AN INTEGRATED LAND-USE AND TRANSPORTATION MODEL

I Wayan Suweda
Dosen Jurusan Teknik Sipil, Fakultas Teknik, Universitas Udayana, Denpasar

ABSTRACT

In terms of operational models, there are various alternative frameworks for modelling of land-use and transport interaction. This literature review however provides an only detailed of MEPlan model that have been currently used to develop the interaction especially in western countries. The intention is to indicate what might be ideal for practical modelling work in the area of study. The review consists of relationship between land-use and transport including the land-use / spatial economic module (LUS), the land-use and transport interface module (FRED), the transport model (TAS) and the evaluation of the system (EVAL). These stages of framework are considered of their representations of physical systems and processes along its implementation issues. The MEPlan model also shows that a wide range of policy consideration can be handled explicitly in the scope of interaction planning process. Thus it can be said that the model is very accommodating and is expected to produce a more realistic plan.

Keywords: MEPlan, planning process, integrated, realistic.

ABSTRAK

Dalam hal aplikasi untuk perencanaan, ada berbagai alternatif kerangka model terpadu/terintegrasi antara guna lahan dan transportasi. Namun tinjauan literatur ini hanya mengkaji model MEPlan secara rinci sebagai model yang saat ini banyak digunakan untuk menganalisis interaksi guna lahan/transportasi tersebut, terutama di negara-negara barat. Tujuannya adalah untuk menunjukkan apa yang seideal mungkin untuk praktek pemodelan di suatu wilayah studi. Tinjauan terdiri dari tahapan interaksi antara guna lahan dan transportasi, meliputi tata guna lahan/modul ekonomi spasial (LUS), tata guna lahan dan modul transportasi (FRED), pemodelan sistem transportasi (TAS) dan sistem evaluasi (EVAL). Kerangka ini dianggap sebagai representasi kondisi fisik lapangan dan proses pelaksanaan tahapan-tahapan interaksi. Model MEPlan juga menunjukkan bahwa berbagai pertimbangan kebijakan-kebijakan dapat diakomodasi secara eksplisit dalam lingkup interaksi proses perencanaan. Dengan demikian dapat dikatakan model ini sangat akomodatif dan diharapkan dapat menghasilkan rencana yang lebih realistis.

Kata kunci: MEPlan, proses perencanaan, terpadu, realistis.

1. INTRODUCTION

It is well known that a change in land-use has a potential impact on the transport system and vice versa. So, in order to describe the interaction between them, different types of model have been developed. Hopefully, based on characteristics of the change which is determined from either plans or observations, a formulation of its relationship can be derived. All of the models describe the land-uses by dividing a study area into zones and then by identifying different types of activity which are located in each zone (Webster *et al*, 1988b). Usually, development is represented by a discrete point in time (most models use 5-year steps to give enough time for the changes) and the activities, which are allocated to every zone, depend on accessibility and land-use supply. Examples of models that explain these interactions may be listed, as follows :

* CALUTAS (Computer Aided Land-Use/Transport Analysis System);
* ITLUP (Integrated Transportation and Land-Use Package);
* LILT (Leeds Integrated Land-use Transport model);
* MEPlan (Marcial Echenique Plan);
* MUSSA (Modelo de Uso de Suelo de SAntiago);
* SALOC (Single Activity LOCation model); and
* Urban Sim (Model simulation of Urban land and floorspace markets).

It is claimed that some aspects of these transportation and land-use relationship models are harder to model compared to the conventional model of 4-stages in transportation planning (Webster *et al*, 1988b). Hunt *et al* (1998) note that "in general, the ability of these integrated model systems to analyse transportation policy impacts (on travel or land-use) depends on the quality and capabilities of the four-stage travel demand model being used, rather than on the integrated modelling system *per se*".

Factually, the basis of the model is the interaction (at any level) between two types of markets that exit in parallel : one concerning **land and the activities** that occupy it and the other concerning **transport** that serves them (Abraham and Hunt, 1998). Nevertheless, the implementation of the model should contain all the important elements that are necessary to be included. So, it can be said that the elements incorporated will often depend on the user of the package who inputs the information. This implies that the model phenomena in the implementation for a specific study are completely under control of the modeller. Basically, the integrated land-use and transports model rest, simultaneously, upon three key assumptions (Echenique and Williams, 1994; and MEP, 1995):

1. transport, as a derived demand, resulting from economic interaction between activities, rather than as an end goal in the activity (for example : the transport of goods from places of production to places of consumption);
2. the quality of transport, which influences the location of activities over time. A better transport facility can offer better accessibility to markets, sources of inputs and other origins / destinations, thereby it increases demands for products, services and, of course, labour as well; and
3. supply and demand for transport and land-use follow market trends, which means that the interaction between supply and demand establishes the prices of both transport and land.

Consequently, **the basic structure of the model** could be constructed, which explains the relationship between land-use and transportation based on these three assumptions, as shown in Figure 1 below. From the figure, it is clear that the structures of land-use (production, consumption and location decisions) are adjusted by a money **price** mechanism, while the transport (destination, timing, mode and route selection) decisions are primarily adjusted by **generalised cost** differences including **delays** (time penalties). At any time, there is always adjustment of supply and demand towards an equilibrium position but it does not occur instaneously. This is because, on the supply side, the planning process and construction or adaptation of buildings takes a long time. On the other hand, on the transport demand side, people can normally change their route or mode quickly. On the land-use demand side, it needs a long time for households, or firms, to carry out a move to a different location or by individuals to change their job or school. These rigidities lead to delay in the adjustment of the system from one equilibrium condition to another. As a result of this lag, the structure continually moves towards, but probably never arrives at, any actual equilibrium state.

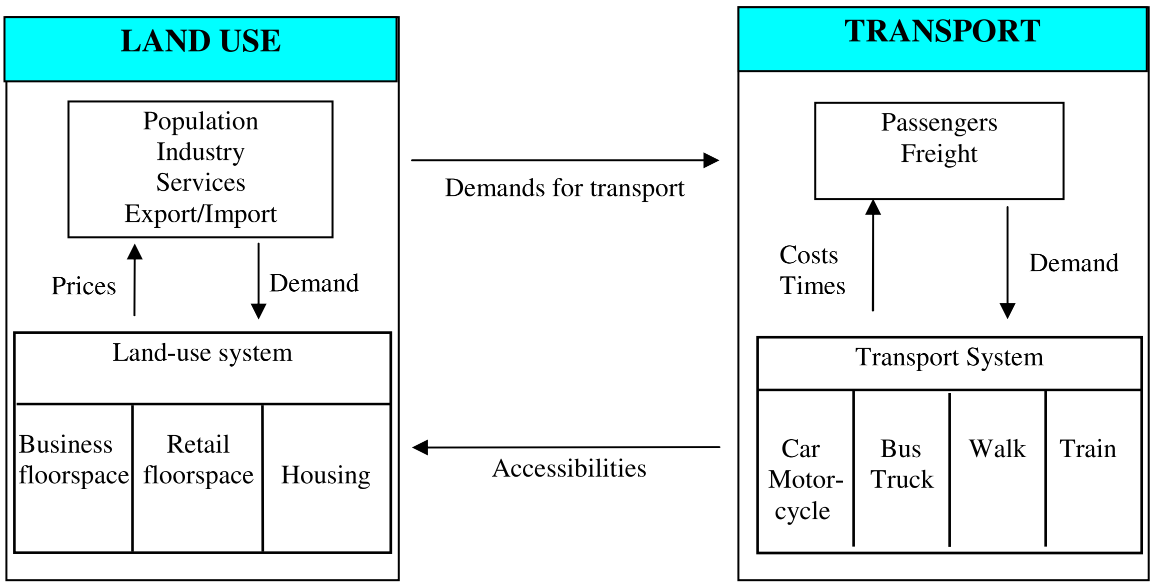

Figure 1 The relationship between land-use and transport in the MEPlan model
Source: Williams (1994).

This should be compared to the conventional approach which usually applies "the classical 4-stage transport model" and also treats the geographical distribution of activities as if they had no relationship to the costs of transport. However, in the integrated land-use and transportation model, the transport costs determine the land-uses and type of activities and, consequently, it will (in turn) influence those transport costs. This temporal change is simulated by considering sequential points in time (Hunt *et al*, 1998).

Regarding all the above relationships, there are 4 main components in an integrated land-use and transportation model, which is treated explicitly and is central of the structure of the MEPlan model. In passing, these also incorporate all the 4-stages in traditional transportation planning. These 4 main components are (Echenique and Williams, 1994):

(1) LUS: the land-use / spatial economic module;
(2) FRED: the land-use and transport interface module;
(3) TAS: the transport model; and
(4) EVAL: the evaluation of the system.

In addition, this integrated model usually operates on a time-period by time-period basis, which means that it is possible to reckon the influence of the previous period of transport on the land-uses and its activities or vice versa. In a given time period, the land market model is run first and then it is followed by the transport market model. The overall structure of the MEPlan and its operation can be drawn as in Figure 2 below.

2. LAND-USE SPATIAL ECONOMIC MODULE (LUS)

The purpose of this land-use / spatial economic module is to estimate the pattern of locations of various land-use factors (e.g. households, firms, travel categories and other floorspaces), within the region being studied (Williams, 1994). This includes their spatial linkages, such as the pattern of journeys to work, to school, to shopping (or trip distribution in conventional transportation planning). Accordingly, the core of this module is the distinction between patterns of various categories of land-use that evolve both through space and through time and also how they inter-relate to each other.

In the structure of land-use, the analysis of residential population is still usually by home-based survey, which means the population is represented by the number of households in each income group or socio-economic group (SEG) in a zone, for example professional and managerial households, other non-manual households, skilled manual and other manual households. The differentiation in households' income-group, which depends on the level of the income, is very important, because each group has their own propensity, such as:

- in competing in the market for housing;
- access to car transport;
- average lengths of their journey to work; and
- pattern of location of the workplaces.

The space distribution of firms is much more influenced by the category of the firm and it may be classified into:

- primary, manufacturing, transportation, construction, etc.;
- financial and professional services;
- retail and distribution;
- education;
- headquarters of industry;
- other public services; and
- other private services.

Two categories of travel in LUS are included, namely person trips and goods trips. For the floorspace factor, retail floorspace, business floorspace and housing floorspace are distinguished.

In order to link between activities, the land-use module employs three types of model from different theoretical backgrounds, which are drawn from the relationship between land-use and transport, as follows:

- a spatially disaggregated "input-output" matrix. This provides the basic mechanism for the model of goods, space and service demand, which can be derived from production of other kind of goods and services (Williams, 1994). For example, any household or firm in a zone will demand a certain quantity of floorspace. Households require residential floorspace, access to employment and various services. Firms demand business floorspace, access to various inputs and business services;

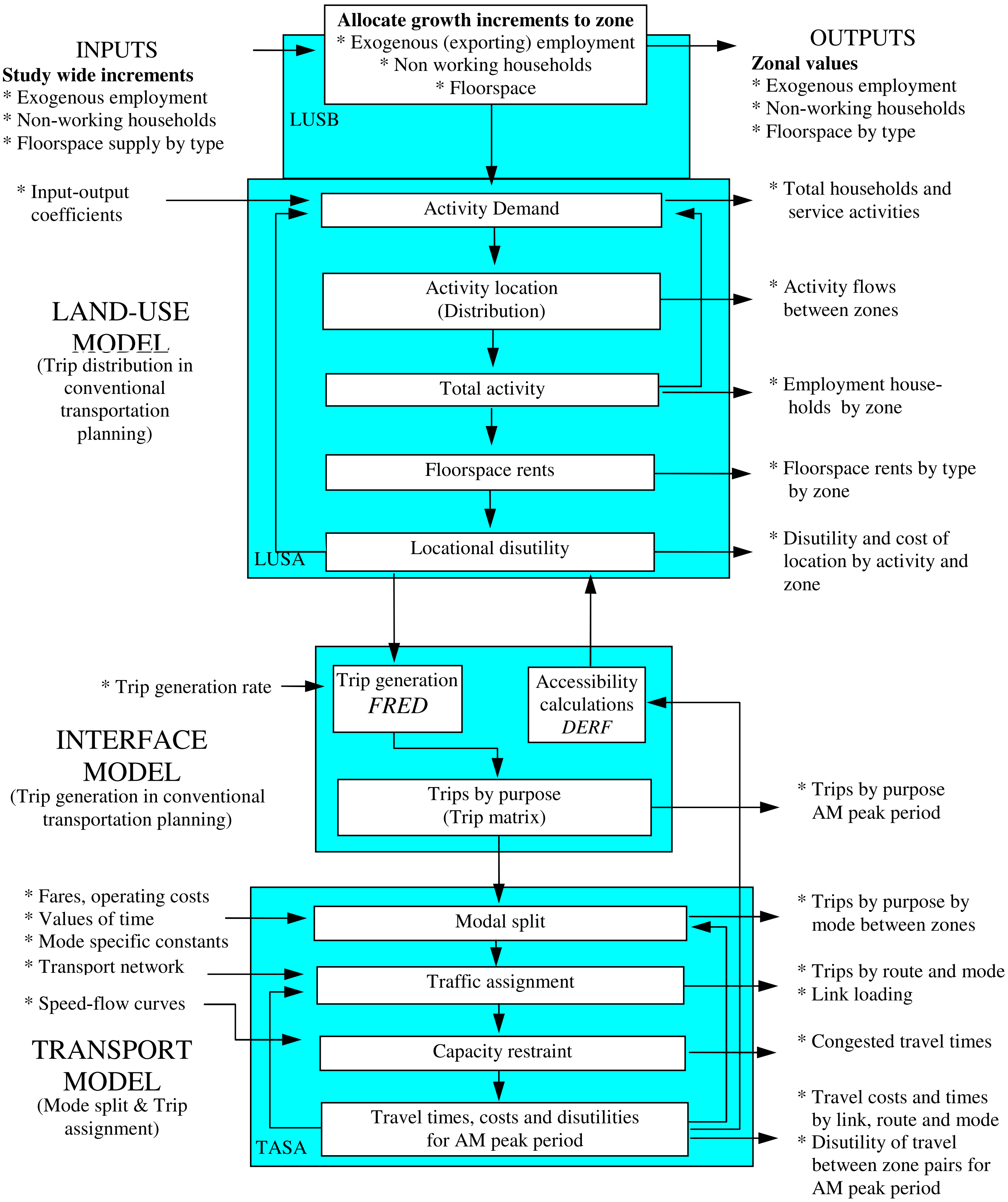

Figure 2 Simplified structure and operation of the MEPlan integrated land-use and transport model
Source: Marcial Echenique and Partners (1995).

* consumption of goods, services and space varies and relate to prices and income (MEP, 1995); and
* spatial choice model, which is based on the gravity model that is used in transportation studies to predict where the "factors" will be located (MEP, 1995).

Thus, these three models will estimate and produce locations for the land-uses, the spatial pattern of trips between them and the pattern of rents. Accordingly, in this model simulation, it also allows a consistent treatment of trip purposes and transport disutilities to be factored into location decisions.

In the MEPlan integrated land-use and transport model, the other idea in estimating zonal attraction is that households tend to locate in areas containing people of similar socio-economic condition (Webster *et al*, 1988b). This is usually governed by the cost of living (floorspace rent, transport, services, etc.), the accessibility, especially to suitable employment, attractiveness to that SEG, environmental quality, social hierarchy composition are very likely to have a significant impact to this household floorspace. The attraction factors of this household location also include the amount and availability of residential floorspace. Two more aspects that should be considered are constraints (e.g. the available quantity of land), which influence the prices directly, and externalities (e.g. the proportion of open space, unpolluted areas), which have impact on the location of activities and the price of land (MEP, 1991a).

3. TRANSPORTATION INTERFACE MODULE (FRED)

Unlike the conventional four-stage model in transportation planning, which separates the trip generation from subsequent stages, the MEPlan integrated land-use and transport model estimates the number and distribution of trips directly from the results of the land-use model. The interface module FRED, where land-use linkages are transformed into peak or off-peak trip origin-destination matrices by purpose and socio-economic group (SEG), has two main elements:

1. using outputs from the land-use model (land-use trade matrix), it calculates the peak hour trip matrices by type that are input to the transport model; and
2. in reverse, it converts the generalised costs of travel estimated by the transport model into accessibility between all zone-pairs, for use in the land use model.

(For example: Labour will produce Home - Work trips,
Retail/service will produce Home - Shop trips).

Therefore, it can be seen that the trip patterns are more related to the activity location procedures and the changes do not show themselves until the following time period. Changes in land-use will produce immediate changes in demand for transport (i.e. work trip pattern, modal split, road congestion, etc.), whereas changes in the transport have more gradual effects upon the pattern of land-uses and trades (i.e. land-use allocation, house prices/rents, industrial location, retail location, employment/population location, etc.). This process is illustrated in Figure 3.

4. THE TRANSPORT SUB-MODEL (TAS)

The purpose of the transport sub-model (TAS) analysis has three main elements :

1. demand for transport i.e. a matrix of Origin-Destination trip volumes;
2. supply of transport i.e. an integrated network of nodes and links for road and rail;
3. adjustment of the demand - supply factors.

This stage divides the trip matrices into different transport modes (modal split / choice), which usually represent several home-based trip purposes, and then assigns the vehicles onto the links of the road and/or rail network (traffic assignment). The modal choice procedure used is a multi-level hierarchical logit model of mode alternatives with different parameters, which is, in general, based on a combination of the costs, time, and quality of service of the each mode. This sub-model differentiates between travel by private modes and public transport, which depends largely on the characteristics of the study area, e.g. the car-ownership of each socio-economic group (because, in turn, this will affect the modal split mechanism for car-available and non-car-available people). In addition to the transport mode, the sub-model usually does not consider trips made by “composite” public transport or by two-wheeled vehicles or by walking, because “composite” public transport may be included directly in form part of public transport, walking (as a private transport category) and motorcycle (labelled as a private car).

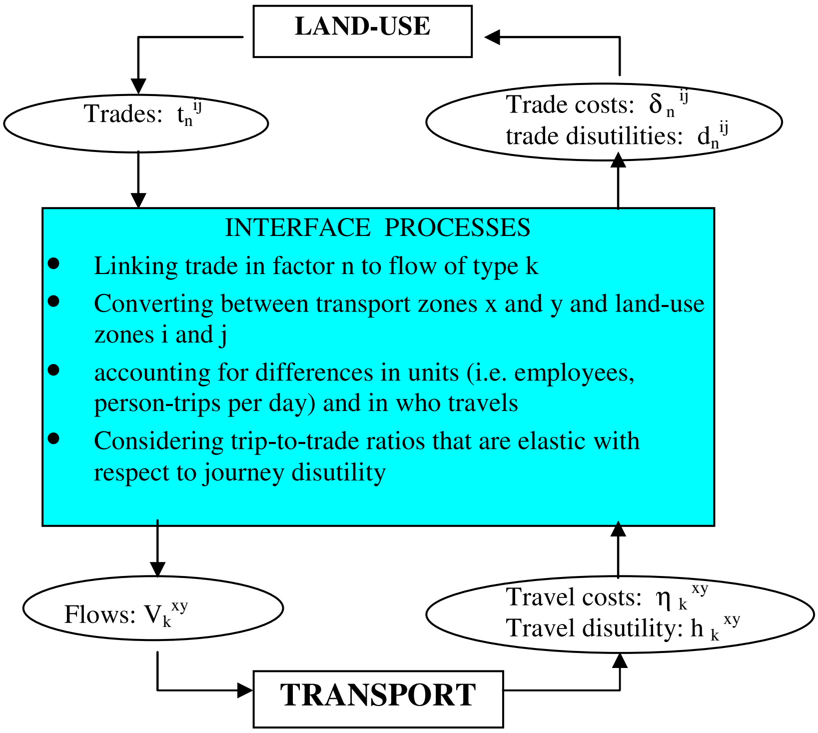

Figure 3 The interface process (Echenique and Williams (1994)).

Also, the MEPlan integrated model usually contains a representation of networks at varying levels of detail, which serves each mode on a link-by-link basis. This includes : link length, link travel time, link capacity, link level of service (LOS), routeing of public transport and other travel characteristics (i.e. interzonal travel time, cost, etc.). Then, the trip assignment procedure is a probabilistic multi-path algorithm, based upon a stochastic user-equilibrium assignment procedure. By carrying out the capacity restraint on the link, it also should be possible to represent congestion by adjusting travel times on any links as the traffic flow approaches its capacity. Accordingly, once the assignment is complete, the loads are used to estimate a new set of travel time and costs on congested links, which, in turn, is used in the next iteration (see Figure 4, below).

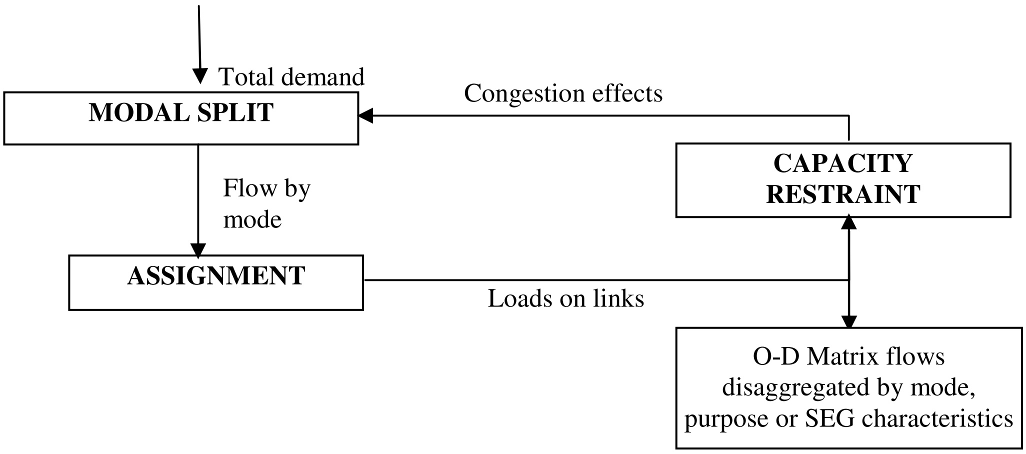

Figure 4 Elements of the transport sub-model (TAS) (Marcial Echenique and Partners (1991a)).

The iterations are continued until the path-building process and the congestion will have been stabilised. In short, it can be said that most of the integrated models are capable of producing travel patterns which are disaggregated by mode, purpose and/or socio-economic group characteristics.

4. EVALUATION OF THE MEPLAN INTEGRATED LAND-USE AND TRANSPORTATION MODEL

The purpose of the evaluation is to assess the impacts of some specific types of policy, in order to test alternative policy-inputs in building a model. From Figure 5, below, it can be seen that the evaluation module provides the interface between the model and decision-makers for testing to decide the best policy. This last stage may also include a cost-benefit analysis of a particular policy. It represents both land-use and transportation benefits and also produces further indicators on the performance of the systems, such as average speeds, energy use, pollution emissions, distribution of benefits by socio-economic group (SEG).

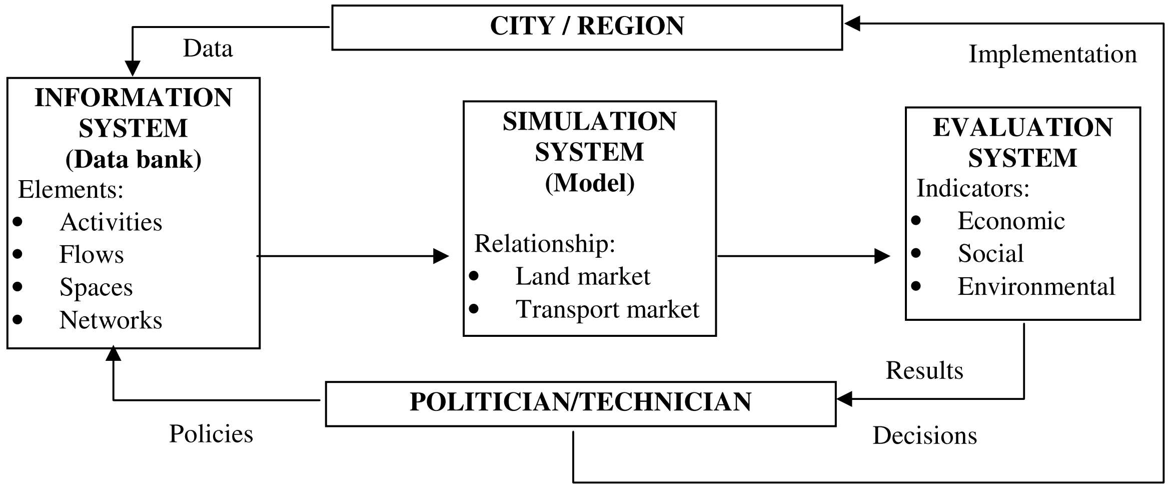

Figure 5 Evaluation in the planning system (Echenique and Williams (1994)).

Table 1 below compares some more detail indicators which are usually available in the evaluation system of the MEPlan integrated land-use and transport model. These include : economic, social and environmental indicators, with which either single or a combination of several policies may be tested, for example in the provision of infrastructure, changes in taxation and regulatory policies. Each of the above evaluations usually refers to one period of time or to a certain adjustment of the demand - supply factors. This means that the results of evaluations are mostly a function of the situation, condition and toleration of the people to anticipate all the supply factors.

Table 1 Indicators in evaluation system of the integrated land-use and transport

	ECONOMIC	SOCIAL	ENVIRONMENTAL
LAND USE	Development cost	Density and floorspace per head	Pressure on scenic area
	Land/property prices	Community integration	Open space provision
	Land user benefits	Benefits by socio-economic group	Separation of homes/ noxious industry
TRANSPORT	Infrastructure and maintenance	Accessibility	Traffic noise
	Service operation costs and revenues	Travel time savings	Traffic air pollution
	Benefits to travellers and freight shippers	Benefit by socio-economic group	Unsafety in term of accidents

Source: Echenique and Williams (1994).

5. CONCLUSIONS

The MEPlan modelling framework provides a well-tested mechanism for land-use and transport dynamic simulation and it is able to represent the bidding process for land and trade-offs between land costs, supply costs and transportation. Therefore, the land markets are key to the model. In addition, the representation of land and floorspace markets and the bidding for space that occurs make MEPlan consistent with much of classic urban economic theory. However, MEPlan is not a micro-simulation model, so the aggregate behaviour of decision makers are modelled instead of the individual decisions of random decision makers. This makes each factor with only one price per zone, which is less realistic but much simpler than modelling the full workings of heterogeneous markets. In an ideal situation, some available data such as land and space consumption rates, the price of various type of land and buildings, the relationship between economic and trip rates, and trip cost and disutility for different trip types and modes would be for a calibration factor within the model. Finally, the MEPlan model includes redevelopment and, if information on floorspace is available, it might be appropriate to move the representation of redevelopment to develop a wider range of floorspace categories.

6. ACKNOWLEDGEMENTS

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REFERENCES

Abraham, J. E. and J. D. Hunt (1998). **Firm Location in the MEPlan Model of Sacramento**, Manuscript for the Transportation Research Board Annual Meeting 1999, Washington D.C.

Echenique, M. H. and I. N. Williams (1994). **Integrated Land-Use and Transport Planning**, MEPlan Ltd., Cambrigde, England.

Hunt, J. D., D. S. Kriger and E .J. Miller (1998). **Current Operational Urban Land-Use Transport Modeling Framework**, Manuscript for TRB 1999, Washington D.C.

Marcial Echenique and Partners Ltd. (1991a). **MEPlan in the Policy Process**, Cambridge.

Marcial Echenique and Partners Ltd. (1991b). **Technical Introduction to the MEPlan Package,** Cambrigde, England.

Marcial Echenique and Partners Ltd. (1994). **MEPlan : User Reference Manual (URM) 3.0,** Cambrigde, England.

Marcial Echenique and Partners Ltd. (1995). **MEPlan Model of London and the South East (LASER),** Scenario Tests for London**,** Final Report, MEP, July 1995.

Marcial Echenique and Partners Ltd. (1998). **MEPlan Beginners Guide,** February 1998, Cambridge, England.

Webster, F.V. *et al* (1988a). **Urban Land-Use and Transport Interaction**, Athenaeum Press Ltd, Newcastle upon Tyne, England.

Webster, F. V., F. H. Bly and N. J. Paulley (1988b). **Urban Land-Use and Transport Interaction: Policies and Models**, Report of the International Study Group on Land-Use/Transport Interaction (ISGLUTI), HMSO, London.

Williams, I.N. (1994). **A Model of London and the South East**, Environment and Planning B : Planning and Design 1994, Vol. 21, pp.535-553.