport modelling was in its infancy in the 50s but techniques and research and studies have proceeded apace since then and it is now a major profession with many journals, conferences and learned publications devoted to it. Research continues and modelling techniques are under continuous improvement.

Other References

General descriptions of models are to be found in the transport modelling books which have been published and many modelling courses provide introductory guides. One other more readily available text, which goes into this in a little more detail, and includes a critique, is "A Transport Modeling Primer', by Edward A. Beimborn, available on the University of Wisconsin-Milwaukee website (www.uwm.edu/Dept/CUTS/primer.htm).