Institute of Transport Studies
Graduate School of Business
The University of Sydney

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AN OVERVIEW OF PIMMS: AN AREAWIDE URBAN TRANSPORT POLICY EVALUATION MODEL

David A. Hensher
W.G. Waters II*
William Zhu
Rhonda Daniels

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TITLE: An Overview of PIMMS (A **P**ricing and **I**nvestment **M**odel for **M**ulti-Modal **S**ystems): An Areawide Urban Transport Policy Evaluation Model

ABSTRACT: The resurgence of interest in building better cities provides an opportunity to develop improved land use-transport models; models which are responsive to a wide variety of planning options, in contrast to current urban transport models which are only suitable for evaluating a limited number of major infrastructure options. A wide set of policy tools includes new infrastructure such as private tolled roads, light rail, bus priority systems; travel demand management through road pricing, area licensing and banning of cars in particular locations; and land use incentives/disincentives such as zoning for higher density activity, and more stringent environmental standards. To be responsive to a wide range of policy choices, it is desirable to develop models with a strong foundation in individual behaviour. This paper presents an overview of a project funded by the Australian Research Council. The aim is to develop a computer-based forecasting tool to give planners more flexibility in evaluating strategies designed to improve the performance of cities.

AUTHORS: David A. Hensher
W.G. Waters II
William Zhu
Rhonda Daniels

CONTACT: Institute of Transport Studies
Graduate School of Business
The University of Sydney NSW 2006
Australia

Telephone: + 61 2 550 8631
Facsimile: + 61 2 550 4013

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INTRODUCTION

The performance of urban systems is a high agenda item in many countries, including Australia. It is motivated in large part by the growth of city size and the importance of cities in the generation of wealth. But cities also make a disproportionate contribution to the destruction of the quality of the physical environment. Building better cities, a recurrent theme in Australia, recognises that all is not well in the metropolis. Congestion on the roads and in rail public transport, the emission of pollutants from automobiles, the high costs of servicing spatially dispersed residential living, and the steadily declining financial base for public provision of infrastructure, have contributed to the recognition that some priority should be given to rethinking how we plan and evaluate transportation in our cities. In particular, there is a growing belief that we need to develop a comprehensive land use-transport strategy.

Although "comprehensiveness" is not a new idea, the interpretations of what constitutes a comprehensive approach are diverse. "Comprehensive" means we recognise that policies designed to make the metropolis more productive, environmentally responsive, energy efficient and a desirable place to live and work, must be the outcome of an assessment process which can adequately capture the wider set of economic, social and environmental benefits and costs. The methods currently available to translate the ideals of broad objectives into operational planning tools have been in the main slight variations on the 4-step modelling tradition which has been implemented since the early seventies.

An improved transport planning and evaluation framework must embody three improvements over current planning procedures:

1. better integration of transport activity and land use, both in the choices made by individuals regarding where they live, what activities they engage in and what travel is necessary, and recognition that transport and land use policies are interrelated and both must be incorporated in urban transport forecasting.
2. models of forecasting travel must be more sensitive to factors influencing individual choices of activities and travel; this is necessary both to have a greater understanding of influences on travel behaviour and so that a wider range of policy actions can be modelled.
3. more explicit representations of environmental impacts of alternate transport-land use arrangements; and the development of criteria to incorporate environmental concerns into the evaluation of alternate investment or public policy decisions. At

present, it is still common practice to treat many environmental impacts qualitatively as either statements of presence or in magnitudes of resource consumption without an appropriate societal (monetary) value being associated with them. This often results in environmental impacts having limited influence on the final decision.

The set of models of travel behaviour controlling the demand for travel and hence the aggregate movement flows between production and attraction zones has been predominantly limited to trip generation, trip distribution and modal split for peak commuter travel only. The limitations of these models are increasingly apparent: it is increasingly recognised that a number of travellers are modal "captive" (eg. commuters with access to a company car, and the carless), particularly in the short to medium term; that switching travel to different times of the day may be a more likely behavioural response than switching modes; institutional reform is opening up a greater choice of working hours and hence trip departure times. All these suggest some needed improvements in models of travel demand. Furthermore, the chaining of multi-purpose trips, widely recognised in the travel behaviour literature but ignored in most comprehensive transport studies, is another growing feature of every day commuting. The difficulty of using public transport for multipurpose trips is a factor explaining in part the difficulty in getting people to shift from the automobile to public transport.

A prerequisite for developing better urban travel forecasts is to explicitly link aggregate demand predictions with the determinants of individual behaviour. There is an extensive literature on behavioural travel modelling which has not yet been integrated into urban transport planning frameworks.

Comprehensiveness should offer the possibility of evaluating alternative shape and density scenarios for urban activities, in addition to a more innovative set of transport strategies such as road pricing, tollroads, employer-based incentives to encourage car pooling and use of public transport, and major reform of time-of-day pricing for all transport services as well as major transport infrastructure projects.

PIMMS - A **P**ricing and **I**nvestment **M**odel for **M**ulti-modal **S**ystems is motivated by the need to develop a land use-transport modelling structure which is capable of evaluating a much broader set of land use and transport scenarios than is possible with existing urban areawide transport planning software. PIMMS also places special emphasis on the quantitative integration of a very broad set of environmental impacts into the evaluation of alternative metropolitan scenarios and their incorporation into the indicators defining urban performance.

FOUNDATIONS OF PIMMS AND COMPARISONS TO CURRENT MODELLING FRAMEWORKS

The performance of a metropolitan area reflects the outcome of individuals' preferences for activities and their locations, matched with natural features of the landscape as well as planning/legal constraints which characterise the local environment. Public policy constraints evolve over time as part of the process of trying to reconcile the aggregate preferences of the population with available land and urban infrastructure. The policy constraints can be viewed as a layered hierarchy of operating structures (eg. laws, regulations, codes of practice, zoning) which continuously evolve to define an urban system and influence the level of urban performance.

Thus a key concept underlying PIMMS is recognition that the evolution of urban structures will reflect the collective outcome of individual decisions by households and firms. To accurately forecast future scenarios of urban areas, it is important to incorporate behaviourally-sensitive components in the modelling framework.

The micro foundations of PIMMS are discussed in two sections. First is an overview which contrasts PIMMS with existing urban transport modelling frameworks. This is followed by a more detailed discussion of the individual components of PIMMS and how micro-based models are aggregated to produce aggregate travel patterns for an urban area. The third section addresses the environmental impact components of PIMMS; followed by a brief conclusion.

The Importance of Micro Foundations for Macro Forecasts in Urban Transport Planning Frameworks

Existing urban transport planning frameworks make use of macro forecasts of travel flows in order to plan for and evaluate alternate transport infrastructure investments. They are "macro" forecasts because they refer to aggregate travel flows among origins, destinations and along corridors. Aggregate forecasts are what are necessary for evaluating major network or mode-corridor investments.

Macro forecasts typically are developed from aggregate origin and destination volumes with a limited number of variables in the model. Such models are not capable of examining the influence of many policy variables such as pricing policies, parking charges, public transport service standards, zoning restrictions, or other non-investment policies. This is because the forecasts and models generally do not incorporate any explicit links with underlying behaviour of consumers in making choices about residential location and/or choice of work place. The only exception in standard transport planning frameworks is that of mode choice. Here it is common for predictions of travel on road versus public transit to be based on empirical studies of individual behaviour. But even here, the standard urban transport planning framework predicts mode choice in terms of a single relationship among a few variables (primarily travel time and travel cost) applied to all travellers, from all zones, differentiated by only a few personal characteristics such as income and whether or not they own a car.

Studies of individuals' mode and destination choice reveal a wide array of influences on these choices. These are abstracted from in standard macro forecasts. In order to have urban transport planning models which can incorporate the impacts of a variety of transport projects and policies, it is necessary to have travel forecasts which can aggregate over a number of traveller-mode-destination characteristics. The PIMMS project is attempting to draw on the knowledge gained from extensive research on individual travel and location decisions, and incorporate this knowledge into macro forecasts of urban travel patterns. This will assist in understanding and explaining the evolution of urban spatial patterns, and provide a better basis for linking public policy/investment decisions with people's and firms' personal decisions about urban living and travel.

There is a second reason for emphasising micro foundations for macro forecasts in urban planning models. It is to develop a better link between transport project/policy decisions and the long term effects on land use patterns and transport. By necessity, urban transport models are calibrated on existing travel volumes and patterns, and related to current land uses. Forecasts consist of extrapolations of population and zonal growth to generate predictions of future travel, and this provides the basis for comparing alternate transport plans. It is well known that there are feedbacks between transport strategies and land use. That is, land use patterns are a major determinant of travel patterns, but in the long run travel conditions influence land uses and locations. Building in such feedbacks in urban transport planning is a difficult challenge. The emphasis on micro foundations for the aggregate forecasts makes it possible to draw on studies of long term behavioural responses of people regarding transport and location, and to incorporate such linkages into the transport planning framework.

In summary, the micro-based approach to urban transport planning and evaluation in PIMMS offers prospects for improved transport planning and land use decisions. It will:

1. incorporate a richer specification of people's behaviour and hence their reaction to various transport and land use policies;

2. allow a wider range of policy variables to be explored compared to current infrastructure-dominated models;
3. facilitate closer links between the research community conducting micro studies of individual decision making and those developing forecasts for transport planning purposes; and
4. help identify and incorporate feedbacks between transport and land use policies.

The following schematics try to portray characteristics of a micro-based policy-sensitive urban transport forecasting and planning framework.

PIMMS Compared to the Traditional Urban Transport Modelling System (UTMS)

It is instructive to contrast PIMMS' micro-based modelling framework with the traditional UTMS which has guided urban transport planners for almost three decades (albeit with many refinements and modifications over the years). Figure 1 is a schematic of a simplified traditional UTMS (neglecting some feedbacks). The key points to note are that the predictions of trips and their pattern are based on macro models. The mode split module is applied to aggregated data from the previous two modules, although the parameters typically were based on micro-based studies of mode choice behaviour.

The use of the UTMS for long range prediction consists of extrapolation of (exogenous) population and land use patterns, combined with alternate modification to transport system applied to the UTMS model calibrated on existing circumstances. System performance measures (such as travel times and costs) provide a basis for comparing alternate infrastructure decisions.

Figure 1: Simplified Traditional Sequential Urban Transport Modelling System (UTMS)

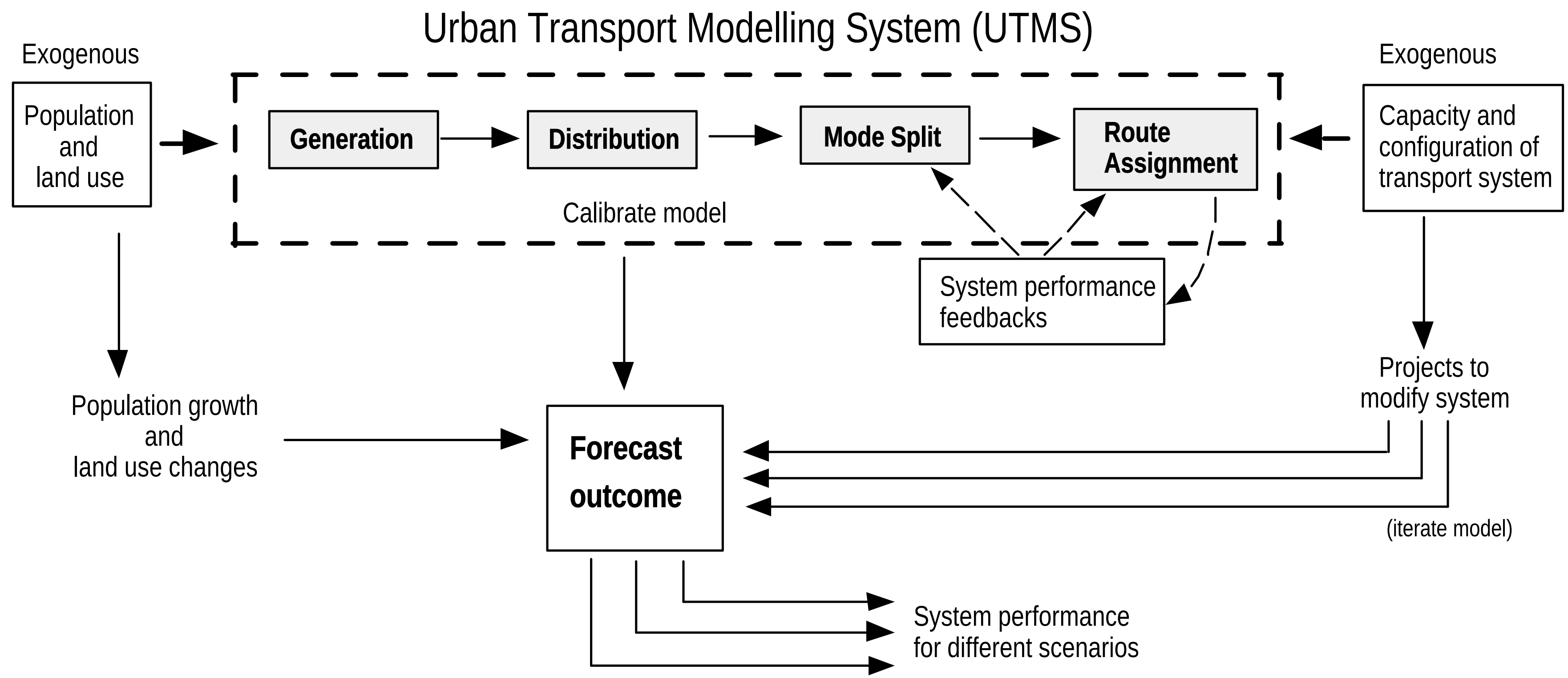


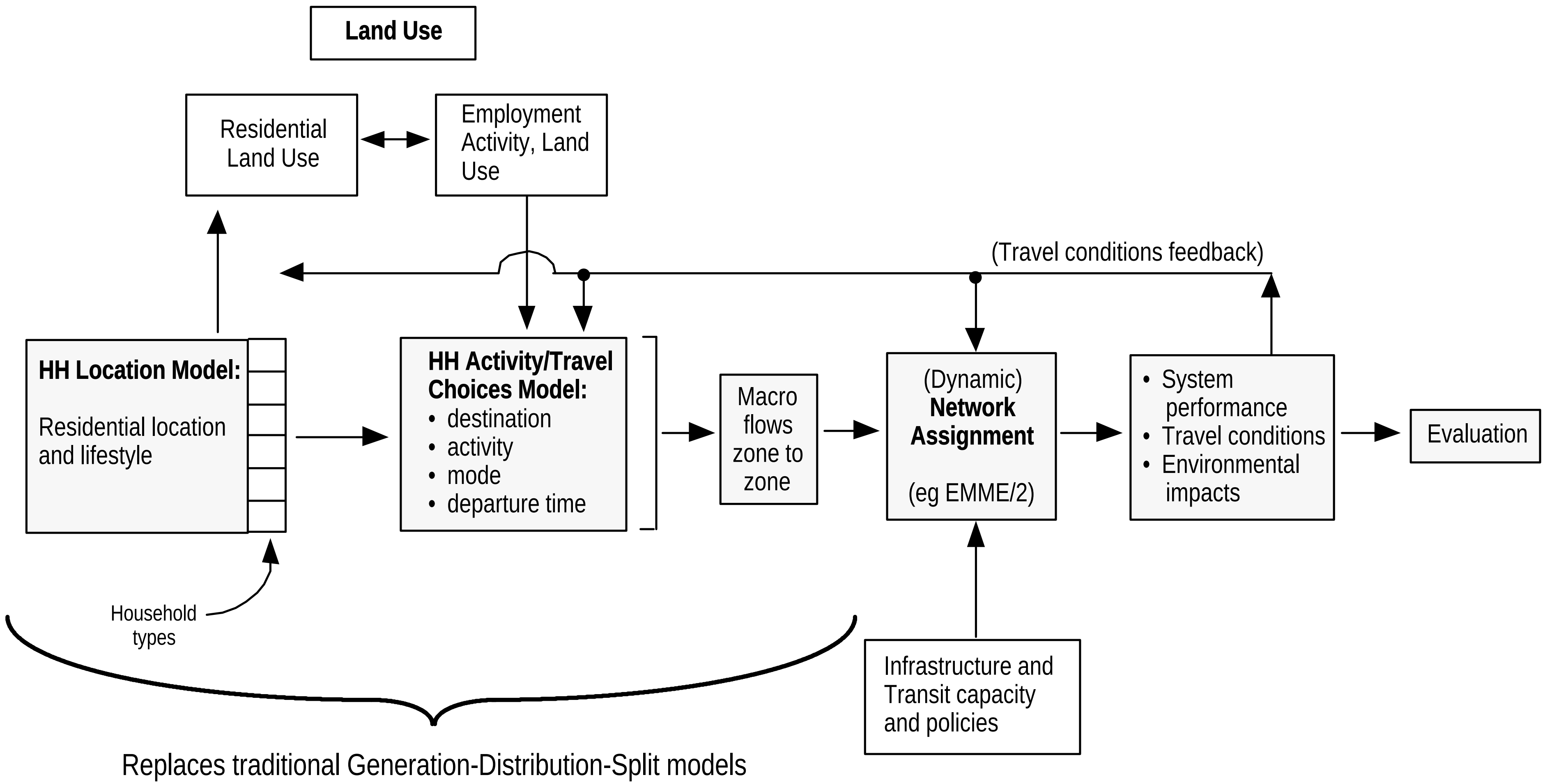
Figure 2 is a schematic of a simplified version of PIMMS. There are three key characteristics to note. First is the replacement of sequential macro models for trip generation, distribution and modal split with joint household decision models for location, travel, destination and mode choice. These are indicated by the three left-most shaded boxes in Figure 2. Different household (HH) types have different preferences regarding life style and residential location, influenced by transport and land price tradeoffs. The interactions of this demand with the supply of land sites and location of employment/activity centres determines the spatial dispersions of household types. Households then make joint activity-travel decisions which include choice of destination, mode and departure time. These micro decisions are aggregated to produce the macro travel forecasts among origins and destinations.

This is a much more demanding modelling framework than that of the traditional UTMS, but it offers the prospect of reflecting more influences on people's decisions and thus more accurate and useful models.

The second characteristic to note is the recognition that many variables which are exogenous in the short run are endogenous in the long run. Primarily this refers to incorporating feedbacks on land use (both industrial/commercial location as well as residential) from transport system performance. This requires introducing location decision models into the long term forecasting framework. In the simplified Figure 2, this is represented by the "travel conditions feedback" (more detail provided in subsequent discussion).

A third characteristic is the incorporation of policy variables which influence individual decision making (such as pricing policies, public transport operating policies, land use controls, etc.). Thus a richer array of policy options can be explored, compared to the traditional UTMS.

Figure 2: Overview of PIMMS Framework



A MORE DETAILED REVIEW OF PIMMS

The general framework of PIMMS was outlined above and in Figure 2. This section provides a more detailed discussion, and a more detailed schematic illustrated in Figure 3.

Household Micro Decision Models

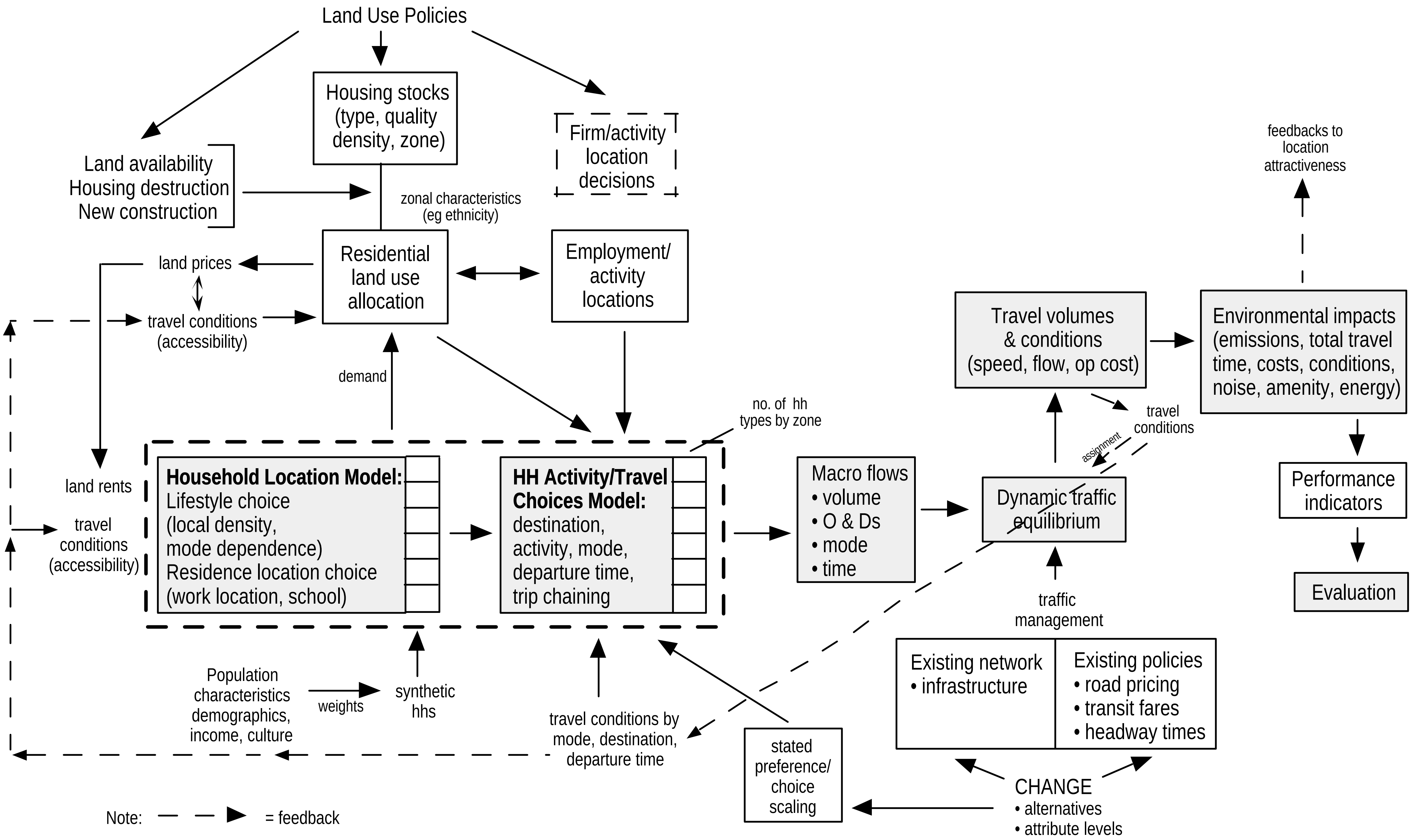
The behavioural *heart* is represented by a number of hierarchically-linked location, mobility, and travel choice models. The unit of analysis for modelling location choice is either a household or a firm; the unit of analysis for modelling travel choice is an individual or a firm; and for mobility choice (eg. automobile ownership) the unit of analysis is the household. The location, mobility and travel choice decisions involve evaluating available choice alternatives within a utility maximisation framework. In this discussion of PIMMS we concentrate on an individual/household’s location choice and set aside the firm’s location choice. We recognise that firms have to be included in a broader approach.

The household decision models are one of two broad types. The first (indicated on the left hand side of Figure 3) is primarily a residential location choice model, but it embodies lifestyle preferences as well as desires for accessibility to employment and other activity centres. Households with preferences for greater land (lower density living) with a variety of activity interests adopt a location and lifestyle heavily dependent on auto travel. Because land prices and transport accessibility are linked, it is necessary to explicitly link individual’s choice of lifestyle and residential location with land use and prices. These linkages are indicated in the left side of Figure 3.

Land Use Modelling

The land use module (upper left portion of Figure 3) incorporates several components. The demands for living and travelling space must be matched with available residential areas; and there are corresponding demands for commercial/industrial land use. It is necessary to model land prices since these are an influence on people’s residential location (and housing type) and, hence, subsequent travel decisions. A land use model should be able to explain spatial patterns of development; i.e. how land prices vary among zones and distances from employment/activity centres (see note 1).

Figure 3: Detailed PIMMS Framework



A limited number of representative ("synthetic") household types are specified which are assumed to exhibit similar lifestyle-location-travel behaviour. For example, dual income households without children differ from single income earners with large families, and both differ from retired households. The regional population of the various household types (indicated on the lower left of Figure 3) enables the modelling of location by interacting the available land use (the upper left of Figure 3) with available supplies. Residential location decisions are made in the light of lifestyle preferences, incomes and transport/land price trade-offs.

Each location will be defined by a spatial entity such as a traffic zone, which offers a set of location-specific attributes such as land area, number and types of buildings, open space for passive and active use, zoning regulations and location rents (i.e. property values); the location and property values are endogenous in the model. These elemental attributes can be combined through suitable quantitative procedures (eg. components analysis) to define locational macro-states. Individuals and/or households are assumed to choose residential and employment locations from the available set of locations. Firms are assumed also to choose business sites from the finite set of alternatives. The probability of selecting each location for a particular activity will be influenced by preferences for location-specific attributes, decision-maker specific attributes (eg. income), and accessibility requirements (eg. to workplaces and other activity sites for each member in the decision-making set).

Land use patterns are largely given in an initial simulation of the model. There are initial stocks of housing types (detached, semi-detached, townhouses, flats), of given quality and land use densities in various zones. In addition to housing characteristics, there may be other influences to consider such as ethnic mix which can affect individual's choice of residential location. There is an extensive literature to consult on residential location choice, housing type choice, tenure choice and determinants of land prices (eg. Hensher 1978, 1980, Borgers and Timmermans 1993, Borsch-Supan 1987, Timmermans et al. 1992, and Weinberg 1979).

Over time, changes in land use policies and growth will affect land availability. Growth in population and possibly per capita travel demand, along with changes in transport capacity and policies, all will affect travel conditions hence demands for land use. These must be incorporated into the equilibration of the residential land use allocation model.

The location/dispersion of employment and activity centres must also be incorporated in a land use model. Again, these are largely given for an initial simulation of the model. Over time new firms enter and existing industries will relocate. Different types of industries face different locational pressures. There are some secular trends at work eg. a shift to warehousing distribution systems which emphasise fewer land-intensive warehouses and greater transport activity. Some firms and industries will relocate if travel conditions become too onerous.

In order to model employment location, it will be necessary to identify a number of industry types according to their influences on location. It is unclear how much modelling will be necessary for non-work activities. For strategic purposes, the precise location of local shops and schools is not important; broadly they will gravitate in response to population locations. But the emergence or promotion of regional centres may have to be modelled explicitly because they affect employment opportunities and especially traffic flow patterns and congestion.

Activity/Travel Decisions

One of the major weaknesses of the majority of metropolitan-wide computer-based transport planning model systems is the narrowness of the behavioural sensitivity of the set of travel choice/demand models. Despite the vast literature on traveller behaviour, the trio of single purpose trip generation, trip distribution and modal choice models remain highly restrictive. While not denying the importance of these traditional models, it is important to recognise the inability of such models to explain why individuals switch their time of travel (departure time), why some individuals are captive to a particular means of transport, why trip chaining occurs etc.

This brings us to the second set of household decisions models: those for activity/travel decisions. Given the location/distribution of households by type by zone, and the location of employment and other activity centres, travel decisions are then modelled by household type. Travel decisions are joint destination-activity-mode-departure time decisions. PIMMS expressly focuses on the interaction and tradeoffs among these activities. The location of households relative to employment was determined in the land use allocation model. Hence the choice of destinations is already determined for the journey to work. The commuter trip however still involves a modal choice and departure time choice.

The set of travel choices to be modelled must be capable of including the full range of travel-related strategies which are on the research and action agendas of government agencies. Under serious consideration for including in PIMMS are the timing of trips, departure time choice (i.e. the peak spreading phenomenon), route choice, route captivity, mode choice, mode captivity (i.e. no car or access to a business-registered vehicle), trip chaining, multi-purpose travel and tours (facilitating a more direct linkage to participation in out-of-home activities - Bovy et al. 1992), automobile fleet size and type choice, parking choice, frequency and destination choice.

By viewing the travel and mobility task as more than the am peak period of two hours, which is the empirical context of all transport planning models in Australia and most models elsewhere, we begin to observe the wider set of complex household constraints on an individual's trip making behaviour, as well as the strategies adopted to minimise the disutility of travel. With increasing flexibility in working hours, the departure time choice (and preferred arrival time at the workplace) and the tolerance to late-arrival at work play an important role in peak-spreading and in increasing the probability of staying with the automobile (Chang and Mahmassani 1989, Henderson 1992).

For mode choice, we consider a rich set of alternatives so that we can investigate the demand for high occupancy vehicle lanes, bus priority systems and more traditional infrastructure changes (roads, light and heavy rail). For non-work trips, there are wider substitution possibilities including modifying the activity chosen (eg. cancelling a trip altogether if travel conditions were too onerous) and destination choice. These travel choices are usually modelled separately or not at all in existing urban transport models.

A number of institutional considerations such as the choice of working hours, lifestyle preferences and intra-household constraints will be embedded within the set of travel/location choice models to enrich their behavioural explanation. The set of micro-level location, travel and mobility choice models, detailed below, are structured as a system of discrete-continuous choice models with theoretically valid linkages using inclusive value and selectivity indices (Hensher et al. 1992).

There is a probability distribution of these various choices by household type. Given the various locations of household types, facing different travel distances, opportunities and travel conditions in various zones, one can simulate an aggregate outcome of travel for each zone.

To link the set of location and travel choices at the micro level to the population of interest, a prototypical or synthetic sample of households can be defined for a closed population to represent a known number of households in a classified structure of household types (Bovy et al. 1992). An expansion weight is attached to each synthetic household to identify the contribution of each household type to the overall flow of traffic on the system between each location and within each location. (Synthetic households can be defined in a number of ways, see Hensher et al. 1992 and note 2).

Together with a definition of the base transport infrastructure (network configuration), modal levels of service and costs, the descriptions of each synthetic household are used to obtain a matrix of location and travel/mobility choice probabilities associated with the full set of behavioural choices (reported and applied at various levels of disaggregation to suite the application), which when expanded up to the population at the location unit level (i.e. the traffic zone) will provide the macro flows indicated in the centre of Figures 2 and 3.

Aggregate Travel Flows and Network Equilibrium

The macro flows are traffic volumes by mode to all destinations from all origins, by time of day. These are influenced by the availability of facilities (infrastructure), pricing policies and travel conditions (congestion). Therefore feedbacks are necessary to equilibrate traffic volumes and the use of the road and public transit networks. A network assignment model (see Appendix for description of EMME/2) is incorporated for this purpose. The primary feedbacks are labelled "travel conditions" in Figures 2 and 3. They influence travel behaviour, i.e. choice of mode and departure time, and can influence destination and/or activities pursued (trip purpose). In the longer run they influence location and land use patterns. The ability of EMME/2 to handle feedbacks of travel conditions on choice of departure time, and hence the duration and timing of peak loads, will require careful assessment. Historically, traffic assignment procedures use a single am peak period as their data base and "equilibrate" on it.

Road network capacities as well as transit capacities, prices and service conditions (eg. headway times) are specified in EMME/2. Because the travel generation process is based on micro-behavioural models, it is possible to incorporate a number of service characteristics and non-investment policies on travel decisions and hence network equilibrium. This is highlighted in the middle bottom of Figure 3. Existing capacities and policy variables are specified, along with the prospect of modifying either or both.

The influence of travel conditions on activity/travel demand could be incorporated as an "extended generalised cost" (EGC) concept, although it is preferable to explicitly incorporate different price-service influences on travel (and location). For example, it is preferable to model the influence of travel times under different degrees of congestion separately from the influence of, say, congestion pricing. Similarly, the influence of changing bus fares would be entered separately from the influence of changing headway times between buses, or different bus travel times made possible by bus priority lanes.

Within an equilibrium framework, the set of travel-specific variables influencing individual choices are themselves dependent on macro-choices, through system-wide descriptors such as congestion, waiting time etc. Because individual travellers freely change the location and timing of travel in response to travel characteristics (travel times, costs, comfort etc.) which in turn depend on the amount of travel at a particular time of day on individual links in a network, equilibration is essential. Explicit treatment in an equilibration model of elastic time of day switching must be accommodated. The concept of a shifting peak can make the whole notion of a fixed peak period misleading since there are no stable boundaries marking its beginning and end (Small 1992:114, Henderson 1992). Cost relationships with endogenous scheduling are required to properly account for the dynamics of the speed-flow throughout the day. Current practice treats a network for each time of day as being independent (i.e. zero cross-elasticities, see note 3). All of the trip-related choices are combined in a way that allows equilibration to be made over all or a selected-subset of the travel choice decisions. The recent literature on dynamic traffic assignment offers a number of algorithms for handling temporal switching (Arnott et al. 1992, Cascetta and Cantarella 1991, Drissi-Kaitouni and Hameda-Benchekroun 1992, Janson 1991, and Vythoulkas 1990).

A key element still to be worked out is the need to feedback travel conditions during short time periods in order to accommodate people shifting their departure time because of the degree of congestion prevailing at their preferred departure time. Henderson (1992) has discussed this problem of peak shifting and how a failure to allow for it leads to an overestimate of benefits and excessive capacity investment. This arises due to gross overprediction of travel cost savings from capacity expansion and the omission of significant scheduling cost savings from capacity expansion.

In handling this problem, one would ideally monitor the speed/flow relationships every minute (with departure time probabilities guiding the redistribution of traffic by time of day). This would feedback to an adjustment process whereby travellers modify their departure times as congestion worsened (Chang and Mahmassani 1989). Increasing travel demands on the system partly spreads the peak period duration (the “shifting peak”) rather than assume a fixed peak period with ever increasing levels of congestion. The peak spreading phenomenon is an important characteristic of urban transportation (Gordon et al. 1990) which is not handled in existing urban areawide transport planning procedures. Failure to recognise this phenomenon is likely to give misleading predictions of the impact of congestion pricing on both modal split and revenue.

A minute-by-minute update of speed/flow conditions probably is not necessary, although the simulated time periods will need to be fairly brief during peak periods. When congestion is less severe, it would not be necessary to have minute to minute feedbacks regarding travel conditions. Software should be capable of giving the user a choice of time periods throughout the 24 hours and even for different days (Cascetta and Cantarella 1991). It probably is not necessary to monitor speed/flow relationships throughout the network. It might be sufficient to monitor speed/flow/congestion at a few key points in the network and use these as an index to travel conditions throughout the network. In a recent paper, Drissi-Kaitouni and Hameda-Benchekroun (1992) propose a model which leads to a network structure which is a temporal expansion of the base network, including queues; suggesting that the dynamic traffic assignment problem may be viewed as a "simple" static traffic assignment problem over the expanded network. We are investigating this possibility and how we might efficiently integrate a solution algorithm into EMME/2.

System Performance Measures and Evaluation

Given the road and transit network capacity, handling the total travel demands will imply particular levels of congestion and travel conditions, total travel time etc. By altering road or transit capacity, the change in the overall travel time and cost in the system would be the inputs for a benefit-cost analysis of the changed capacity. This is essentially how existing urban transport models are used for project evaluation. An additional feature of PIMMS is that it can evaluate a variety of policy actions such as changes in pricing or other changes such as service quality or regulatory changes such as traffic management schemes. Having a strong behavioural foundation for household responses to policy variables will enable PIMMS to evaluate a wider range of policy alternatives than can be adequately handled with current urban transport models.

A further feature of PIMMS is expanding the measures of system performance to include environmental impacts as well as traditional user benefits of cost and time savings. This involves two steps. First is to develop indicators of environmental concerns which can be linked to predictions of equilibrium traffic flows and travel conditions. For example, an air emissions model can be incorporated to indicate pollution levels associated with different traffic volumes at different speed/flow conditions (Bowyer et al. 1985). Quality of transit service such as crowding and uncertain arrival and transit times can also be linked to overall indicators of travel conditions.

The second step in incorporating environmental impacts is the valuation problem. That is, developing quantitative measures for valuation of environmental impacts so they can be incorporated into project evaluation along with traditional measures of economic benefits and costs. The environmental evaluation components of PIMMS are represented by the right-most part of Figure 3. Further details are given below.

Since PIMMS incorporates land use feedbacks this raises the possibility of exploring still broader evaluation measures to gauge overall urban system performance. Perhaps neighbourhood amenity indicators can be developed to augment benefit-cost measures. The latter are dominated by measures based on travel volumes and conditions. For example, one might be able to explore land use policies which attempt to reduce travel needs by a different configuration of land use for both residences and commercial activity. The dream of planners everywhere is to devise a living arrangement which can provide high standards of living while reducing the side effects of the extensive travel associated with current spatial arrangements. PIMMS has the promise of being able to evaluate a very wide set of transport and land use policies.

Environmental Impacts

Environmental amenity is often worsened by major urban infrastructure projects such as transport projects. People derive amenity from aspects of their physical environment including "greenness", open space, view, air quality, noise and sunlight. The physical environment also determines levels of social amenity such as congestion, privacy, community interaction and accessibility. However the impact of a project on the environment and the corresponding change in amenity is often not fully considered in the project balance sheet, because it is difficult to value environmental amenity. An important aspect of the PIMMS project is an attempt to include environmental impacts and their valuation in the evaluation process. The cost-benefit method of project evaluation in which costs of a project are weighed up against the benefits in terms of a cost/benefit ratio or net present value, means that unless a monetary value can be placed on the environment, it tends to be ignored in the evaluation procedure.

Environmental amenity is a non-market good which makes it difficult to value, particularly to determine a monetary value. Several different methods have been used by researchers to value natural resources which are non-market goods including the hedonic price approach, the travel cost method and contingent valuation.

In the *hedonic price method*, a good is seen as a bundle of attributes where the market price of the good (say a house) reflects the levels of attributes of that good (eg closeness to parks, clean air, view). The market price of the good is regressed against its attributes in order to assign values to attributes. It has been used extensively to elicit values for amenity in urban areas including air quality, noise, parks and views. For instance the value people attach to clean air can be determined by calculating the premium paid for properties in clean air areas. By comparing the prices of many properties with different levels of the attribute, while statistically controlling for the effect of other attributes, values can be ascertained.

The *travel cost method* has been used extensively to value recreational sites, where the value of the site is the cost of obtaining the good, that is the cost of travelling to the site. Travel costs are used as proxy values to estimate demand functions for a non-market good. Non-market goods which have been valued using this method include goose hunting permits, recreational boating, forest management and saltwater beaches. It could also be used to value urban parks. Unless combined with a hedonic approach, the travel cost method cannot be used to value the individual characteristics of a site.

Contingent valuation (CV) is a stated response technique in which people are asked how much they are willing to pay for a benefit, or willing to accept as compensation for a cost, contingent on there being a market for the good. It is used to value goods for which there is no current market to determine their value. Methods of eliciting values include open-ended questions, iterative bidding, payment cards, or “take it or leave it” referendum questions. Payment mechanisms for values include property taxes, community charges, income or sales taxes, fares, subscription schemes, or an abstract instrument. CV has been used extensively to value a wide range of natural resources or amenity, including visibility, aesthetic damage, water based recreation, conservation, and hunting permits, as well as other public goods. Although it has not been used to value aspects of the urban environment, it is the most suitable method for determining values for environmental amenity for several reasons.

Contingent valuation is applicable to a wide range of environmental resources and can be used where other techniques are not appropriate or feasible (Wilks 1990). The technique provides richer data than is obtainable through other methods. For instance, the hedonic approach determines values based only on observed behaviour (house prices). The response to existing resource levels is observed, and it is not possible to experiment by changing levels to determine the response to different scenarios. However, the CV method enables a number of scenarios to be presented to one person and values obtained for different levels of a resource, perhaps reflecting the different options available for a proposed project.

It is important to be aware of the limitations and methodological problems of contingent valuation. The technique has been criticised on several grounds, primarily the possibility of bias in results, and the disparity between measures of willingness to accept and willingness to pay values (see McFadden 1991 for a critique). It is widely recognised that the CV method tends to underestimate willingness to pay, and overvalue environmental assets when the criterion is willingness to accept compensation. Bias may arise from: strategic behaviour on the part of individuals, the hypothetical nature of the exercise, the information given in the exercise, the method respondents are asked to use to indicate their values, or the values given as the starting point in an exercise, but can be overcome by careful survey design. Other areas of concern include the high refusal rates for participation in CV studies, difficulties in aggregating up from a small sample to obtain community or regional values for goods, and validation of results (does the survey instrument measure what it purports to measure ?).

In the attempt to value aspects of the urban environment for use in project evaluation, there are several issues to consider. These include:

- defining urban environmental resources and amenity: what resources are included, and how will these be defined to survey respondents
- determining existing amenity levels once a resource is adequately defined: the amenity people derive from a given level of environmental resource varies according to their attitudes, perceptions and beliefs. For instance, it is widely recognised that clean air and low noise represent good amenity but beyond that, it is subjective.
- environmental change: identifying the environmental impacts of a project under evaluation, determining changes in resource levels, and relating impact to existing amenity
- ensuring results are transferable: ideally, valuations should have some element of transferability, rather than being relevant to one project only
- environmental standards: environmental standards may be useful to obtain values. However standards only exist for some levels of amenity such as noise or air quality. Standards do not currently exist for other aspects of amenity.
- valuation functions: most reported work on CV values has focused on the actual values, and not so much on determinants or explanatory variables which could be used to develop a valuation model. A desirable outcome of work would be development of valuation functions for input into the benefit-cost calculation, which are sensitive to the specific application. For example, a parameterised valuation equation for view could be defined as a linear additive function of a person's income, age, and property value.

There are also specific issues to consider arising from use of the contingent valuation technique. It will be important to clearly identify and define the good to be valued, and to make the exercise as realistic as possible for respondents. The choice of payment vehicle will be critical in any experiment. As well as obtaining monetary values for goods, it may be necessary to value goods in terms of other environmental resources, recognising that in reality aspects of amenity are traded off against each other. For instance, the erection of noise barriers to reduce road noise may mean destruction of a stand of trees on the edge of the roadway. The issue of tradeoffs is poorly understood, as few studies ask people to assign values relative to their total budget. For instance, studies have revealed that people are willing to pay higher electricity bills to preserve air quality, but not where the money is coming from. It may be necessary to phrase CV questions in terms of what percent of their total budget respondents would be willing to pay for a particular good.

CONCLUSIONS

This overview identifies the current thinking on an improved procedure for developing and evaluating land use and transport policies designed to improve the overall performance of cities. The primary emphasis of the project over the next two years is on methodology and demonstration. The need to apply the approach to complex networks is a longer-term objective once we have established the practicality of the entire procedure on a small but realistic network. All model applications work will be undertaken using the zonal system and networks from the Roads and Traffic Authority of NSW Future Directions Study (1992). Where suitable data is not available, we will simulate data for both model estimation and population data on traffic (especially in the non-peak period).

The structure of PIMMS allows new modules to be added, giving maximal flexibility to the idea of comprehensiveness. In addition, graphical reporting procedures are provided, making it easier to visually interpret the spatial and aspatial implications of alternative strategies. Links with multi-media presentation technology are planned. Our ambition is to see PIMMS as the new urban transport modelling tool for major cities in Australia.

NOTES

1. The recent Industry Commission inquiry into taxation and financial policy impacts on urban settlement has investigated the determinants of the demand for land in Sydney and Melbourne (Industry Commission 1992). This will be an important data source in the development of PIMMS.

2. An appealing procedure, developed in Hensher et al. (1992:177-181) involved defining a number of core socioeconomic variables used to construct a multi-way contingency table with each cell identifying the number of households represented by the synthetic household described by the cell attribute levels. Within each cell, a non-core set of socioeconomic characteristics are defined and a set of behaviourally plausible pairwise cross-tabulations determined together with an hierarchy of such tabulations to condition the selection of socioeconomic levels between each tabulation. Each core cell would generate a number of synthetic households with internal weights which sum to the core cell weight. The synthetic household structure can be used to reweight the population over time to reflect target value distributions corresponding to the socioeconomic and demographic scenario of interest in a simulation. Bovy et al. (1992) and Gunn et al. (1992) give further information.

3. Two Phd topics linked to PIMMS emerge out of this brief commentary:

a. Developing and estimating a system of travel choice models to explain departure time choice (trip scheduling), route choice, trip chaining (frequency of stops en route), modal captivity, given time budgets.

b. Equilibration methods allowing for time-of-day switching in a network. Included in the research will be a closer look at speed-flow functions (Fare et al. 1982, Willson 1991), especially dynamic speed-flow relationships, and the way bottlenecks, queues etc, affect the short run variable costs. Ken Small's recent text (Small 1992) is a good starting point. The link between these two PhD's is clear: the first provides the "generalised utility" or "(extended) generalised cost" which feeds into the temporal equilibrium system.

APPENDIX - DESCRIPTION OF EMME/2

EMME/2 is a computerised multi-modal transportation planning and evaluation system which provides planners a set of comprehensive tools for demand modelling, network analysis and evaluation. It has the capability of implementing a wide variety of travel demand forecasting models, ranging from the simple road or transit assignment or the classical four step models (trip generation, distribution, modal split, assignment) to the implementation of multi-modal equilibrium procedures that integrate demand functions directly into the assignment procedures. It provides the tools for scenario comparison and analysis. Transport planners can make direct use of tools provided by EMME/2 for future scenario comparisons and make changes in the road and transit network or even changes in the socioeconomic characteristics of the urban area.

The EMME/2 system was initially developed at the Centre for Research on Transportation of the University of Montreal, Canada. The present version (6.1) of EMME/2 includes the most recent developments in the modelling of demand and route choice on road and transit networks. EMME/2 has been implemented on mainframes, mini-computers and the most recent generation of microcomputers. Presently, it has been installed for use by over 200 organisations in Canada, the USA, Europe (Italy, France, Switzerland, West Germany, Belgium, Greece, Sweden, Finland, Norway, Demark, Austria, United Kingdom), the People's Republic of China, New Zealand, Australia, Thailand, Israel, Japan, Saudi Arabia, and Chile.

The EMME/2 package consists of about 50 modules which are subdivided into five groups: Utilities, Network Editor, Matrix Editor, Function Editor, Assignment Procedures and Results. It can process a network of up to 10,000 nodes and 32,000 directional links. The program was coded in standard ANSI Fortran 77 and has been designed for easy transferability to various computers. It is currently implemented in the following operating systems:

- MS_DOS: IBM PC/AT, PS/2 or compatibles using 80386/7 in protected mode and Definition DSI-780 coprocessor boards.
- UNIX: SUN, HP9000 and others
- VMS: all the DEC VAX line of computers
- VMS/TSO: IBM 308x, 309x, 4381

Data in EMME/2 are stored in the file called data bank and the system consists of independent modules each of which shares the EMME/2 subroutine library. All data between modules occur only via the data bank. Once the data bank is set up, the planner may engage in the planning process with the advantage of instantaneous visualisation input data, results of computations and information retrieved from the data bank, all in graphic or tabular form.

EMME/2 itself is not a modelling package. Rather, it provides a very flexible environment for transport modelling. Through EMME/2's network editor, users can establish a substantial large network model for any traffic flow analysis. EMME/2 contains mechanisms for selectively providing detailed information for individual, grouped, or all elements of the network. Information may be presented in text or graphic formats based on user-defined options.

Cost and benefit analysis and travel choice modelling can be performed through the matrix editor and function editor. The matrix editor provides a powerful tool for any type of matrix manipulations and the calculation is very fast. The function editor can be used to build mathematical formulae and equations, which can be presented in graphic format.

The assignment procedures provided by EMME/2 are implemented in sophisticated algorithms and ensures consistent results for the purpose of scenario comparison and evaluation. The traffic assignment procedure is a vine-building equilibrium assignment method with fixed or variable demand. Many application specific path and link attribute or link to link sub-area matrices may be computed in addition to the usual assignment results. The transit assignment procedure is based on the concept of optimal strategies. The assignment of individual transit trips is also possible.

Figure 1: Simplified Traditional Sequential Urban Transport Modelling System (UTMS)

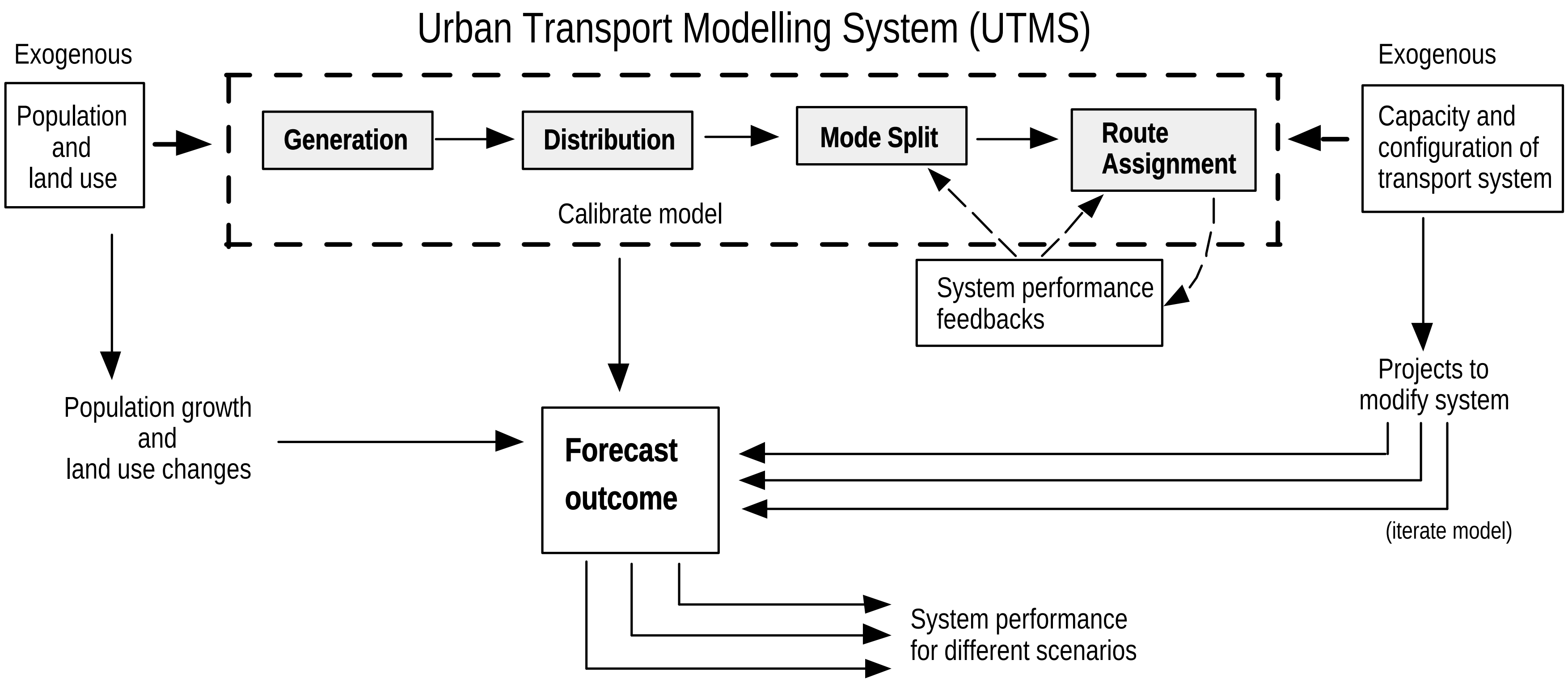


Figure 2: Overview of PIMMS Framework

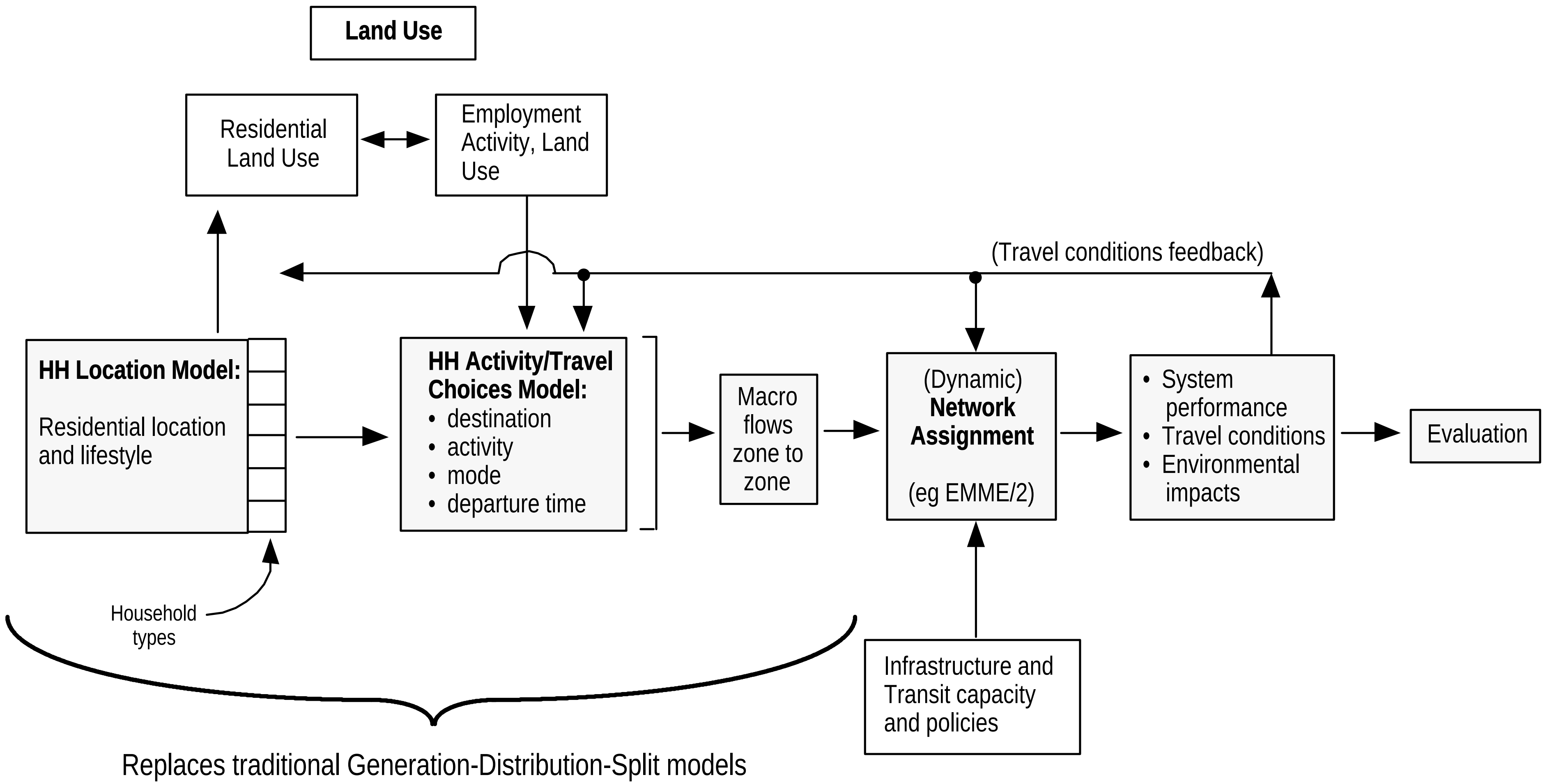
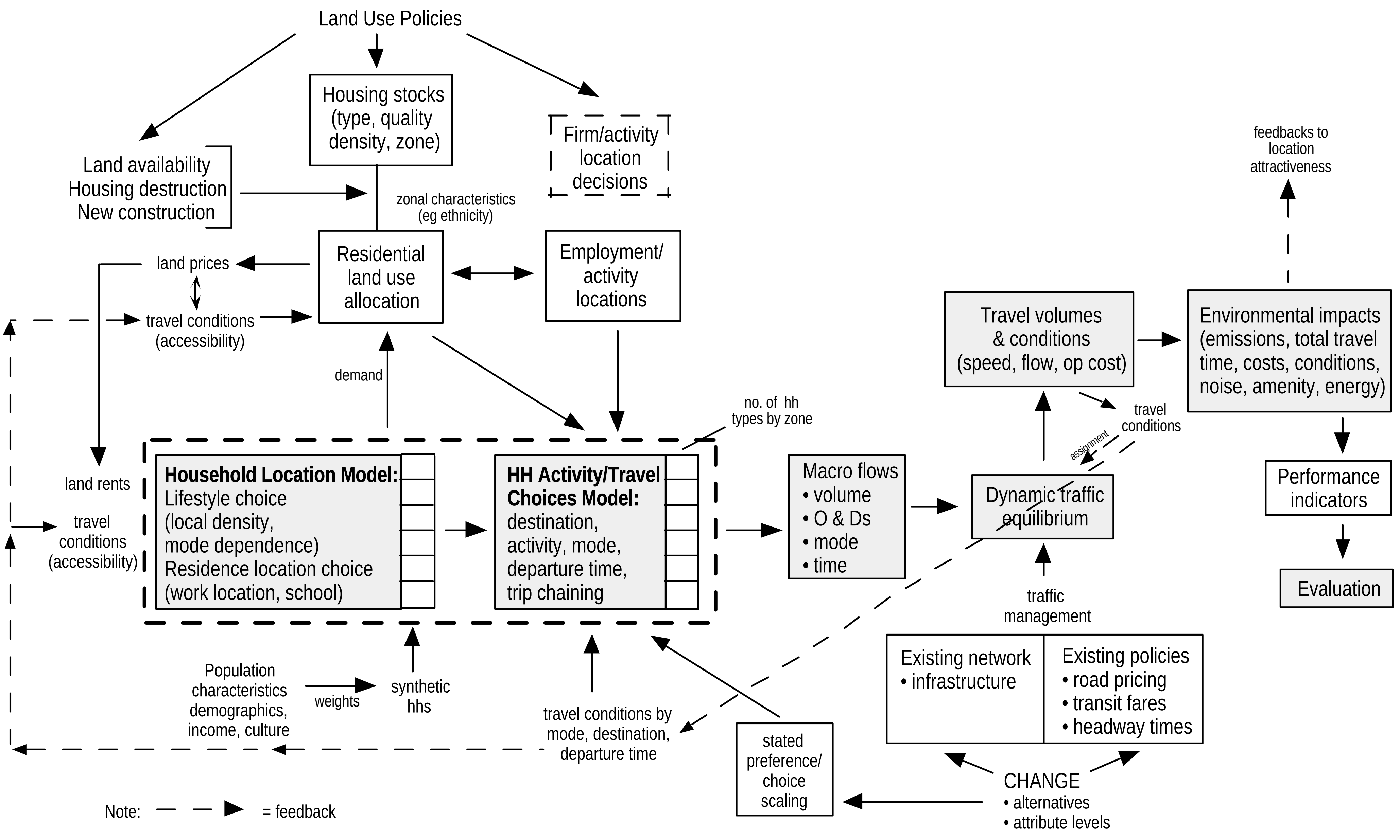


Figure 3: Detailed PIMMS Framework



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*Visiting Professor at ITS from the Faculty of Commerce, University of British Columbia
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