

TRANSPORT PLANNING MODELS – AN HISTORICAL AND CRITICAL REVIEW

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1. INTRODUCTION

It is almost 50 years since the first comprehensive urban transport studies took place in the United States (in Detroit (1953) and in Chicago (1956)). During that time there have been changes to the processes adopted, but this paper argues that the general approach to transport analysis in South Africa remains fundamentally the same as in those first studies - an aggregate four-stage computerized transport model.¹ Over time there has been a steady increase in the complexity and apparent sophistication of these models. They are in common usage both locally and internationally, and many variants of computer modelling suites have been developed. However, despite the considerable cost of model development, and their short shelf life, there has been surprisingly little critical review of their performance in South Africa. It would appear that computer modelling is accepted as a mainstay of transport planning efforts, and the need for a model goes largely unquestioned.

In this paper the historical development of transport planning is traced with a particular focus on the development of transport planning models. Criticisms of conventional transport planning models are highlighted (section 2). The focus of the paper then moves to South Africa. The evolution of transport planning models is traced (section 3), and comment on them is outlined (section 4). In section 5 the current South African policy environment is detailed and the role of conventional aggregate four-stage transport modelling in that context is discussed (section 6). Finally some alternatives to conventional models are briefly described.

2. INTERNATIONAL EVOLUTION AND CRITICISM OF TRANSPORT PLANNING MODELS

Evolution of Transport Planning Models

In this section the evolution of transport planning models is briefly traced, through a consideration of the policy developments and socio-economic environments which have influenced transport model changes. In this way it is possible to identify four periods of model development:

- 1950s – 1960s: developments in response to accelerated highway construction and advances in computing;
- 1970s – 1980s: developments in response to criticisms of aggregate methods;

¹ The four stages of the model include: trip generation (how many trips will be made); trip distribution (where will they go); modal split (what mode will be used); and trip assignment (what route will be taken).

- 1980s – 1990s: developments in response to criticisms of static, trip-based analysis;
- 1990s: developments in response to environmental pollution, and policy shifts towards travel demand management (Behrens, 2002).

Each of these is considered briefly in turn.

Prior to the 1950s travel analysis used data from traffic counts to assess the use of transport systems. Whilst such approaches were adequate when considering present-day issues, any predictions were coarse and were based on a consideration of historical trends. During the 1950s highway construction, especially in the United States accelerated rapidly and with it came a requirement for more sophisticated prediction tools, in order that pavements could be designed, and the economic impacts of such schemes be assessed and prioritised more accurately. The development of computers during this period provided obvious tools to process the large quantities of data required to model entire urban systems. The pioneers of these first models were mainly engineers with a 'positivist' outlook, that is the belief that relationships such as those found in natural science could be extended to urban systems (e.g. that of gravitational attraction which influenced the development of trip distribution models). They assumed that it would be possible to forecast human behaviour with some degree of accuracy. The key method to emerge during this period of rapid development was the 'aggregate four-stage model'.

The pioneering American studies in the 1950s established procedures which were institutionalised in the 1960s via the '3C process'. From the time of the 1962 Federal Aid Highway Act, urban areas had to undertake a 'continuing, comprehensive and co-operative transportation planning process' in order to receive funding. The technical travel forecasting processes required were described in various manuals published by the Bureau of Public Roads.

The assumptions of the developers of aggregate four-stage models were that:

- it was possible to predict a future land-use pattern independently of changes to the transport system;
- it was possible to predict travel behaviour based on household data averaged over a zone;
- relationships between household characteristics and travel behaviour would remain steady over (long periods of) time;
- travel decisions were made principally on the minimization of travel time and cost;
- interzonal, average weekday, peak hour vehicular trips provided an adequate picture for the purposes of transport system improvements.

Criticisms of Transport Planning Models

By the mid 1960s opposition to the transport developments of the previous decade had started to emerge (Atkins, 1977; Healey, 1977; Batty 1994; Harris, 1994; Klosterman, 1994; Pas, 1990). This concern heightened in the early 1970s when a series of political crises across the developed world, including the end of the post-war boom, fuel shortages and damagingly high inflation in the UK led to citizen unrest over many issues, including transport. This was especially the case in inner city urban areas where highway construction had displaced some communities. A new type of study emerged during this period (Allen, 1985) which was less computer dependent, more open to public participation, and included a broader range of evaluation criteria, such as environmental and equity issues. (The previous focus had been largely on economic appraisal). However,

although the process of planning was amended slightly during this time, the computer models used were fundamentally the same as the aggregate four-stage models developed in previous decades. In 1973 Lee produced a damning critique of the large-scale urban models common at that time, within which he highlighted seven fundamental flaws:

- hypercomprehensiveness (trying to do too many things at once);
- grossness (too aggregate to be meaningful or useful);
- hungriness (requiring vast amounts of data);
- wrong-headedness (with a poor match between theory used in the models and actual human behaviour);
- complicatedness (the outputs were difficult to interpret, and required adjustments to get realistic results);
- mechanicalness (the computers introduced errors due to rounding); and
- expensiveness.

This criticism from the United States was later joined by criticism from the United Kingdom. Atkins (1977) memorably stated that:

"we have a series of excessively complicated and expensive models using unsubstantiated and biased techniques to provide information of dubious accuracy for answering the wrong questions". He arrived at his conclusion following a review of transport planning studies undertaken in the UK to that date.

In response to the criticisms three new analytical methods emerged: land-use transport interaction models (which modelled the impact of transport changes on the land-use system over time, and vice-versa); disaggregate methods (which constructed travel-choice models for individuals rather than for households or zones) and micro-simulation methods, (an improvement on the aggregate assignment procedure, to take account of driver behaviour at vehicle or 'platoon' level).

Despite these improvements to transportation modelling technique during the 1970s and early 1980s, practitioners tended to remain with the familiar aggregate four-stage model and in 1986 Atkins was able to compile another damning compilation of criticism. These critical voices commented on the redundancy, inefficacy and wastefulness of mainstream methods in transport planning.

In the 1980s and 1990s further modelling developments emerged in response to the critics: dynamic methods and activity-based methods. Dynamic methods were developed in response to the 'static' nature of most preceding approaches. Travel analysis had been based on data from one cross-section of time, but critics argued that since transport behaviour across generations and sectors of the population vary over time, so transport responses will change over time also. However these changes, it was argued, are more complex than we may assume, and not under a constant state of re-appraisal as the economic utility model assumes. Rather there are critical periods (such as a house, employment or school change) when transport is reappraised, and these adjustments profoundly impact all subsequent travel in that household. Dynamic methods collate longitudinal data in order to properly address this topic.

Activity-based methods emerged in the late 1970s and early 1980s in response to the limited behavioural theory underpinning the conventional aggregate four-stage models. In activity-based approaches the observation of the trip is replaced by a detailed consideration of the activity which leads to the trip. It was argued that it is not possible to understand (and so to change) travel behaviour without a much deeper understanding of

the human lives impacted by the transport system under study. Hence activity-based methods are crucially different from aggregate methods in that they focus on household and personal activity scheduling rather than trips as isolated events.

The final period of development during the 1990s saw fundamental changes in transport policy in the developed world, including the passing of the Clean Air Act Amendments (CAAA, 1990) and the Intermodal Surface Transportation Efficiency Act (ISTEA, 1991) in the US. These two pieces of legislation provided for (in the case of CAAA) actions (such as enhanced public transport, the provision of HOV lanes and congestion pricing) to counteract pollution problems, and, (in the case of ISTEA) unprecedented flexibility in the transfer of funds between highway and public transport investment. CAAA and ISTEA challenged the transport professional to be able to accurately forecast transport emissions, and in response to this the US government launched a substantial programme of work in transport modelling: The Travel Model Improvement Programme (TMIP). Although the work is still in progress, a microsimulation model of some detail has been developed – TRANSIM – which should allow air emissions to be forecast at a fine level of spatial detail. (Lakshanan, 1998).

Despite these developments, and in the face of growing concern over the realism of the forecasts, mainstream practice in local government and in most consultancy practice has remained firmly entrenched in the use of aggregate four-stage models. Concern over this caused the new Professor of Transport Policy at University College London to state in his inaugural lecture “our ability to treat the new policies analytically; to understand their effects; to assess their costs and benefits; is seriously hindered by our inheritance of a tool-kit that is bright, impressive, of unchallengeable intellectual achievement, and wrong” (Goodwin, 1997).

Such statements were part of growing dissenting voices against mainstream practice in the UK during the 1990s. The start of this dissent can be traced back to the 'New Realism' conference of 1991. The conference acknowledged the impossibility of increasing the capacity of the road network to address both the forecast traffic levels, and the environmental problems associated with such traffic. There was a realisation (supported by the SACTRA report of 1996) that in congested areas increases in road capacity were likely to induce more traffic than would otherwise be the case. Thus the conclusion was that if supply could not be made to meet demand, then demand would have to be changed to meet supply. Hence, the need for demand management and the realisation that 'different policies will result in different forecasts' (Goodwin, 1997). The aggregate methods still widely used in practice had not been designed to evaluate demand-management policies and fell far short of what was required, hence the development of 'strategic appraisal methods', discussed in more detail later.

In the next section of this paper the adoption of transport models over time in South Africa is considered.

3. EVOLUTION OF TRANSPORT PLANNING MODELS IN SOUTH AFRICA

Transport modelling in South Africa began in earnest in the 1960s. From then until the early 1980s data was widely collected in order to calibrate MINI-TRAMP and DELTRAN four-stage models. These models were applied in most major urban centres and were usually developed for typical morning peak periods. During this time there was also a limited application of land-use-transport interaction models. From the mid-1980s to the early 1990s some attention was turned to the analysis of the impacts of apartheid on the

travel patterns of black workers. Some of these studies used activity-based methods or collected longitudinal data whilst others used more conventional household surveys or screen line counts.

During the early 1990s there was renewed interest in general data collection in order to calibrate newly acquired four-stage modelling software – EMME/2. Whilst internationally there are numerous software packages available, it has been shown that South Africa has almost blanket use of EMME/2. (Davies, Rontiris and De Roodt, 1995) Most of the models still in use have been calibrated for the morning peak period.

4. CRITICISMS OF THE SOUTH AFRICAN APPROACHES

Apart from the general criticisms of aggregate four-stage models highlighted above, there has also been some limited concern voiced in South Africa regarding the appropriateness of these models to local conditions. Specifically, Davies et al (1995) pointed to the following problems:

- The importance of walking is sometimes overlooked;
- There is poor interaction between public transport and private transport models;
- There is a lack of qualified professionals;
- Technology transfer is “black-box” rather than a source of knowledge;
- The combi-taxi mode is not easily matched with EMME/2; and
- Social stresses inhibit good data collection required for accurate modelling.

Other authors, writing about the developing world specifically, have raised major concerns regarding the appropriateness of the aggregate four-stage model for developing world conditions. Dimitriou (1990:169) suggests that many of the problems with the four-stage model can be traced back to the assumptions underpinning the earliest models, which are largely inappropriate for developing world conditions. For example, the US developers of the 1950s saw the urban transport problem as mainly one of how to overcome motorised traffic congestion. This is sensible in a country where the majority of residents are vehicle owning. The converse is true in developing countries. In addition, early developed world models were not used to study informal transport and so this essential travel mode is treated in an ad-hoc manner in most models. Aggregate four-stage models assume some long term stability in the variables affecting travel demand. This presumption is especially questionable in a rapidly growing developing country.

More recently, Vasconcellos (2001) has been equally critical of the application of aggregate four-stage models in developing countries. He points out that not only is the use of transport models flawed from technical and ideological standpoints, but there are also problems with how the outputs are used in appraisal. Full environmental appraisal (which would include a full safety analysis; disruption and costs to non-motorised transport users) are generally not present. The attribution of monetary costs to accidents and time, which is necessary for economic appraisal, becomes particularly problematic in the developing world where there are large variations in values due to, for example, extreme differences in incomes.

5. THE CURRENT SOUTH AFRICAN TRANSPORT POLICY ENVIRONMENT

This section outlines the current South African transport policy environment, which points towards likely areas of planning effort over the next decade. Moving South Africa, the detailed policy plan which distils the more general policy statements of the National White Paper, and helps to identify areas which (if Moving South Africa is to be implemented) will need to be investigated more widely:

- Lack of affordable access to the public transport system;
- An ineffective public transport system, ageing vehicle fleets and poor cost recovery from subsidised fares;
- Increasing car dependence for some segments due to lack of alternatives and relatively cheap car travel;
- A combination of apartheid spatial distortions and current dispersion which result in high commuting distances.

Moving South Africa goes on to suggest that there is a need to resist further dispersion, promote investment in public transport rather than road building and to consolidate non-motorised modes. In the light of this, three action sets are proposed:

- Densification of transport corridors, which should improve levels of service through corridor-based public transport offering increased speeds and frequencies;
- Optimal deployment of modes, which requires customer-based planning “matched to local travel patterns...and the preferences of specific customer segments”; corridor supportive infrastructure investment such as priority or dedicated bus and taxi ways and intermodal transfer stations and tough road space management “through a combination of controls and pricing, backed by improvements in the public transport system”.
- Improving firm level performance in the provision of urban transport services. (Wilkinson and Behrens, 2002)

What does all of this mean for urban transport analysis and modelling? It points towards an increased emphasis on:

- walking, as an important mode for those without access to motorised transport; as a mode used to access public transport; and as an alternative for choice users to motorisation;
- public transport and taxi systems;
- detailed knowledge of customer needs
- integration of modes; and
- demand management

within a framework of integrated land-use and transport planning, aiming towards densification. Clearly these are not areas of strength for the aggregate four-stage model, but what are the alternatives? The next section discusses possible alternatives to the conventional approaches.

6. THE NEED FOR ALTERNATIVE APPROACHES TO TRANSPORT ANALYSIS

The transport policy of South Africa has been lauded (De Saint Laurent, 1998), and it certainly appears to have many elements which, if implemented, could lead to fundamental change in transport conditions. The key to change, then, is operationalising the policy, that is, moving the policy from words in a report to action on the ground. In order to operationalise the policy there must be a re-orientation of all elements involved in implementation towards policy goals. Transport planners working for government (either

directly, or through private consultancy), are key actors in the operationalisation of policy. We suggest that most transport planners in South Africa today would support the broad aims of the transport policy, even though there may be some disagreement over the detail. However, even those practitioners who are fully supportive of policy *will be confounded in their aim of implementing policy if they continue to use only the aggregate four-stage modelling approach described above*. The reasons for this are that the conventional modelling process acts as a filter to precisely the type of information and knowledge required in order to sensibly implement the local policies.

With respect to public transport, conventional modelling treats public transport as an adjunct to vehicular models, where the focus is on operational characteristics of private vehicle flow such as flow size, flow speed and delays to the neglect of information regarding waiting times, queue sizes, passenger comfort, ease of transfer and safety – matters known to be important to public transport users.

A customer-focused plan requires that the detailed needs of customers are known and addressed. In order to look at customers in the first instance, the developers of the Moving South Africa project had to commission new surveys in order to supplement the poor level of information available at that time. Indeed, it has recently been found that, as a result of a focus on motorised traffic, commutes and morning peaks in past travel surveys, there is very little published information in South Africa regarding non-home-based, non-work, off-peak and non-motorised trip-making. Regarding matters of equity conventional models fall far short of ideal. At best they can provide average journey times for peak period trips across different types of users. A detailed consideration of equity requires at the very least an explicit consideration of walking trips, and of trips taken by those not working, or not of working age. Such trips may well be infrequent, irregular and non-symmetric and so will tend to be either missed, or misinterpreted, by conventional modelling tools.

A major thrust of recent policy, demand management, was not conceptualised at the time conventional models were developed. These conventional models were developed to address questions of 'how much?' and 'where?' road capacity should be built. They were never intended to consider whether capacity should be added at all, or if any other (demand management) techniques could be adopted. Hence the four-stage model using fixed trip matrices and exogenous growth factors will inevitably answer 'yes' when asked if roads will become over capacity in future. In a self-fulfilling prophesy, the four stage models built to consider road infrastructure improvements will implicitly tend to promote roads, since alternatives are not easily part of the four stage modelling process.

Given this discussion, it seems clear that there is a need for some alternative approaches, and these are discussed in the final section of this paper.

7. CONCLUDING REMARKS – SUGGESTIONS FOR ALTERNATIVE APPROACHES

The damning critique of conventional practice and the re-orientation of transport policy in South Africa requires practitioners to undertake a fundamental re-evaluation of the tools which they are employing. Vasconcellos (2001) argues that the developing world requires a 'sociological approach' to transport, which focuses on individuals instead of vehicles; lives instead of trips; within a framework of equitable provision. The tables below contrast the prevailing technical approach with the proposed sociological approach. It can be seen from this comparison that a sociological approach brings to the fore information, which highlights inequities, but which is often masked in conventional approaches due to insufficient or over aggregated data.

It can be seen that such a sociological approach would require detailed, disaggregated data from individuals as opposed to vehicular travellers. An activity-based approach could supply such data. Activity diary surveys produce rich personal and household data, and activity scheduling models enable a much wider range of possible behavioural responses to transport system changes to be predicted (e.g. travel substitution, trip inducement, trip suppression). Importantly these techniques have the capability of identifying those individuals and households with greatest transport disadvantage, and of analysing the activity scheduling and trip-making consequences of demand management strategies². However, activity scheduling models are unlikely to be of practical use for some time, and even when refined they would still suffer from data-hungriness and costliness. A rather more cost-effective approach to forecasting individual responses would be to use Stated Preference techniques, which have already received some attention in South Africa. These can assist decision-makers in understanding how various categories of users may respond to proposed change, at reasonable cost when compared with other (network-based modelling) approaches. (Although Stated Preference is also not without its problems).

Strategic policy appraisal models also have promise as they predict the potential impact of different travel demand management policy scenarios on travel behaviour quickly and (relatively) cheaply. They are essentially multi-modal 'equilibrium' models in which the demands for different modes of transport are balanced with the available supply, using an iterative process. (Roberts, 1997)

In conclusion, the conventional four-stage aggregate transport planning model will form part of the planners toolkit for a while to come. It is useful for providing the data required for cost-benefit evaluations, and for assessment of operational efficiency, but the underpinning assumptions behind this type of model are at odds with New Realist transport planning and no amount of refinement to these models will enable them to fully meet the requirements of contemporary policy.

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² Activity-based approaches have received some recent preliminary attention in Gauteng.

Approach	Nature of data	Preferred focus of explanation	Preferred elements of evaluation	Typical factors considered in the analysis (examples)	
				Transport quality	Traffic accidents
Technical	Quantitative	Vehicles	Economic efficiency (cost-benefit analysis)	Vehicle conditions (volume, speed, density)	Number of accidents by type
Sociological	Quantitative and qualitative	Individuals, family, social groups and classes	Economic and social efficiency; equity analysis	Vehicle conditions and quantity of people involved, analysed in the light of their social and economic characteristics and their access to different transport means	Accidents by type, and by characteristics of people involved (age, gender) analysed in light of their social and economic characteristics, their behaviour, their level of education

Table 1: Differences between prevailing and proposed approaches to transport (adapted from Vasconcellos, 2001: 39, 40)

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