Presentation Draft

A NEW URBAN TRAVEL MODEL

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1. Introduction

Urban travel models are perhaps not the best example of how to structure a global model. Nonetheless, a city can be viewed as a system not less complex than a group of settlements in a country, or a group of nations in the world. This is especially true when the concepts underlying such models are examined closely. When decomposing the problems to be modeled, human behavior under constraints appears to be a common denominator in most of them. Thus, it is hoped that this paper will add its share to a better understanding of human behavior.

This paper presents intermediate results from an on-going effort to develop a new urban travel model. This model, called the Unified Mechanism of Travel, or UMOT for short, was first conceptualized for the World Bank, and further developed for the U.S. Department of Transportation (Zahavi, 1979). It is being extended now to include urban structure within a dynamic feedback framework.

A principal reason for the attempt to develop the UMOT model was dissatisfaction with the operation of conventional urban travel models under rapid and fluctuating changes in their inputs, such as fuel prices. However, in order to develop a better model, one has first to identify what might be wrong with previous models. While doing so, it became increasingly evident that conventional urban travel models displayed many conceptual difficulties, most of which seemed to be in conflict with basic principles known in system theory (Kalman, 1978).

Since the author's discipline is in the field of travel models, not global models, the following list of conceptual difficulties applies specifically to conventional urban travel models. Even so, it will come as no surprise if some of them may seem to be familiar to modelers in other fields.

The paper is divided into two principal parts. The first part details some of the basic problems encountered in conventional urban travel models, as well as the way in which they are resolved in the UMOT model. The second part presents the general structure of the UMOT travel model, together with several reflections on its extension to include urban structure. The purpose of these two parts is to encourage, and benefit from, a dialogue between modelers of different disciplines about their experience in modeling large scale systems of human interactions.

Because of the complexity of the subjects discussed in this paper, and in light of the space constraint imposed on it, the paper is presented in a simple, telegraphic, form.

2. The UMOT Model vs. Conventional Travel Models

The UMOT model is based on the predictable regularities observed in the mean travel time and money expenditures per representative traveler of different socioeconomic groups. Since these regularities are observed to be transferable both between cities and over time in a country, the expenditures are regarded as "travel budgets" which, under certain conditions, are applied as constraints on travel behavior.

One useful way of applying travel budgets as constraints is within the microeconomic theory of consumer behavior, where consumer utilities are maximized under explicit constraints. By this theory, as one of several available to the UMOT model, the utility of spatial and economic opportunities to which a person travels, represented by the average daily travel distance, is maximized under the explicit constraints of time and money budgets allocated to travel.

The application of explicit constraints is a powerful tool, since the constraints eliminate the need for much of the coefficient calibration of conventional models. Thus, once the constraints and the unit costs of all alternative modes are known, the model produces estimates of such travel characteristics as daily travel distance, modal share, and car ownership.

Perhaps the best way of explaining the UMOT's distinctive aspects is by listing a few of its unique characteristics, which distinguish it from conventional travel models.

- Causality

  Causality in modeling travel behavior is typically assumed a priori. for example, it is typically assumed in travel models that car availability per household increases trip generation. Namely, car ownership is the cause, while more trips is the effect. However, it might be also argued legitimately that the need for more travel generates car ownership levels.

  In the UMOT model there are no assumptions about unilateral, fixed, causality. The process is based on a systemwise approach, where all travel components interact with each other and with the transport system through a simultaneous dynamic feedback process. Thus, each component can be both cause and effect, depending on the feedback step.

- Calibration and Validation

  Conventional travel models are calibrated to the observed travel choices. Thus, both the independent and dependent variables must be known before such models can be calibrated. For instance, a model which is required to estimate trip rates per household is calibrated (fitted) to the observed trip rates, and the calibration process becomes a balancing act between the two sides of an equation. Such a model is then validated by its ability to reproduce the same observations to which it was fitted. This may be regarded as a tautological process.

In the UMOT model no desired output is ever calibrated to the observed values. The outputs are the expected choices, which are then compared with the observed choices - not fitted to them - for the model's validation.

For example, the process can be started by assuming that each and every household in the urban area owns, say, 5 cars. Such an assumption, of course, is absurd. Nonetheless, the travel system converges rapidly to the observed car ownership levels, by the households' socioeconomic characteristics.

- Transferability
  Conventional travel models usually must be recalibrated in each separate city. The coefficients, fitted to cross-sectional data, are then assumed to remain fixed over time for each city. However, a prerequisite for a model's temporal transferability in one city is considered to be its spatial transferability between cities at one point in time, a condition which is not always met by conventional models.

  The UMOT model is based on the relationships that apply to the travel budgets, relationships which have been observed to be transferable both spatially and temporally in one country. Furthermore, there are no fixed coefficients associated with the choices in the UMOT process, and the model is activated through all its phases for each endogenous and exogenous change. Even the constraints are not constant, but can vary in response to endogenous and exogenous factors.

- Stable Parameters
  Conventional models are based on trips. However, the definition of a trip, and its related trip distance, trip time and trip cost, is ambiguous to a large extent since trips are linked/chained/clustered and combined into "tours" in various ways during the calibration phase of the models. Thus, the basic travel data in a city can vary according to the chosen definition of a trip, resulting in different models.

  The UMOT model is based on travel components that remain unchanged by any definition, which are the total daily travel components, such as the daily travel distance, and the daily travel time and money expenditures per traveler/household. Thus, there can be only one model for one data set.

- Organization Process
  A conventional travel model is divided into many sub-models; car ownership sub-model, trip-generation sub-model, trip mode-choice sub-model, and trip-distribution sub-model. Each sub-model is further sub-divided by trip purpose and/or mode, with no explicit interactions between the various sub-models. Moreover, each sub-model is based on a large number of independent variables, and one disaggregate car-ownership sub-model boasts of 21 variables which are used in various combinations for different population segments. An additional problem is that many of the independent variables are used repeatedly and/or alternately in

separate sub-models. For example, income is used as one independent variable of several in the car ownership sub-model, while later car ownership and income are used as two of the independent variables in the trip generation sub-model, and so on. Although multicolinearity is recognized, the multiplicity of variables is kept in such models, mostly in order to allow each explanatory variable to be forecasted separately in each sub-model.

In the UMOT model there is only one organizing principle which operates the travel system: an objective function which represents the individual travelers/households attempts to maximize their spatial and economic opportunities within their travel constraints, with dynamic feedback between the individual travelers/households and the transport system. Furthermore, factors which are regarded in conventional models as independent or dependent variables of the so-called causal relationships, and which often alternate between sub-models, are regarded in the UMOT model as either input to, or output from, the process. For instance, income is an explicit input to, while car ownership is an explicit output from, the process. In short, in the UMOT model there is only one organizing principle, which encompasses all population segments and all travel components within one interactive process.

- Equilibrium vs. Disequilibrium

  Conventional urban travel models are usually based on the assumption that the demand is in equilibrium with the supply. Thus, by definition, each alternative scenario must reach, or at least approach, equilibrium between demand and supply.

  However, it is equally valid to say that it is the amount of possible disequilibrium associated with alternative futures which generates forces that dynamically change urban structure, often in unexpected ways. The UMOT model attempts to measure, as one of its outputs, the amount of potential disequilibrium affecting households of different socioeconomic and locational characteristics.

As can be seen from the above examples, there are some significant differences between the UMOT travel model and conventional travel models. Such differences are reflected not only in the concepts underlying the models, but also in the way the models are activated. To mention one example: conventional models regard travel distance as a disutility, measured by the time and money costs required to overcome distance between origin-destination pairs. In the UMOT model daily travel distance is regarded in utility terms, representing the benefits of access to spatial and economic opportunities within the urban area. Such a conceptual difference literally turns the conventional modeling process upside-down; daily travel distance is a final output of conventional models, while it is the first output of the UMOT process.

Two comments are now called for, in order to put the above comparisons in the right perspective. First, putting all conventional travel models under one heading probably does injustice to some of them. The purpose of the comparisons, however, is to emphasize the prevailing general approach to modeling travel, rather than to single out a specific model. The second comment is that the UMOT model is not yet an operational model. It is still in its development stages, and although results have been very encouraging, only further development will tell whether it is successful in fulfilling its expectations.

A simplified description of the UMOT structure is presented in the following section, in order to enable the reader to judge better the systemwise approach underlying the UMOT travel model, and perhaps also assist in its further development.

3. The UMOT Structure

Figure 1 presents a simplified flow chart of the UMOT travel model, showing the feedback processes.

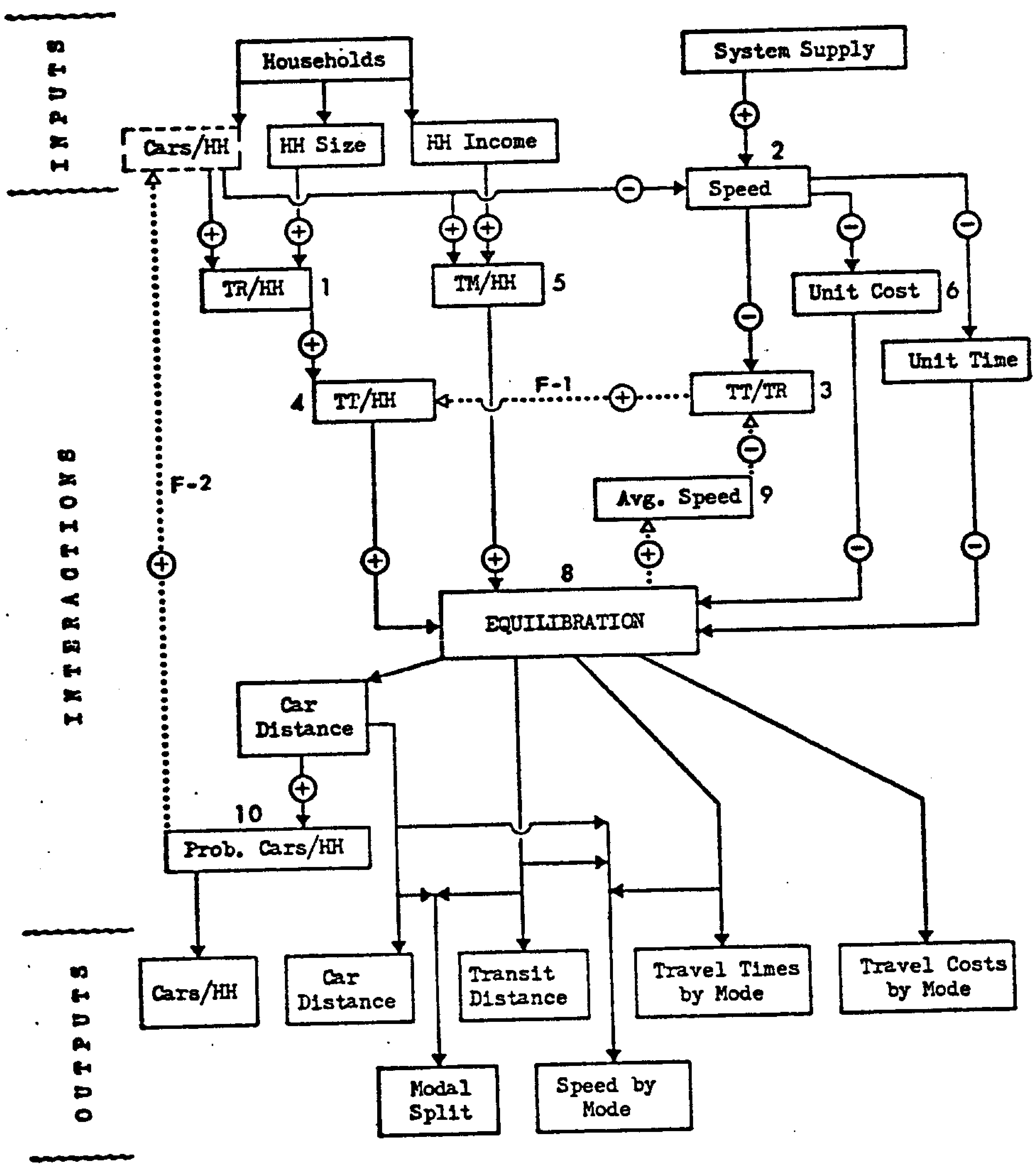

Figure 1 : Flow Chart of the Interactions between Travel Demand, System Supply and Car Ownership, the UMOT Model

——▶ Input/Output flow

5 Interaction. Effect of Input on Output is expressed by ⊕ or ⊖

•••••▷ Feedback

Perhaps the best way of describing the systemwise approach used in the UMOT model is by an example. Both travel time and money budgets affect, and are affected by, the level of car ownership of a specific household. The process can be started, for example, by assuming that each and every household in the urban area owns, say, 5 cars. Such an assumption, of course, is absurd, but at this stage the travel constraints take over and drive the travel system, based on given unit costs, to result in (i) the estimated travel distance by each mode, (ii) the estimated car ownership levels, (iii) the interaction between the estimated number of cars and a given road network results in new unit costs of travel, which are fed back into the travel distance phase, and (iv) repeating the process by iterations results in the rapid convergence of the travel system (where all travel components, including the travel budgets, interact with each other) to outputs which agree with the observed travel and car ownership levels in the urban area.

In short, there is no need to calibrate separate sub-models for the travel components, such as for car ownership levels; the process responds to any input, even an absurd one, and it adjusts the system to converge to expected values within the organization principles. Borrowing an expression, the UMOT process can be termed as a "self organizing system". In all cases tested until now, the expected values of travel components were found to match the observed ones.

At this stage one more point should be brought up. It was mentioned in Section 2 that predictable regularities had been observed in travel time and money expenditures per average traveler/household. This does not mean that each and every traveler/household spends a fixed amount of time and money on travel each day. Predictable regularities were also observed in the variations around the mean values. For instance, the coefficient of variation (standard deviation over mean) of travel time per average traveler was found to be similar in a wide range of cities in both developing and developed countries, and for different population segmentations. Thus, once the mean and the coefficient of variation per average traveler belonging to a population segment are known, the probability of an individual traveler to behave as his group can be deduced.

The last subject to be mentioned in this paper is the integration of travel and urban structure within the UMOT process, a project which is presently in progress for the U.S. Department of Transportation (Mobility Systems, 1980). The theoretical part is an extension of the UMOT travel utility theory to urban structure, including residence-job locations and the dynamic effects of changes in endogenous factors (e.g., household income, household size) and exogenous factors (e.g., transport system, travel costs) on urban structure. The empirical part is the study of travel probability fields, as explained below. It was encouraging to find out that the theory predicted the observations. Because of lack of space, only the travel probability fields are mentioned, below.

Conventional travel models deal with the spatial distribution of trips through the trip distribution sub-model, which requires lengthy calibrations of trip origin-destination matrices and travel impedance relationships, as well as an extensive description of the transport system. The notion of travel probability fields, on the other hand, is based on the predictable regularities observed in travel time and money expenditures and their extension to the spatial distribution of trips. Instead of dealing with single trips, it is possible to consider, and describe, them in terms of a continuous statistical distribution. Indeed, it was verified that the travel probability fields can be described statistically, and that they respond to endogenous and exogenous factors in expected ways. Such travel probability fields are now being developed as a direct link in the representation of urban structure as a variable in the UMOT urban model.

An additional subject which is now under investigation is the application of bifurcation and catastrophe theories in the UMOT model, in order to describe possible sudden changes (jumps) in travel behavior and/or urban structure under continuous changes in exogenous factors, such as travel costs. Conventional urban travel and urban structure models, which are continuous in form, are unable to identify and describe critical points after which there is a sudden change in the behavior of individuals, or a city, under continuously increasing pressures, although such phenomena are known to occur. But this, of course, is a subject for an additional paper.

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