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THE CONTRIBUTION OF ACTIVITY-BASED MODELS FOR ANALYSING TRANSPORTATION AIR QUALITY IMPACTS

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Abstract

Activity based modeling treats travel demand as derived from the demand for activities. This approach has important advantages for emission and air-quality analysis and for the evaluation of transportation control measures. An ideal activity-based model system will describe the chain of activities in which each person is involved during the day. Such a model can provide perhaps the best information on miles of travel by mode, by vehicle age and class, by time of day and location, driving cycles, percentage of cold and hot starts, and time and locations of starts, needed for the analysis and evaluation of emissions and air quality benefits of transportation control measures. This paper describes the advantages of activity based modeling for emission and air quality purposes and compares the advantages of four different level of developments in travel demand modeling for emission purposes.

INTRODUCTION

Activity-based modeling treats travel demand as derived from the demand for activities, with travel decisions forming part of the broader activity of scheduling decision. This approach has important advantages for emission and air-quality analysis and for the evaluation of air-quality benefits from transportation-control measures (TCM). An ideal activity-based model system will describe the chain of activities in which each person in the household is involved during the day. The information on an activity includes the location, start and end times, mode of travel, and travel time. Such a model, together with a traffic microsimulation application, can provide perhaps the best information on miles of travel by mode, by vehicle age and class, by time of day and location, driving cycles, percentage of cold and hot starts, and time and locations of starts, all needed for an analysis and evaluation of emissions and air-quality benefits of transportation control measures.

Activity-based modeling has been discussed in the literature since the 1970s, but practical applications have been implemented only recently. Some tour-based models have been estimated and applied in the U.S, among them the Boise urban model (Shiftan, 1995) and the New Hampshire statewide model (Rossi and Shiftan, 1997). In Europe, tour-based models have been developed in the Netherlands (Daly et al., 1983; and Gunn et al., 1987), in Denmark (Algers et al., 1995), and Italy (Cascetta and Biggiero, 1997). The tour-based models can be viewed as a step toward activity-based modeling but with only some of the benefits that activity-based models can have for air-quality purposes.

The first application of an activity-based model in the U.S. was recently developed for Portland, Oregon. (Cambridge Systematics, 1997a). The purpose of this paper is to examine the new application of the Portland model with respect to its advantages for emission and air-quality analysis and for evaluation of the air quality benefits of TCM, and whether the advantages of an ideal activity-based model system for air-quality purposes can be achieved with the current application. The advantages of the current application are compared to the traditional four-step model.

The paper first describes the important transportation variables for air-quality analysis. These are the variables for which we expect to have better estimates by using an activity-based model. Following this description, the paper briefly presents the current application of the Portland model and then lists the advantages of this model for emission and air-quality purposes. These are compared with the advantages of four different levels of development in travel-demand modeling for emission purposes, ranging from the traditional four-step model to an ideal activity-based model. Finally the paper investigates the advantages of the activity-based model for evaluating the air-quality benefits of some common transportation-control measures.

IMPORTANT VARIABLE FOR AIR-QUALITY ANALYSIS

Emission and air-quality analyses is based on vehicle-activity data and vehicular emission rates. The accuracy of the emission and air-quality estimates can be no better than the underlying transportation information. There are many transportation variables that affect emissions and different variables affect different pollutants. Cambridge Systematics (1997b) provides a table prioritizing the transportation data desired for emission modeling. The following variables have been identified as the most important for emission analysis:

VMT (Vehicle Miles of Travel) -- Among all pollutants, VMT is the most critical transportation input for emission estimating. Errors in these estimates directly impact the calculations, since emissions are calculated as the product of VMT and emission rates.

Travel by Mode and Occupancy Rates for Auto Modes -- The mode of travel and the occupancy rates for auto modes directly affect the number of vehicle trips and, therefore, VMT and the number of starts.

Percentage of Cold/Hot Starts -- This is an important parameter used by emission-factor models. Vehicles in the cold-start mode generally have emissions that are several times higher than these during warm-up operation. This factor is important mainly for VOC and CO.

Speed/Acceleration/Driving Profile -- Speed, acceleration, and driving profile can have a significant influence on emissions. CO and VOC emissions are much higher at low speeds, whereas NOx emissions are higher at high speeds.

Travel by Time of Day and Time/Location of Starts - Travel by time of day and the time and location of starts can be used in conjunction with the emission-factor model output to obtain better estimates of spatially and temporal distributed emissions.

Travel by Vehicle Class and Model -- Emission rates vary by vehicle class and model.

Travel by Facility Type - Different facility types have different patterns of travel, average speed, and driving profiles; therefore, vehicles traveling on different facility types will have different emission rates.

THE PORTLAND ACTIVITY-BASED MODEL

The application of the Portland Activity-Based Model is the result of a combined effort by the Portland Activity-Based Model Demonstration Project and the Portland Traffic Relief Options Study (PTROS), which demonstrates congestion pricing. The demonstration project focused on the design of the model system and some model estimation, and the congestion-pricing project made some simplifications to this design, completed the model estimation, and prepared a software program with which to apply the models. The differences between the demonstration project design and the implementation used by the PTROS project together with a detailed description of the model appear in the Demonstration Project Report (Cambridge Systematics, 1997a).

Overview of the Portland Activity Based Model

The Portland Activity-Based Model System was estimated using data from a 1994 household travel and activity survey. The system is designed as a series of disaggregate logit and nested-logit discrete choice models and it assumes a hierarchy of model components: lower-level choices are conditional on decisions at the higher level, and higher-level decisions are informed from the lower levels through logsum (accessibility) variables. A diagram of the model system as currently implemented by Portland Metro is shown in Figure 1. The sections that follow describe the decisions that are explicitly modeled in the system and indicate the important variables for air-quality purpose to which they can contribute. Table 1 summarizes the contribution of the different decisions modeled in the system for the different variables required for an air-quality analysis.

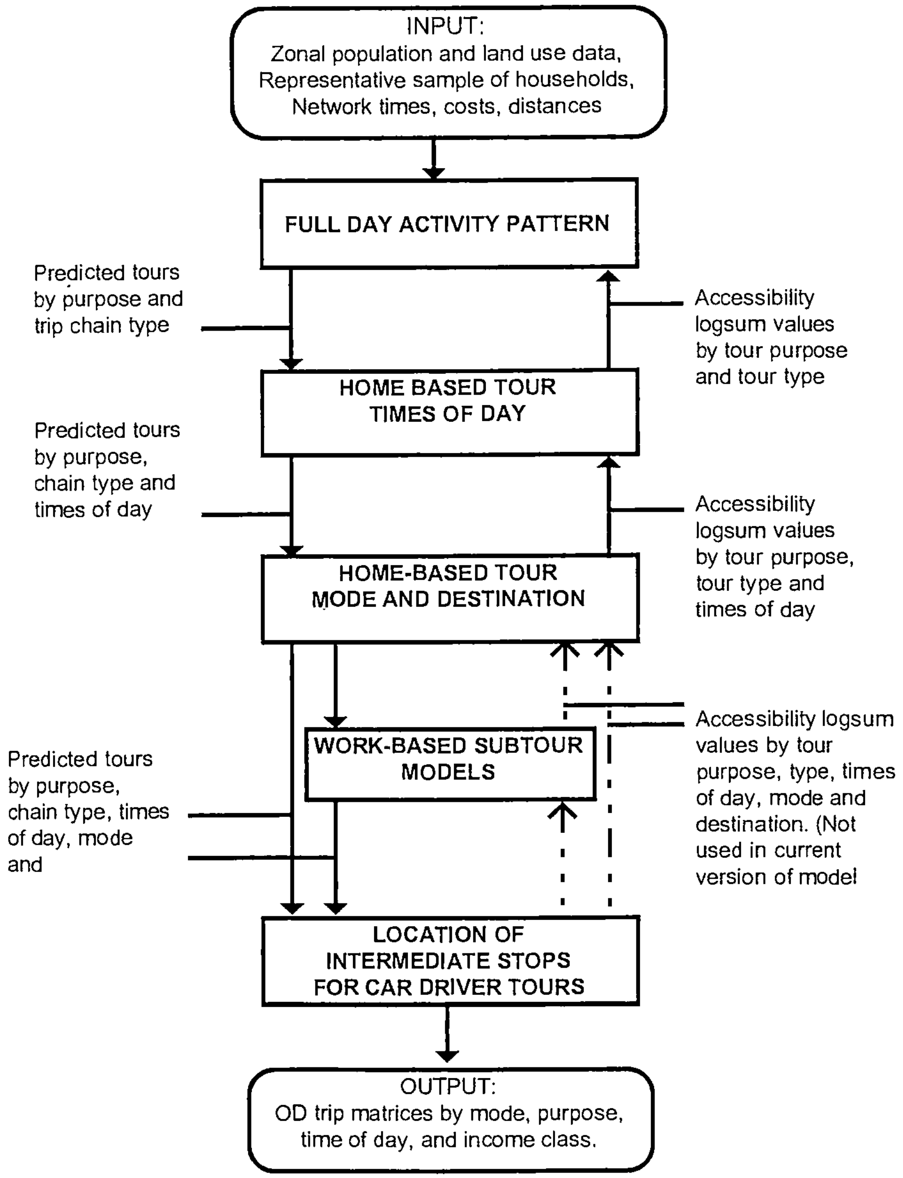

Figure 1 - Activity-Based Model System Overview (Source: Cambridge Systematics 1997a)

Table 1 - The Contribution of Decisions Modeled in the System for the Analysis of Emission Variables

	VMT	Mode of Travel	Cold/Hot Starts	Driving Profile	Vehicle Class	Time of Day	Facility Type
Daily Activity Pattern	+		+				
Timing of Activities			+			+	
Mode and Destination Choice	+	+	+		+		
Work Based Subtour	+	+	+				
Location of Intermediate Stops	+						

Full-day activity pattern

The full-day activity-pattern model stands at the highest level of the system. This model predicts a person's primary activity during the day as work/school, household maintenance, or discretionary, and either at home or as part of a tour away from home. A tour is defined as a sequence of trip segments that start at home and end at home. A major contribution of this approach is that it includes at-home activities. This feature allows the model to treat the entire range of activities throughout the day, including trade-off between in-home and away-from-home activities.

The full-day activity-pattern model also determines the type of primary out-of-home trip chain. The tour type is defined by the number and sequence of any intermediate stops made between the home and the primary activity. For work tours, this model also determines whether or not any work-based "sub-tours" (trip chains beginning and ending at the workplace) were made during the day.

The full-day activity-pattern model also predicts the number of additional "secondary" tours are made during the day. Secondary tours include any trip chains made away from home that do not include the primary activity. The model predicts the main purpose of each secondary tour and whether intermediate stops will be made on the way to and/or from the main destination.

In terms of the important variables for emission analysis, the full-day activity-pattern model directly affects VMT, number of starts, and the percentage of cold and hot starts.

Home-based tour time of day

Once the full-day activity pattern is determined, a time of day model predicts the combination of departure times from home and from the primary activity for each tour away from home. The day is broken down into five time periods: Early = 3 AM to 7 AM, AM Peak = 7 AM to 9:30 AM, Midday = 9:30 AM to 4 PM, PM peak = 4 PM to 6 PM, and Late = 6 PM to 3 AM. The time-of-day decision directly affects travel and starts by time of day and, to some extent, the percentage of cold/hot starts.

Home-based tour mode and primary destination

Once a person's activity pattern is determined in terms of the number, purpose, timing, importance, and complexity of tours made throughout the day, the model system predicts further choices for each of those tours separately. The key model applied at the tour level is a joint destination and mode-choice model that depends on the tour purpose and complexity as well as on the road and transit service levels along all segments of the tour. This model estimates the probability that each zone in a sample of zones will be the primary destination, and that each of nine modes will be the main mode for the tour. The nine possible main modes are as follows: drive alone, drive with passenger, auto passenger, LRT with auto access, LRT with walk access, bus with auto access, bus with walk access, walk, and bicycle. The choice of mode affects both VMT and the number of starts in terms of the number of vehicle trips, and the choice of destination affects VMT through distance traveled.

Work-based sub-tour models

Work-based sub-tours are trip chains that begin and end at the workplace (e.g., going out for lunch). The system contains additional models for such work-based "sub-tours," which are similar to the models for home-based tours. These models predict the timing, destination, and main mode of any work-based sub-tour and are strongly conditional on the timing, mode, and destination of the primary tour between home and work. In the current application only the mode and destination model is a disaggregate one. The work-based sub-tour is a full tour model affecting VMT, mode of travel, number of starts, and percentage of cold/hot starts.

Locations of intermediate stops

The lowest-level model in the system determines the location of any intermediate destinations visited between the home and the primary tour destination, conditional on the main mode and on the location and timing of the primary tour activity. These models are applied for each tour predicted to contain intermediate stops. In the current version of the model application, the intermediate stop model is applied only for tours made by car and only for one intermediate stop in each half tour. In addition the intermediate stop model is applied on an aggregate zone-to-zone level, and the logsum from these models is not used in the higher level tour models. Location decisions affect VMT through trip lengths.

ADVANTAGES FOR EMISSION AND AIR-QUALITY ANALYSIS

This section describes the advantages of activity-based modeling for emission and air-quality purposes by showing how the estimate of each of the transportation variables required for air quality analysis can be improved by activity-based models. The advantages of four different levels of development in travel-demand modeling are compared for their ability to provide the required input for emission estimates. These four levels of development are as follows:

- The traditional trip-based four-step model.
- An activity-based model system recently developed for Portland, Oregon. This system represents the most advanced application of activity-based modeling in the U.S.

- The original design of the Portland Model. This design is more ambitious than the applied model system. Work is continuing on enhancing the model system to match this original design. The main elements missing in the current application from the original design are a one-acre grid-cell system to replace the current aggregate traffic-analysis zone system, the incorporation of disaggregate intermediate stops, and work sub-tour models in the model system, and the implementation of time and space availability constraints to account for dependencies between activities.

- An ideal activity-based model system. Current applications, including the original design of the Portland model, still lag behind an ideal activity-based model system, as described in the introduction.

Table 2 shows the capability of the different transportation models of providing accurate estimates for each of the important transportation variables needed for emission analysis. The first column lists these variables. There is no column for the ideal activity-based model system, as it is assumed that an ideal system will provide full and accurate information on all these variables. The second column describes the capability of the full design of the Portland model of providing information on these variables and lists the design aspects that limit these capabilities. The third column describes how the capabilities of the current application of the Portland model in regard to these variables vary from the full design, and the last column compares these capabilities with those of the traditional four-step model. The sections that follow discuss in more detail each of these variables and the contribution of the different levels of model development to their accuracy.

Vehicle Miles of Travel (VMT)

An ideal activity-based model can predict any trip including intra-zonal and other short trips, given that it is applied together with a precise zone system and a detailed traffic microsimulation. The full design of the Portland system calls for a one-acre grid-based system, and therefore will be able to provide more accurate VMT, given that the road network is expanded to match this level of detail. The full design is limited in accurately predicting VMT because of the restricted number of stops it modeled for each tour. The model distinguishes among a limited number of tour types in terms of the number of stops and their order. It distinguishes among tours with no stops, tours with stop or stops on the way to the primary destination, tours with stop or stops on the way back from the primary destination, and tours with stop or stops in both directions. The model makes no distinction, however, between only one stop in a given direction and more than one stop. Therefore, the model does not predict the exact number of stops, but only the minimum number of stops. As a result, VMT can be underestimated, unless an appropriate adjustment factor is made based on the raw survey data. The level of underestimation can be studied by using the raw survey data and comparing the VMT of actual tours from the survey with the VMT of the appropriate predicted tours having a limited number of stops. The current application of the Portland model uses an aggregate zone system and, therefore, does not represent the VMT of internal trips. The activity-based model predicts the number of trips, including internal trips, so it is possible to make some corrections for internal trips. This is not different from the information obtained from the traditional four-step model for internal trips. Both the current application and the traditional four-step model system underestimate VMT by not including some local roads and intra-zonal trips. In terms of emissions, these are usually trips at low speed with frequent acceleration/deceleration and, therefore, may have a significant influence on emissions.

Table 2: The Capability of Transportation Models to Provide Estimates for Variables Required for Emission Analysis

Variable	The Full Design of the Portland Model System	Current Application of the Portland Model	Traditional Four Step Model System
Fraction of cold/hot starts	limited by the coarse definition of time of day and the limited number of stops on tour	limited by the coarse definition of time of day and the limited number of stops on tour	Provides no information on the time span from the previous trip.
VMT	A more detailed zone system will provide a more accurate prediction of VMT. The limited number of stops on tour limit the accuracy of VMT.	The lacks of the intermediate stop model and an aggregate TAZ system limits the accuracy of VMT and underestimate it.	Underestimate VMT by not including some local roads and intrazonal trips.
Mode Choice	The model predicts the main mode of the tour as one of nine modes but does not identify the specific mode for each trip segment.	Same as the full design.	There is no dependency between mode of trips in one tour. Limit mostly in TCM analysis
Time/location of starts	Can predicts location accurately, but time is limited to the coarse definition of time periods.	The use of an aggregate TAZ system, and the lack of the intermediate stop model further limit the distribution accuracy.	Time of day is usually more coarse than in the Portland model and rarely time of day is a choice model.
Speed/ acceleration/ driving profile	Can be done using a traffic microsimulation	Will use traditional assignment, so same as four steps	Only through the use of post-processors.
Travel by vehicle class/age	Auto ownership model does not include vehicle class and age.	Same as for the full model.	None

Travel by Mode and by Occupancy Rate for Auto Modes

An ideal activity-based model system can predict the mode of travel for each tour as well as deviations from the main mode of the tour in the trip segments. Both the full design and the current application of the Portland model predict the main tour mode as one of nine modes: drive alone, drive with passenger, auto passenger, LRT with auto access, LRT with walk access, bus with auto access, bus with walk access, walk, and bicycle. The model does not identify the specific mode for each trip segment, and the main tour mode can mean a different combination of modes in the different trip segments. For example, a tour mode of bus with walk access can mean a person who took a bus with walk access to the main destination and back, but it can also mean a person who was an auto passenger to the main destination and then rode a bus with walk access back home. In assigning modes in the Portland model, an effort was made to define the main tour mode in a way that would not affect VMT by different modes. In the above example, our person, whether as an auto passenger or as a bus rider, does not add VMT to the system. The traditional four-step model predicts the mode for each trip segment. The main contribution of activity-based modeling regarding mode choice lies in the response to TCM. In the four-step model, changing the mode of a trip in response to TCM will not affect related trips, because there is no dependency between trip segments. In an activity-based model system, a person who shifts from auto driver to light rail in response to TCM has to change the modes of all trip segments in this tour.

Cold/hot Starts

The prediction of trips as parts of a tour, and of tours as part of a daily activity pattern, can identify whether a trip is a cold or a hot start. An ideal activity-based model will predict the start and end time for each trip and the time between the end of the previous trip and the start of the current trip; therefore, it can identify the mode of operation.

The limitation of the Portland model in providing such details results from two factors. First, as described in the VMT section, both the full design and the current application treat a maximum of one stop in each half tour. The second limiting factor in both designs are the time periods defined for the time of day model. As described above, the Portland model distinguishes among only five different time periods: before, during, between, and after the AM and PM peaks. This coarse definition of time makes it impossible in many cases to identify the time between trips. Even for a one simple tour of home-work-home, a combination of midday-midday can be leaving home at 10 AM and returning at 11 AM or it can be leaving home at 10 AM and returning at 4 PM. A combination of AM peak-midday can mean either leaving home at 9 AM and returning at 10 AM or leaving home at 8 AM and returning at 4 PM. Another limitation of the current application is the lack of time choice element in both the intermediate stop and the work-based sub-tour models. Therefore, we can know only the leaving home time for the tour and the leaving the main destination time to begin the return leg of the tour. If there is a stop on the way to work, the current application assumes that it is made in the same time period of leaving home; it cannot identify the time between that stop and the start of the return leg of the tour. The Portland model improves input for an air-quality analysis over a traditional four-step model by indicating whether a trip is the first of the day and by providing some window on the time span between trips. A traditional four-step model provides no information about cold/hot starts.

Speed/Acceleration/Driving Profile

Speed, acceleration, and driving profiles are not derived from the activity-based model, but rather from a traffic microsimulation model. An activity-based model, however, can provide better trip data for a traffic microsimulation model in order to obtain more accurate driving profiles. The Portland model uses a traditional assignment process, and therefore does not offer improvement over a traditional four-step model. Improvements to these processes can be made by using post-processors.

Travel by Time of Day, and Time and Locations of Starts

An ideal activity-based model system would predict the time and location of all starts; however, the few problems already identified above with the current Portland application do not enable such a prediction at this stage. For both the full design and the current application, these shortcoming include the coarse definition of time and the limited number of stops in a tour. Additional shortcomings in the current application are the use of an aggregate zone system and the lack of a disaggregate work sub-tour and of intermediate stop models. All these factors make an accurate prediction of the time and location of starts difficult. The Portland model, however, improves on the traditional four-step model by providing a time-of-day-choice model that offer more time periods than do most models. Time of day is not one of the four steps of the four-step model, and only a few areas have it as an additional step. Others simply apply some factor, based on traffic counts or travel behavior surveys, to account for time of day.

Travel by Vehicle Class and Model

An ideal activity based model may include auto ownership, vehicle class, and vehicle model as well as an auto assignment to household members and trips. Such a model would be able to provide travel according to vehicle class and model. Portland uses an auto ownership model that does not include vehicle class and age, and therefore, it can not identify travel by these variables. There is no plan to extend this capability as part of the current development of the activity-based model system although Portland conducted a vehicle-buying survey recently that may be used for such an improvement.

Travel by Facility Type

Travel by facility type results from assignment. Once the trip table has been obtained by using an activity-based model or a traditional four-step model, travel by facility type can be obtained by using a traditional assignment process or a traffic micro-simulation model. The problems here have more to do with the estimation of VMT on local roads as was discussed above.

THE ADVANTAGES FOR TCM ANALYSIS

This section describes the advantages of activity-based modeling for estimating the air-quality benefits of TCM. The previous section described how activity-based modeling can improve the estimation of emissions for a given transportation scenario; this section focuses on estimating the change in emissions as a result of implementing TCM. The advantages of activity-based modeling lies in its ability to give a better prediction of travelers' responses to TCM and, therefore, to provide a more accurate estimate of the changes in the transportation variables important for emission analysis from the implementation of a TCM. One of the main advantages of the activity-based modeling system is its ability to consider the secondary effects of TCM. Secondary effects are adjustments to the activity pattern that have to be made in response to the primary effect. For example, a transit subsidy may make a commuter change his or her mode from drive alone to transit; this is the primary effect of the TCM. Because, however, the person no longer drives to work, there can be no stop on the way back to buy groceries. Therefore, when the person returns home, he takes the car and drives to a nearby store. This is the secondary effect. In such cases, the advantages of TCM may be limited, and the reduction of the work auto trip is offset by a new shopping auto trip. Only an activity-based model can deal with these secondary effects. The ability of the current application to deal with secondary effects is restricted because of the limited number of stops in the model, the lack of time choice element in the work-based sub-tour and intermediate stop models, and the lack of intermediate stop logsum variables in higher level tour models. Table 3 and the next sections show the capability of the different transportation models of providing response to some of the common TCM and describe the advantage of activity-based modeling for this purpose.

Telecommuting

One of the main contributions of the Portland model is its ability to distinguish between in-home and away-from-home activities and to make the trade-off between work and any other activity at

Table 3: The Capability of Transportation Models to Estimate Response to TCM

TCM	The Full Design of the Portland Model System	Current Application of the Portland Model	Traditional Four Step Model System
Telecommute	Can distinguishes between in home and away from home activities. Response to telecommuting measures is limited by the availability of such measures as variables in the primary activity model.	This feature is fully developed as in the full design without telecomuting explanatory variables.	No way to deal with trade-off between at home and away from home activities.
Travel demand management	Can model the responses and all their secondary effects. The range of TDM that can be modeled is limited by the availability of auxiliary models based on stated preference data or some other data designed for this purpose, and by the limited number of stops in the model.	Can model the response to TDMs as the full model, but is further limited in modeling the secondary effects because of the lack of the work subtour and the intermediate stop models.	Can model only TDMs where the effect can be represented in terms of time and/or cost, and this ability is usually limited to the mode choice step only
Land use	Land use changes can affect all travel decisions and these should be reflected in the activity pattern.	Limited by the lack of the work sub tour and the intermediate stop models.	Can model to the extend that land use variables affect trip generation and distribution, and occasionally mode choice.
Transit improvements	Can model the responses and their secondary effects, and can consider the feasibility of the response based on the daily activity patter.	Limited in modeling secondary effects, because of the lack of the work subtour and the intermediate stop models. Limited in considering the feasibility of the response because of the lack of time and space constraints.	Can model only primary effect, and usually limited to mode choice effects.
Traffic flow improvements	In the lack of traffic microsimulation the advantage of the activity based model for this group of TCM is limited	same as the full application	Sensitive only to the extent that these improvements are translated to time saving.

home or away from home. Theoretically, such a model can fully respond to telecommuting measures. Variables representing telecommuting options, however, are not included in the Portland model and data, and therefore the primary activity model is limited in its sensitivity to telecommuting measures. Enhancing the model to be sensitive to telecommuting options is feasible but requires appropriate data. In the current application, the model can predict the trade-off that people make between staying at home and going on tour for a specific activity as a response to travel variables (time, cost) and to socio-economic variables, but not as a response to telecommuting policies, unless these can be measured in terms of cost and time saving. The four-step model deals only with the trips, not with activities, and therefore, it cannot deal with telecommuting at all.

Travel Demand Management

The main advantage of the activity-based model in modeling the response to travel demand management (TDM) measures is in its ability to catch secondary effects as described above. There is a wide range of TDM measures: public education and marketing, alternative work schedules, paratransit and vanpool programs, guaranteed ride home; in addition there is the market-based mechanism, including employee financial incentives and subsidies, congestion pricing and a toll program, emissions and VMT fees, fuel taxes, and parking pricing. The ability of a model system to be sensitive to a specific TDM measure is limited by the availability of an auxiliary model for such a purpose. Such a model can be based on stated preference data or revealed preference data regarding before and after if such measures were already applied. The current application of the Portland model was implemented to test congestion pricing as part of the TROS project described above. The current application can model the response to TDM measures as long as these measures are represented by explanatory variables included in the model. In other cases, such as described above for telecommuting, an auxiliary model is required. The current application is limited in modeling secondary effects because it models only a limited number of stops in the tour. The traditional four-step model system can usually model responses to TDM as long as they can be represented in terms of time and/or cost, and this ability is usually restricted to the mode-choice step. Because cost measures are rarely included in trip distribution and generation models, those effects cannot be modeled. Therefore, the four-step model is quite limited in its ability to model responses to TDM.

Land-Use Measures

Land-use measures include mixed development, concentrated development in centers or corridors, and pedestrian-friendly site design. Land-use measures can affect all activity and travel decisions; therefore, only an activity-based model can be sensitive to such measures. The importance of activity-based modeling to model responses to land-use measures lies in its ability to consider secondary effects and time and space constraints. However, to fully accounts for land use policies a residential choice model and a primary work place model including log-sum variables from the tour models will need to be estimated. Traditional four-step models can be sensitive to land-use measures as long as land-use variables affect trip generation, distribution, and mode choice. Some land-use measures are usually included in trip-generation models, less often in trip distribution; but they are rarely included in mode-choice models

Transit Improvements

The advantage of activity-based modeling to predict responses to transit improvement, in addition to capturing secondary effects, is in the ability to model mode switching more accurately by considering the feasibility of such a response, based on the daily activity pattern. For example, if a person has to drop a child at a day-care center not before a given time and then be at work not after a given time, the person may find it unfeasible to switch the home-daycare-work auto half-tour to an auto tour of serving the child and a transit trip to work; nevertheless, all other variables show that the person would be willing to make such a switch under specific transit improvements. As in the case of TDM, the current application of the Portland model is limited in modeling secondary effects as well as in considering all time and space constraints because of the limited number of stops in the model. It does represent, however, a significant improvement over the four-step model in which the trip segments of the same tour are modeled independently of one another. In such cases, a transit improvement only during the morning commute can show some shift to transit by the four-step model that is not going to occur, because travelers will not shift to transit unless the service in both directions of their tour will improve.

Traffic-Flow Improvements

This set of TCM is unique in that it does not try to alter travel demand; rather, it simply improves the flow of traffic so that it occurs under conditions that are more favorable in terms of emissions. Intelligent Transportation Systems (ITS) can also be viewed as improving the supply by providing drivers with real-time information. Because this group of measures does not try to alter demand, the advantages of activity-based modeling is limited. The implementation of traffic micro-simulation is more important for this group of measures.

CONCLUSIONS

Although the theory behind an activity-based travel-demand model is very attractive for obtaining the detailed accurate output needed for emission and air-quality analysis, the development and application of such a model are very complicated. The activity-based model recently developed for Portland is the most advanced of this type developed to date. Its application, though, still lacks many features that were simplified in order to make the model applicable within the Metro capabilities and for a reasonable running time. This paper shows that these simplifications lead to obtain only some of the advantages of an ideal model system. Much development is still needed to achieve the type of information that air-quality analysts would like to have. In analyzing responses to TCM, however, activity-based modeling has important advantages over the traditional four-step model. Therefore, it is an important tool, and should be used to assist policy-makers in order to decide on the implementation of TCM. As computer-processing time and disk space continuously improve over time, the models can improve accordingly. Following are priorities in improving the activity-based modeling system for emission and air-quality purposes over the full design of the Portland activity-based model system.

1. **More refined time-of-day periods** - Time of day is one of the most important variables for emission analysis in order to distinguish among cold and hot starts and to determine temporarily distributed emissions. Time of day is a challenging modeling issue. Ideally, time of day should be treated as a continuous variable or be broken down into many periods.

2. **More tour types to distinguish among more intermediate stops on the tour** - The limitation of the current design that it does not to distinguish between one and more stops in each direction of a tour, limits its ability to accurately estimate VMT, number of starts, and the percentage of cold and hot starts. It also limits the ability to consider secondary effects and potential trade-off between more stops on a tour and more tours.

3. **Interactions among household members** - In order to fully represent secondary effects, there is a need to consider interactions among household members in so far as sharing household responsibilities that require travel and assigning vehicles to household members when there are fewer vehicles than drivers.

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