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Development of Weekend Travel Demand And Mode Choice Models

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16. Abstract

Travel demand models are widely used for forecasting and analyzing policies for automobile and transit travel. However, these models are typically developed for average weekday travel when regular activities are routine. The weekday models focus primarily on peak period travel, which are dominated with work and school trips. Given that weekend travel is largely generated for discretionary activities and is significantly affected by seasonal variation and special events, it is not surprising that weekday models are not adequate to forecast weekend travel.

This report documents an effort to develop a pilot weekend travel demand forecast and mode choice model for New Jersey. The research team utilized a holistic approach that balances state of art research and practical modeling applications for multiple agencies. The pilot model, produced via enumeration applications, not only incorporated up-to-date understanding of dynamics of weekend travel behavior but also obtained consensus from various agencies in New Jersey so it will be implemented.

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The bulk of the pilot model calibration was performed by sub consultants, PB Inc. and AECOM, Inc. Robert Donnelly, Peter Vovsha and Jeffrey Roux were instrumental in specifying the methodology and producing the pilot weekend travel demand forecast and mode choice model for New Jersey.

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INTRODUCTION

Current travel demand forecast models, instigated by the federal mandate (US Congress, 1991) of Long Range Transportation Plan (LRTP) for metropolitan areas, are reasonably accurate in projecting work trips and peak hour travel. However, national trends revealed that work trips are becoming a declining portion of total trips, and off-peak travel volumes on weekends may exceed peak hour congestion.

According to the National Household Travel Survey (NHTS, 2001), as shown in Figure 1, the share of commuting trips in terms of vehicle miles traveled (VMT) has decreased from 34 percent in 1969 to 27 percent in 2001. The same trend was confirmed for intercity travel as documented in the American Travel Survey (ATS, 2001).

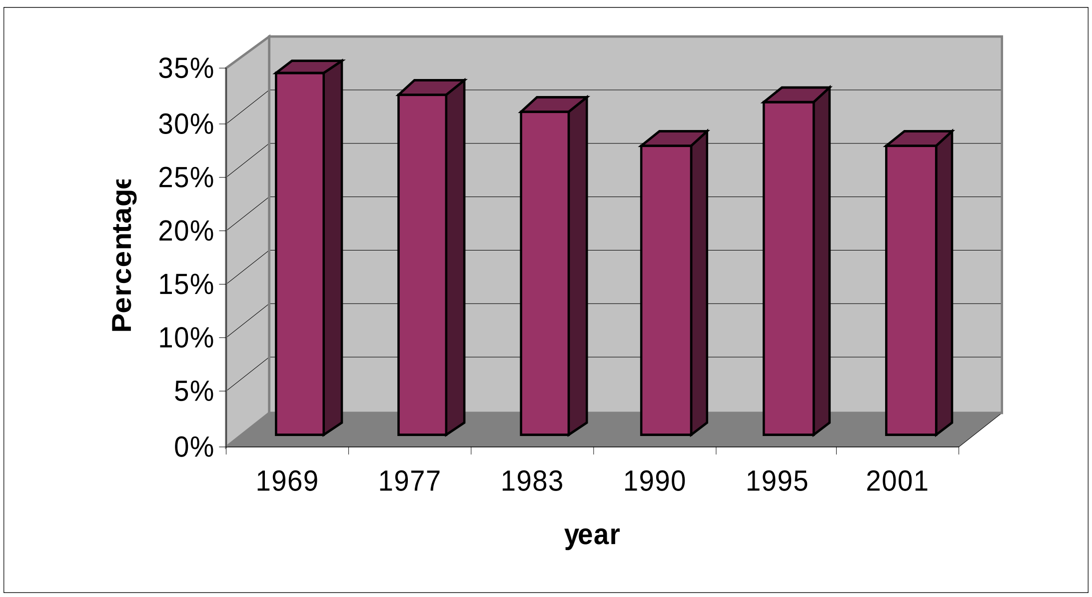

Figure 1. Decreasing shares of commuting trips by VMT

New Jersey, one of the most densely populated and transit friendly states, has a rather large share of transit mode. It is not difficult to conclude, given the large portions of other trips besides commuting during peak hours, that there is a risk that the need for additional highway and transit capacity will be significantly understated when relying on existing models, which may place New Jersey at a disadvantaged position in securing Federal funding for capital projects. There is a need, therefore, to develop new models that more accurately predict multimodal travel for non-work purposes, especially on weekends.

Recognizing the large amount of staff time and funding spent on weekday commuting travel, it is inevitable for us to draw attention to the weekend travel since the person trip rates during the weekends are only marginally lower than those during the weekday. As demonstrated in Table 1, the survey data collected by the North Jersey Transportation Planning Authority (NJTPA) show a difference of only 0.4 to 1.4 percent between weekday and weekend travel by two difference sources (PBQD, 2000).

Table 1. Weekday and weekend trip rates

	RT-HIS		NJPTA	
	Weekday	**Weekend**	**Weekday**	**Weekend**
Sample Size (Number of Households)	4,541	275	321	128
Estimated Mean (Number of Trips per HH)	8.80	7.71	10.35	8.53
Difference between Weekend and weekday	0.4%		1.4%	

The travel characteristics and dynamics of weekday and weekend are likely to be fairly different even when the magnitude of travel per household is compared. According to Lockwood, Srinivasan, and Bhat (2005), the weekend activity-travel participation is largely non-work oriented in contrast to weekday activity participation, which is centered on work or other mandatory activities. The weekend travel is not likely to follow the same peaking characteristics as weekday travel. The special traffic generators, such as sports, concerts, and cultural events during weekends result in traffic characteristics that are very different from that of typical workday traffic.

In addition, air pollution concerns, demand shift from weekday to weekend and general social consideration of promoting physically-active recreational pursuits help to argue that weekend travel warrants careful attention for comprehensive travel demand modeling, as well as for evaluating policy actions aimed at alleviating congestion, improving air quality, and enhancing the overall quality of life.

In our effort to assist NJDOT and NJ TRANSIT develop weekend travel demand and mode split models, New Jersey Institute Technology (NJIT) is leading a project team composed of Parsons Brinkerhoff (PB), Inc. and AECOM Consult (AECOM), two leading travel demand modeling firms and Dr. Robert Cervero, an outstanding scholar with expertise of identifying factors affecting mode share, transit ridership, and sustainable development. This report documents the research process, which includes a series of surveys, data analyses and model calibration that produced a pilot travel demand forecast and mode choice model for New Jersey.

RESEARCH OBJECTIVES

The purpose of this research is to specify a model that can be used to forecast weekend travel that incorporates the following processes: trip generation by trip type, time of day, origin-destination pattern, and mode choice. To derive the ultimate product of this project, the research team has undertaken the following:

1. Examined the state of the art in model development for non-work, off-peak, and weekend travel;

2. Evaluated alternative multi-modal modeling approaches, explicitly considering the impacts of various factors such as congestion on mode shifts;

3. Reviewed available models and travel survey data at NJDOT, NJ TRANSIT and the local MPO's;

4. Identified data deficiencies and statistical validity of alternative approaches;

5. Developed requirements and standards for incorporating changes to accommodate weekend travel into existing model frameworks;

6. Recommended a course for the development of multi-modal weekend travel demand forecasting models suited to the needs of New Jersey;

7. Calibrated a pilot model that demonstrates the methodology and procedures to develop weekend travel demand forecast and mode choice model for New Jersey.

RESEARCH APPROACH

It is critical to develop an implementation plan to accomplish the objectives. The research plan has defined the project management approach and detailed procedures and protocols to complete the research on time and within budget. The detailed task structures presented in the following sections provided tangible measurements toward the ultimate achievement of the entire project.

This research was organized into to three major phases. Phase One included a literature review and was completed within three months after receiving Notice to Proceed (NTP). The completed literature review is attached in Appendix 1.

Phase Two included tasks that examined the current models used in New Jersey and investigated the state of practices in relevant travel demand modeling from other agencies and consultants. Both documents on inventory of travel demand models in the Tri-state area and survey of state of art practice in North America are attached as Appendix 2 and 3, respectively.

Phase Three included those tasks that specified methodology, gathered data, and, calibrated the pilot model. During the project period of three and half years, the project team has monitored the local, regional and national progresses on the weekend travel demand models, updated the literature and data collection continuously and ensured the leading edge of the pilot model for weekend travel demand forecast and mode choice model in New Jersey. The following sections document the modeling specification, data development, and actual calibration of the pilot model for New Jersey.

MODEL SPECIFICATIONS

The purpose of this section is to outline a framework and general specifications for future weekend travel demand forecasting models in New Jersey that could be developed as extension of the standard weekday models, which will serve a range of possible planning purposes. As part of this task, specifications are detailed for a special model focusing on the Central New Jersey to Manhattan weekend travel market that would be developed as a demonstration of weekend modeling methods.

The conventional four-step travel demand models used by various agencies in New Jersey are widely accepted to forecast both automobile and transit travel demand for a *typical weekday*, generally a non-summer weekday when work and school activities are routine. Similarly, the activity-based New York Best Practice Model (BPM) is also restricted to a weekday focus as currently implemented. In the design and planning application of these models, the focus is primarily on peak period travel, in which regular work and school travel are dominant. It is not surprising, given the much larger share of non-mandatory or discretionary travel that occurs during the weekends, the greater influence of seasonality on these activities, along with the substantial scheduling and impacts of major weekend special events, that the current models are inadequate to meet the challenges of modeling weekend travel demand, and to forecast it for either road facilities or transit services.

This section provides an outline of the issues that confront modelers in developing new tools to forecast weekend travel, provides a recommended structure for these models, a framework for their development, and a description of the required supporting data.

Typology of Travel Demand Forecasting Models

While different in certain important respects that will be discussed, the fundamental principles and methods for the development of models of weekend travel demand are largely the same as those of the much more prevalent regional models that focus on typical weekday travel. As such, the addition of weekend modeling and analysis to a current weekday focus, designed in the context of different planning issues, can be implemented by extension and adaptation of the basic components of the current weekday models, to provide both efficiency in the use of data and modeling resources, as well as to encourage a consistency of the travel analysis. So, the discussion of general specification for regional weekend models logically starts with a review of the four basic structures of travel demand models, all of which are used in the NY/NJ region for a range of highway, transit, and transportation planning issues.

Figure 2 shows in a simplified way how the essential components of demand and supply (network simulation) are implemented in each of the main model types, namely:

1. Activity-based / Tour Structure
2. Conventional Four-Step / Trip Based
3. Transit-Only / Trip Based
4. Sample Enumeration

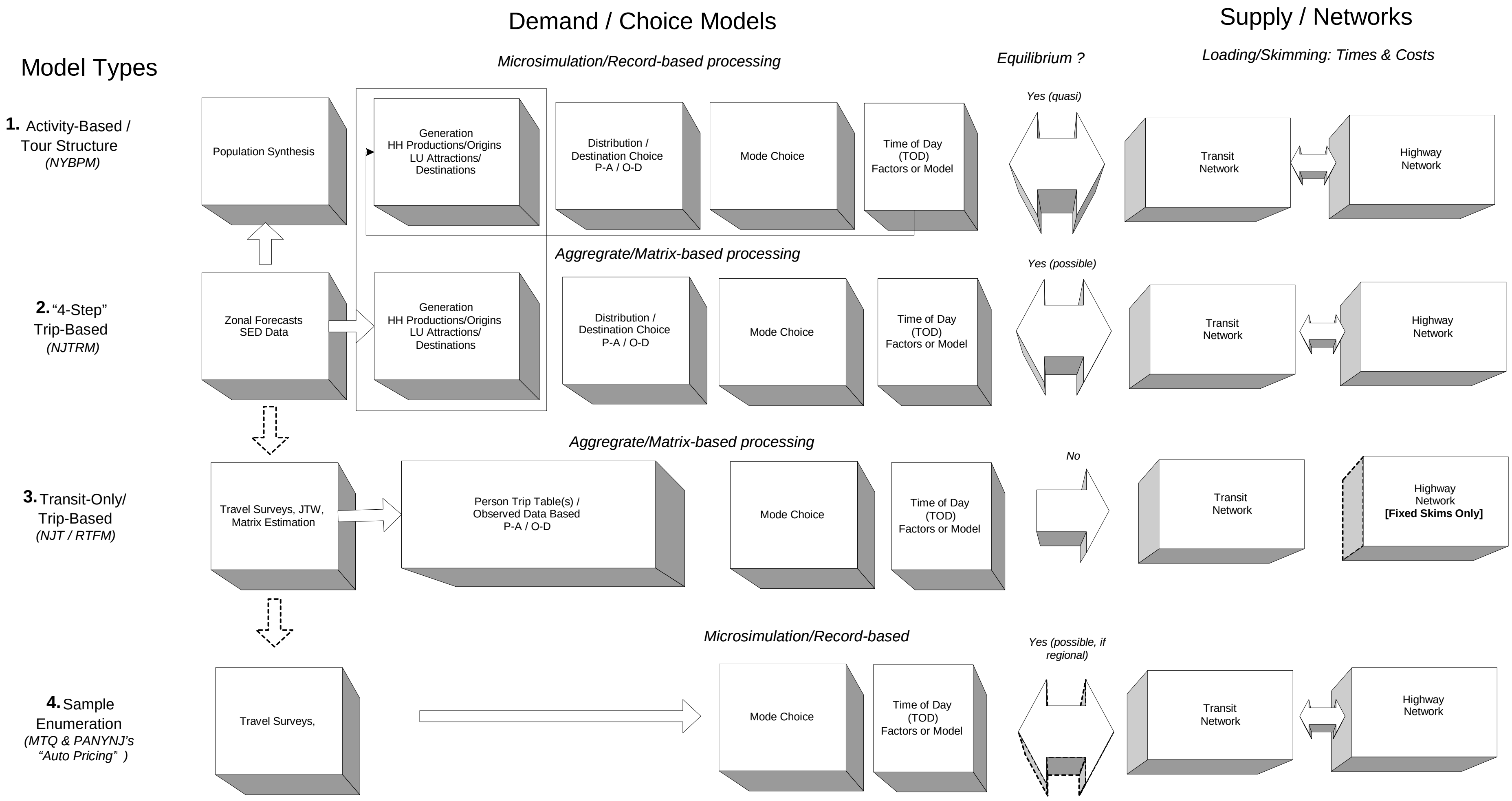

Figure 2. Typology of travel demand forecasting models

The figure also illustrates in a general way how each of the model types handles the basic sequence or processing flow in which zonal level land use and demographics used to generate travel productions and attractions, origin-destination flows are created, mode and other choices are predicted, and networks are used to forecast volumes and level of service on specific transportation facilities, such as roadways and transit stations, as well as to support an assessment of a condition of demand/supply equilibrium.

With respect to methodology, these model types vary in the manner in which they address each of these basic steps, including the substitution of observed or synthesized data for full modeling of the earlier stages of the model flow, as well as in the basic units of travel that are modeled – individual trips with aggregated market segments, or chains of trips as in the activity-based with micro simulation of individual households, persons and tours.

The difference in these model types also reflect the range of different planning issues that they are intended and used to address, and the importance of particular measures and requirements for accuracy, or policy sensitivities associated with these planning issues, that include:

- Provision of sufficient transportation capacity/service to meet growth or changes in demand, e.g. focus on peak period congestion;
- EPA based transportation conformity analysis for mobile source emissions and air quality modeling, such as daily VMT, VHT, and speeds by subareas;
- FTA "New Starts" evaluation - user benefits and cost/effectiveness analysis for transit.
- Transportation pricing – managed lanes, area pricing, etc. including revenue and systems performance evaluation;
- Other travel demand management strategies.

While these issues are generally addressed primarily by a direct modeling of typical weekday travel, there are varying elements and requirements associated with each of these for the consideration of weekend travel. Without explicit regional models for weekend travel, these are usually only indirectly addressed with count-based or other factors applied to the weekday modeled results, but could and would ideally be modeled directly with methods designed in a manner appropriate to importance of weekend travel in the context of each issue.

Model Type 1: Activity-based / Tour Structure:

Models of this type, such as the NYMTC BPM covering the 28 county NY/NJ and CT metropolitan area, use tours as the unit of modeling, where a tour, or "journey pairs" in the BPM, is defined as the full set of chained trips made by and individual while traveling from and back to their place of residence, or workplace such as "an at-work sub-tour".

In the first stage of the modeling, the zonal socioeconomic and demographic data are used to synthesize a full population of households and persons in the region, with characteristics corresponding to the zonal data. Rather than processing aggregated zone-to-zone tables by a limited number of market segments as done in the conventional models, the activity-based models use individual records in each subsequent stage of the modeling processing, with full information about each possible to be retained, and generate explicit discrete outcomes by applying Monte Carlo micro-simulation to the probabilities determined by each of the logit choice models – auto availability, tour production or frequency, mode and destination choice. In other words, rather than yielding a sum of probabilities for a given choice within a market segment, as done in the conventional model, e.g. 55% transit share of low-income work trips, the micro-simulation of the activity-based model yields a discrete outcome for each individual and each of their choices modeled. For example, transit will be selected for about 55 of 100 the records for individuals of this type.

As in the NYMTC model, the current standard practice is to aggregate the discrete model outcomes to produce final trip tables, aggregated by mode and by time of day, to load onto the highway and transit networks with conventional static assignment methods, however at some point in their future, these models can be directly linked to dynamic traffic assignment. The implementation of feedback and methods to promote convergence of travel times approximating a demand/supply equilibrium condition has been recently implemented with the BPM.

An important consequence of this "list-based" data structure and the fixing of discrete outcomes, is that full and logical information about prior choices modeled, such as drove to work, is available to inform and constrain the subsequent choices modeled, as drove to lunch, or to capture important interactions, such as intra-household and joint travel that affect the travel in real ways. This technology can provide a stronger behavioral realism to the modeling of weekend travel, in the same way that it does to typical weekday.

In addition, given the high degree of possible substitutability of weekday and weekend non-work activities that people travel for, an activity-based framework would clearly be the most robust in modeling weekend travel, as a subset of total travel made over the course of a week. That said, the extension of weekday activity-based models to include weekends by adding a "day-of-week" model component within a weekly or multiple-days per week framework, would increase the detailed travel diary data collected in household diaries by at least a magnitude of two, over the usual collection of a single weekday's travel.

Model Type 2: Conventional Four-Step / Trip Based

The conventional four-step, trip based model represent the most common type of travel demand model used by MPOs and other agencies for regional planning. In contrast to the activity-based approach, the standard "4-Step" sequence of travel choice models are implemented in an aggregate manner, applying the distribution, Gravity or logit destination choice, to the market segmented zone-level trip ends produced in the generation stage, followed by mode choice, typically multinomial or nested logit, models to the P-A or O-D matrices, and accumulating the derived probabilities of each choice by market segment as the model progresses.

The final trip tables -- by mode and by time of day -- are the sum of the aggregate probabilities. The NJTRM mode used by NJTPA is of this basic type. Like the Type 1 model, but unlike Type 3 and 4, there is both a trip generation and distribution stage in which trip ends and person travel flows are modeled from either base year or future year zonal socioeconomic/demographic data inputs. The implementation of feedback of travel times to approximate a demand/supply equilibrium condition is routinely done with these models.

The limitations of the conventional model that pertain to weekday travel, also apply to its application to weekend travel, namely limitations on its capacity to capture behaviorally realistic responses to some important planning issues. In addition, the possibility of considering weekend travel in the larger context of a weekly agenda is clearly not feasible in this case. On the other hand, and as discussed in the next section, these models are the most likely platform for extension to weekend analysis, with much of the same methods, data structures and network approaches to model weekend travel in a way which could be reasonable and consistent with standard weekday modeling.

Model Type 3: Transit-Only / Trip Based

As shown in Figure 2, the emphasis of these models is squarely on the accuracy of forecasting transit ridership, and especially in direct response to improvements in transit service, sometimes regionally, but generally within a specific corridor or travel market where improvements are planned. Both the NJ Transit Model and the MTA's Regional Transit Forecasting Model (RTFM) are of this type and are used for both long-term major transit improvements planning, as well as relatively short-term and operational planning.

Given this focus, and consistent with the "fixed person trip table" approach that FTA guidance calls for in the assessment of transit "New Starts" projects it could fund, considerable data are developed to produce total person flows by mode, with origin-destination data by mode, synthesized to counts, and combined to obtain total person flows as "fixed" inputs to the mode choice model for the base year. These person trip tables are estimated for future years with Iterative Proportional Fitting (IPF) methods, based on changes in zonal socioeconomic and demographic forecasts. Where sufficient O-D survey data by all relevant modes can be obtained, as has been the case in the NY/NJ region in the past, this can be a practical way to obtain good, even if at the same time static or "snapshot", measures of total travel flows between parts of the region. This means that when estimated transit and other mode shares that are modeled in the Type 3 models are applied to these "empirically-based" flows, errors in ridership forecasts that stem from errors in underlying person trip tables in either the Type 1 or 2 models should be reduced.

While transit times and costs are simulated with network and path-building methods, the mode choice model uses a set zone-to-zone of highway time and costs, "O-D skims", which are typically borrowed from the regional model, for the base and the future scenario year. The modeled highway trips are typically not assigned to the highway network for an analysis of impacts on the road system, and no attempt to establish equilibrium is made or considered necessary, particularly within the FTA New Starts framework.

Where the analysis of weekend travel is primarily related to the evaluation of new transit services, this model type is the logical platform for extending the forecasting beyond the typical weekday focus. It requires a set of O-D surveys by mode and counts for the weekend market within the corridor, similar to the weekday set, in order to establish reasonable person trip flow inputs to the model choice and transit assignment procedures. For New Starts analysis, it offers a more explicit way to assess the important and possibly growing component of the transit User Benefits that will stem from weekend ridership, than the simple annualization factoring approach that employs "weekday equivalents" developed from day of week count ridership data.

Model Type 4: Sample Enumeration

Sample enumeration models represent one of the more important and most prevalent examples of the other types of travel demand models used for transportation planning. The "Auto Pricing" model developed by the Port Authority of NY/NJ for Trans-Hudson auto drivers was of this type, as well as the recently developed Joint Model of Airport Choice and Mode of Access for regional air passenger demand in the New York/New Jersey region (also for the PANYNJ). These models share some of the features of both the Activity-Based and the Transit Only model types. Like Type 1, their implementation is performed with disaggregate records processing, in this case individual response records (with expansion weights applied) from an O-D survey, and can feature micro-simulation outcomes applied to the probabilistic results of the choice models. Like Type 3, they include choice models focused on mode and other travel choices for a given origin-destination or fixed travel market that is predetermined; in this case the travel patterns of the survey respondents. They can be estimated with either a Stated Preference (SP) component (as in the "Auto Pricing" model), or with revealed preference data (RP), or with both SP and RP combined.

Where survey data can be collected to support them, sample enumeration models can be used to model weekend travel effectively, especially where the planning issues to be addressed are reasonably focused on a specific issue, corridor and set of markets, this can be a relatively efficient method of modeling weekend travel. This is the type of model that is proposed for the Pilot / Demonstration Model of this research.

Consistency with and Extensions of Weekday Models

For both reasons of consistency and efficient use of modeling resources, it makes sense that travel demand models to be developed for regional or special market weekend travel analysis be built off the data and methods used for the existing or planned set of weekday models to the extent possible.

While there are important differences in the nature of weekday and weekend travel, and the planning issues of concern for each, the same fundamental modeling approach and structure can ideally be applied for both weekday and weekend travel. A similar general modeling approach and the use of a common data and software infrastructure can result is possible with respect to the following fundamental components of the models:

- Zonal data
- Networks – highway and transit
- Software platform and model application procedures
- Counts and other validation data
- Comparable travel performance or measures of effectiveness

Despite the commonalities, there are a number of important attributes of weekend travel that complicate and may limit the utility of a simple extension of weekday methods, and which represent challenges in obtaining levels of behavioral realism and model validation comparable to their weekday counterparts.

In contrast to the more stable typical weekday travel market, weekend travel is characterized by:

- Much lower proportion of mandatory travel, and much higher proportion and mix of "non-mandatory" travel with much less temporal constraints than the regular work, university and school that dominate weekday travel.

- Larger share of travel for sports and other recreational activities, religious services, as well as special events.
- Greater variation in day-to-day travel, including the influence of season
- Stronger impact of proximate holidays on scheduling and travel for weekend activities.
- More variable diurnal distribution and with varying peaking patterns, and no set AM and PM peak periods as the focus for demand / capacity analysis.

In addition, there probably is a need to model either a "typical Saturday" and/or a "typical Sunday" or both, since a "typical Weekend day" as an average of a typical Saturday and Sunday would not be a useful focus in most cases. This implies either doubling, or increasing by threefold the "day type" dimensions of the region modeling.

The implications for organizing the extension of conventional regional models to weekend travel, considering these commonalities and differences with weekday travel, are discussed in the next section with respect to each of the four major components of the conventional four-Step models where this approach can be adopted.

- Generation – production and attraction, trip ends;
- Distribution – geographic flows, P/A's or O/D's;
- Mode Choice - trip tables by mode and time of day;
- Network Assignment – highway link volumes and times, transit riders.

Model Components: Basic Four-Step Structure

Even the conventional four-step modeling approach is used as the basic framework for weekend travel forecasting, each of the models will require some level of transformation in order to reflect the following specific aspects of weekend travel behavior:

Travel Generation

It would be advisable for the household trip production to include more detailed segments of discretionary travel. For example, by singling out planned joint activities, visiting relatives and friends, all-day travel, etc. On the other side of generation, zonal trip attraction model would benefit from more detailed segmentation by land-use type with possible singling out unique facilities, such as major sport arenas.

At a minimum, and consistent with the activity/travel purpose structure of the weekday model, a standard set of trip generation models for the following is recommended:

- Home Based Work – HBW;
- Home Based Shopping – HBS;
- Home Based Recreation – HBR;
- Home Based Other – HNO, including University and School;
- Non-home based - NHB.

It has been noted that joint travel by household members is more common for non-mandatory travel, and is a significant component of weekend travel that ideally should be modeled. In an activity-based model, it is possible to model joint travel in the travel generation stage, corresponding to the decision made at this stage to make a joint trip. A limitation of the conventional model is that joint household travel must unrealistically be accounted for in the mode and occupancy choice stage of the model, with household attributes used only indirectly to account for multiple members of the household traveling together, as a High Occupancy Vehicle (HOV) model, if made by auto.

Distribution or Destination Choice

As for weekday models, the distribution stage is typically formulated as either a gravity type model, or a logit type destination choice (DC) model. The logit-based destination choice model can be constructed with composite time and cost utilities reflecting accessibilities provided by all modes of travel, by either using a generalized costs formulation, or the "logsum" of the mode choice model. An advantage of this approach for weekend modeling would be to provide an opportunity for including additional and perhaps specialized attraction or destination size variables, where the data can support them that are relevant to the extent and range of weekend discretionary travel, such as beaches, parks, regional malls, sports facilities. These attractions, size variables, can be made an integral part of utility calculation in the DC model. Also, especially appropriate for discretionary and maintenance activity travel that dominates the weekend, where the quality and precision of the attraction variables may be relatively inaccurate, as discussed previously, the DC model can be implemented with "relaxed" constraints on the non-home or attraction end, allowing the distribution of these trips to be less bound by the often crude estimates derived from the generation model for of these zonal data size variables.

It is expected that the weekend trip distribution model will show generally longer distances observed for discretionary travel, as well as reflect a known phenomenon of "positive utility of travel" when travel time / distance are intentionally not minimized within certain limits. This is an issue that should be considered and as it affect the calibration of the weekend distribution models.

Mode and Occupancy Choice

An important question that only substantial data analysis could fully answer is: Are the travel sensitivities, utility coefficients, associated with weekend travel the same as for weekday? It is possible that weekend mode choice model should reflect a somewhat different set of preferences compared to regular weekday models, with possible greater sensitivity to transit service convenience, less sensitivity to in-vehicle time, and either a higher or lower willingness to pay depending on specific activities, so-called situational value of time for example.

The actual differences between sensitivities in weekday and weekend travel to the principal measures of transportation level of service that are typically included in the models are not really known, either average values or their distribution across individuals and situations, but they must either be asserted, if assumed to be small, or estimated for the standard set:

- In-Vehicle time
- Out-of-Vehicle time
- Tolls/Fares/Costs
- Value of Time - implied.

Depending on the resources available, the weekend models will either need to adopt and adapt parameters from related markets represented in the weekday models, for corresponding activities/purpose, or be able to use new parameters of the utility expressions in the mode choice model estimated specifically for weekend travel with a full statistical model estimation process. The latter is clearly preferable, but requires the collection and development of sufficient weekend travel behavior survey data, along reliable matrices of travel times and costs for each mode taken from weekend highway and transit networks, and supporting zonal land activity data.

Time of Day Factors

Peak factor / time-of-day choice model for weekends may need to have a substantially different structure than for weekdays, with additional possible segmentation by Saturday / Sunday, each with identified peak periods of varying length, and possibly summer / winter seasonal factors. The temporal structure of the weekend model could take various forms, including a possible partitioning daily demand into the following assignment periods, for example:

- Saturday, Sunday or average weekend day
- Core peak periods
- Other Off-peak

Highway and Transit Networks - Path-building and Assignment

For a general regional model of weekend travel, level-of-service (skim) matrices need to be developed for both highway and transit in order to accurately forecast weekend travel demand by mode. These could be created by standard path-building procedures, but with generalized cost parameter consistent with the weekend mode choice model parameters where possible.

Generally, the link attribute information contained in the weekday highway networks would typically be the same and could be directly used for weekend analysis, with generally off-peak operating policies and conditions in place. Weekday hourly capacities, link volume groups, vehicle delay functions, and other assignment parameters could serve as defaults for weekend analysis, unless data and analysis supports otherwise.

Weekend transit level-of-service (skim) matrices will need to be developed in order to accurately represent the weekend transit services available throughout the region. Transit skims and the automobile level-of-service characteristics can be taken from the regional models, and would be used as the key input into the weekend mode choice models. Methodologies need to be developed in a cost-effective manner that can accurately represent weekend transit service in the region. Potential approaches for the development of weekend transit skim matrices include:

- Developing and maintaining a new weekend transit network for a network-based approach.
- Borrowing weekday off-peak network as a surrogate for the weekend transit networks.
- Developing an alternative coding approach to facilitate the development of a spreadsheet type model for weekend travel.

Data Implications and Requirements

In general, the same basic zone-level population, employment and other land activity data could be used for weekend models as those available from the weekday models, but existing databases may be lacking to some degree in measures suited to weekend activity patterns, when the role of employment and enrollment as “anchors” of the predominant mandatory travel on weekdays will be less important. Adequate “attraction” variables specific for a range of important non-mandatory trip purposes that comprise much of weekend travel may be lacking and if they could be developed have the potential to improve weekend models.

There are three basic types of survey data that can support the development of weekend travel demand models, either for estimation of model coefficients, or for the calibration of the models with respect to aggregate targets derived from survey expansion, or for both purposes:

- *Detailed travel diary surveys*: such as the 1997/98 Regional Travel – Household Interview Survey done for the 28 county NY/NJ/CT regional area. For comparable levels of statistical reliability, including weekends in this type of survey can substantially increase the scale of the survey, with at least as large a sample of households required for Saturday and Sunday as for the weekday, and probably larger due to the greater variability of weekend travel.

- *Intercept Origin-Destination Surveys* – such as NJ Transit onboard bus and rail surveys, or the PANYNJ Interstate crossings surveys of auto drivers. Focused on particular modes in specific corridors or facilities, these weekend surveys can establish calibration targets for travel models, or serve as the basis to implement for a sample enumeration type model focused on these markets.

- *Stated Preference Surveys* – special surveys with trade-off "games" used to estimate sensitivities to new choices or travel attributes that are difficult to measure in the "revealed preference" HIS or OD surveys

- *National Census and Travel Surveys* - The US Census, including CTPP and PUMS data are provided information only on home-to-work journeys, a minor component of weekend travel. Prior National Personal Transportation Surveys (NPTS) or the current American Community Survey (ACS) with their coverage of all travel purposes can provide useful information to support weekend models, but without specific geographic indicators, and with typically limited samples in a given region, the utility for model development is limited.

- *Counts* – Weekend traffic and transit counts need to be compiled to calibrate and validate weekend models, typically by similar dimensions used for weekday models – link group type by hour (or period) for highway, and station boarding's by sub mode and/or subarea for transit.

Validation Methods

Where possible, the validation of weekend models should follow the same basic principles and approach as for weekday models, with similar measures supported by the observed data, including:

- Expanded aggregate trip generation, distribution, and mode choice statistics from the household surveys;
- Volume/count deviation by facility and area types;

- Transit boarding by service type and/or sub-regional area;
- Transit statistics and ridership profiles from the on-board transit survey
- Weekend traffic and transit counts;
- Independent statistics on attendance / capacity of special events by location.

There are no clear standard of acceptability for weekend models, and due to the inherent greater variance of travel during weekends, the effects of seasonality, and the higher incidence of special events that will all be reflected in variance in the "observed" data targets, it would seem lower expectations for model results are appropriate.

Specifications for the Pilot Model

Based on the inventory of survey and other data conducted as part of the work done in the first year of the research, it was determined that no travel survey data currently exists that can support the implementation of a travel demand model for a general regional weekend transit analysis in New Jersey. Toward the end of the second phase of this study, a consensus emerged that a pilot model may be the first step before a statewide weekend travel demand forecast and mode choice model can be developed in the future.

Corridor / Travel Market Focus

A number of specific corridor or special travel markets were considered as candidates for the development of a research demonstration weekend travel demand model, and one that would be particularly relevant to transit planning issues. Given the strong diversity of activities that determine weekend travel patterns and their varied impacts on the capacity of transportation infrastructure and services, the research team anticipated that different approaches could be needed to address relevant issues for specific facilities, which serve specific corridors and specific travel markets. Consideration was given to the methods and data required to develop efficient and practical methods needed to address what are some of the current planning issues that have been identified by NJ Transit as important, and could benefit from better weekend analysis and forecasting, including:

- Rail and bus travel to New York
- Intra-Jersey bus travel on certain routes.
- Bus travel to Cape May and other NJ coast locations
- Hudson-Bergen LRT

As a result, a decision has been made to focus the next data and model development step of the research on the first of these, and to develop a pilot or demonstration application tool addressing this rapidly growing Trans-Hudson weekend rail and bus transit market from Central NJ to Manhattan.

Required Data Development

To support the development of this model, it was determined that a relatively small rail and bus riders survey should be conducted, focused on weekend travel from Central NJ to Manhattan. The survey and the model will focus on the inbound Saturday afternoon peak travel period.

Combined with the recent set of Interstate crossing auto driver and passenger surveys done by the PANYNJ that included both weekdays and weekend travel in December 2006, this new transit survey would provide the missing part of a needed and timely data on auto/transit mode shares needed for the estimation and development of an initial weekend travel forecasting tool.

- PANYNJ auto surveys (2006)
- New rail and bus onboard survey – weekend
- NJT Rail survey follow-up (internet based) – ticket and passes – weekend rates

Mode Choice Estimation

The mode choice model will be estimated by constructing an estimation data set that is comprised of the auto and transit survey records, combined with travel time and cost information developed to represent typical Saturday conditions in the Central NJ to Manhattan corridor. These will be developed and processed with weekend networks derived from and integrated with the NJ Transit model networks.

Various methods of segmentation for travelers, classification of travel activities and type, including individual and group travel, will be tested to determine the most appropriate and robust structure for the model. A multinomial or nested logit choice model will be estimated that can be implemented for forecasting.

Validation and Testing

The model calibration and validation will be structured to include careful comparison of the model results with the available sources of information, and a possible subsequent adjustment of the modal parameters in order to better match the established targets. Validation targets will include aggregate ridership and travel volume targets taken from NJ TRANSIT, PANYNJ, and other relevant survey data. The data and methods used to the model, its validation and sensitivity testing should be documented in a Technical Memorandum.

Data Sources and Assembly

It is concluded in the first phases of the research, the PANYNJ has collected both weekday and weekend data in 2006, which may serve as an anchor piece for potential development of weekend models if additional transit user surveys may be supplemented. After securing the PANYNJ survey data, NJ TRANSIT has allocated fund to conduct a small set of rail and bus surveys along the central New Jersey to Manhattan Corridor.

Bus Survey

Ann onboard bus survey was designed for Coach USA Line 100 starting from Port Authority terminal in Manhattan. The survey was carried out on a Saturday, June 21, 2008, between 9 am to 6 pm, and a sample of 104 records was obtained.

The survey data includes information on trip purpose, party size, person characteristics, travel frequency, bus departure time, household income, household composition, and access/egress modes as shown in Appendix 4. For this analysis, 67 records were useable, corresponded to respondents traveling between Manhattan and the Central NJ transit catchment area. The bus survey record origin and destination ends were flipped to match the eastbound directionality of the rail and auto records, and the modeling framework. The coordinate (latitude/longitude) information was used to tag origin and destination zones to the records.

Rail Survey

The research team also conducted an onboard survey along the North East Corridor Line collecting nearly 418 records. The survey was administered to riders boarding the train primarily at Hamilton, Princeton Junction and New Brunswick stations. A sample of 150 records based on origin and destination locations was extracted for this analysis. The survey collected information on trip purpose, party size, person characteristics, household income, travel frequency, departure time, household composition, and access/egress modes as shown in Appendix 5. The origin and destination coordinate information was used to tag origin and destination zones to the records.

Auto Survey

The auto survey data for this study came from the 2006 Trans-Hudson crossing origin-destination survey conducted by the Port Authority of New York and New Jersey (PANYNJ). The survey was a paper-based questionnaire distributed to over 234,000 motorists that used one of the three PANYNJ's Hudson crossings on a Tuesday, Saturday or Sunday. The survey collected information on trip purpose, vehicle occupancy, person characteristics, household income, auto ownership, number of drivers in the households, travel frequency, departure time and others. For the purpose of weekend model, only the 253 Saturday survey records which started from the transit catchment area and ended in Manhattan were considered.

The auto survey includes all trips during the day, whereas rail and bus surveys were carried out during specific time period from nine am to six pm. The auto survey weights were normalized to the total (weighted) number of auto users who reported departure between nine am to six pm. A second correction was applied to auto weights to account for multiple person trips for each High Occupancy Vehicle (HOV). For such cases, the auto weights were multiplied by vehicle occupancy (party size) to get auto person trips.

The zip-code information in the PANYNJ auto survey was used to tag origin and destination zones. For the 102 records in the survey that had missing information on destination location or zip-code in Manhattan, the destination zip-codes were imputed based on records with valid information. Trip purpose and proximity of origin were used to filter survey records with available destination information (such records are referred as "donors" records). A python code was developed and used to create a distribution of destination zip-codes for donors and randomly select destination zip-code.

Level-of-Service Data Development

Table 2 shows the sample description for the survey dataset by auto, bus and rail. Only the variables available in all three surveys could be used for model calibration. The number of recreational / shopping / other trips is nearly three times as the number of work-related/personal business trips, as expected for a weekend travel to New York City. Sample represents that bus riders travel alone more frequently as compared to both rail and auto riders. Many, 77 percent, of the trips by auto, are made in groups (HOV), which in effect reduces the cost of traveling when considered as divided among all travelers sharing the same vehicle. The person characteristics, such as gender and age group are for the primary respondent (or decision-maker) from each group. Weekend travelers with higher household income prefer rail and auto modes to bus, as expected.

Table 2. Survey sample description

	Bus Sample		Rail Sample		Auto Sample	
	Count	**%**	**Count**	**%**	**Count**	**%**
Total	67	100%	150	100%	253	100%
Trip Purpose						
Work, School and Personal Business	27	40%	18	12%	76	30%
Recreation, Shopping, Social and Others	40	60%	132	88%	177	70%
Party Size						
1	45	67%	62	41%	59	23%
2 or more	21	31%	77	51%	194	77%
Missing or Unknown	1	1%	11	7%		0%
Gender						
Male	25	37%	66	44%	166	66%
Female	40	60%	84	56%	84	33%
Missing	2	3%	-	0%	3	1%
Age Group						
Missing or Unknown	8	12%	5	3%	5	2%
Under 18	-	0%	2	1%	-	0%
18 to 34	13	19%	50	33%	40	16%
35 to 54	19	28%	49	33%	116	46%
55 to 64	18	27%	25	17%	51	20%
65 and older	9	13%	19	13%	41	16%
Household Income						
Under $25,000	5	7%	18	12%	5	2%
$25,000-$49,999	12	18%	7	5%	18	7%
$50,000-$74,999	8	12%	7	5%	31	12%
$75,000-$99,999	12	18%	31	21%	37	15%
$100,000-$149,999	7	10%	22	15%	77	30%
$150,000-$199,999	5	7%	27	18%	29	11%
$200,000 and over	6	9%	24	16%	35	14%
Missing	12	18%	14	9%	21	8%

Level-of-Service skims were developed by AECOM Transportation for weekend Rail and Bus service using the North Jersey Transit Demand Forecasting Model (NJTDFM) networks, and Saturday fares and service attributes. The skims were available for both drive access and walk access. Figure 3 shows the availability of rail and bus skims by origin zones, respectively. Drive access transit skims were used for zones where walk access skims were not available or where drive distance was greater than 0.5 mile. Since the transit modes in the model are defined by egress type (walk, transit or taxi), the LOS variables were developed by each egress type.

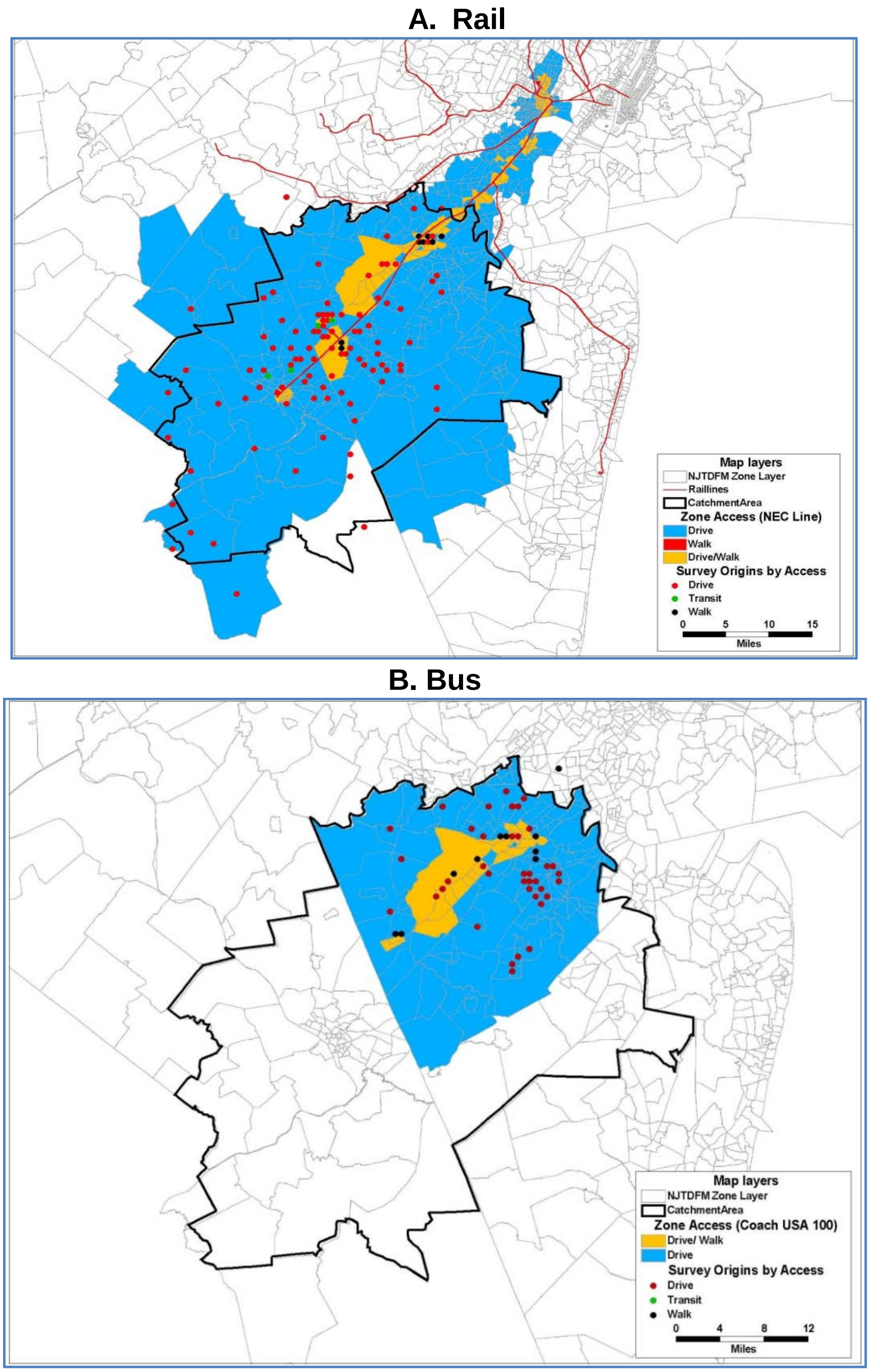

Figure 3. Availability transit skims by origin zones

Walk egress skims were extracted from original skims where no transfers were made to subway or bus in New York City. For zones where walk egress only skims were not available from the original skims, walk egress skims were imputed for all zones within three miles of station, such as Penn Station and WTC for Rail Skims and Port Authority Terminal for Bus Skims. Transit egress skims were also extracted from original NJTDFM skims. For a few observed records, transit egress skims were not available from NJTDFM outputs. For destinations in such cases, transit egress skims were imputed by adding available subway connections from stations to destination zone. For taxi egress, no skims were available from the NJTDFM outputs. These skims were computing by adding taxi travel time and costs from stations to destination zones to the transit skims to stations as shown in Table 3.

Table 3. Extraction and imputation of transit skims by egress type

Egress Type	**Bus**	**Rail**
Walk	1)Skims Extracted where NYC Subway IVTT=0 2) Skims to PA Terminal + Walk time for zones within 3 miles	1)Skims Extracted where NYC Subway IVTT=0 2) Skims to Penn Station or WTC + Walk time for zones within 3 miles
Transit	1)Skims Extracted where NYC Subway IVTT>0 2) Skims imputed for zone 1862	1)Skims Extracted where NYC Subway IVTT>0 2) Skims imputed for zones 1851, 1760 and 1751
Taxi	Skims to PA Terminal, taxi times and fare imputed	Skims to Penn Station/WTC Station, taxi times and fare imputed

AECOM also provided weekend highway skims including free flow travel time, distance and auto tolls. The delay due to congestion was calculated as 10 percent of free flow time and average congestion delays at Hudson crossings were estimated using Skycomp queuing data. The parking costs for Manhattan were adopted from the NJTDFM.

PILOT MODEL

The purpose of this section is to describe the development of a proto-type weekend travel demand forecasting model, focused on weekend mode choice and transit ridership forecasting, for evaluation and use and potential extension by New Jersey Transit, as one additional instrument it its toolbox for analysis of various planning policies.

Appendix 6 provides additional technical details in the form of User Documentation, describing both how to apply the model, as well as the calibration process that has been used for the current model, and which could be replicated in the future as other data are developed to extend the models scope – geographically, temporally, or in terms of additional transportation modes, such as ferries or PATH.

Within the limited resources and scope of this research project, the proto-type model focuses on the weekend travel market consisting of travel to Manhattan by residents of Central New Jersey, and area well served with both bus and rail service, as options to driving by auto and use of the Port Authority of NY & NJ's Trans-Hudson crossings. Within Central Jersey, a NJ Transit Catchment area was defined to represent the transit corridor most directly served by both bus and rail to Manhattan, specifically Coach USA Route 100 bus service, and the Northeast Corridor (NEC) rail service from Hamilton, Princeton Junction, and New Brunswick stations. As shown in Figure 4, this subarea is comprised of six counties, all of Mercer, most of Middlesex, and part of Monmouth (Western), Somerset (Southeastern), Bucks (Eastern), and Burlington (Northwestern). The weekend forecasting tool developed accounts for and models auto, bus and NEC rail for trips from the Central NJ Catchment area origins to Manhattan destinations, for eastbound Saturday travel, roughly nine AM to six PM.

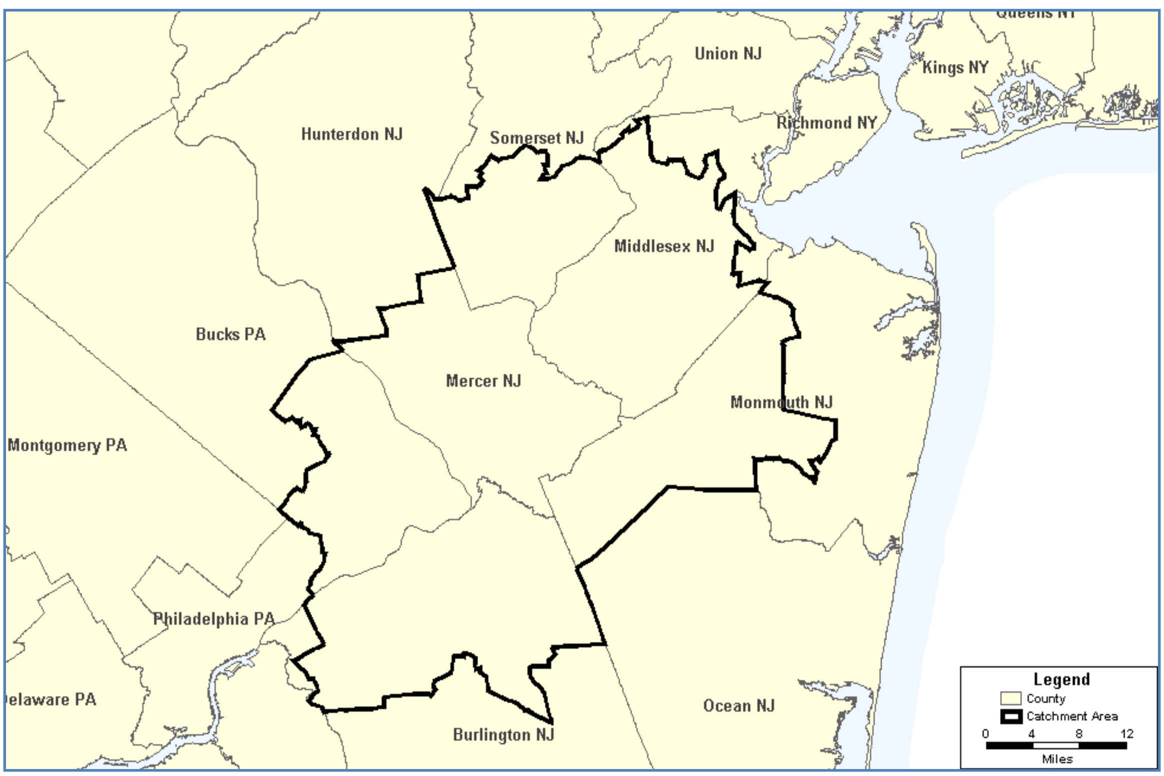

Figure 4. Transit catchment area in central New Jersey

Model Structure

The calibrated model has a Nested Logit (NL) structure, with transit mode options grouped together in a bi-level nest as shown in Figure 5. This structure was adopted based as both logical and consistent with the mode choice model of the weekday North Jersey Transit Demand Forecasting Model (NJTDFM).

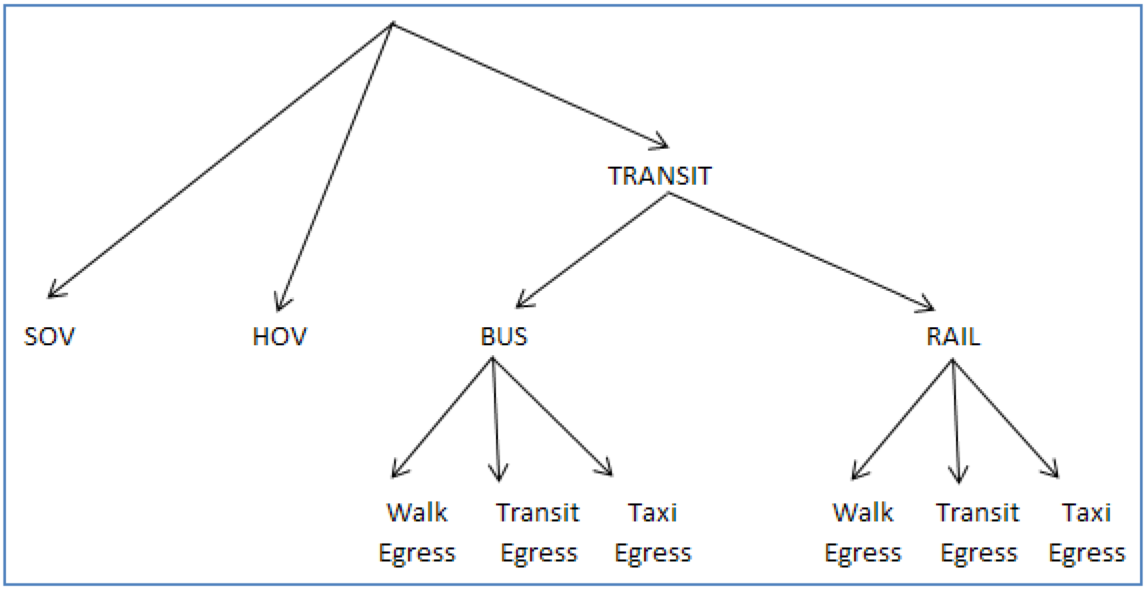

Figure 5. Nested logit model structure for weekend mode choice model

The utility for each mode choice includes level-of-service variables for that mode (such as travel time, cost and distance), traveler socio-economic characteristics, household characteristics (such as income, car ownership/availability), travel frequency and travel party size. The observed utility V_{ijmq} of choosing mode *m* by an individual *q* between zone pairs *i-j* is given is shown in Equation (1)

$$V_{ijmq} = \beta_m^0 + \sum_d \beta_m^d D_{jd} + \sum_k \beta_m^k T_{ijmk} + \sum_k \beta_m^k C_{ijmk} + \sum_p \beta_{mp}^l L_{pq} \qquad (1)$$

Where,

β_m^0 is the mode specific constant,

D_{jd} is the dummy for destination district,

T_{ij} represents various mode specific times (travel time, delay, walk time, wait time etc),

C_{ijk} represent various mode specific costs and parking costs,

L_{pq} are traveler and trip characteristics, such as gender, age group, party size, income, frequency of travel.

The true utility (U_{ijmq}) of an alternative is the sum of observed utility (V_{ijmq}) and random error term (ε_{ijmq}). In NL models, some alternatives share common components of the random error term. The probability of choosing a mode *m*, where m = SOV, HOV or Transit, is shown in Equation (2).

$$P(m) = \frac{\exp(V_m)}{\exp(V_{sov}) + \exp(V_{hov}) + \exp(\mu_1 \Gamma_{transit})} \quad (2)$$

$$\Gamma_{transit} = \log\left[\exp(\mu_2 \Gamma_{bus}) + \exp(\mu_2 \Gamma_{rail})\right] \quad (3)$$

where,

V_m is the utility of mode *m,*
μ_1 is the nesting coefficient (where, $0 < \mu_1 \leq 1$) of transit nest,
$\Gamma_{transit}$ is the maximum expected utility of the transit nest,
μ_2 is the nesting coefficient (where, $0 < \mu_2 \leq 1$) for bus and rail nests,
Γ_{bus} is the maximum expected utility of the bus nest and
Γ_{rail} is the maximum expected utility of the rail nest.

Equation 4 shows the calculation of maximum expected utility (Γ_k) for nest k.

$$\Gamma_k = \log\left[\sum_k \exp(V_k / \mu_2)\right] \quad (4)$$

The probability of choosing a transit mode *t* such as bus-walk egress, rail-taxi egress in the lower level nest *n,* i.e., bus nest or rail nest is given by the product of the probability of choosing mode *t* given *n,* $P(t/n)$, probability of choosing *n* given *transit (* $P(n/transit)$)and probability of choosing transit, $P(transit)$ as shown in Equation 2).

$$P(t) = P(t/n) \times P(n/transit) \times P(transit) \quad (5)$$

$$P(t/n) = \frac{\exp(V_t / \mu_2)}{\sum_T \exp(V_T / \mu_2)} \quad (6)$$

$$P(n/transit) = \frac{\exp(\mu_2 \Gamma_n / \mu_1)}{\sum_N \exp(\mu_2 \Gamma_N / \mu_1)} \quad (7)$$

The nesting coefficients for the transit nest and lower level bus/rail nest were adopted from NJTDFM and set to 0.5.

Choice Alternatives, Variables and Segmentation

For this study, eight mode choices were considered as shown below:
1) Single Occupancy Vehicle (SOV)
2) High Occupancy Vehicle (HOV)
3) Bus with Walk Egress
4) Bus with Transit Egress
5) Bus with Taxi Egress
6) Rail with Walk Egress
7) Rail with Transit Egress
8) Rail with Taxi Egress.

Mode Availability Rules

The auto and rail mode is available for all origin locations within the catchment area. However, bus service is limited to a part of catchment area as shown in Figure 3. Between the auto modes, SOV is only available for persons traveling alone, and HOV is only available when traveling in groups. For any record, either SOV or HOV is available, and both of them are never available together. In case of no-car availability, SOV mode is unavailable and a negative penalty is applied for HOV.

Explanatory Variables and Formation of Choice Utilities

The explanatory variables considered in the model for analysis are Level-of-Service variables, person characteristics, household variables, travel characteristics and others. Following is a list of explanatory variables:
1) Level of Service (LOS) Variables
    a. Auto Free Flow Travel time, congestion delays
    b. Auto Operating costs – distance based costs, tolls and parking costs
    c. Transit In-Vehicle Time, Wait Times, Walk Times, Fare, Transit Distance
    d. Park and Ride related – time, distance and parking cost
    e. Taxi Egress – time and fare
2) Party Size
3) Person Characteristics – Gender , Age Group
4) Household Income
5) Frequency of Travel – low (less than 2 times per week), high (2 or more times per week)
6) Destination District – Lower Manhattan, Valley, Midtown and Upper Manhattan

The LOS variables and party size may assume specific numerical values; while the rest are dummy variables, i.e. are categorical classifications (nominal) with value 1 or 0. In addition to this, mode specific constants were also calibrated in the utility component.

Segmentation

The model is fully segmented by trip purpose, work related vs. recreation, since significant behavioral differences are found. The observed data shows a more HOVs and fewer SOVs are used for recreation/others as compared to work/person business trips as shown in Table 4. The rail share for recreation/other purpose is three times as compared to rail for work related purpose.

Table 4. Observed (weighted) mode shares by trip purpose

Mode	Work and Personal Business		Recreation and others	
SOV	735	19%	573	6%
HOV	2,741	72%	7,502	78%
Bus -Walk Egress	40	1%	116	1%
Bus -Transit Egress	10	0%	24	0%
Bus -Taxi Egress	85	2%	109	1%
Rail -Walk Egress	125	3%	505	5%
Rail -Transit Egress	55	1%	687	7%
Rail -Taxi Egress	6	0%	119	1%
Total	**3,798**	**100%**	**9,633**	**100%**

The model is partially segmented by car availability. It directly affects the mode choices through availability rules and accounts for captive transit users. Party size variable affects the impact of auto related costs and taxi fare directly by distributing the costs over all persons in the group. Also, it affects auto mode availability – allowing only HOV for groups and SOV for alone travelers.

Table 5. Observed (weighted) mode shares by party size

Mode	Traveling Alone		Traveling in Group	
SOV	1,308	55%	-	0%
HOV	-	0%	10,243	93%
Bus -Walk Egress	74	3%	81	1%
Bus -Transit Egress	34	1%	-	0%
Bus -Taxi Egress	144	6%	50	0%
Rail -Walk Egress	298	13%	332	3%
Rail -Transit Egress	467	20%	275	2%
Rail -Taxi Egress	40	2%	85	1%
Total	**2,365**	**100%**	**11,065**	**100%**

Model Calibration

The coefficients for level of service, costs and nesting coefficients were adopted from the NJTDFM Base year 2000 models as shown in Table 6. The income constants as shown in Table 7 were adopted from NJTDFM weekday model and interpolated based on CPI adjusted survey income categories.

Table 6. Model coefficients for level-of-service variables

Parameter	Work/School/ Personal Business	Recreation/ Social/ Shopping/Other
LEVEL OF SERVICE VARIABLES		
AUTO IVTT (minutes)	-.04195	-.00789
RAIL/LONG FERRY IVTT (minutes)	-.03222	-.02616
NON-RAIL/LONG FERRY TRANSIT IVTT (minutes)	-.04306	-.03488
WALK (minutes)	-.06444	-.05232
WAIT (minutes)	-.06444	-.05232
XFERS 1)5.3min 2)6.9 3)7.6 4)8.2 5+)8.6	-.04306	-.03488
DRIVE ACCESS TIME (minutes)	-.06444	-.05232
DRIVE COST (1990 cents)	-.001573	-.000296
TRANSIT FARE (1990 cents)	-.001615	-.001308
RAIL/LONG FERRY DIST (in LN(miles*100))	0.8027	1.5010
BUS DIST (in LN(miles*100))	0.2836	0.9974
NESTING COEFFICIENTS		
Transit Nest	0.5	0.5
Bus and Rail Nest	0.5	0.5

Table 7. Model coefficients for household income categories

Parameter	SOV	HOV	Rail	Bus
Work/School/Personal Business				
Income <=25K	-3.0000	0.0000	-1.1240	0.0000
Income 25K -50K	0.0000	-0.1000	-0.1254	-0.7900
Income 50K -75K	0.1467	-0.0533	-0.6588	-2.1180
Income 75K -100K	0.0000	-0.2500	-0.4500	-1.1370
Income 100K -150K	0.0000	-0.3000	-0.4500	-1.4000
Income 150K -200K	0.0000	-0.4000	-0.5383	-1.5430
Income > 200K	0.0000	-0.5000	-0.5534	-2.0670
Missing Income	0.0000	-0.2500	-0.4500	-1.1370
Recreation/ Social/ Shopping/Other				
Income <=25K	-3.0000	0.0000	0.0000	0.0000
Income 25K -50K	0.0000	-0.1000	-0.7500	-0.6900
Income 50K -75K	0.0000	-0.2000	-0.7500	-0.9100
Income 75K -100K	0.0000	-0.2500	-0.9000	-1.0700
Income 100K -150K	0.0000	-0.3000	-1.2500	-1.3100
Income 150K -200K	0.0000	-0.4000	-1.3700	-1.5400
Income > 200K	0.0000	-0.5000	-1.5000	-1.8650
Missing Income	0.0000	-0.2500	-0.9000	-1.0700

Mode specific constants for other segmentation variables such as car availability, destination district, gender, age group and frequency of travel were estimated and incorporated in the model as part of the calibration process.

The model was calibrated using a manual iterative process to match the observed data, i.e. the observed auto, bus and rail shares from the combined Saturday survey data, with trip-based expansion factors applied. The model is implemented in an Excel spreadsheet and adjustments to coefficients were calculated in a series of iterations. The adjustments were calculated as natural log of ratio of observed data to modeled data by mode and purpose which were accurate for MNL calibration. Since, our model is a Nested logit, these adjustments were scaled down, 1/2 for mode specific constants and 1/3 -1/4 for other coefficients, before adding to the coefficient/constant for the next round of calibration to slowly reach convergence. The adjusted coefficients are calculated in sheet “Base Calibration” of the model spreadsheet, refer to User Documentation for more details. With few rounds of calibration, as the base modeled values match the observed values better, the scale down factors were further reduced to refine adjustments. Table 8 and 9 show the other calibrated constants and coefficients by purpose.

Table 8. Calibrated model mode constants and other coefficients for work/school/personal business

Parameter	SOV	HOV	Bus – Walk	Bus-Transit	Bus – Taxi	Rail-Walk	Rail-Transit	Rail-Taxi
CONSTANTS	4.2479	6.9365	-1.2369	-3.2454	-1.3929	-6.2832	-6.8074	-8.3064
DESTINATION IN MANHATTAN								
Downtown	0.0125	0.1966	1.2201	1.2201	1.2201	-0.7961	-0.7961	-0.7961
Valley	-0.4121	0.2869	-0.4611	-0.4611	-0.4611	-0.8230	-0.8230	-0.8230
Midtown	0.0624	-0.0529	-0.8286	-0.8286	-0.8286	0.4297	0.4297	0.4297
Upper	-0.1331	0.0789	0.0050	0.0050	0.0050	0.1322	0.1322	0.1322
CAR AVAILABLE								
Yes	-0.1588	0.4538	-1.1333	-1.0512	-1.0847	-1.6506	-1.7407	-1.5347
No	-99	-9	-0.7802	-0.7802	-0.7802	-0.1406	-0.1406	-0.1406
PARTY SIZE								
Alone		-99						
2 or more	-99							
GENDER								
Female	-0.1226	0.0604	0.5490	0.5490	0.5490	-0.1074	-0.1074	-0.1074
Male	-0.1065	0.1142	-0.3512	-0.3512	-0.3512	-0.0060	-0.0060	-0.0060
AGE GROUP								
Less than 35 yrs	0.0721	0.1618	-1.1746	-1.1746	-1.1746	-0.0214	-0.0214	-0.0214
Older than 35 yrs	-0.2441	0.1183	0.1974	0.1974	0.1974	-0.2436	-0.2436	-0.2436
FREQUENCY OF TRAVEL								
< 2 times per week	0.5048	0.5725	-1.5553	-1.5553	-2.3914	-1.2770	-1.2770	-1.2770
2 or more times per week	-0.5708	-0.3830	-0.5921	-0.3290	-0.6260	-0.7669	-0.5290	-0.5745

Table 9. Calibrated model mode constants and other coefficients for recreation/social/shopping/others

Parameter	SOV	HOV	Bus – Walk	Bus-Transit	Bus – Taxi	Rail-Walk	Rail-Transit	Rail-Taxi
CONSTANTS	2.8378	4.8852	1.6273	0.7106	1.3989	-1.9524	-1.7005	-3.2677
DESTINATION IN MANHATTAN								
Downtown	-1.5923	0.4571	-2.2269	-2.2269	-2.2269	-3.9728	-2.7005	-5.1377
Valley	0.4013	0.1757	-1.0077	-1.0077	-0.8732	-1.1212	-1.0382	-1.1212
Midtown	-0.3184	-0.2760	0.2774	0.2774	0.2774	0.6555	0.6555	0.6555
Upper	-0.0583	-0.1252	0.1549	0.1549	0.1549	0.2976	0.2976	0.2976
CAR AVAILABLE								
Yes	0.1311	0.1643	-0.8633	-0.7509	-1.4638	-0.6074	-0.6886	-0.4464
No	-99	-9	0.7727	0.7727	0.7727	0.0571	0.0571	0.0571
PARTY SIZE								
Alone		-99						
2 or more	-99							
GENDER								
Female	-0.3158	-0.6792	1.0376	1.0376	1.0376	1.2413	1.2413	1.2413
Male	-0.3170	-0.1518	-0.5634	-0.5634	-0.5634	-0.0804	-0.0804	-0.0804
AGE GROUP								
Less than 35 yrs	0.1266	-0.2991	-0.0243	-0.0243	-0.0243	0.3824	0.3824	0.3824
Older than 35 yrs	0.0290	-0.0014	0.1896	0.1896	0.1896	-0.0220	-0.0220	-0.0220
FREQUENCY OF TRAVEL								
< 2 times per week	0.8040	0.6419	-0.4476	-1.0576	-0.3632	-0.9401	-1.3667	-0.8585
2 or more times per week	-1.2330	-0.8872	-0.1416	0.2650	-0.1178	-0.2937	-0.2896	-0.2919

Sensitivity Testing and Findings

A number of sensitivity tests were carried out using the final calibrated model and reported here. These tests include the types of forecasting applications the model can address, including policy analysis related to changes in level-of-service such as improvement in rail travel time, reduction in transit fare, doubling of transit frequency on weekend, higher auto tolls and increase in highway congestion. Demographic changes at the origin level can also be analyzed by this model. The results of some of the sensitivity tests are summarized below.

Test 1: Double Highway Congestion

In this test, the auto congestion delay, travel time over free flow time and delay at Hudson crossing, was doubled. The results of this test are shown in Table 10. The shifts in modes show a 12 percent reduction overall in SOV trips, two percent in HOV and increases in bus trips on the order of 25 percent, and rail 16 percent. The mode shifts in Work-related are much stronger that for the larger weekend travel market of Recreation and Other purposes, which is forecast as relatively insensitive to the increase highway congestions and delays. Interestingly, shifts to bus are stronger for persons traveling alone, while shifts to rail are stronger for group travel.

Test 2: Reduce Bus Fare by Half

Reduction in Bus fare attracts some of the rail users to bus and very few auto users. The travelers are more likely to switch between transit modes than switching from auto to transit. Also, bus policies will not affect as much as auto or rail related policies because availability of bus service is limited to smaller area. The results of this test are shown in Table 11. This indicates a very minor shift of one percent from auto, and about five percent of rail riders shifting to bus.

Test 3: Improve Rail In-Vehicle Travel Time

For this test, the In-vehicle travel time for Rail transit was improved by 10 minutes. Under this policy, a lot of bus riders would switch to Rail transit since switches between transit are more likely. The results of this test are shown in Table 12. This scenario yields about a 12 percent increases in Saturday rail trips, with shifts from both auto, two percent SOV and one percent HOV reduction, and bus, about 20 percent of decreases.

Table 10. Percentage change in trips under doubling of highway congestion

All Trips

Mode	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	638	-16%	578	548	-5%	1,341	1,186	-12%
HOV	2,697	2,629	-3%	7,486	7,393	-1%	10,183	10,022	-2%
Bus -Walk Egress	42	63	50%	119	127	7%	161	190	18%
Bus -Transit Egress	11	18	65%	23	25	7%	34	43	26%
Bus -Taxi Egress	90	145	62%	107	113	6%	196	258	31%
Rail -Walk Egress	130	199	52%	512	556	8%	643	754	17%
Rail -Transit Egress	58	95	63%	688	738	7%	747	833	12%
Rail -Taxi Egress	6	11	77%	119	132	11%	126	143	14%
Total	**3,798**	**3,798**	0%	**9,633**	**9,633**	0%	**13,431**	**13,431**	0%

Summary by Party Size

Traveling Alone

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	638	-16%	578	548	-5%	1,341	1,186	-12%
HOV	-	-		-	-		-	-	
Bus -Walk Egress	40	59	48%	53	55	4%	93	114	23%
Bus -Transit Egress	10	17	62%	13	13	3%	23	30	29%
Bus -Taxi Egress	70	105	50%	54	55	2%	124	160	29%
Rail -Walk Egress	105	144	38%	233	245	5%	338	390	15%
Rail -Transit Egress	48	70	47%	360	372	3%	408	442	9%
Rail -Taxi Egress	4	6	51%	35	36	5%	39	42	10%
Total	**1,040**	**1,040**	0%	**1,325**	**1,325**	0%	**2,365**	**2,365**	0%

Traveling in Group

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	-	-		-	-		-	-	
HOV	2,697	2,629	-3%	7,486	7,393	-1%	10,183	10,022	-2%
Bus -Walk Egress	2	4	99%	65	72	10%	68	76	13%
Bus -Transit Egress	1	1	111%	10	12	13%	11	13	18%
Bus -Taxi Egress	19	40	107%	53	58	10%	72	98	36%
Rail -Walk Egress	26	54	110%	279	310	11%	305	364	19%
Rail -Transit Egress	10	25	137%	329	366	11%	339	391	15%
Rail -Taxi Egress	2	5	127%	85	96	13%	87	101	16%
Total	**2,758**	**2,758**		**8,307**	**8,307**		**11,065**	**11,065**	

Table 11. Percentage change in trips under reduced bus transit fare

All Trips

Mode	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	752	-1%	578	573	-1%	1,341	1,325	-1%
HOV	2,697	2,694	0%	7,486	7,470	0%	10,183	10,164	0%
Bus -Walk Egress	42	50	20%	119	158	33%	161	208	30%
Bus -Transit Egress	11	15	35%	23	37	60%	34	52	52%
Bus -Taxi Egress	90	105	17%	107	138	30%	196	243	24%
Rail -Walk Egress	130	121	-7%	512	487	-5%	643	608	-5%
Rail -Transit Egress	58	54	-7%	688	656	-5%	747	711	-5%
Rail -Taxi Egress	6	6	-7%	119	113	-5%	126	119	-5%
Total	**3,798**	**3,798**	0%	**9,633**	**9,633**	0%	**13,431**	**13,431**	0%

Summary by Party Size

Traveling Alone

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	752	-1%	578	573	-1%	1,341	1,325	-1%
HOV	-	-		-	-		-	-	
Bus -Walk Egress	40	47	19%	53	71	33%	93	118	27%
Bus -Transit Egress	10	14	34%	13	20	58%	23	34	48%
Bus -Taxi Egress	70	82	17%	54	68	27%	124	150	21%
Rail -Walk Egress	105	96	-8%	233	221	-5%	338	317	-6%
Rail -Transit Egress	48	44	-8%	360	340	-5%	408	385	-6%
Rail -Taxi Egress	4	4	-8%	35	32	-7%	39	36	-7%
Total	**1,040**	**1,040**	0%	**1,325**	**1,325**	0%	**2,365**	**2,365**	0%

Traveling in Group

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	-	-		-	-		-	-	
HOV	2,697	2,694	0%	7,486	7,470	0%	10,183	10,164	0%
Bus -Walk Egress	2	3	35%	65	88	34%	68	90	34%
Bus -Transit Egress	1	1	41%	10	17	62%	11	18	60%
Bus -Taxi Egress	19	23	18%	53	70	33%	72	93	29%
Rail -Walk Egress	26	25	-4%	279	266	-5%	305	291	-5%
Rail -Transit Egress	10	10	-1%	329	316	-4%	339	326	-4%
Rail -Taxi Egress	2	2	-3%	85	81	-4%	87	83	-4%
Total	**2,758**	**2,758**		**8,307**	**8,307**		**11,065**	**11,065**	

Table 12. Percentage change in trips under improvement of rail travel time

All Trips

Mode	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	751	-2%	578	558	-3%	1,341	1,309	-2%
HOV	2,697	2,691	0%	7,486	7,426	-1%	10,183	10,117	-1%
Bus -Walk Egress	42	37	-12%	119	89	-25%	161	126	-22%
Bus -Transit Egress	11	10	-8%	23	17	-27%	34	27	-21%
Bus -Taxi Egress	90	82	-9%	107	82	-23%	196	164	-17%
Rail -Walk Egress	130	151	16%	512	571	11%	643	721	12%
Rail -Transit Egress	58	69	17%	688	756	10%	747	824	10%
Rail -Taxi Egress	6	7	18%	119	135	13%	126	142	13%
Total	**3,798**	**3,798**	0%	**9,633**	**9,633**	0%	**13,431**	**13,431**	0%

Summary by Party Size

Traveling Alone

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	751	-2%	578	558	-3%	1,341	1,309	-2%
HOV	-	-		-	-		-	-	
Bus -Walk Egress	40	35	-12%	53	39	-26%	93	74	-20%
Bus -Transit Egress	10	9	-9%	13	9	-27%	23	19	-19%
Bus -Taxi Egress	70	63	-10%	54	41	-23%	124	105	-16%
Rail -Walk Egress	105	120	15%	233	254	9%	338	374	11%
Rail -Transit Egress	48	56	17%	360	386	7%	408	442	8%
Rail -Taxi Egress	4	5	18%	35	38	10%	39	43	10%
Total	**1,040**	**1,040**	0%	**1,325**	**1,325**	0%	**2,365**	**2,365**	0%

Traveling in Group

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	-	-		-	-		-	-	
HOV	2,697	2,691	0%	7,486	7,426	-1%	10,183	10,117	-1%
Bus -Walk Egress	2	2	-17%	65	50	-24%	68	51	-24%
Bus -Transit Egress	1	1	-3%	10	8	-27%	11	8	-26%
Bus -Taxi Egress	19	19	-3%	53	41	-23%	72	59	-18%
Rail -Walk Egress	26	31	18%	279	317	13%	305	347	14%
Rail -Transit Egress	10	12	19%	329	370	12%	339	382	13%
Rail -Taxi Egress	2	3	20%	85	97	14%	87	100	15%
Total	**2,758**	**2,758**		**8,307**	**8,307**		**11,065**	**11,065**	

Test 4: Double the Rail Frequency

Under this scenario, the doubling of rail frequency is analyzed by reducing the initial wait time by half. The results of this test are shown in Table 13. This test of substantially improving headways produces a similar but somewhat stronger effect than Test 3. Rail ridership in projected to increase by about 21 percent, with shifts from auto, four percent of SOV and one percent of HOV reduction, and bus, about 28 percent of decreases. With more than 85 percent of the base auto

trips in HOV in this weekend travel market, even small shifts in the shares of this group, yield relatively large increases in the numbers of transit users.
These tests conducted with the proto-type weekend mode choice model, show a reasonable sensitivity to the types of changes in the weekend transportation system that would be of interest to NJ Transit planners, and demonstrate the utility of the data and modeling approach developed in the research, and the potential value of extending it to other corridors of interest with respect to transit planning transit and weekend travel demand.

Table 13. Percentage change in trips for improvement in rail frequency

All Trips

Mode	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	744	-2%	578	547	-5%	1,341	1,292	-4%
HOV	2,697	2,688	0%	7,486	7,394	-1%	10,183	10,082	-1%
Bus -Walk Egress	42	34	-18%	119	76	-36%	161	110	-32%
Bus -Transit Egress	11	9	-13%	23	14	-39%	34	24	-30%
Bus -Taxi Egress	90	78	-13%	107	71	-33%	196	149	-24%
Rail -Walk Egress	130	162	24%	512	599	17%	643	761	18%
Rail -Transit Egress	58	74	27%	688	788	15%	747	863	16%
Rail -Taxi Egress	6	8	29%	119	143	20%	126	151	20%
Total	**3,798**	**3,798**	0%	**9,633**	**9,633**	0%	**13,431**	**13,431**	0%

Summary by Party Size

Traveling Alone

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	763	744	-2%	578	547	-5%	1,341	1,292	-4%
HOV	-	-		-	-		-	-	
Bus -Walk Egress	40	33	-18%	53	33	-38%	93	66	-29%
Bus -Transit Egress	10	9	-13%	13	8	-38%	23	17	-27%
Bus -Taxi Egress	70	60	-15%	54	36	-33%	124	96	-23%
Rail -Walk Egress	105	128	23%	233	264	13%	338	392	16%
Rail -Transit Egress	48	61	26%	360	398	11%	408	459	12%
Rail -Taxi Egress	4	5	27%	35	39	14%	39	45	15%
Total	**1,040**	**1,040**	0%	**1,325**	**1,325**	0%	**2,365**	**2,365**	0%

Traveling in Group

	Work and Related			Recreation and Others			Total		
	Base	Policy	% change	Base	Policy	% change	Base	Policy	% change
SOV	-	-		-	-		-	-	
HOV	2,697	2,688	0%	7,486	7,394	-1%	10,183	10,082	-1%
Bus -Walk Egress	2	2	-25%	65	42	-35%	68	44	-35%
Bus -Transit Egress	1	1	-5%	10	6	-39%	11	7	-37%
Bus -Taxi Egress	19	18	-5%	53	35	-33%	72	53	-26%
Rail -Walk Egress	26	33	29%	279	336	20%	305	369	21%
Rail -Transit Egress	10	13	30%	329	391	19%	339	404	19%
Rail -Taxi Egress	2	3	32%	85	103	22%	87	106	22%
Total	**2,758**	**2,758**		**8,307**	**8,307**		**11,065**	**11,065**	

SUMMARY

In our effort to develop a pilot weekend travel demand forecast and mode choice model for New Jersey, the research team had proposed a holistic approach that balances state of art research and practical modeling applications for multiple agencies. The pilot model, produced via enumeration applications, not only incorporated up-to-date understanding of dynamics driving weekend travel behavior but also obtained consensus from various agencies in New Jersey so it will be implemented.

Specifically, weekend transit level-of-service (skim) matrices were developed in order to accurately forecast weekend travel demand by mode. The weekend level-of-service matrices serve to characterize the weekend transit services available throughout the region. These transit skims along with the automobile level-of-service characteristics (from MPO model) were used as the key input into the weekend mode choice models. The research team has worked with NJ TRANSIT to execute a model development process that, in a cost-effective manor, accurately represented weekend transit service in the region.

The findings of this research provide the NJDOT and MPOs with a blue print for their future modeling improvement effort. A large number of entities, such as Metropolitan Planning Organizations (MPO), various levels of local, state and federal government agencies, consulting firms and academicians may benefit from the broad implementation of the results of this research. Of course, there are also potential obstacles for the implementation of the pilot weekend travel demand and mode choice model due to the status quo and enormous effort involved in the modeling development and improvement processes. However, progresses are inevitable given the significant changes in travel behavior affected by multiple forces, such as energy cost, climate change, and green movements. NJ TRANSIT is applauded in leading the charge and the research team is very proud of the contributions made via this research in our long term quest to understand travel behavior and improve transportation planning in order to achieve the ultimate intermodal coordination and multimodal efficiencies for better quality of life.

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APPENDIX 1. LITERATURE REVIEW

The conventional travel demand forecast models, widely used in various planning organizations in New Jersey and North America, were built on the observation of human behavior since the middle and later part of the last century. The foundation of those travel demand forecast models is highway travel related to commuting trips. Continuously updated and perfected by the travel behavior research and computation capability, the current travel demand models are reasonably accurate in projecting work trips and peak hour travel.

Propelled by the tsunami waves of telecommuting, e-purchasing, and cybernetic infrastructure, the transportation systems built to serve travel demand of last century may not fit the modern lifestyles of 21st century citizens. Recent travel data have revealed that commuting trips are becoming a declining portion of total travel. Off peak travel, especially on weekends, can often exceed weekday, peak hour volume, thereby creating unanticipated congestion. Fewer people are commuting to work, but the overall trip volume, travel length, and destination points are on the rise, largely because of increased leisure, recreational, or other non-working trips.

There is a risk that the need for additional highway and transit capacity may be misaligned, if relying on existing models, which focus on commuting trips and peak period travel. The need for developing new models that accurately predict multi-modal travel for non-work purposes, especially on weekends, is urgent. New Jersey Department of Transportation (NJDOT), partnered with New Jersey Transit (NJ TRANSIT), has commissioned New Jersey Institute of Technology (NJIT) to explore the feasibility of developing weekend travel demand and mode split models. This Technical Memorandum (TM) documents the research team's effort and findings in reviewing literature related to weekend travel behavior and modeling techniques that forecast travel demand, especially mode share, on weekends.

Travel Behavior on Weekends

It is necessary to understand travel behavior on weekends and driving forces behind trip volume before anyone may be able to accurately project future travel demand or mode share. Conventional transportation models produce travel estimates on an average basis for average weekday conditions. However, the levels of vehicle travel vary significantly by hour throughout the day and from weekdays to weekends as well. Coinciding with the growing volume of weekend travel, the number of studies that investigate travel behavior on weekends is growing also. The following section reports some basic descriptions of weekend travel behavior in terms of trip generation, activity allocation, temporal distribution and mode choice.

Trip Generation

Parsons Brinkerhoff Quade and Douglas (PBQD) Inc., (2000) analyzed travel data collected in the 1997/1998 Regional Travel-Household Interview Survey (RT-HIS) and weekend travel data from the 1995 Nationwide Personal Transportation Survey (NPTS). The primary purpose of the RT-HIS travel survey was to collect data for weekday travel in order to support the development and updating of forecasting models of weekday travel demand. The study area includes 12 counties in New York, 14 counties in New Jersey, and two counties in Connecticut. The NPTS weekend data for the metro area are taken from a sample of 1,602 households, while RT-HIS includes a small sample of 275 households in the 13 counties that comprise the jurisdiction of North Jersey Transportation Planning Authority (NJTPA). The weekend data were collected in the RT-HIS to supplement the NPTS “national” sample for these counties.

As demonstrated in Table 14, the general relationship between weekday and weekend travel can be observed consistently through both NPTS and RT-HIS datasets. Total daily trips per household on weekends are slightly lower than those on weekdays, while the total working trips per household on weekend is much lower, about one third of those on weekdays. The relationship between weekend and weekday daily household trips by automobile is similar to that of total trips, but the portion of transit trips on weekends is much lower, about one third or one fifth according to NPTS and RT-HIS, respectively.

Table 14. Daily trips per household on weekday and weekend

	NPTS			**RT-HIS**		
	Weekday	**Weekend**	**Weekend/ Weekday**	**Weekday**	**Weekend**	**Weekend/ Weekday**
Total Trip Rate	10.35	8.53	**82%**	8.8	7.71	**88%**
Work Trip Rate	3.52	1.11	**32%**	2.73	0.59	**22%**
Vehicle Trip Rate	9.13	7.58	**83%**	8.03	7.11	**89%**
Transit Trip Rate	0.39	0.13	**33%**	0.52	0.12	**23%**
Distance in Miles	7.4	8.2	**111%**	8.4	10.1	**120%**
Travel Time (Min)	17	15.5	**91%**	21.2	21.6	**102%**
Average Speed (mph)	21.8	23.7	**109%**	19.4	21.2	**109%**

Source: PBQD, 2000.

The reduction of the total number of trips taken on weekends is made up by the increase in travel distances. As demonstrated in Table 14, the travel distances on weekends range from 11 to 20 percent more than those on weekdays according to NPTS and RT-HIS data. The average travel time on weekends in comparison to weekdays is mixed: NPTS shows a shorter time on weekends, while RT-HIS data recorded almost identical weekday and weekend travel time. These times may be affected by the average speed in a particular sample, but generally the average speed on weekends is higher than that on weekdays.

An early description of weekend travel is included in a study conducted by Rutherford, McCormack, and Wilkinson (1996). Recognizing that the journey to work still dominates transportation research while travels for shopping, recreation, family and personal business are the fastest growing elements of household vehicle miles traveled (Comsis, 1994). This study has gathered travel behavior data on weekends in various mixed use neighborhoods in the Puget Sound area in Seattle, WA. Based on a pool of 775 people, 450 households, the study team collected trip distribution between Saturday and Sunday, trip purpose, mode, length and duration. Frequency of trips, number of people in party, and trip chaining information was also collected for weekend travel. Consistent with the PBQD study, this study showed that total travel miles on Saturdays were about 25 percent greater than those on Sunday, and Saturday travel was 12 percent greater than on the average weekday. Average distance per trip for weekend travel was essentially identical to that on weekdays.

Kumar and Levinson (1995) studied the allocation of time and trip making across time of day, day of week, and month of year. The study revealed that time spent in travel on each weekend day, Saturday and Sunday, exceeds that on any weekday. The time of day patterns for shopping and other trips for workers and non-workers are both rational: travel by non-workers peak in midday away from rush hour, whereas travel by workers peak just after work, indicating trip chaining.

Another comprehensive description of weekend travel is by Agarwal (2004) who analyzed weekend travel behavior using the 2001 NHTS. The author focused on the households in urban areas that traveled on weekdays and weekends. The sample contained 5,318 households traveling on weekends and 14,470 households traveling on weekdays. Findings of the study include fewer vehicle trips, more shopping and recreational trips, longer distance and duration travelled, more auto share and non-motorized mode share, and higher occupancy rate on weekends than on weekdays.

In addition to the volume of travel occurring on weekends, a number of studies have documented the sensitivities of weekend travel. Goodman (1979) observed that under the condition of a gasoline shortage, weekend travel dropped more than weekday travel in the Baltimore region in 1979. A possible explanation is that weekend travel tends to be discretionary. The speculation was further proved by a comparison of traffic volume changes along freeways and arterials during the week and on weekend under similar gasoline shortage conditions. As demonstrated in Figure 6 the trip reduction on weekends in July (17%) is almost eight or nine times of that on weekdays for the same month along freeways.

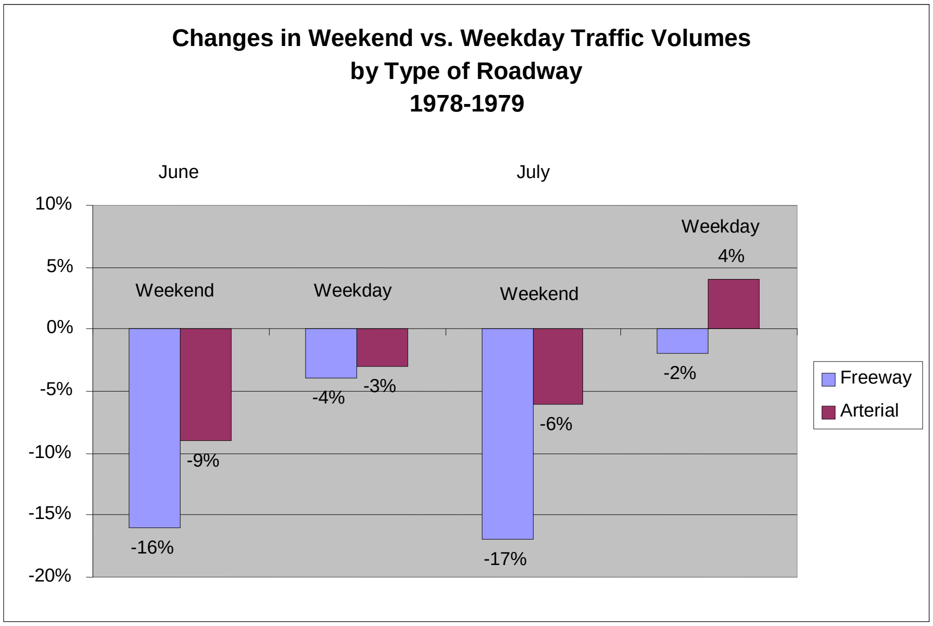


Figure 6. The sensitivity of weekend trip generation

Source: Goodman, 1979.

Activity Patterns

It is essential to understand the activity patterns and time allocation logic on weekends due to distinguished flexibility and variability of weekend travel. Compared to the defined destination and rigid arrival times of commuting trips during the week; weekend travel, dominated by social; shopping; and recreational purposes, may be easily altered by the traveler's preferences, travel services, and concurrent travel conditions.

Lockwood, Srinivasan, and Bhat (2004) conducted an exploratory analysis of weekend activity-travel patterns using the data from the 2000 San Francisco Bay Area Travel Survey. The study pointed out some key differences of travel behavior on weekdays and weekends. Most of the findings in the study agree with those in the PBQD study. Specifically, weekend activity-travel is found to be predominantly leisure oriented and undertaken during the mid-day period. The average trip distances are longer during the weekends. The transit shares are lower but the occupancy levels in personal automobiles are higher. This may be attributed to the non-work nature of weekend trips, which increase the reliance on using a personal vehicle because of joint activity participation or traveling to

activities that begin or end at flexible times. Finally, the study also analyzed activity sequencing and chaining characteristics on weekends.
Bhat and Misra (1999) carried out another exploratory analysis of the activity-travel patterns of non-workers in the San Francisco Bay Area. The activity patterns of non- workers are not confined to weekends only; however, it may largely represent weekend travel since large portions of weekend travel is non-work related. The study examined the travel characteristics of non-workers in three dimensions: number of stops of each activity type, trip chaining, and the temporal sequencing of activities. Trip chaining is important as Erlbaum (1977) found that trip-chaining policies oriented at weekday and weekend non-work travel would save 10-13% of automotive energy. Table 15 highlights a few important characteristics in non-worker activity-travel patterns in San Francisco Bay Area.

Table 15. Characteristics of non-worker activity travel

Number of Stops by Activity Type	Less serve passenger activity
	More serve passenger stops with a high number of younger children
	Caucasians participate in more activity stops outside home
	Single parent less likely to participate in recreational activity
Chaining Behavior	Serve passenger stops least likely to be linked with other stops
	Shop stops most likely to be chained
	retired couples and woman likely to chain
	Household with more vehicles unlikely to chain
Sequencing Behavior	Serve passenger stop most likely to be the first stop
	Shopping activities least likely to be the first stop
	household with young children likely to begin with serve passenger activity
	Personal business and recreational stops frequently linked with shopping stops
	Older individual participate earlier in the day in recreation and later in the day in shopping

Source: Bhat and Misra, 1999.

O'Fallon and Sullivan (2003) conducted a weekend travel study in New Zealand in order to assess policy tools for decision-makers to manage weekend traffic congestion. The study analyzed three largest urban areas in New Zealand based on the 1997/98 New Zealand Household Travel Survey. The authors concluded that the trip purpose varies significantly between weekdays and weekends while there is very little variation between Saturday and Sunday. In contrast to the large number of work and educational trips on weekdays, social/recreational and shopping trips take precedence on the weekend, as shown in Figure 7. Moreover, the trip purposes also affect the departure time of each trip, which formed different patterns on weekdays and weekends as exhibited in Figure 8.

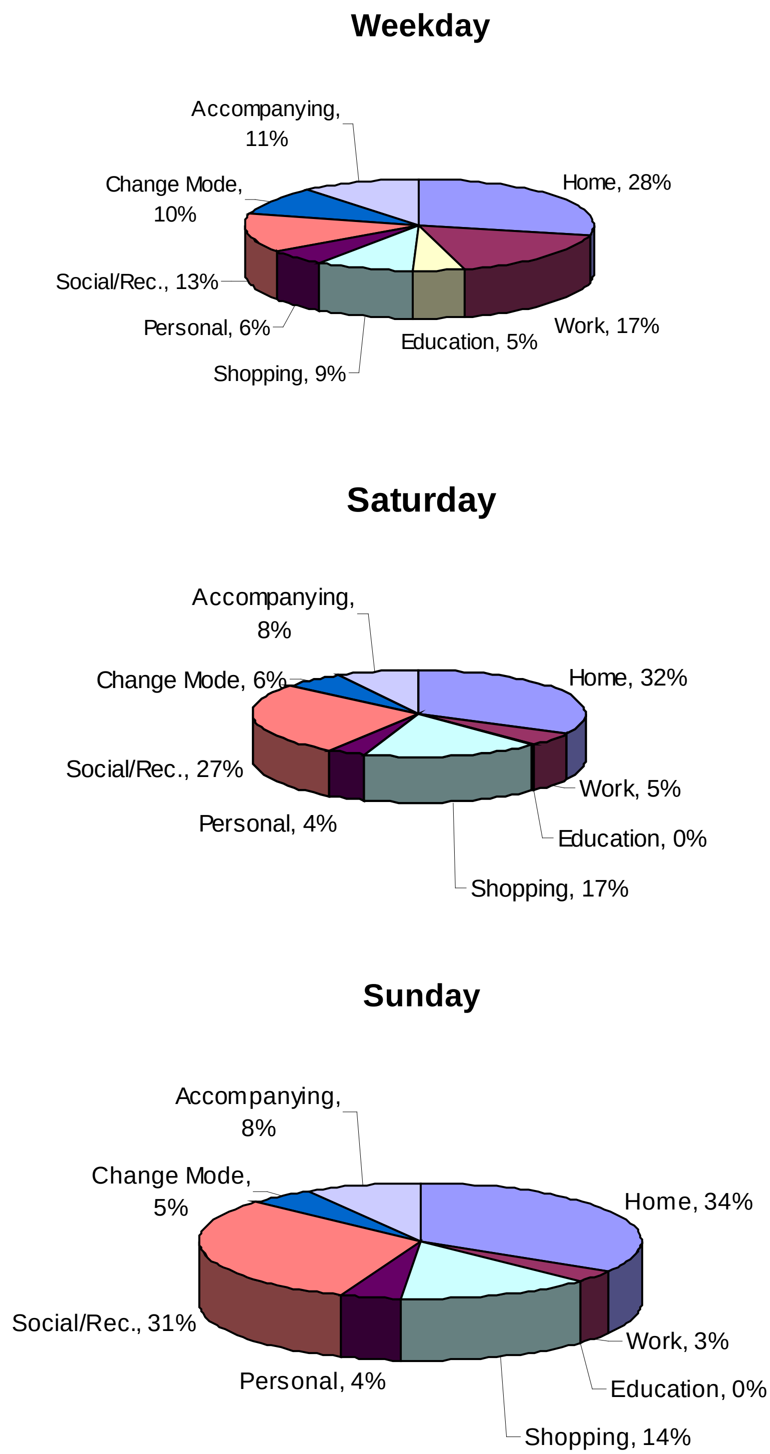


Figure 7. Trip purposes by day of travel

Source: O’Fallon and Sullivan, 2003.

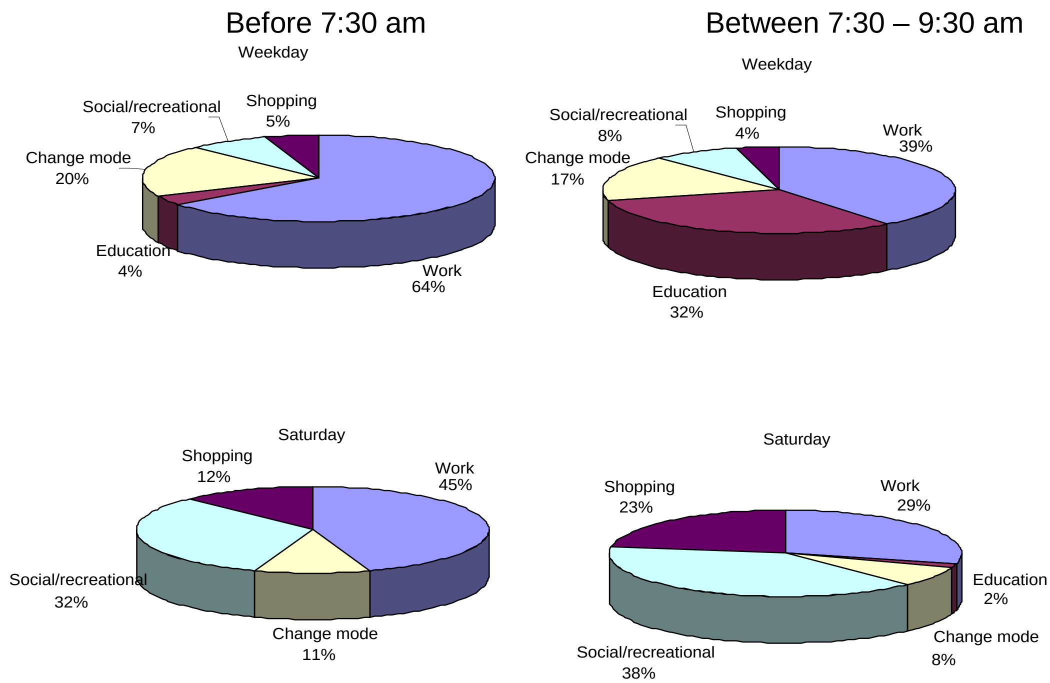


Figure 8. Variations in trip purpose between weekdays and Saturdays by different departure times

Source: O'Fallon and Sullivan, 2003.

Prasetyo et al (2003) compared the activity priority and time allocation in Japan and Jakarta. The study found that individual preferences seem to influence how Japanese and Indonesians allocate their time, including weekends. For example, people who choose socialization as their top priority spent 64% of their time over the weekend socializing.

Leisure travel is becoming extremely important in the public transport industry, and the demand and potential on weekends and during holiday times are of particular interest. Several studies focused specifically on recreational trips over the weekend. According to 1995 NPTS, trips to out-of-home recreational activities constitute about 23% of all trips over the weekends, and the average recreational trip length is around 13 miles, over twice the length of an average shopping trips. Yai et al (1995) pointed out that the total recreational vehicle kilometers per day over the weekend is much higher than the total daily commute vehicle kilometer on weekdays.

Some studies have focused on weekend travel behaviors of different demographic groups, For example, Rothe (1986) surveyed 1,368 students enrolled in grades 10, 11 and 12 in Canada. The weekend activities in which the majority of students participate on an "always", "often" or "sometimes" basis are: visiting friends, dating, attending parties, playing sports, hosting friends, and driving around with friends.

Temporal Distribution

Schlich (2001) found that there is a lot of variation on weekends as compared to weekdays because of a smaller number of individual obligations on weekends. Zhou & Golledge (2000) found considerable differences in travel patterns on weekdays and weekends. Sunday was described as the most depressed travel intensity day as compared to Saturday which was considered to be the day on which activities for relaxing or “clean up” that is, finishing something that hadn’t been done over the week.

Rakha and Van Aerde (1995) did a qualitative and quantitative analysis of 75 days of freeway management data along Interstate 4 in Orlando, Florida. It was found that in the absence of incidents, the temporal and spatial variations in traffic conditions were very similar for weekdays but varied considerably relative to the typical conditions during weekends.

The difference between O’Fallon and Sullivan (2003) and the two previous U.S studies is that the former contrasted Saturday and Sunday patterns with weekday travel behavior, as demonstrated in Table 16. This study also derived a daily trip volume pattern based on the number of trips per person by day of travel, as shown in Figure 9.

Table 16. Volume of travel contrasting weekdays, Saturday, and Sunday

	Weekdays	Saturday	Sunday
Unweighted Sample Size	3,649	1,272	1,337
Number of trip legs (mean per respondent)	5.2	4.4	3.6
Distance, excluding walking (median km per trip leg)	4	4.4	4.8
Distance using surface transport, excluding walking and trip legs 60+ km or more (mean km/day per respondent)	26.6	26.3	22.7
Distance driven (mean km/day per licensed driver)	30.2	26.4	19.8
Distance driven (median km/day per licensed driver)	20.4	12.9	5.5

Source: O’Fallon and Sullivan, 2003.

According to Parsons Brinkerhoff (2000), data from NPTS and RT-HIS both confirmed that about half of all weekend travel occurs midday, between 10 am and 4 pm on weekends, while about half of all weekday travel occurs during the morning and afternoon peaks, as depicted in Figure 10.

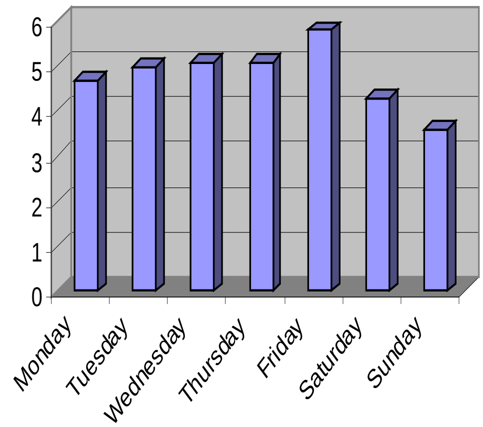


Figure 9. Number of trips per person by day of travel

Source: Source: O'Fallon and Sullivan, 2003.

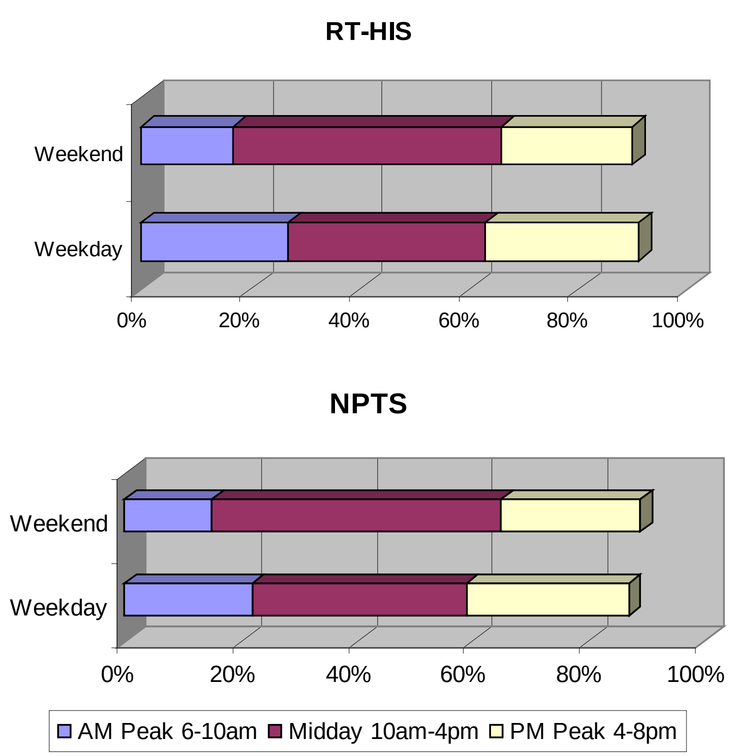


Figure 10. Traffic volume comparisons between weekday and weekend

Source: PBQD, 2000.

Quint and Loudon (1994) combined regional forecasts with supplemental traffic count data on time-of-day and vehicle type distribution of travel to improve the temporal resolution of the transportation forecast model. They presented the hourly traffic variation in eight counties in San Joaquin on weekdays, Saturdays, and Sundays. Saturday time-of-day distributions for collector and local roadway facilities have the greatest degree of variability over the 24-hr period. Sunday peak period is distributed over three to seven pm. The collector and local roadway distributions fluctuate dramatically throughout the middle of the day.

Fwa (1993) described automobile travel characteristics in Singapore by contrasting weekdays, Saturdays and Sundays. Most people in Singapore work a half-day on Saturday, resulting in a midday peak between one and two pm. Trips made after five p.m. still contributed about 40 percent of all trips made by car on Saturday. No pronounced peaking periods were found on Sunday. Trips were spread evenly between 9:30 am and 9:30 pm. Compared with working trips, the miscellaneous trips have the characteristics of lower average distance, higher occupancy level, and lower mean trip speed.

According to Agarwal (2004), in an urban area of three million or more population, transit rides on bus and light rail peak at noon to two pm while the metro peaks from three to seven pm on weekends. However, the analysis did not address the specific travel pattern on Saturdays and Sundays.

Given the significant number of recreational trips on weekends, a number of studies devoted their attention to the temporal distributions of recreational travel on weekends. Houghton-Evans and Miles (1970) reviewed the recreational travel patterns in the countryside of the U.S. and Great Britain. It was found that the British public was likely to follow more limited travel patterns, with a greater emphasis on day and half-day trips on the weekend. While there are many differences between the two countries, such as land size and road network, the authors found something in common: the recreational trips undertaken in country areas are dominated by the mode of motor car, and the average vehicle occupancy is higher. A great popularity of a Sunday afternoon trip into the countryside is found in both countries.

TRB (1976) found that recreational travel is largely influenced by preferences for times of departure from and return to home. As a result, recreational traffic demands peak near urban fringes on Friday late afternoons, coinciding with weekday commuter peak, and on Sunday evenings. On the other hand, the arrival times at, and departure times from, the recreational destination showed no strong peaks. Thus, the most serious outbound concentrations were on Friday evening, and Sunday evening for the inbound. Saturday traffic concentrated on departures in morning and afternoon, as well as of returns in the afternoon and evening. However, the peak was broad.

Several studies (Voorhees and Associates, 1974; and Maring, 1971) showed that Sunday was the mostly peaked day of travel in recreational areas. In urban areas, inbound trips home on Sundays are the highest, Friday evening outbound peak was next, and the Saturday peak was lowest and more spread out.

Robinson (1970) studied the recreational impact of multi-purpose reservoirs. Data were obtained from nearly 12,000 interviews, representing 25 percent of arriving trips at the park entrances, which were conducted over weekend periods during June, July, and August from 1967 through 1969. It was found that 75% of all trips arrived at the reservoir during the weekends, with approximately 50% of all weekend trips arriving on Sundays. In terms of hourly arrivals, 62% of all Sunday arrivals come in between 11 am and three pm.

In a survey done in Missouri in 1968 (Maring, 1971), peak hours of the year for recreational trips were found to concentrate on weekends, primarily on Sundays. The outbound lanes on Interstate 44 were heavily traveled on Friday between three to eight pm, and the inbound lanes were heavily traveled on Sunday from three to nine pm. The peaking in the inbound lanes on Sunday was significantly higher than that on the outbound lanes on Friday, indicating a concentration of travelers returning to the city on Sundays.

Green (1991) made a significant contribution to the analysis of recreational travel on weekends by collecting the arrival and departure patterns of special event attendees. As documented in Figure 11, fewer than 50 percent of patrons actually arrived at the site an hour prior to the start of the event. Nearly half of the attendees arrived at the site less than one hour prior to the start of the event, which means a large amount of traffic peaked during the single hour before the start of the event.

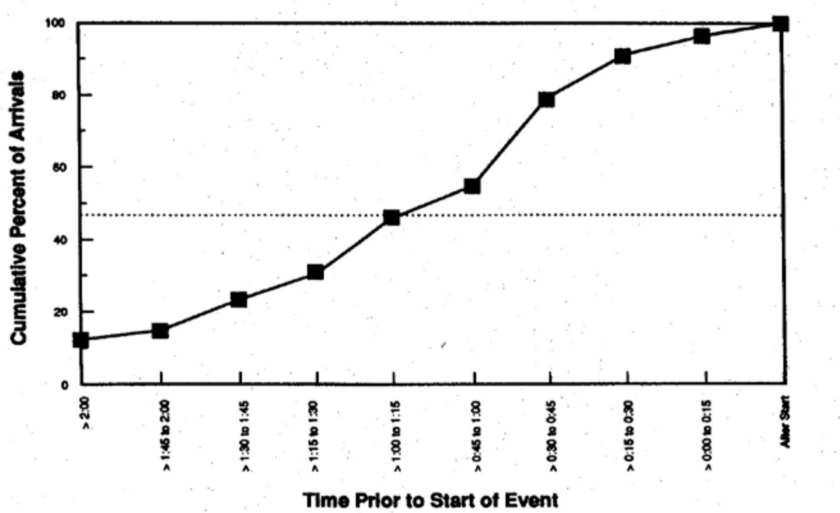


Figure 11. Accumulative percent of arrival by arrival time

Source: Green, 1991.

Mode Choices

Regarding mode share on weekends, PBQD (2000) found that auto passenger trips constitute a substantially larger share of trips on weekends than they do on weekdays, with higher levels of vehicle occupancy. As depicted in Figure 12, transit mode shares are lower on the weekends and walking as a mode remains relatively constant on weekends.

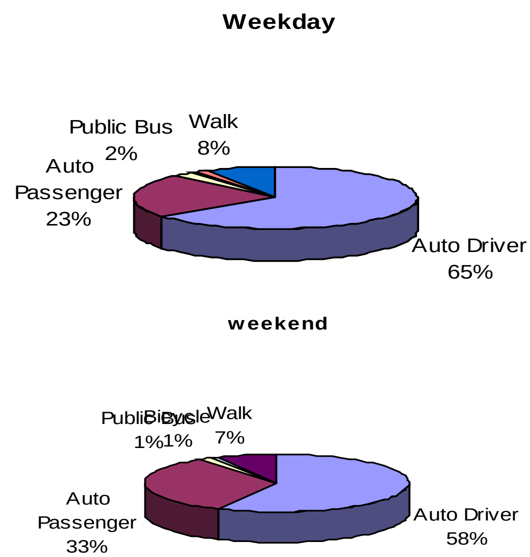


Figure 12. Mode choice comparison between weekday and weekend

Source: PBQD, 2000.

A recent study of freeway performance and use of HOV lanes on weekends (Ishimaru, Hallenbeck, and Nee; 2000) indicated that weekend car occupancy rates are much higher than those on weekdays. As a matter of fact, depending upon the facility and time of day, about 30 to 60 percent of vehicles traveling on weekends were eligible to use HOV lanes.

O'Fallon and Sullivan (2003) carried the observation of weekend travel further by contrasting weekdays, Saturdays, and Sundays in terms of mode choices. As demonstrated in Figure 13, the proportion of trips by "vehicle driver" was constant between weekdays and weekends even though a small decrease, five percent, was observed on Sundays. Another constant mode between weekdays and weekends was "cycling", which was largely used by the younger age group, under 25. It looks like the reduction in other modes, such as walking, bus and train was largely made up by the increase in "vehicle passenger" mode.

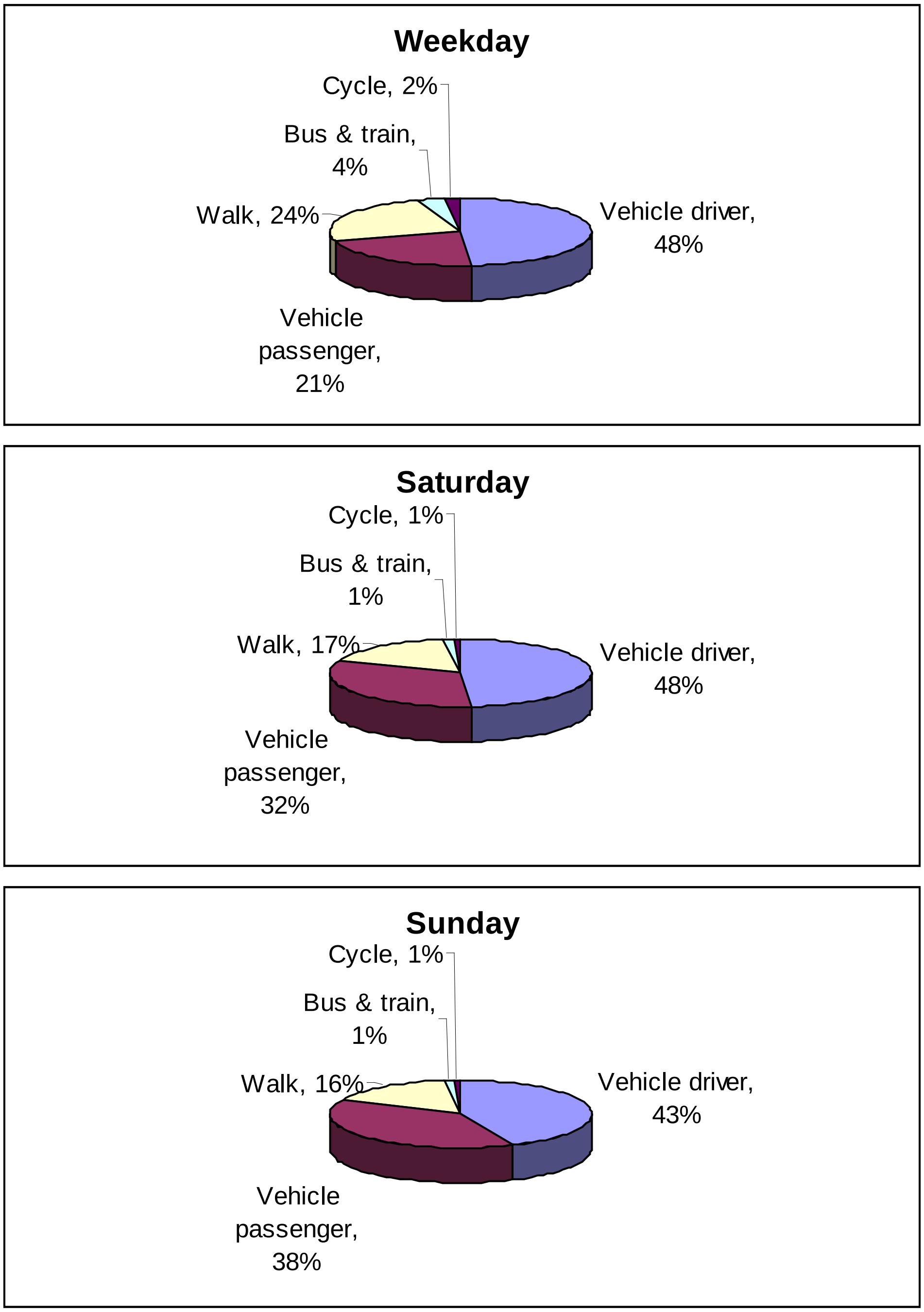


Figure 13. Trip mode share by day of travel

Source: O'Fallon and Sullivan, 2003

New Jersey Transit (NJ TRANSIT) conducted a series of passenger surveys of commuter rail services on summer weekends in 1992, 1993, and 1996 on the New Jersey Coast Line (NJCL), a 67 mile long commuter rail line between Bayhead and Newark, Hoboken, and New York City (Marchwinski, 1998). On-board surveys were carried out both on Saturdays and Sundays during late afternoon and evening for all eastbound trains (to Newark/New York) between approximately 3 pm and 9 pm. With a response rate of 35 percent, the surveys captured some glimpses of recreational travel on weekends using commuter rail services.

Two thirds of the travelers originated from New York City and one third from urban areas of northern New Jersey. They visited the shore for the weekend. More than half of the riders spent one or two nights at the shore, typically weekend-oriented travelers, and another 10 percent stayed more than two nights. About one third (36%) of weekend riders were day trippers either Saturday or Sunday. A total of 2,900 riders utilized the eastbound service during the five hour survey period and 1,725 riders traveled during the same period on Saturday. One interesting fact is that the Sunday peak ridership was approximately equal to the weekday morning peak period on two commuter rail lines in Northern New Jersey.

Another focus of the weekend travel description is the mode split at large special events and its effects on air quality (Green, 1991). Driven by the increasing interest in large special events as a means of economic development, the study examined a number of special events in nine large metropolitan areas nationwide to assess the travel behavior during the special events and their impact on air qualify. The study surveyed baseball, football, and large concerts in Baltimore, Chicago, Cleveland, Denver, Detroit, Kansas City, Los Angeles, New York and St. Louis to obtain the necessary data.

After synthesizing and analyzing the data collected, Green presented a summary of the travel behavior during the large events and factors affecting mode choices. As documented in many mode choice models, parking cost is a major determinant in the decision to drive alone, carpool, or take transit. However, the impact on auto occupancy rate is not very significant when comparing parking cost under and above $4. On the other hand, a strong correlation was discovered between the ticket price and auto occupancy. When the event ticket is less than $10, the auto occupancy rate is 2.96, but 2.56 when the ticket is more than $10.

Some historical data also help us understand how weekend travel has evolved and been affected by various economic, energy and travel environments. A study conducted by the Opinion Research Corporation (1975) for the Federal Energy Administration documented the amount of weekend overnight travel and the modes utilized. As shown in Figure 14, more than half of the respondents made recreation trips in 1974, ranging from one or two trips per year, 17%, to 13 to 24 trips per year, four percent. Among these, the largest mode share is auto (86%), followed by bus (5%), plane (3%), and train (2%).

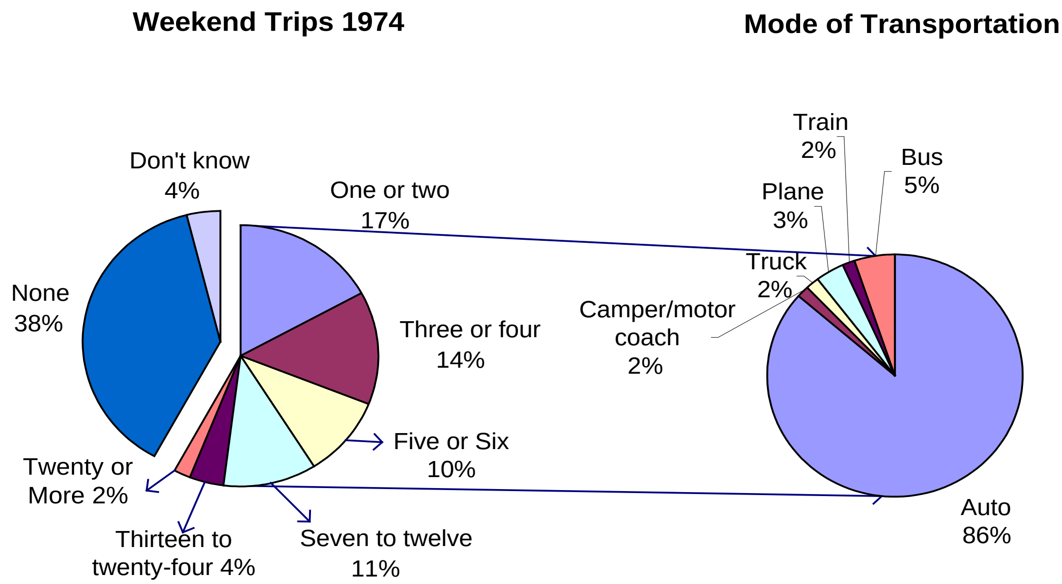


Figure 14. Weekend trip generation and mode share

Source: Opinion Research Corporation, 1975.

General Characteristics of Weekend Travel

A preliminary consensus on weekend travel has been derived based on the literature presented above. In general, weekend travel volume, in terms of number of trips per person per day, is slightly lower than that on weekdays. Trip generation on Sundays is even lower than that on Saturday. Some researchers named Sunday as the “Day of Rest” in terms of travel volume. On the other hand, weekend travel may not be necessarily lower than weekdays when measured by personal miles traveled (PMT) or vehicle miles traveled (VMT) since some of the weekend travel, especially recreational trips, cover longer distances.

The purposes of weekend travel are largely recreational, shopping, and social activities while work and educational trips are only small portions. The temporal distribution of weekend travel is very different from that of weekdays. A longer and higher peak usually forms around midday, such as from ten am to two pm or from 11 am to three pm. The peak period may vary depending on the characteristics of the urban area, but the single peak period is confirmed. A mode share pattern on weekends is characterized by a higher automobile mode, including both driving and passenger, and a lower public transportation share. On the other hand, the average auto occupancy rate is higher on weekends than on weekdays.

Impact Factors on Weekend Travel

It is important to identify the activity and travel patterns on weekends and it is critical to link the prevailing patterns with causal or driving forces. Detailed analysis of variables or factors that affect travel choices is a vital intermediate step to connect the travel patterns observed to a future travel demand forecast. Therefore, this section presents a few studies that have made connections between social, economic, land use, or preference factors and travel behavior on weekends for various purposes and mode choices.

Agarwal (2004) found the impacts of household size, income, and age on both weekday and weekend travel. For example, as the number of persons in the household increases, both the weekday and weekend person trips increased in the same proportion but the vehicle trips increased at a lower rate, almost flattening after two or more persons in the household. Lower income households made almost the same number of trips on both weekdays and weekends but the difference increases drastically as household income increases. Children between 0-15 years of age were found to make more trips on weekends as compared to those on weekdays. Older persons made fewer person trips on weekends as compared to those made on weekdays.

Bhat and Srinivasan (2004) found income, household structure, employment status, bicycle ownership, location and seasons have effects on weekend travel. Income affects participation in discretionary and relatively expensive activity pursuits, but does not affect participation in less discretionary and less expensive activity pursuits. Single parents and adults in nuclear family households are more likely to participate in physically active recreational episodes. Adults employed full-time are most likely to participate in non-maintenance shopping and personal business activities on the weekend. Households with bicycles are more likely to participate in physically active recreational activities. The seasonal effects reflect a lower propensity to participate in recreational and maintenance shopping during the winters compared to other seasons.

O'Fallen and Sullivan (2003) have examined the differences between weekday and weekend travel and have found that they are influenced by a number of demographic and other personal characteristics: age, gender, ethnicity, household type, number of people in a household and personal and household income. The authors have observed that auto ownership explains some of the variation in mode share and mode shift between weekday and weekend. It is common knowledge that household with fewer or no automobiles available make more transit or walking trips. However, it is interesting to observe that, as shown in Table 17, the small number of households without any motor vehicles, 6%, have the highest portion of people making walking and public transit trips on weekdays and weekends, and a great share of cycling trips on weekdays.

Table 17. Auto ownership and trip mode by day of travel

		Number of Household Vehicles					
Day of Travel	Travel Mode	Total	None	1	2	3	4 or more
Weekday	Unweighted Count	N=31,007	N=1,590	N=8,016	N=13,595	N=5,349	N=2,457
	Vehicle driver	48.3%	1.5%	42.0%	51.5%	59.3%	64.2%
	Vehicle passenger	21.3%	15.4%	22.5%	22.7%	19.8%	17.3%
	Walk	24.2%	61.3%	28.9%	20.7%	17.1%	15.1%
	Bus &train	3.5%	12.7%	3.7%	2.8%	2.5%	1.9%
	Cycle	1.8%	5.8%	1.9%	1.9%	0.7%	0.7%
	Other	0.8%	3.2%	1.0%	0.5%	0.5%	0.8%
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Saturday	Unweighted Count	N=5,664	N=204	N=1,587	N=2,774	N=790	N=309
	Vehicle driver	48.1%	10.4%	43.9%	51.0%	61.0%	64.4%
	Vehicle passenger	32.0%	20.6%	33.2%	34.4%	30.5%	16.5%
	Walk	16.5%	61.2%	18.8%	12.0%	6.5%	15.3%
	Bus &train	1.4%	3.8%	2.2%	0.8%	1.1%	0.0%
	Cycle	0.9%	2.0%	1.3%	0.8%	0.2%	0.5%
	Other	1.0%	2.1%	0.7%	1.0%	0.6%	3.2%
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Sunday	Unweighted Count	N=4,808	N=154	N=1,463	N=2,296	N=506	N=389
	Vehicle driver	43.1%	1.9%	37.5%	44.7%	53.9%	59.0%
	Vehicle passenger	38.1%	37.3%	39.9%	39.4%	29.2%	34.0%
	Walk	15.8%	54.5%	19.1%	13.5%	13.5%	4.8%
	Bus &train	1.0%	37.3%	1.6%	0.5%	0.6%	1.3%
	Cycle	0.9%	1.2%	0.9%	0.9%	1.3%	0.5%
	Other	1.0%	0.8%	1.0%	1.0%	1.4%	0.4%
Total	All Mode	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The authors also documented significant differences between the genders in their modal use by day of travel. As demonstrated in Figure 15, the mode share on weekdays is very similar for men and women, with women more likely to be vehicle passengers and men more likely to be vehicle drivers. Both genders followed a similar trend in modal shift between weekdays and weekends, such as less walking, less use of public transportation and more vehicle passengers. There is a sizable change in drivers on weekends as compared to weekdays. The most remarkable change is that females switch from walking, public transportation, and driving to become vehicle passengers: the female trips as passengers double from 24% on weekdays to 43% on Saturday and 50% on Sunday, while the share of “vehicle driving” trips fell from 45% to 36 % on Saturday and 32% on Sunday, respectively.

One of the early attempts to capture the transit market on weekends was documented in a report by Crain and Associates, Inc. (1982). Under a grant from Urban Mass Transportation Authority, the three year demonstration program tested the feasibility of providing a seasonal recreation transit service from low income urban areas in and near the city of Los Angles to six parks located in the Santa Monica Mountains west of Los Angles. Closely monitoring the participants and service providers, this program documented a general profile of recreation transit users on weekends, such as age, gender, household income, ethnic background and auto ownership. A typical transit share was also recorded in this report. Another important point demonstrated in this study is that transit ridership has constantly increased from the previous year due to improved services and a major marketing effort.

A regression analysis was conducted by the Opinion Research Corporation (1975) to assess the factors that affect the way in which the respondent or the chief wage earners go to work and their attitude toward mass transit. As indicated in the analysis, the most important nondemographic variable that affects someone’s travel mode choice is the degree of congestion along highways. The most important demographic variables highlighted in this study are education, income and age. Education is positively related with the use of mass transit; that is, the higher the education of a given individual, the more likely that individual is to use mass transit. Holding education constant, however, income is negatively correlated with use of mass transit; that is, for a given level of education, the higher the income, the less likely an individual is to use mass transit and the more likely one is to drive in one’s own car.

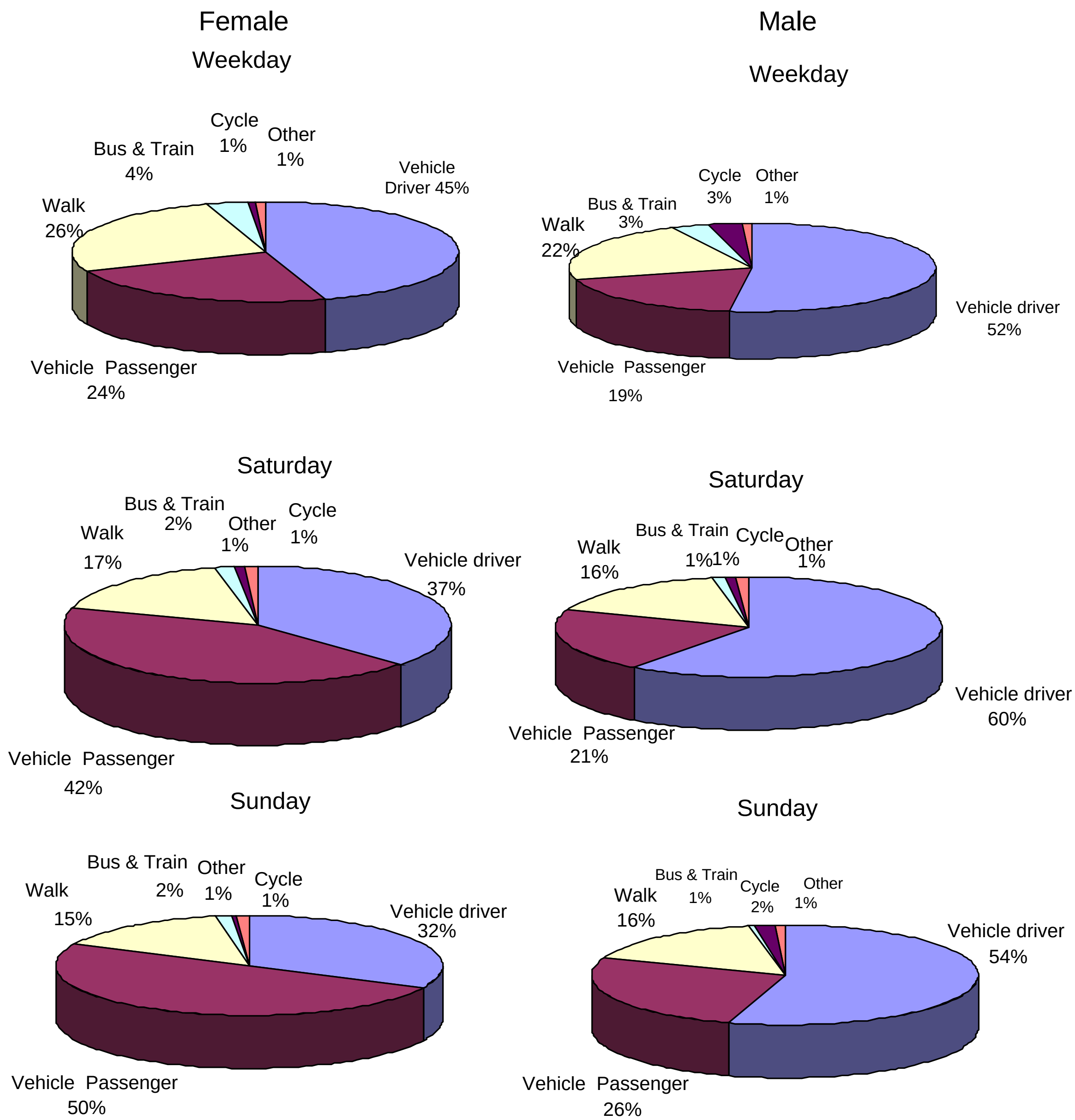


Figure 15. Gender differences in travel modes by day of travel

Source: O'Fallon and Sullivan, 2003.

Population density has certain impact on the auto occupancy rate on weekend travel, as reported by Green (1991). As demonstrated in Figure 16, lower densities result in longer travel times and distance to form a carpool, making carpool a less attractive mode. Another important influence on mode share for special events is the availability of public transportation or the perception of the availability. In other words, the availability of an individual public transportation mode is not necessarily measured by the service capacity but how visually it is presented in the communities or users. For example, given the same service capacity, a rail transit service maybe more visible than a bus service, therefore, the perception of the rail availability is higher than that of the bus services. Another discrepancies observed in this study is the ownership or operator of the public transportation services. For example, the ridership increases, for two executive years in this study area, ranged from 8.9 percent for government operated public transportation services to one percent for chartered public transportation services. The cause of such discrepancy needs to be investigated.

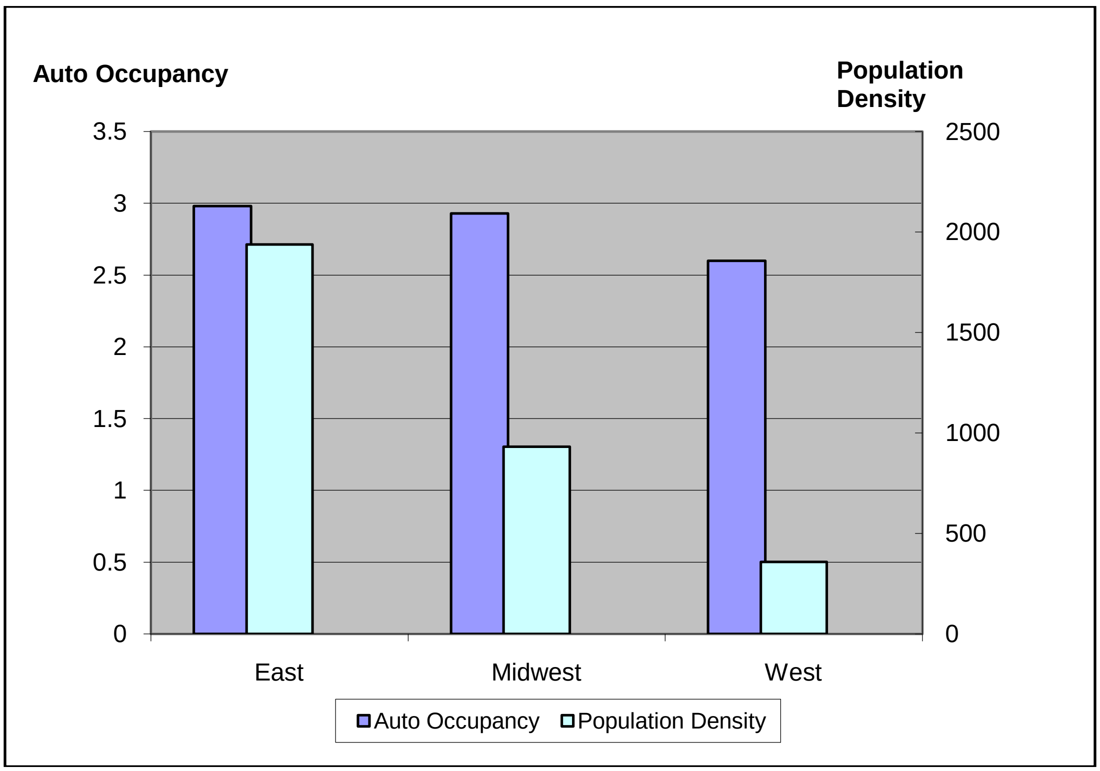


Figure 16. Auto occupancy rate and population density in different regions, USA

Source: Green, 1991.

Newman and Bebendorf (1983) discussed the Santa Barbara Bicycle Paratransit Demonstration Project, which integrated bicycles and transit to promote local transit ridership. Both the weekday and weekend ridership increased during the demonstration period, with a 35% increase on Sunday and a 26% increase on Saturday.

Factors that affect weekend travel were identified in the existing literature as shown in Table 18. A number of typical demographic and socio-economic factors, such as auto ownership, age, gender, income, employment status, and household type, are identified as factors that affect weekend travel. Other land use and transportation related attributes, such as residential density or access to various public transportation services, are also included in various studies. The significance levels of each attribute vary from location to location, but the general signs are usually consistent with expected values. We also want to exercise caution when applying those attributes in our model development since the majority of these researches were conducted in various international cities in other countries, such as Netherlands, New Zealand, Korean, Singapore, Japan, Indonesia, and Philippines, which may have very different land use, transportation and activity patterns, not to mention the differences in socio-economic and cultural preferences.

Table 18. The impact factors of weekend travel

Authors	Year	Study Area	Data Source	Factors	Study Purpose
Van Der Hoornl	1979	Netherlands	1975 survey in Netherlands	Car ownership, Residential density, Work or student status	The effect of various factors on travel time expenditure between weekday and weekend
O'Fallon and Sullivan	2003	New Zealand	1997/1998 New Zealand Household Survey	Vehicle ownership, gender, household type	Identify the characteristics of weekend travel patterns vs. weekday
Yai, Yamada, & Okamoto,	1995	Japan	Nationwide Recreation Travel Survey	Age, Gender, Income,	Recreational travel demand forecast
Bhat and Misra	1999	Netherlands	1985 time use survey of Netherlands		
Yamamoto	1999	Netherlands	1985 time use survey of Netherlands	Presence of children, gender, income, work location, flexible work hours, auto ownership	
Bhat and Srinivasan	2004	San Francisco	2000 San Francisco Bay Area Travel Survey	Income, season, household structure, presence of children, working status, residential density	
Bhat and Srinivasan	2004	San Francisco Bay Area	2000 San Francisco Bay Area Travel Survey	Income, household structure, bicycle ownership, age, employment status, gender, driver license, internet use, location effects, seasonal effects	
Kim, Kim and Chung	2004	Republic of Korea	Household Travel Survey in Seoul Metropolitan in 2002		Examine weekend travel pattern for future policy
Ejes, and Marquez	2002	Metro Manila	1996 Survey of Trip Generation Characteristics of Metro Manila	Income, auto ownership, accessibility to bus stop, jitney stop, and taxi	Understand weekend travel pattern and to tackle the congestion problem
Rutherford et al	1996	Three Greater Seattle area Neighborhoods	A two-day travel diary and demographic survey of 900 households		Explore the nature of weekend travel in the mixed-use neighborhoods

Development of Weekend Models

Given the considerable travel characteristic differences between weekdays and weekends, simply transferring weekday models to weekends may not be appropriate from a travel forecasting perspective. Starting in the 1970s, there were increasing concerns that transportation planning processes had not given proper attention to recreational travel, primarily done on the weekend. A few studies (Leohardt, 1971 and Bellomo and Mehra, 1974) have proposed multi-phased concepts for long range planning of urban transportation facilities to serve the weekend travel demands of metropolitan areas. Recommended methods included a variety of modeling techniques but have not been implemented due to limited availability of empirical data.

Structured Equation Models

Voorhees and Associates (1974) developed a sequential weekend travel demand model, consisting of trip generation, trip distribution, and trip assignment. The general framework, as described in Figure 17, is not significantly different from that of conventional four-step travel demand forecast models, but the inclusion of a recreational facility trip attraction module for a subcategory of recreational trips lent itself as the pioneer model in estimating weekend travel. The recreational trip attractions are expressed as:

$$TA^P_j = f(C^P_j, a^P_j, t^P_j)$$

Where:

TA^P_j = Trip attraction for P (water-oriented, non-water oriented) recreational trips in zone j

C^P_j = Vector of capacity of size indices specific to type P facilities in zone j

a^P_j = Vector of quality indices specific to types P facilities in zone j

t^P_j = Vector of highway level of service characteristics in zone j

TRB (1976) developed the Recreational Traffic Planning Model (RTPM), which provided separate estimates of weekend recreational traffic, for both 2-day weekends and 3-day weekends, during the summer season. For a number of highways serving recreational travel, it has been found that the peak hours of the year are concentrated on weekends rather than during more familiar weekday morning and evening rush hours. RTPM derived estimates of total weekend recreational traffic by aggregating the five major components of this demand:

- participating in outdoor recreation;
- visiting friends and relatives;
- attending spectator events;
- visiting second homes; and
- driving around without a specific destination.

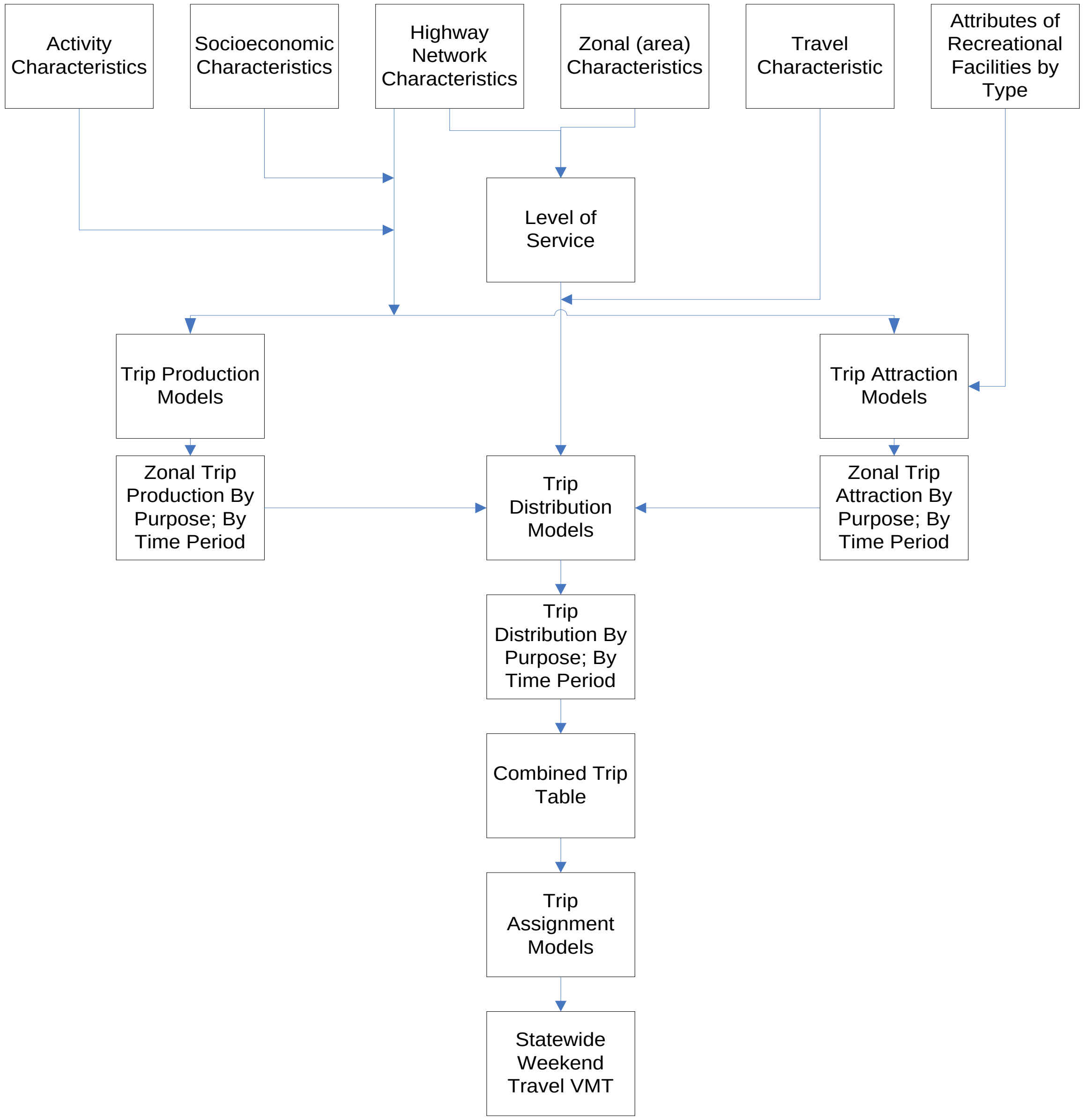


Figure 17. Framework for statewide weekend travel model

Source: Voorhees and Associates, 1974.

Compared to the scarce modeling development for weekend travel in the US during recent years, other international efforts look almost abundant. One of the studies conducted by Kim, Kim, and Chung (2004) developed multilevel structure equation models (SEM), which combine features of SEMs and multilevel analysis to estimate the complex relationships among exogenous and endogenous variables of weekend travel. Using data collected in the Seoul Metropolitan Areas Transportation Survey in 2002, the study gathered travel information during weekends to distinguish differences in travel patterns between the two worker groups, five working days and six working days a week. The data contains person, household, and travel information on Saturdays for 3,700 households in Seoul and its suburban areas. Travel data include every trip reported as having been made on Saturdays, such as trip purpose, mode, start and end times, origin and destination, and distance derived. Activity duration was also derived from the sequential travel information.

Applying the same modeling structure presented in Figure 18 to both five working day and six working day groups, the study derived various significant levels of individual variables on the trip characteristics. As found in this study, there were strong relationships among socio, demographics, activity participation, and travel behavior; which were simultaneously captured by the multilevel SEM structure. The variables applied in this model may serve as good candidates for our further analysis and development of weekend travel demand and mode split models.

Joining the international landscape of weekend travel behavior studies, Ejes and Marquez (2002) developed a demographic and activity based model of spatial and temporal distribution of travel demand of the1996 population in Metro Manila. After grouping various exogenous and endogenous variables into four distinct groups of socioeconomic status, mobility, activity participation, and travel behavior, the authors used income and logtime as indicators of socioeconomic status and travel behavior respectively. They used four variables to measure mobility: auto ownership, jitney access, bus access and taxi access, some of which are unique in the Metro Manila area. Trip purpose variables used in the conventional models, such as work, social and other, were adapted as indicators of activity participation. After distinguishing direct and indirect impact of variable categories and calibrating corresponding models, the authors presented a summary which proved that socio economic status and mobility measures were all significant variables that directly affect activity participation and travel behavior. The only exception is mobility variables including various accesses to public transportation, para-transit, and auto ownership, which was not significant in the total effects even though they were significant in both direct and indirect models. This puzzling result is hard to explain or verify since no detailed modeling structure and variable data were provided in the paper.

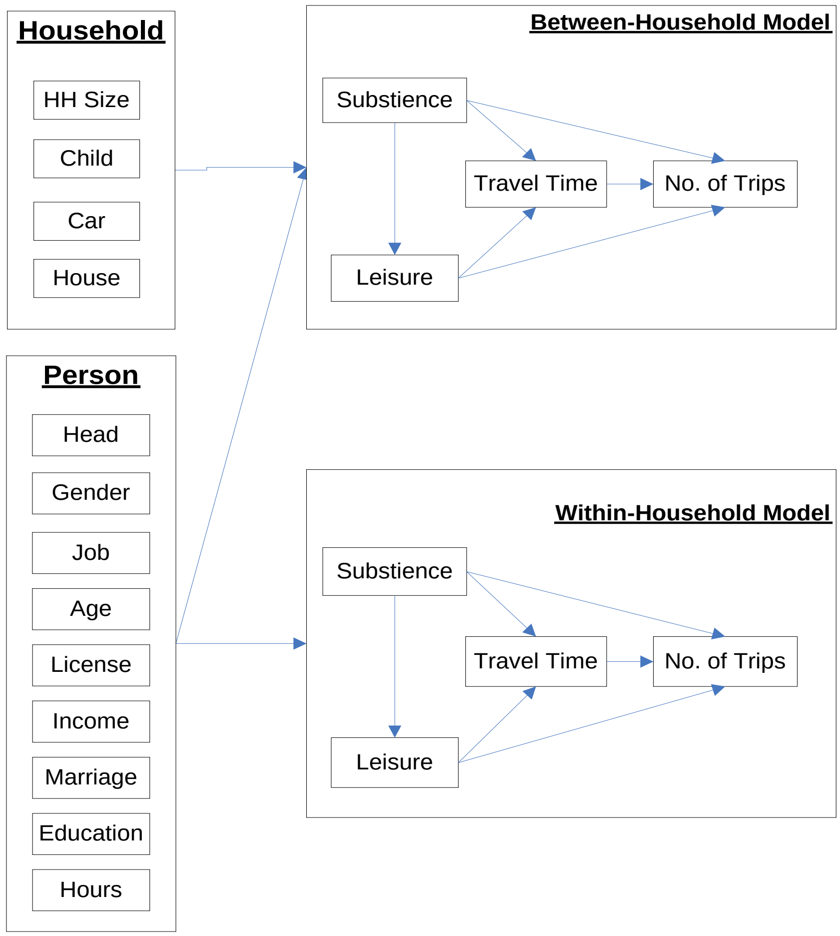


Figure 18. Modeling structure for two different working groups

Source: Kim, Kim, and Chung; 2004.

Activity Based Models

As today's travel forecast emphasis shifts from evaluating long-term investment-based capital improvement to understanding travel behavior responses to shorter-term congestion management policies, researchers have focused on more behaviorally based travel models, such as activity-based models, since the 1990s. Activity-based approaches to travel demand analysis view travel as derived demand. That is, the demand for travel is derived from the demand for activities, and consequently, that an activity-oriented approach will increase predictive accuracy, flexibility, and policy responsiveness beyond the previous generation of trip-based models (Waddell et al, 2001). Several operational analytic frameworks within the activity analysis paradigm have been formulated and some metropolitan areas have implemented these frameworks.

While there has been substantial progress in the development and implementation of activity-based travel analysis efforts, almost all of these efforts have focused on weekday activity-travel patterns (Bhat and Srinivasan, 2004). Only recently have a few studies adopted an activity-based modeling approach to analyze weekend travel patterns by using the 2000 San Francisco Bay area travel survey.

Bhat and Srinivasan (2004) examined the frequency of individual participation in out-of-home non-work episodes over the weekend. According to the authors, the framework was the first to adopt an activity-based framework to examine weekend activity participation. The conceptual framework considered all the relevant attributes of individual activity and travel patterns on weekends, and classified them into three levels: pattern, tour, and episode. Pattern-level attributes include the number of stops of each activity type and the sequencing of all episodes (both stops and in-home episodes). The tour-level attribute is the travel mode for the tour. Episode-level attributes include the episode duration, travel time to the episode from the previous episode, and the location of out-of-home episodes (i.e., stops).

Since it was infeasible to joint modeling of all the attributes simultaneously, an analytic framework to model the representation was developed, as shown in Table 19. The proposed framework considered the pattern-level attributes first, followed by the tour-level attribute of mode choice, and finally the episode-level attributes. The underlying basis for such a framework was that the decisions regarding pattern-level attributes are driven by the basic activity needs of the individual, and so they are considered to be at the highest level of the analysis hierarchy. In contrast, decisions regarding the episode-level attributes tend to be driven primarily by scheduling convenience, short-term temporal constraints, and travel conditions. Therefore, these attributes were relegated to the lowest level of the analysis hierarchy. The tour-level attribute of travel mode choice was positioned at the intermediate level of the analysis hierarchy since it affects the attributes of all out of-home episodes within the tour (Bhat and Srinivasan, 2004).

Bhat and Gossen (2004) examined the participation in recreational activities over the weekends. The choice set characterizing the type of recreational episodes included in-home, out-of-home, and pure recreational episode. Pure recreational episodes were defined as trips pursued for the sole purpose of the recreational value obtained from the trip, such as bicycling and joy driving. This study focused on the substitution between in-home and out-of-home recreational activities.

Table 19. Modeling hierarchy, attributes, and approaches

Model Hierarchy	Attributes	Modeling Approach
Pattern Level	Number of non-work/non-school stops in the day of each activity	Multivariate ordered response choice model
	Number of in-home episodes; Sequencing of all activity episode	Multinomial logit with pattern string as the unit of analysis
Tour Level	Mode choice for tour	Discrete Choice
Episode Level	First (morning) home-stay duration	Hazard-based duration model incorporating unobserved heterogeneity
	Travel time to episode; Episode duration	Simultaneous linear regression equation system
	Location of stops	Disaggregate spatial destination choice model

Source: Bhat and Srinivasan, 2004.

Bhat and Lockwood (2004) focused on out-of-home recreational episodes during the weekend. Specifically, the study focused on analyzing the determinants of participation in physically active versus physically passive pursuits and travel versus activity episodes. Travel episodes are recreational pursuits without any specific out-of-home location, such as walking, bicycling, and joy driving. Activity episodes are pursued at a fixed out-of-home location. The study formulated a mixed multinomial logit model for the four types of out-of-home recreational episodes: (1) physically active recreational travel, (2) physically active recreational activity, (3) physically passive recreational travel, and (4) physically passive recreational activity. It is anticipated that the disaggregation of the broad recreational activity purpose facilitates better analysis and the modeling of the activity travel dimensions

Sall et al (2004) proposed a weekend analysis framework that included work episodes, specifically, whether an individual works over the weekend, if s/he works, whether the individual works at home or outside the home, and the time of day of the work. This framework also used the pattern, tour, and episode-level representation of the Bhat and Srinivasan framework, but used the work start time and end time as “pegs”. Thus, work start time and end time were modeled first and then the day was divided into five periods: (1) Before morning commute, (2) morning commute, (3) midday, (4) evening commute, and (5) after evening commute.

As we can see, the activity-based travel demand forecast models for weekend travel is still confined to framework development stages. No calibrated operational model has been documented in the existing literature. On the other hand, it is possible that recently completed or current on-going efforts producing weekend travel demand forecast models may not be reflected in the existing literature due to the time lag of publications. The next tasks of this project will survey various Metropolitan Planning Organizations, public transit agencies, consultants, and the research community to assess the state of practice in forecasting weekend travel demand and model choices.

Summary

Our extensive literature search and review has discovered a long historical trail of intense interest in estimating and managing weekend travel since the later 1960s, as early as the travel demand forecast modeling approaches were formed. It is clear that weekend congestion has been growing worse through the past half century, while travel volumes on weekends have reached new heights in recent years.

The research team has developed an initial understanding of the general characteristics of weekend travel based on our literature review. We have gathered a number of demographic, socioeconomic and other characteristics that have been identified as potential driving forces or factors that affect weekend travel. Some early conceptual frameworks and attempts in calibrating travel demand forecast and model split models for weekend travel have been identified. However, no operational models of such functions have been produced. The next steps of this project are to assess the state of practice in modeling weekend travel by surveying appropriate entities and specifying a framework to produce weekend travel demand forecast and mode choice models.

APPENDIX 2. EVALUATION OF TRAVEL DEMAND FORECAST MODELS IN NEW JERSEY

The urban transportation modeling system (UTMS) is often used to predict the number of trips made within an urban area by type (work, school, or social); time of day (peak, mid-day, or night); zonal origin-destination (O-D) pair; the mode of travel used to make these trips; and the routes taken through a transportation network by these trips (Meyer and Miller, 2001). Developed since the middle of the last century, the UTMS was originally designed and is best suited for long range, comprehensive planning, but has been used in one form or another in a wide range of planning applications. While the UTMS has been extensively employed within the transportation planning field for more than half a century, it has also been seriously criticized from many points of view for almost the same length of time.

From the point of view of weekend travel, the best description of UTMS might be "none". The UTMS simply does not have any independent functions to estimate or forecast weekend travel. On the other hand, all types of weekend travel, such as shopping, recreational, social, or work, might be implicitly modeled in various forms of existing UTMS models. Of the official tools utilized by more than 200 Metropolitan Planning Organizations (MPO) in the US and other transportation agencies, UTMS is the predominant, if not the only, tool for travel demand forecasting. Therefore any effort in measuring the magnitude or impact of weekend travel has to interact or build on the existing UTMS.

In New Jersey, there are at least six existing travel demand models that are focused on or related to the Garden State, as shown in Table 20. A brief review of each model will be provided in this Technical Memorandum, which will serve as the basis for developing a weekend travel demand forecast and mode choice model for New Jersey. Due to diversified travel patterns, modal preferences, and capabilities of each jurisdiction, the models in New Jersey vary by size, complexity, and structure. The following sections describe each travel demand model pertaining to the weekend travel demand forecast model development.

It is also important to assess the need and ability to develop and maintain a weekend travel demand forecast model for each agency and to understand how the proposed model will interact with the existing weekday travel demand forecast model. The project team has conducted interviews with the Metropolitan Planning Organizations' (MPO) staff to identify expectations and preferences for a weekend travel demand forecast model by each agency. The interviews are also recorded in the following sections.

Table 20. Existing travel demand forecast models in New Jersey

Agency	Platform	WEEKEND MODULE	Weekend Data
NJTPA	TRANPLAN	No	Small Amount
SJTPO	Cube/TP+	Yes	Some
DVRPC	TRANPLAN w/ Evans Algorithm	No	Small Amount
NYMTC	TRANSCAD	No	Small Amount
NJ Transit	TP+	No	Some
NJ DOT	Cube	No	None

North Jersey Regional Transportation Model (NJRTM)

The North Jersey Transportation Planning Authority (NJTPA), along with the New Jersey Department of Transportation (NJDOT), maintains the North Jersey Regional Transportation Model (NJRTM), which covers the thirteen northern counties of New Jersey as shown in Figure 19. This model is a traditional four-step model that focuses on weekday commuter patterns. It has a transit component module that takes into account intra New Jersey transit trips as well as Trans-Hudson trips to and from New York City, but this component has not been updated in several years. One could say that this model is more highway based. It can forecast traffic for the morning and evening peak periods and the off-peak periods.

The NJRTM was developed using TRANPLAN to provide most of the standard planning functions. The NJRTM is based on the traditional four-step travel demand forecasting process, which estimates trip generation, trip distribution, mode choice, and network assignment in sequence.

The NJRTM region covers the thirteen northern counties of New Jersey, containing 1451 Traffic Analysis Zones (TAZ). The highway network links were stratified into nine facility types and four area types, and the transit network included nine transit modes and four non-transit modes.

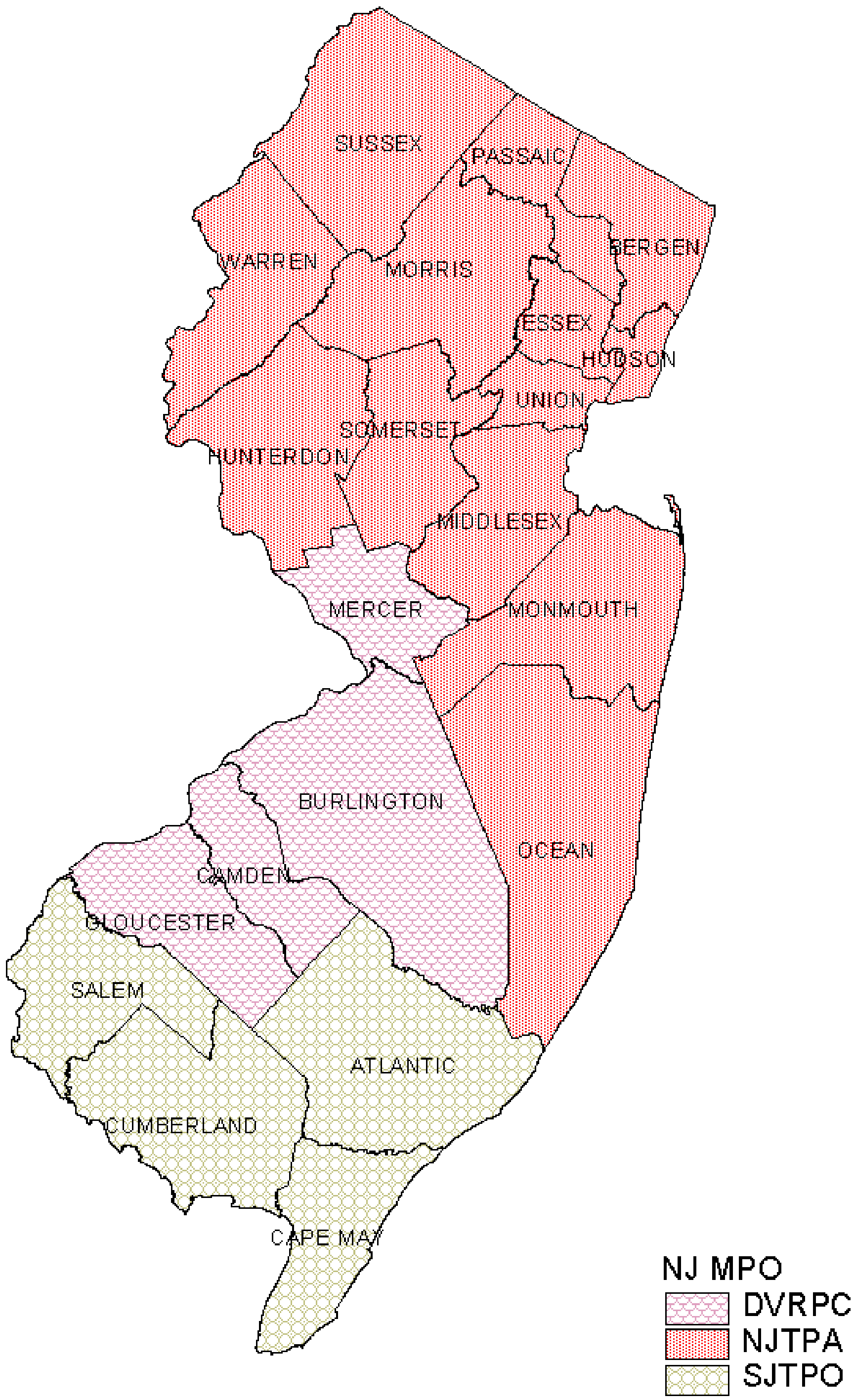


Figure 19. Jurisdiction for three different MPOs in New Jersey

Trip Generation

The NJRTM trip generation model was developed to estimate daily person-trips for the region. The NJRTM has three trip types and four trip purposes that are used throughout the modeling process. The trip types are external-to-external trips (EE), external-to-internal (EI) trips and internal trips. Trip purposes include home-based work, home-based shop, home-based other and non-home based. The primary objective of the NJRTM is to forecast all aspects of travel that occur within northern New Jersey. The estimation of externally-related travel, while a significant component of the regional travel, is of secondary importance in the forecasting process.

However, one characteristic that distinguishes the NJRTM region from the standardized setting of most regional models is its proximity to a huge trip attractor (New York City), directly adjacent to the modeled area, with a substantial amount of transit trips between the modeled area and the external zones. The NJRTM takes advantage of the Hudson Waterfront Model (HWM) developed by New Jersey Transit to specifically forecast the Trans-Hudson travel between New York City and New Jersey. Estimates of EI trips destined to New York City are adopted directly from HWM.

Trip production in the NJRTM is estimated with standard cross-classification techniques, with four income groups and six person-per-household categories, which essentially create a 24-cell matrix of income-per-household categories. A specific trip production rate was developed for each trip purpose from the household interview survey. Table 21 demonstrates the trip rate matrices for home-based work and home-based shopping trips.

Table 21. Trip rate for different trip purposes

Home-Based Work Trip Rates							
Income Rage	1	2	3	4	5	6	Average
<$14,999	0.33	0.57	1.56	2.48	2.48	2.48	0.8
$15,000 - $29,999	0.9	1.13	2.43	2.48	2.48	3.78	1.64
$30,000 - $49,999	1.14	2.11	2.43	3.06	3.06	3.78	2.53
$50,000 or more	1.14	2.49	3.06	3.46	3.46	5.35	3.23
Total	0.63	1.57	2.48	3.08	2.99	4.21	2.06
Home-Based Shopping Trip Rates							
	1	2	3	4	5	6	Total
<$14,999	0.39	0.92	0.92	0.92	0.92	1.76	0.67
$15,000 - $29,999	0.39	0.92	0.92	0.92	0.92	1.76	0.75
$30,000 - $49,999	0.39	0.92	0.92	1.2	1.2	1.76	1.13
$50,000 or more	0.39	0.92	0.92	1.2	1.2	1.76	1.06
Total	0.39	0.92	0.92	1.04	1.22	1.76	0.91

Source: North Jersey Regional Transportation Model Update, 1996

Trip Distribution

Since the data available from the household interview survey does not provide comprehensive information on "attraction" end of trips, calibration of attraction models at the zonal level was only carried out for home-based work and home-based shopping trips. For the home-based other and non-home-based trip purposes, the regression analysis was performed at a more-aggregate level.

The NJRTM trip distribution process controls the allocation of trip ends to potential destinations throughout the region. The gravity model structure was used to distribute both the internal trips and a segment of the EI trips. The EI trips subject to distribution by the NJRTM are those not destined to the New York City external zones. The gravity model in the trip distribution process was applied separately for each trip purpose. The formulation of the gravity model is:

$$T_{ij} = \frac{P_i A_j F(t_{ij}) K_{ij}}{\sum_i^j A_j F(t_{ij}) K_{ij}}$$

Where:

T_{ij} = Trips between origin zone i and destination zone j
P_i = Trip productions at origin zone i
A_j = Trip attractions at destination zone j
t_{ij} = Impedance from origin zone i and destination zone j (usually time)
$F(t_{ij})$ = Friction factor for impedance value t_{ij}
K_{ij} = Adjustment factor for origin zone i and destination zone j

In order to increase its sensitivity to a wider range of cost-related policy variables as well as to better reflect the multimodal nature of travel in the NJRTM region, the trip distribution process utilizes a multimodal impedance term that fully reflects the level of service attributes of all available transportation modes serving each origin-destination zonal pair. For the home-based work trip purpose, the travel times between the zones were estimated using an assumed set of congested speeds applied to the highway network links. For the remaining internal trip purposes, un-congested speeds were used to estimate zone-to-zone travel times.

Mode Choice Process

The mode choice module allocates the person trips for each origin-destination zonal pair into the available travel modes. The mode choice model, is applied only to trips that are internal to the region, defines the available travel modes separately for work and non-work trip purposes. For the home-based work trips, four auto modes were permitted (drive-alone, HOV-2, HOV-3, and HOV 4+), as well as two transit modes (walk access and drive access). The mode choice models utilize nested-logit structure for each trip purpose, which permits the use of the denominator of the mode split model equation as a measure of impedance between zones. The nested-logit structure is shown in Figure 20.

For the non-work trip purposes, simple logit is applied. The models were developed using general relationships identified between the home-based work and non-work models in other regions.

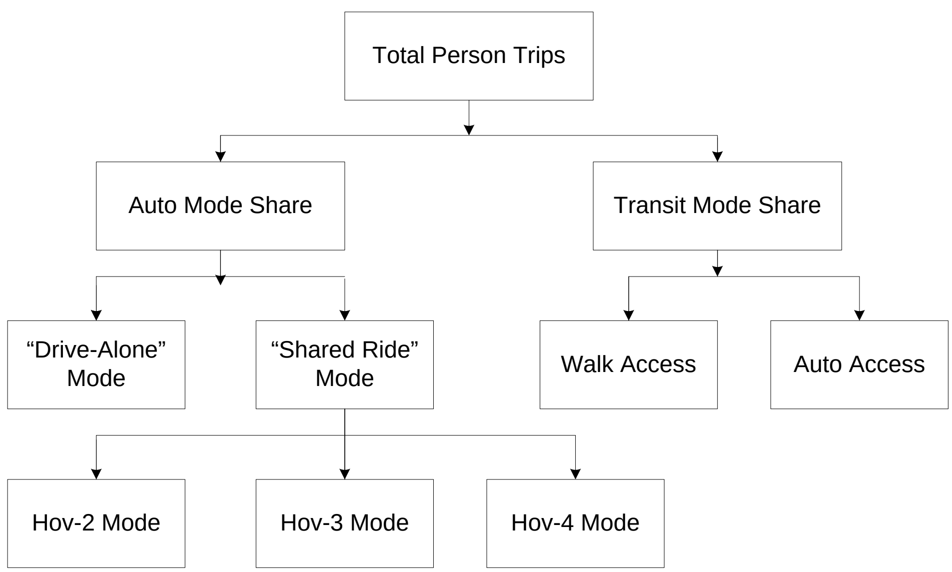


Figure 20. Mode choice structure for home-based work trips

Source: North Jersey Regional Transportation Model Update, 1996

Time of Day Modeling Process

The time-of-day modeling essentially prepares separate trip tables that represent the various time periods used in the highway assignment. These trip tables are converted from a production-attraction format to origin-destination format as part of this process. The NJRTM estimates the highway travel demand for three time periods as part of the assignment process. These periods include the AM peak period (6:30 to 8:30 AM) and PM peak period (3:30 to 6:00 PM) as well as a general off-peak period, which accounts for all the remaining portions of the day.

Staff Interview

A few members of the project team met with the NJTPA staff on February 6, 2007. The NJTPA staff informed us that there is an on-going in-house effort to update the NJRTM. The new model will be called the Integrated Model. The projected completion of such effort is in the later spring or early summer, 2007. The highlights of the updates include replacing the 1990 Census data with 2000 census information for the social, economic, and demographic input. The modeling area is expanded beyond the 13 county jurisdictions, to include portions of Connecticut, the five boroughs of New York City and other New York downstate counties, as well as Southern New Jersey and parts of Pennsylvania north and west of Philadelphia.

The trip generation module includes more trip purposes, such as university trips, airport trips, and home-based strategic trips. The strategic trip may be an emerging concept, which addresses service trips made by plumbers, UPS delivery, or real estate agencies. The idea is stimulated by a study conducted by the Baltimore Metro Council (BMC) and may be directly related to weekend travel demand models.

The Integrated Model also includes bicycle and pedestrian trips as separate modes (trips are generated but not assigned), which may also be relevant to the weekend model. The transit network remains the same as the current version, which has been adopted by the NJ Transit Model.

As part of the long range regional transportation plan, the NJTPA is updating the Strategy Evaluation process, which will address accessibility, mobility, congestion and safety by including performance measures for individual municipalities and places. The previous 158 District system has been disaggregated into about 400 “places”, which consist of multiple Traffic Analysis Zones (TAZ’s). Performance measures are generated to assess the “needs” of a particular place. Then strategies are applied to the needs districts to develop a range of possible solutions that can be used to address the needs of that place. With this system the NJTPA can generate infrastructure projects for their Transportation Improvement Plan (TIP) and Regional Transportation Plan (RTP).

As suggested by Ms. Goldman, Manager of Corridor Studies and Project Planning, the NJTPA and its stakeholders are kicking off a new Visioning Process for Regional Transportation Planning (RTP) 2009; it is important to raise the awareness of the rapid growth of weekend travel.

Focusing on the travel conditions in the jurisdictions of the NJTPA, the staff has mentioned quite a few important aspects to be addressed in the weekend travel study. For example, the shopping trips on Saturdays in Bergen County are extremely high because all the stores are closed on Sundays. There is a large volume of trips from North Jersey or Manhattan to the northern NJ shore area, such as Ocean and Monmouth Counties, which were not addressed in the NJRTM or the SJRTM. The majority of trips to the Pocono Mountains occur on weekends. An O-D survey at bridges both with and without tolls over the Delaware and Hudson Rivers will help identify the trips that originate from North Jersey, Manhattan, and other areas of New Jersey.

Another important observation by the NJTPA staff is that a large portion of citizens residing in a few selected urban areas, such as Newark, are extremely transit dependent. Their transit use for commuting on weekdays may be decent even though it is not the most convenient or comfortable. Their transit use on weekends may become impossible due to dramatic reduction or gaps in transit services and diversity of their travel destinations and trip purposes. A weekend travel demand and forecast model may help to direct service development and identify "most needed" services in the future. A weekend model may also help to evaluate the impact of some Environmental Justice Projects.

As for the future directions of weekend travel demand forecasting and mode choice models, the NJTPA staff has expressed their strong desire to be informed and involved in the development process. Given the limited knowledge of weekend travel and lack of research or development of weekend models, a consensus has been reached that the immediate next step is to collect data. When comparing the options of a focused effort of weekend data collection and a general household survey including weekend data, the NJTPA staff tends to suggest that a weekend travel data collection may be needed since large surveys have already been accumulated for the weekday commuting trips. The NJTPA staff has also suggested that the project team should collaborate with other on-going data collection efforts, such as the Newark Bus Service Survey in North Jersey managed by James M. Gilligan, Manager, Bus Service Planning, New Jersey Transit Corporation. The consultant team consists of Abrams-Cherwony, Urbitran, and Howard Stein, Hudson.

When collecting weekend data, a number of potential locations or areas have been identified that have high potential for weekend activities during some particular season or time of the year. Examples include

- Trips to Manhattan during Xmas or summer season;
- Trips to Manhattan for other cultural activities – theaters or museums, etc;
- Recreational trips to the Jersey shore in the summer;
- Casino trips to Atlantic City;
- Spectator trips to various ball games, concerts or other special events;
- Shopping and recreational trips to regional malls or other shopping centers.

As for the expectations for the weekend travel demand model, the NJTPA staff has expressed their desire to have a model that can be integrated with their existing weekday models. The weekend model should be able to identify the "hot spots" in various places, especially if those "hot spots" are different from weekday hot spots or show worse congestion than weekday places. It is also important to identify and correlate the potential for some discretionary trips to shift between weekday and weekend due to excess weekday congestion. The staff also suggested that a number of subarea/ market based models rather than one statewide model might deliver better or at least more targeted results.

South Jersey Travel Demand Model (SJTDM)

The South Jersey Transportation Planning Organization (SJTPO) maintains a travel demand model for the four southern counties in New Jersey. This enhanced four-step model contains 24 different trip purposes and is the only model in New Jersey that attempts to explicitly model special generators and recreational travel. It was originally developed from a beach survey done back in 1996. It is primarily calibrated to a Summer Friday evening peak. It has the coding in place to generate weekend/recreational based trip tables by pivoting off the Friday trip table, but it has not been calibrated to weekend travel.

The South Jersey Travel Demand Model (SJTDM) follows the traditional four-step modeling process of Trip Generation, Trip Distribution, Mode Split and Trip Assignment. However, the model contains several enhancements within these steps that make it useful to the weekend modeling effort, including time-of-day and day-of-week conversions and the presence of recreational trip purposes. Internally the model was originally built to run under the MinUTP platform but has since been upgraded to run under the much improved TP+ platform. There are also many stand-alone specific programs that were written into the model chain and can be executed in-stream. The model chain consists of over 420 discrete steps and is run under the CENTRAL batch processor developed and maintained by GarTech.

Networks and Zonal System

The SJTDM network and zonal system includes the counties of the SJTPO jurisdiction of Atlantic, Cape May, Cumberland and Salem as well as several counties within the DVRPC jurisdiction in New Jersey and Pennsylvania. This extended network system recognizes the link between recreational destinations in the SJTPO region and the travel market that extends to Philadelphia that feeds this market.

The primary study is the four-county SJTPO region which contains about 1400 internal traffic analysis zones (TAZ's). The TAZ's are based on census geography and are combinations of 1990 block groups and tracts, except for

Atlantic City. The Atlantic City TAZ system is centered around the major industries of casinos, hotels and retail sites. By itself Atlantic City contains over 425 zones.

The extended secondary network in the DVRPC region covers Burlington, Camden, Gloucester and Mercer counties in New Jersey as well as Philadelphia and other eastern Pennsylvania counties. The network was generated from existing and projected roadway networks available at the time of model development. Software constraints caused the development team to create abridged versions of these networks, consolidating roadway links and TAZ's as needed.

Trip Generation and Demographics

Demographics for the SJTPO region are derived from SJTPO Board-approved population, household, income and employment estimates at a municipal scale. Other socioeconomic inputs include school enrollment, life cycle information, transit related data (e.g., parking costs, park and ride lot capacities) and recreational data.

The non-recreational trip production module uses a cross-classification model stratified by income and other characteristics such as number of workers or household size. Within this module is a submodel which varies trip rates by life cycle, household size, number of workers, and income. The non-recreational trip attraction model is initially stratified into seven trip purposes whose inputs are total employment, employment density, proportion of employment by type, household density, area type and income as demonstrated in Figure 21.

Purpose	Abbreviation	Description
Home-Based Work	HBW	From home to work; work to home
Home-Based School	SCH	From home to school; school to home (includes all school trips: primary, secondary, university, vocational)
Home-Based Shop	HBS	From home to shopping; shopping to home (includes eating out and other "quasi-purchasing"-based trips)
Home-Based Other	HBO	All other home-based trips not included above (except special recreational trip purposes)
Non-Home-Based Journey to Work	JTW	From a non-home location to work; from work to a non-home location (i.e., on the way to or from work)
Non-Home-Based At-Work	ATW	Both trip ends at a workplace (lunch, midday errands, business-related trips)
Non-Home-Based Non-Work	NWK	Non-home to non-home segments of a trip chain which both starts and ends at home
Truck	TRK	Heavy trucks
Commercial	COM	Commercial vehicles (no heavy trucks)

Figure 21. Non-recreational trip purposes

Source: Model Development and Validation Report for South Jersey Transportation Planning Organization. 1999

Recreational trip generation for the SJTPO region focuses on fourteen trip purposes listed in Figure 22 and are stratified into three categories: 1) casinos and hotels; 2) special generators in Atlantic City (e.g. Convention Center, other entertainment); 3) shore based events and activities in Atlantic and Cape May counties.

Purpose	Abbreviation	Description
Casino Access Trip	CAC	Non-work, from home to casino, casino to home
Casino Visit	CVT	Travel between Atlantic City casinos
Casino Bus	CBS	Casino access trips via chartered bus
Event Access	EAC	Non-work, from home to Atlantic City, Atlantic City to home
Event Visit	EVT	Travel between events and casinos
Seasonal Work	SWK	From home to work, work to home
Overnight Beach Access	BAC	From home to shore town, shore town to home
Daytrip Beach Access	DAC	From home to shore town, shore town to home
Beach	BCH	One trip end at beach, other trip end at home*
Boardwalk	BWK	One trip end at boardwalk, other trip end at home*
Shopping	SHP	One trip end at shopping location, other trip end at home*
Eat Meal	EAT	One trip end at dining location, other trip end at home*
Other	OTH	All other shore recreational trips not included above with one trip end at home*

* relates to location at which person/group is staying while at the shore

Figure 22. Recreational trip purposes

Source: Model Development and Validation Report for South Jersey Transportation Planning Organization. 1999

Trip Distribution

Trip distribution for the SJTDM is based on the well-known gravity model used by other MPOs and presented in the earlier section of this Technical Memorandum. Calibration of a gravity model generally consists of determining the shape of the F-factor curve for each trip purpose and income level. In addition to the seven non-recreational and thirteen recreational person trip purposes, distribution models were also developed for Commercial and (Heavy) Truck trips. Separate models were calibrated for I/I trips and external trips. Through (EE) trips are handled separately.

Mode Choice

Mode choice is the process of splitting person trips by mode based on a variety of data. These data include purpose, income group, primary mode, and submode. The SJTDM uses a nested logit model to generate these splits as shown in Figure 23. In this approach, a percentage share for each mode is estimated for every origin-destination pair. These percentages are then multiplied by the number of person trips for that origin-destination pair and summed over all origin-destination pairs to estimate the total number of trips for each mode.

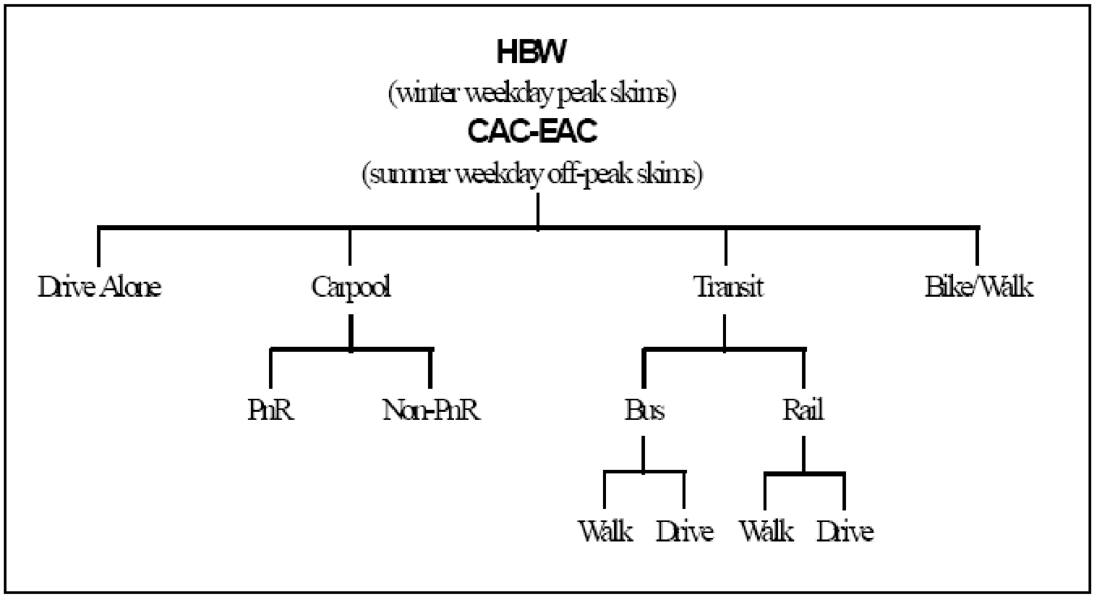


Figure 23. Typical mode choice nesting

Source: Travel Demand Model: Enhancements and Operations for South Jersey Transportation Planning Organization. Technical Memorandum Compendium. 2003.

Temporal Model

The Temporal model is one of the enhancements that enable the SJTDM to generate weekend and seasonal forecasts. To address the seasonal as well as weekday versus weekend issues, the major elements of the South Jersey Travel Demand Model are performed for a "**Full-Activity Day**". This is a hypothetical day in which each trip purpose produces the maximum number of trips. That is, for the home-based work trip purpose the maximum number of daily person trips is generated, distributed, and mode split while the same occurs for all of the other trip purposes, such as school, casino access, and boardwalk trips.

The temporal model is applied to factor each trip purpose from the full-activity day to a user-defined "**Analysis Day**". Four "days" of the week (weekday, Friday, Saturday, and Sunday) were selected for each month, for a total of 48 analysis days. The structure of the temporal model is such that each month and "day" of the week has a factor to adjust the full-activity day to whatever month and day the user has selected. The factors are based on month-to-month variations as well as day-to-day variations for each trip purpose. Each purpose has a "source day".

The outcomes of the temporal model are transit and vehicle trips tables by purpose for four time periods:

- AM peak, six to nine AM,
- Midday, nine AM – three PM,
- PM peak, three to seven PM,
- Night, midnight to six AM and seven PM to midnight.

Trip tables are generated for each of the four time periods listed above. These trip tables can be assigned to the networks to produce period travel forecasts. When summed together, these forecasts represent a daily travel forecast. Using the temporal model the user may also request a peak hour trip table of their choice for any hour of the day.

Several sources were used to develop the temporal model factor tables back in 1997. Because of the lapse of time these sources of data need to be reviewed and refreshed and new sources of data may be available. A rework of the temporal model is high on the priority list for the next SJTDM update which should occur in late 2007 and early 2008.

Traffic Assignment

Highway traffic assignments are performed in a series of steps. First a toll model is applied to account for the effect of tolls on highway impedances. Second, trip tables are split into two categories: "Free" users or toll averse/non-toll facility users; and "Toll" users – those that use a combination of both toll and free paths to arrive at their destination.

Highway assignments are performed using the typical user equilibrium algorithm applied to toll and free paths in the network. A speed feedback loop is applied for three iterations (in model development it was found that three iterations were optimal in achieving reasonable closure) to obtain stable congested network speeds.

Transit assignments for the South Jersey Travel Demand Model use 24-hour transit trip tables in production-attraction format using a TRNBLD module. The selection of the transit network to use for assignment purposes is based upon the selected analysis day. If one of the "summer" months like June, July, or August is selected, then the summer weekday off-peak transit networks are used for assignments. If one of the other months (the "winter" months) is selected, then the winter weekday peak transit network is used.

Delaware Valley Regional Planning Commission Model

The Delaware Valley Regional Planning Commission (DVRPC) maintains a travel demand model for its region that covers four Central New Jersey counties and five Pennsylvania counties including the Greater Philadelphia region. The DVRPC model is also based on a traditional four-step process containing both highway and transit components. The current working version of the model forecasts daily traffic only, but there are versions that model generic peak and off-peak periods. A peak hour model, per se, is not available at this time. The DVRPC model is strictly a weekday commuter based model.

The DVRPC Regional Model has a 1,510 traffic zone system, with most traffic zones being equivalent to census tracts. In order to enhance the accuracy of the DVRPC's travel forecasts and to respond to the new forecasting requirements included in the Clean Air Act Amendments, ISTEA/TEA21, and the Transportation Conformity Rule, DVRPC's travel simulation models were upgraded in 1998. The enhanced DVPRC travel simulation process utilizes the Evans Algorithm to iterate the model, as shown in Figure 24.

Trip Generation

The first step in the process involves generating the number of trips that are produced by and destined for each traffic zone and cordon station. Both internal trips and external trips must be considered in the simulation of regional travel. Internal trip generation is based on zonal forecasts of population and employment, whereas external trips are estimated from cordon line traffic counts. The latter also includes trips which pass through the Delaware Valley region. Estimates of internal trip productions and attractions by zone are established on the basis of trip rates applied to the zonal estimates of demographic and employment data. This part of the DVRPC model is not iterated on highway travel speed, rather, estimates of daily trips by traffic zone are calculated and then disaggregated into peak, midday, and evening time periods.

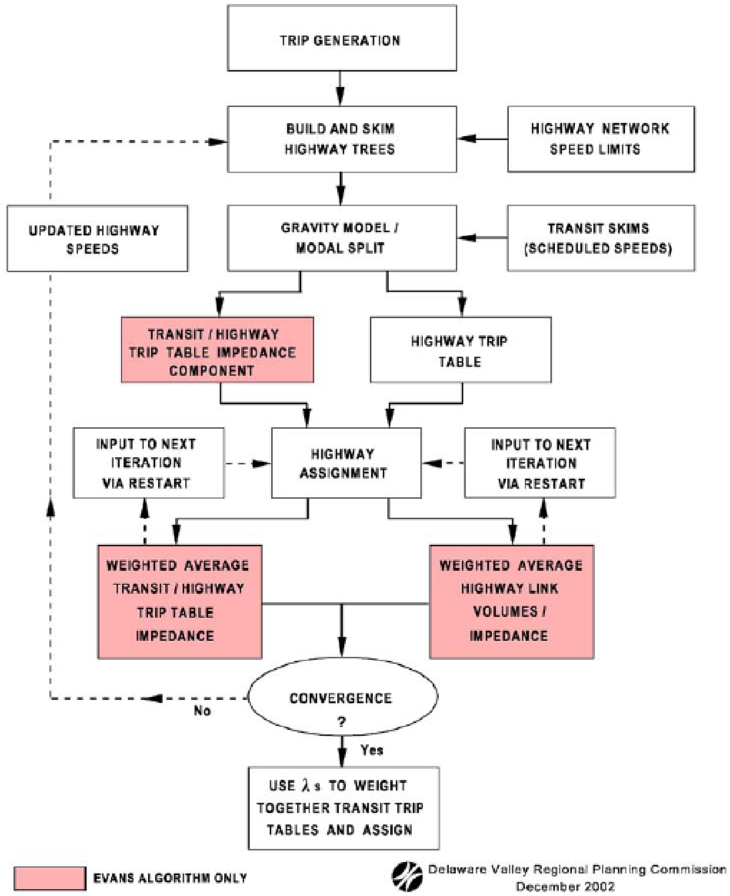


Figure 24. Structure of Delaware Valley regional planning council model

Source: The Enhanced Iterative Travel Simulation Process, DVRPC 2003.

Trip Distribution

Trip distribution is the process whereby the zonal trip ends established in the trip generation analysis are linked together to form origin-destination patterns in the trip table format. Peak, midday, and evening trip ends are distributed separately. For each “Evans Iteration”, a series of eight gravity-type distribution models are applied at the zonal level. These models follow the trip purpose and vehicle type stratifications established in trip generation. Documentation of the trip distribution models is included in the commission report entitled, "1990 Travel Simulation Model for the Delaware Valley Region.”

Mode Choice Process

A nested modal split model is incorporated into the three time periods of the Evans iterative model, as shown in Figure 25. Transit trips with walk or bus access are modeled separately from transit trips accessed via auto mode since different transit networks are used. Following the separate transit assignments, individual transit volumes are merged and summarized to reflect total transit trips. This nested process is executed in a straight forward way within the Evans iterative execution job stream. External-local transit trips are added to the walk/bus approach trip table prior to the walk/bus approach assignment step of the simulation process.

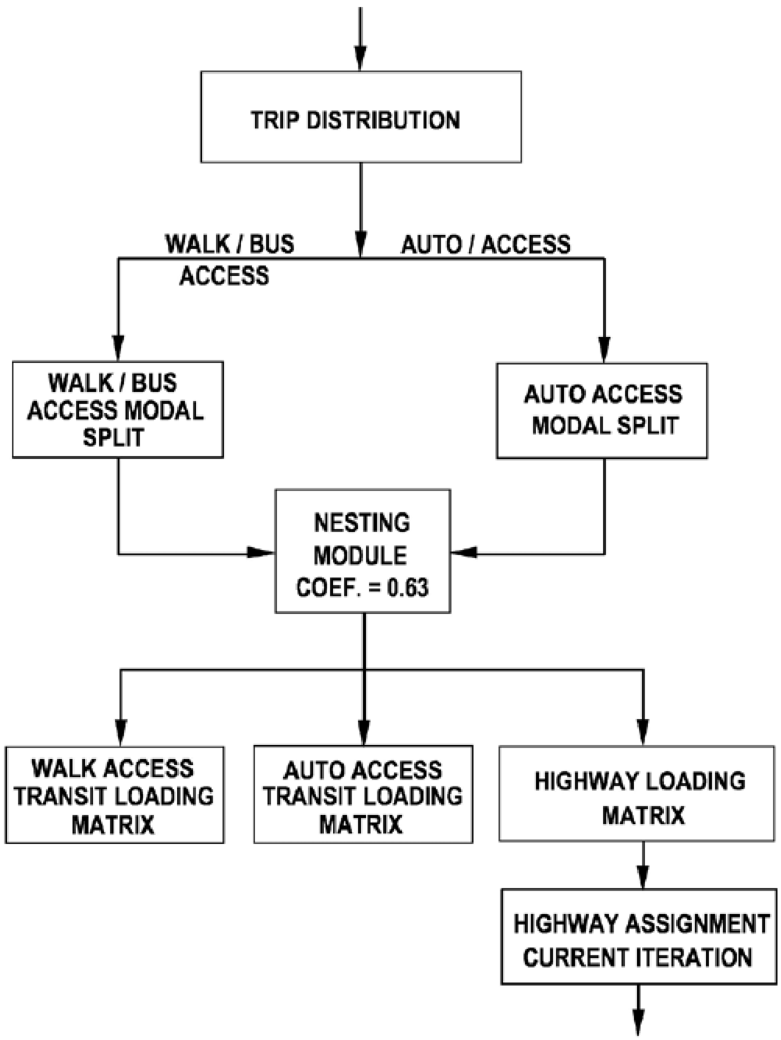


Figure 25. The nested mode choice model

Source: The Enhanced Iterative Travel Simulation Process, DVRPC 2003.

The nested modal split process starts with a base transit network, coded to the DVRPC model specifications. The walk and auto access sub-networks are specified parametrically by using “delete access and egress mode parameters” in UPATH as follows: The walk approach transit network is generated by removing all the auto approach links, mode 3, for both access and egress. The auto approach network is also specified within UPATH. The walk links connecting transit facilities to centroids are made one-way away from the transit lines with the delete egress parameter. This prevents walk access to the transit system on the home end of the trip, but allows walk egress at the non-home end. It is important to note that the network walk links connected to a given centroid are not altered. As with the walk approach network, the time period network is built in DVFARE using the unaltered link, coordinate, and line files. This is advantageous from an operational point of view since the separation of the transit sub-network via auto access and walk/bus access is achieved parametrically through enhanced path building and skimming procedures, rather than through the use of separate transit networks.

Time of Day Modeling Process

The enhanced DVRPC model contains three time periods: peak period, midday, and evening time periods. The disaggregation begins in the trip generation step, where factors are used to separate daily trips into peak and midday travel. Evening travel is then defined as the residual after peak and midday travel and is removed from daily travel. The enhanced process then uses completely separate model chains for peak, midday, and evening travel simulation runs.

The peak period, combined AM and PM, is defined as seven to nine AM and three to six PM, midday is defined as nine AM to three PM and evening as six PM to seven AM. Time of day sensitive inputs to the models such as highway capacities and transit service levels are disaggregated to be reflective of time period specific conditions. Capacity factors are used to allocate daily highway capacity to the peak, midday, and evening time periods. Separate transit networks were required to represent the different levels of transit service that occur in the various time periods.

The “delete access and egress mode parameters” approach explained in the model split section also helps to reduce the number of transit networks from six to three required to run the three period modules. Each time period model within the Evans iterative process is defined as an independent computer process from the gravity model through the highway and transit assignments. This facilitates multi-processor operations in that each time period can be run in parallel in a separate computer thereby reducing the overall computing time to one-third of the time required to run the three period models on a single computer.

Staff Interview

Directed by the NJDOT project manager, Edward Konrath, the project team has contacted Charles Doherty, the director of Technical Services, who in turn directed us to Dr. Thomas Walker, the lead modeler in the DVRPC. Dr. Walker confirmed that the DVRPC model is based on the traditional four-step model including three periods; peak, off peak, and evening. He also stated that the primary focus of the DVRPC model is weekday trips including home-based work, home-based school, home-based non-work and non-home based trips. It also has two classifications of truck traffic and taxi services. The DVRPC model is run on TRANPLAN with a customized Evans Algorithm. It will operate in Cube with some modifications. There are approximately 2000 TAZs in the DVRPC model, of which 1985 are regular zones and 2068 include cordon stations.

The research team was informed that the DVRPC has collected an activity based travel behavior survey in the year 2000 by New Stats with a sample size of 5000 out of two million. Compared to the ratio of 0.6% in both Calgary and San Francisco in recent surveys, a sample size of 0.25% might be too small to be the sole base for developing travel demand forecast models. The agency has no immediate plan to develop activity based models using the data collected since most existing activity based models do not show big improvement but are cumbersome to run. Dr. Walker mentioned that the questionnaire they used for the activity based survey was very similar to that of NYMTC's survey.

One thing Dr. Walker did with the activity based data is to compile the production and attraction data and compare them to the existing model/data, which are very different. Dr. Walker pointed out that the trip production rate for HBW is 1.1 while the existing model uses 1.5.

On the other hand, Dr. Walker mentioned that the SJTPA shore model included large areas of DVRPC if not all. The model has a large geographic base which not only covers the SJTPA area but also a large portion of the DVRPC as well as north Jersey. The network in the SJ areas is very detailed and a skeleton of road and rail networks are provided outside the region, such as DVRPC and north Jersey area.

As for weekend travel demand model, it is not on the priority lists of the DVRPC Long Range Transportation Plan (LRTP) process. Their focus is still the weekday commuting trips since there are no focused weekend trip attractors as predominant as in South Jersey areas. Dr. Walker is willing to provide zonal structure and SE data from the DVRPC if we are going to develop weekend models. He is also willing to review the modeling structure of proposed weekend travel demand forecast model for New Jersey.

New Jersey Transit Demand Forecasting Model (NJTDFM)

NJ Transit maintains the North Jersey Transit Demand Forecasting Model (NJTDFM) that uses the highway components of the NJRTM with enhancements to the mode choice and transit network procedures. This tool is designed to provide Federal Transit Administration (FTA) New Start compliant transit forecasts for both the intra-New Jersey and Trans-Hudson transit markets. There is currently a model under development which will combine the NJTPA and NJ Transit models into one "Integrated" model. But the delivery of a calibrated model is not expected until spring 2007.

The NJTDFM is designed to forecast the average weekday demand for travel within northern New Jersey and Northeastern Pennsylvania between northern New Jersey and adjacent portions of New York and Pennsylvania. It includes an extensive study area, 37 counties, and a detailed zonal system (2053 zones). The NJTDFM operates on the Citilabs TP+ platform.

NJTDFM is a modified four -step model in which the first step, trip generation, and the second step, trip distribution, have been replaced by a process that develops a base year (2000) person trip table from on-board transit surveys, all transit customers, a Trans-Hudson automobile survey, Trans-Hudson automobile travelers, and NJRTM trip distribution model, intra-New Jersey automobile travelers. The person trip table includes estimates of the total number of trips, all modes, for each zone-to-zone combination in the modeling area. Separate tables are prepared for two time periods: peak, six to ten AM or 3:30 – 7:30 PM, and off-peak, all other times, and for four primary trip purposes: home-based work, home-based shop, home-based other, and non-home based.

In addition to the four primary trip purposes, the NJTDFM also includes Newark International Airport air passenger ground access mode choice models. The base year air passenger trip tables were developed from the 1998 Port Authority of New York and New Jersey (PANYNJ) survey of originating air passengers at Newark International Airport and are stratified by two time periods: peak six to ten AM or 3:30 PM - 7:30 PM, and off-peak, all other times, for four air passenger trip purposes: business/resident, business/non-resident, non-business/resident and non-business/non-resident.

Forecast year trip tables are developed by growing the base year trip tables (2000) to the appropriate forecast year using a FRATAR factoring approach. For the primary trip purposes, this factoring approach uses the forecasted growth in population, households and employment by the various MPO in the region, NJTPA, NYMTC, DVRPC and Lehigh Valley, to estimate the growth in person trips between 2000 and the forecast year. For the Newark International Airport air passenger trip purposes, the FRATAR factoring process uses PANYNJ Long Range aviation forecasts to grow the base year trip table to a future year condition.

Highway and transit networks are maintained in order to prepare level-of-service matrices (e.g., time and cost) for each zone-to-zone interchange in the model. These level-of-service matrices are frequently referred to as skim matrices. The transit skim matrices are constructed using the TP+ TRNBUILD module while highway skims are built using the TP+ HWYLOAD module.

The mode choice model uses a nested logit structure where the parameters were estimated from a combination of stated-preference and revealed-preference surveys. The mode choice models use the travel characteristics of the trip (time, cost, etc.), socioeconomic characteristics of the travelers, and the characteristics of the origin and destination zones to predict modal shares for each zone-to-zone interchange. The mode choice models contain a direct interface to the FTA SUMMIT software, which is used for estimating the Transportation System User Benefits associated with a potential transit investment. The choice set for the NJTDFM mode choice model is shown in Figure 26.

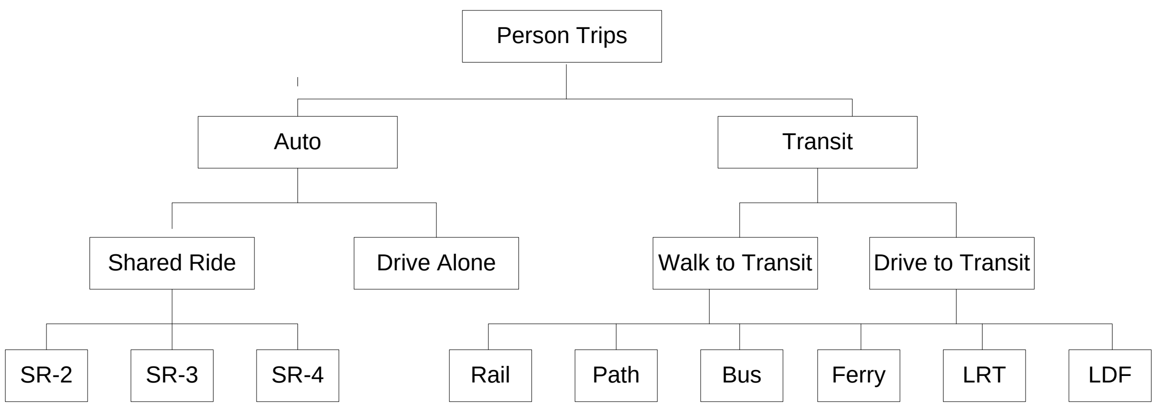


Figure 26. Nested structure for NJ TRANSIT mode choice model

Source: North Jersey Transit Demand Forecasting Model, AECOM Consult, 2005.

In assignment, the zone-to-zone person trip tables are assigned to the best (shortest) path consistent with the travel mode determined in mode choice. Assignment uses the same network representations used in the highway and transit path-building process.

Statewide Truck Model

The Statewide Truck Model, maintained by NJDOT, is used primarily as a tool for analyzing on-road goods movement in the New Jersey region of the northeast corridor. The model contains all of the primary roadways in New Jersey plus portions of Delaware, Pennsylvania, New York City boroughs, and other bordering downstate New York counties.

Truck travel was initially developed using commodity flow data and has been enhanced with data from regional estimates of households and employment broken down into various SIC categories. Trip generation equations were derived and compared to models developed in Phoenix (1991), San Francisco (1993) and Washington. Automobile travel is derived in a trip table merging process involving the three MPO models. As such this model is also a weekday commuter based model. The Statewide Truck Model was initially a daily assignment model only but has been more recently updated to peak period/hour models for use in the Portways and CPIP projects. The statewide truck model is not reviewed in further detail in lieu of information and truck volume data on weekends.

NYMTC Best Practice Model

As one of the major employment and activity centers for New Jersey, New York City attracts a large portion of the residents from New Jersey and is the integral part of the New Jersey travel demand forecast model. The New York Best Practice Model (NYBPM) is unique to the New York City region and may not have direct applicability to New Jersey MPO models. However, the techniques developed and travel behavior observed in the modeling development process may be conducive to the further research of weekend travel and more universal applications.

The BPM area covers 28 counties in New York, New Jersey, and Connecticut. It is comprised of more than 3,500 traffic analysis zones and includes most types of road facilities, from minor arterials and above, and all forms of public transportation, as shown in Figure 27. In addition to ten New York counties in the NYMTC planning region, the NYBPM model area includes the thirteen counties in northern New Jersey that are part of the North Jersey Planning Authority (NJTPA), Mercer County (DVRPC part), Dutchess and Orange Counties in the Hudson Valley, and Fairfield and New Haven Counties in Connecticut. The NYBPM was developed using a combination of customized programs and TransCAD GIS software.

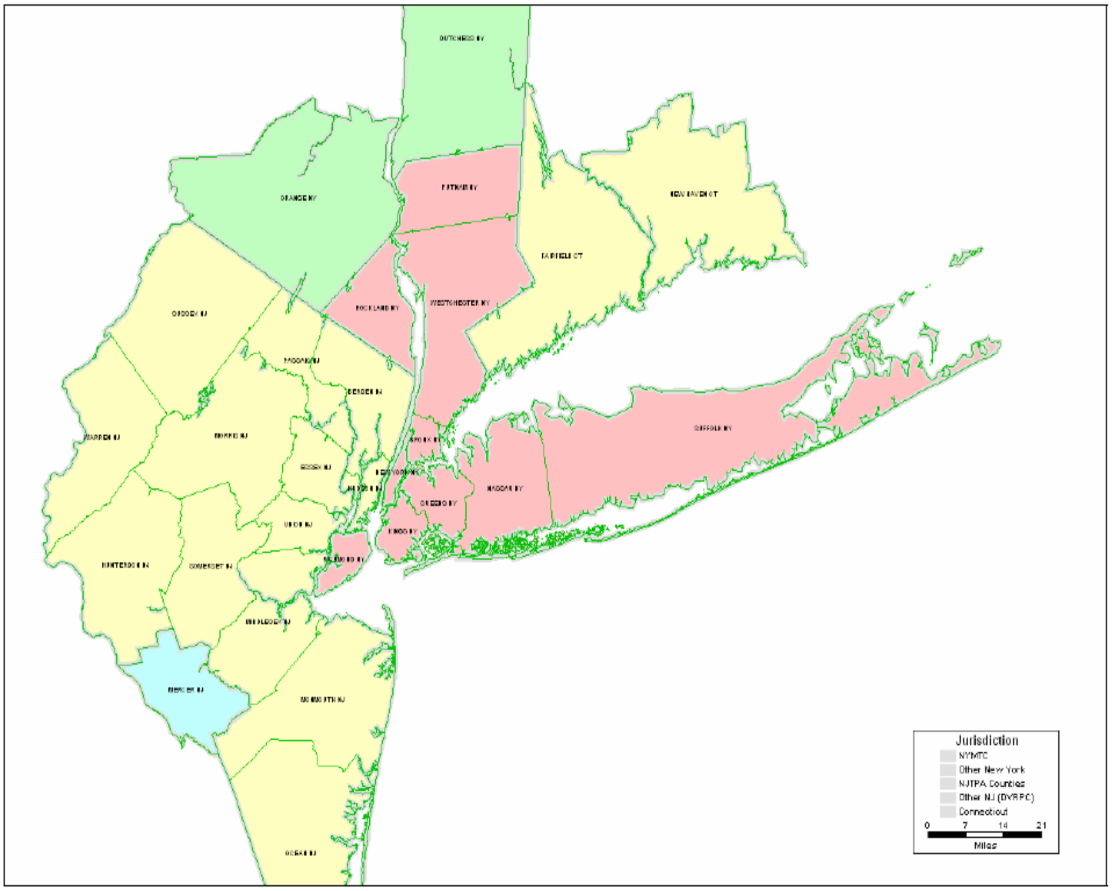


Figure 27. NYMTC and NYBPM model area

Source: Transportation Models and Data Initiatives Final Report, 2005

The NYBPM model consists of four consecutive modules as shown in Figure 28:

- Household Synthesis, Auto-Ownership and Journey Frequency (HAJ)
- Mode and Destination and Stop Choice (MDSC),
- Time of Day Choice (TOD),
- Highway and Transit Assignment.

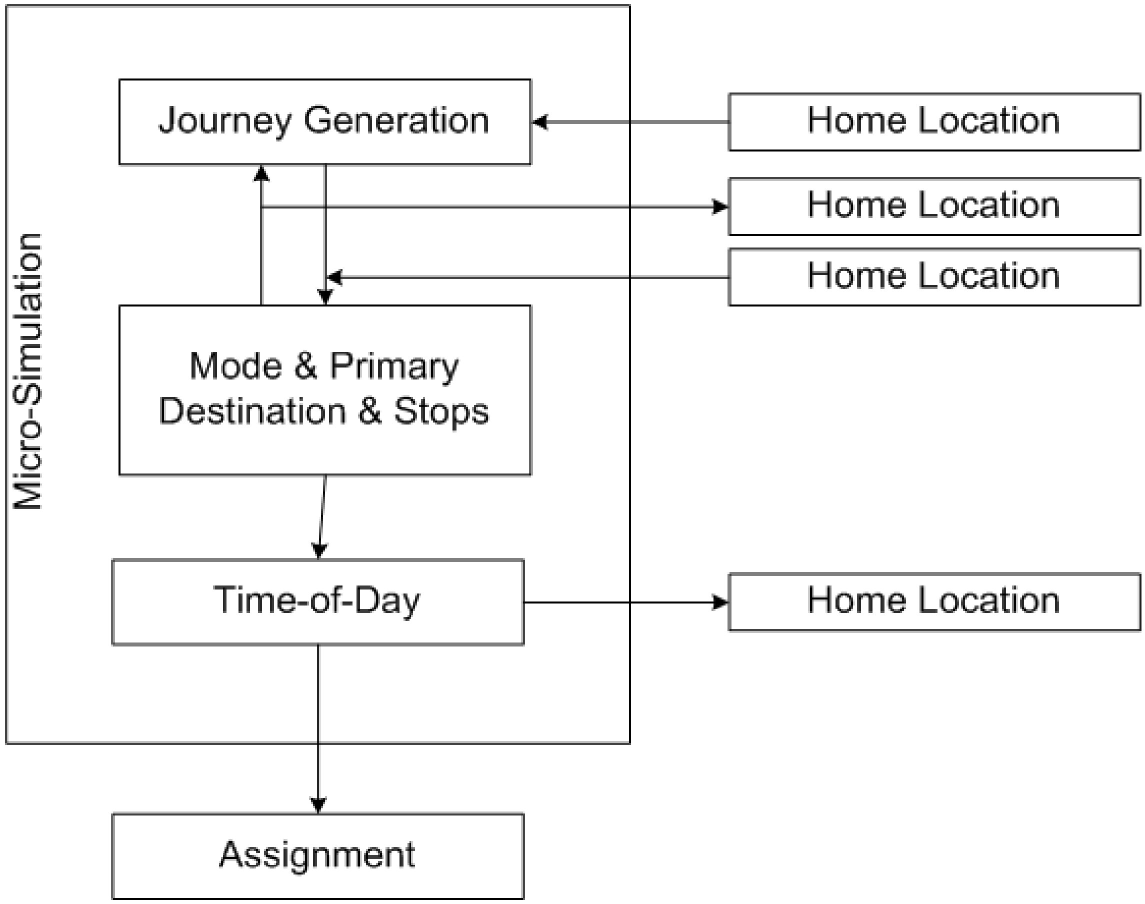


Figure 28. General modeling structure of the NYBPM

Source: Transportation Models and Data Initiatives Final Report, 2005

Journey Frequency

The journey-generation module of the NYBPM consists of three successive models: household population synthesizer, auto-ownership model, and journey-frequency choice model. It predicts the total number of households by income, size, number of children, number of workers and number of autos, and then determines the number of journeys that will be produced for each subgroup over a 24-hour period.

The household synthesis model is designed to create a list of households with the necessary socio-economic attributes in each zone based on the aggregate average zonal target values and seed distribution of households observed in

Public Use Microdata (PUM)S.

The auto ownership model is a discrete choice model that yields probabilities of having a certain number of cars owned by a household as a function of the household size, composition, and income. These fractional probabilities are then used in the Monte-Carlo procedure to generate the most probable choice of the number of cars for each household. Modeling auto-ownership as an individual household choice is different from the aggregate prediction of auto ownership at the zonal level used in conventional models. While the conventional modeling technique treats auto-ownership as a socio-economic attribute of the population that is viewed as an exogenous input to a travel demand model (like household size or income), the new generation of travel demand models include auto-ownership as a travel-related choice that is essentially endogenous with respect to other travel dimensions (like journey frequency, mode, or destination choice). This allows for incorporation of travel and urban environment variables (density, accessibility) into the auto-ownership model making it sensitive to the land-use and network scenarios as well as inclusion of auto ownership into the overall network equilibrium procedures.

In the journey generation model, a tour (pair of journeys) is used as a base unit of modeling, instead of a trip, that is used in the conventional demand models of the previous generation. This allows for full consistency of mode and destination choice across all trips in the tour including the primary destination and intermediate stops. In particular, this has completely solved the problem of modeling “non-home-based” trips that always relied on a very crude zonal estimation in the conventional models. There are three person types and six journey purposes that resulted in thirteen journey-frequency models. The journey purposes include trips for school, university, work, at work, maintenance shopping, and discretionary activities. These models restrict children from implementing journeys to work, at work and to university; and nonworking adults from implementing journeys to work and at work. Each model is a multinomial logit construct having three choice alternatives – no journeys, one paired journey, two or more paired journeys.

Mode Destination Stop Choice (MDSC) Module

This module replaces the traditional trip distribution and mode choice module. Based on the person and household characteristics and land-use densities around the journey origin, this module predicts which modes of travel each person chooses, where the person goes, and if the person stops along the way on the journey. If a person does make a stop on his/her way to work, school or university, this model will predict the location of the stop. Figure 29 illustrates the internal MDSC module.

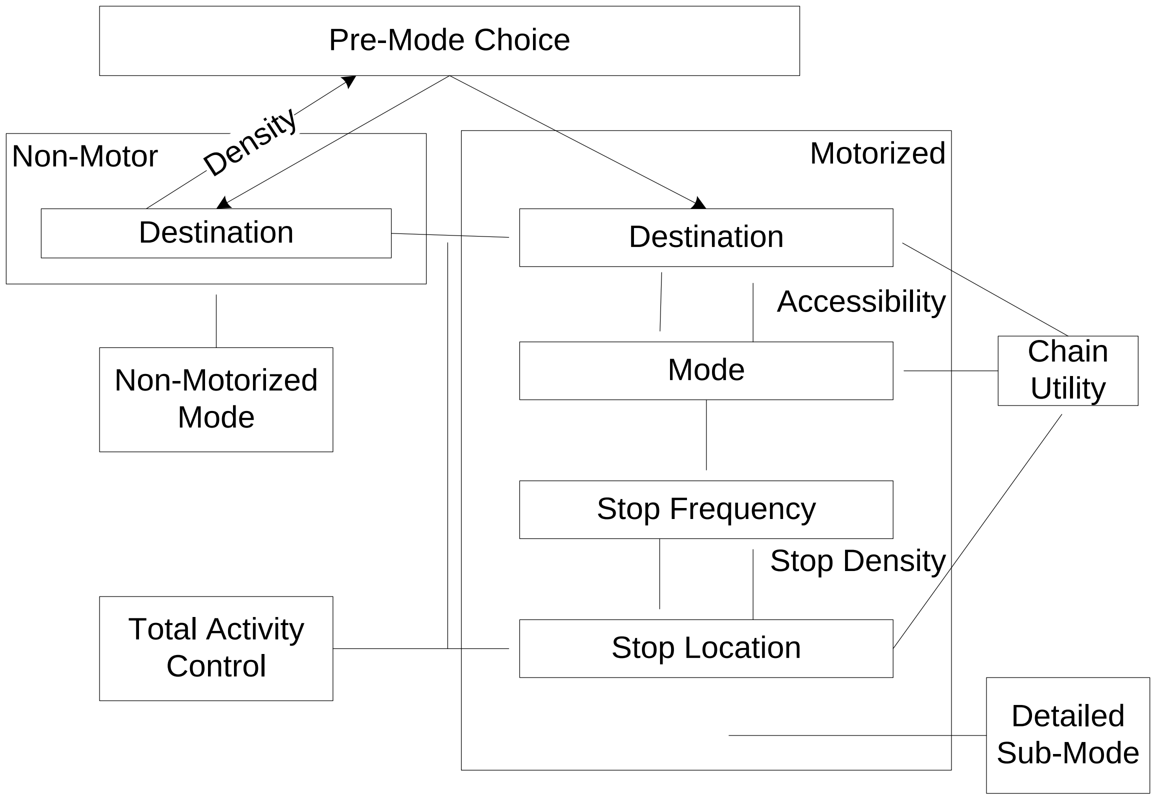


Figure 29. Mode choice module of NYBMP

Source: Transportation Models and Data Initiatives Final Report, 2005

The MDSC module starts with a pre-mode choice, where each journey is assigned to either motorized or non-motorized mode of travel, modeled by a binary logit choice structure. The model has been calibrated for six journey purposes. If the motorized option is chosen, then the motorized branch of the algorithm is activated. First the mode and destination choice for the whole journey is modeled without intermediate stops. It can be thought of as a nested structure where destination choice comes at the upper level of hierarchy while mode choice is placed at the lower level, conditional upon the destination choice. The destination choice model has been calibrated by eight purposes (six original purposes with additional subdivision of journeys to work by three income categories). The decision to model destination choice for journeys to work separately by income categories was made based on the very different spatial structure of residential and work places for low, medium and high incomes in the NY/NJ metropolitan area.

The mode-choice model has been calibrated by six purposes as a nested logit structure with differential nesting depending on the purpose. In most cases drive-alone and taxi modes proved to be in separate nests while transit and shared-ride mode were nested in different combinations. The following variables have generally been the most significant: travel time components, travel cost components, distance for commuter rail (proved to have a strong positive coefficient), mode-income constants, mode-car-sufficiency constants, mode-person-type constants, mode-Manhattan-destination constants, and mutual journey-making (two adults, adult and child) constants.

Time-of-Day Choice (TOD)

The current version of the NYBPM has a simplified timing model based on a set of predetermined look-up tables (often referred as peak/off-peak factors) with percentages of journeys by time periods. The look-up tables are stratified by journey purpose, leg, mode, and some aggregate spatial categories. This simplified technique has produced reasonable results in terms of the aggregate zone-to-zone mode matrices by specified four periods of a day. However, for further development of the time of day models for the NYBPM, it would be desirable to incorporate more flexible timing considerations. This would allow for better replication of individual travel patterns (in terms of journey sequencing and scheduling) as well as make the modeling system more sensitive to policy measures aimed at congestion relief.

Staff Interview

The research team interviewed the New York Metropolitan Transportation Council (NYMTC) staff on March 9, 2007. All sections of the NYMTC Department of Technical Services, Model Development, Model Applications, and Travel Survey were represented. After a brief introduction by Dr. Liu on the objectives and progress of the weekend travel demand and mode choice models for the New Jersey project, Ms. Sangeeta Bhowmick provided a description of the on-going applications of the Best Practice Model (BPM) in the NYMTC jurisdiction. As discovered in our earlier research, one of the potential connections between BPM and weekend travel demand models might be the impact of the air quality conformity determination process, where more and more metropolitan areas identify that the non-confirming days may occur on weekends, especially in the summer. Unfortunately, there is no weekend data collected by the NYMTC, and one of the most important steps for all MPOs in the tri-state area, including NYMTC, is to collect data on weekend travel.

Another important endeavor of the NYMTC is to conduct travel behavior surveys to develop the Best Practice Model II. As reported by Mr. Jorge Argote, the survey manager, the NYMTC is in the process of planning a major travel behavior data collection, which includes not only household interview surveys, but also special generators, such as work places, commercial establishments, stadiums, and airports. Surveys of taxi and other modes are also potentially included in the future. Given the early stages of the survey planning, the NYMTC staff is not sure whether weekend data will be included in the proposed survey. In terms of modeling development, Ms. Larisa Morozovskaya informed the project team that two new modules, land use and freight, are in the development stages of the NYMTC travel demand model. The agency also worked with the New York City Metropolitan Transit Authority (MTA) to incorporate and improve the transit forecast capabilities.

All attendees at the interview agreed that weekend travel is an important segment of overall travel in the tri-state area, but the information is lacking. Greater attention is needed for weekend travel, and more data should be collected to understand weekend travel, its substitute and complimentary patterns to weekday travel, and to improve the capabilities of MPOs in forecasting weekend travel.

Summary

As documented above, there are a number of different travel demand forecast models in New Jersey and surrounding areas. These models are maintained by various MPOs, DOT, and transit agencies, and were built on different platforms, ranging from TRANPLAN, TP+ and TRANSCAD. After a thorough review of the existing travel demand models in New Jersey and interviews with the MPO staff, the research team obtained a detailed assessment of the modeling processes employed as background on what and how each of these models can be used or adapted in the weekend forecasting process in the tasks to follow.

APPENDIX 3. STATE OF PRACTICES IN WEEKEND TRAVEL DEMAND FORECAST

Development of weekend travel demand and mode split model includes two interrelated steps: the first step is to understand the dynamics behind the travel behavior for weekend travel. It includes exploring the similarities and differences between weekday and weekend travel, identifying important factors that affect the travel demand and investigating mode choices of individuals. The second step is to develop tools, such as network or spreadsheet models to simulate the travel behavior or validate the hypotheses that researchers have established in step one.

The research team has already evaluated travel demand models in and around New Jersey as part of Task 2 of Weekend Travel Demand study. This Technical Memorandum documents two other broad surveys outside New Jersey to gather the state of practice of weekend travel demand forecasting. The first survey was conducted using the Travel Model Improvement Program (TMIP) list server, an Internet discussion group by modelers, ranging from academia, consultants, and government employees. The second survey was distributed among selected Metropolitan Planning Organizations (MPO) in North America to gather the current status of weekend travel demand and forecast models.

TMIP Discussions

The Travel Model Improvement Program (TMIP) is a program established about ten years ago by Federal Highway Administration (FHWA) to help planning agencies improve the techniques they use to inform their decision makers on how growth in population and employment, development patterns, and investments in transportation infrastructure are likely to affect travel, congestion, air quality, and quality of life. In order to advance the state of the practice of travel modeling and planning analysis, TMIP provides a variety of services to academics and professionals in the fields of travel modeling and planning analysis, which ranges from seminars and training, email list, clearinghouse, research, and peer review and exchanges (USDOT, 2006).

The TMIP E-mail discussion list is subscribed by more than 700 members of the travel forecasting profession from around the globe. Users post issues or questions to the list initiating discussions among the membership. TMIP list server maintains a continuous, active discussion group on various subjects directly related to travel demand modeling, and many hot topics in analysis and modeling are discussed through the list server.

In April 2006, Dr. Liu, the Principal Investigator of the project, posted an invitation of discussion on weekend travel behavior and forecast model. The email asked about three aspects of weekend travel demand modeling: current weekend modeling development, factors that impact weekend travel, and data collection on weekend travel characteristics.

The Email invitation has stimulated interesting discussions among modelers from all fields, ranging from MPO staff, academia, and consultant. The micro simulation model of weekend travel by household in Calgary had been identified as in the most advanced stages of modeling development by a local MPO, which is elaborated in a section of this TM. A series of travel behavior and transit on-board surveys that included weekend element has also been revealed, which are included in a later section of this TM, too.

The Differences between Weekday and Weekend Travel

One of the important contributions from this list server discussion is the unique characteristics of weekend travel and its spatial and temporal distribution in various geographic locations. As pointed out by one of the responses, (Leve, 2006), there are quite a few cities where significant numbers of people leave the urban area on weekends, typically for various activities associated with "time in the country". The traffic patterns associated with large numbers of people leaving on Friday evening, and to a lesser extent early on Saturday morning, then returning on Sunday evening are quite different from typical weekday traffic patterns. Nevertheless, these traveling characteristics may cause quite significant and extensive congestion. In addition, this congestion may be more perceptible in outlying areas which do not "normally" have congestion problems.

The "weekend tourist" type of travel behavior is certainly more common during the summer months when atmospheric conditions may amplify the effects of local ozone concentrations. In terms of modeling this type of trip, often there is a reasonably well defined "area" outside of the city which is attracting many trips and the challenge is to predict who might be going to this area and from where.

Based on his analysis of San Francisco data, Lockwood, et al (2004) have summarized the following broad numbers comparing weekend day travel to weekday travel:

1. Average number of out-of-home activity episode participations per capita (individual) - 2.11 (average weekday), 1.91 (Saturday), 1.71 (Sunday).
2. Average number of daily person trips per capita - 3.40 (weekday), 3.14 (Saturday), 2.85 (Sunday)
3. Person miles of travel (PMT) per capita - 22.85 (weekday), 21.97 (Saturday), 20.40 (Sunday)
4. Vehicle miles of travel (VMT) by motorized personal automobiles per capita - 15.57 (weekday), 13.36 (Saturday), 12.10 (Sunday)

5. Peak period (defined as more than 23 trips ending per 100 individuals in the population) - 7-9 AM and 3-7 PM (weekday), 11:45 AM-6:15 PM (Saturday), 11:45 AM-2 PM and 3-4 PM (Sunday)
6. Peak of the peak (defined as more than 30 trips ending per 100 individuals in the population) - 7:45 AM-8:45 AM and 5:15 PM-6:15 PM (weekday), none at this intensity level on the weekend days.

A comparative analysis of the weekday and weekend activity-travel participation behavior indicates that the total volume of travel undertaken during weekdays and weekend days are comparable. The total person miles of travel (PMT) is about the same on a typical weekday and on weekend days, while the total vehicle miles of travel (VMT) on Saturdays (Sundays) is about 86% (77%) of weekday VMT. The consensus based on the survey responses suggests that, at the least, weekend activities and travel need some more attention.

The Importance of Analyzing Weekend Travel

Another important result of this list server discussion, after identifying various sources of modeling development and data availability, is the reassurance of weekend travel demand forecast and mode split analysis, as well as its overall impact on the long range transportation planning process.

The characteristics of weekend and weekday travel are quite different, as pointed out by various responses in the list server discussion. There could be unique traffic generators, such as sporting events and concerts, during some weekends resulting in traffic congestion at different network links to those that are congested during the typical workday traffic profile.

The differences between weekdays and weekend days, especially in the temporal profiles of the travel patterns, may have implications for air quality modeling. Specifically, the sustained high volume of weekend trips during the hotter, *i.e.,* mid-day, period can amplify the severity of the impact of emissions on air quality. Further, as a consequence of departure from home much later in the day, compared to weekdays the longer soak times of vehicles prior to first use during weekends, could also increase air pollution from emissions. As pointed out by Dr. Bhat, of the three days exceeding the 125 Parts Per Billion (ppb) ozone level non-attainment standard in the Dallas-Fort Worth area in 2003, two were weekend days, according to an NCTCOG report.

Furthermore, when looking at permanent vehicle recorder stations on interstate highways in many portions of the State of Washington, Shull (2006) stated that the highest travel hours are very often on the weekends. Yes, this reflects a high degree of intercity travel, but again it shows that we must pay attention to more than the typical weekday. As we extract the last bit of capacity from our systems by using former shoulders as lanes, etc, we need to keep in mind that the incidents, special cases, holidays, disasters, etc. will continue to require more and more of our focus (Shull, 2006). It is also possible that transportation control measures intended to regulate traffic flows on weekdays might transfer traffic to weekends.

On the other hand, a number of participants have explained why, rightly or wrongly, not much effort has been placed towards development of Saturday or Sunday travel models. According to Cervenka (2006), in all of the high-growth, low-growth, or no-growth areas, most model applications are still very much focused on finding solutions to congestion and accessibility issues. In other words, a new roadway or rail system is built primarily to relieve current/projected weekday peak period congestion, but this is sometimes influenced by the simpler desire to provide faster or alternative service even in the off-peak hours. The speculation is that even the "30th highest hour" calculations that design engineers love to use wind up almost always being peak hours on weekdays, notable exceptions being roadway designs for special events, traveling to the beach, treatments around regional shopping malls, etc. Therefore, with the exception of these very special localized situations, the implication is that if a transportation system can "handle" weekday peak hour conditions, it will "handle" any weekend condition. The fact that some summer-time ozone pollution exceed the allowable level take place on weekends is definitely something that needs to be taken seriously in the planning process, but in reality, these probably are primarily a result of very unusual atmospheric conditions that get combined with a transportation system that can already be shown to be problematic because it also has lots of unacceptable weekday ozone levels.

The Scope of Weekend Travel Demand Model

The overall responses from the TMIP discussion is optimistic toward the need and purpose of the weekend travel demand forecast and mode split model, but cautions need to be exercised on the scope and investment. As suggested by Cervenka (2006), a clear purpose needs to be stated, before substantial investments are made in the development of weekend-based models. Perhaps what is needed are not full regional weekend models, but "special event" and "sub-area" types of models in which the survey/data collection program can be focused on well-stated objectives.

Since air quality is typically associated with the summer season, it is also suggested that one of the bigger deficiencies in current regional modeling activities is that they are often based on "weekday while schools are in session" non-summer time traffic. We certainly need to acknowledge some of the very strong, and philosophically correct, arguments that are made from time-to-time in support of weekend modeling and weekend-based "problem resolution". That is, even minor, under the limit, ozone situations on summer-time weekends are especially detrimental to a region's health because there are more people spending time outdoors on weekends. If one is to develop a weekend model, perhaps it needs to be specifically a summer-time weekend model.

MPO Survey

As stated in the scope of this research, most existing transit, MPO, and statewide travel demand models, including all of those we are familiar with in New Jersey, explicitly model non-work travel purposes as well as include both peak and off-peak periods, but for a typical weekday. However, systematic or general methodology for estimating travel demands, and mode choice in particular, do not exist for weekend travel analysis, which we know is dominated by non-work travel as well as very specific peak and off-peak periods quite different from weekdays. It is our understanding that improvements in the analysis and forecasting of weekend travel and transportation impacts are the primary focus of this research project.

An in-depth survey is conducted to find out the state of practice both in New Jersey and elsewhere. The research team selected top 45 MPOs in terms of population and 20 MPOs responded.

The MPO survey intends to gather weekend travel demand analysis based on two large focuses. The first focus deals with the current status of weekend travel demand model, data collection and travel behavior, particularly on mode share as addressed by the first four questions. The second focus is on the future plans of each MPO whether they plan to develop a weekend model, are there any factors they think are important to forecast weekend travel, or any modeling structure they would like to suggest. The following section summarizes the results based on the two focuses.

Current Landscape of Weekend Travel by MPOs

None of the MPOs surveyed has a weekend travel demand forecast module in its Long Range Transportation Plan (LRTP) model. However, Southern California Associations of Government (SCAG) is planning to issue a Request for Proposal (RFP) for developing a weekend travel demand forecast. The weekend forecast model will be parallel to its original weekday model and based on a four-step forecast structure. The driving force behind this initiative is clearly concerns for air quality in various corridors. Many of the days that exceed air emission standards in southern California area are on weekend days.

Among the 20 responses to the survey, four have done individual household travel behavior surveys since 1995. Among these household surveys, weekend travel information has been collected by South California Association of Governments (SCAG), Metropolitan Transportation Commission (MTC), Atlanta Regional Commission (ARC), and Oregon Department of Transportation and Service of Metropolitan District. Most of the data set and summary reports of the household surveys are accessible from internet, except the data set from SCAG.

It is interesting to note that these household surveys which contain weekend travel information are done in similar formats. For example, a two-day travel diary was collected for each member of the household. The combinations of two-day diary include: Sunday and Monday, Monday and Tuesday, Tuesday and Wednesday, Wednesday and Thursday, Thursday and Friday, Friday and Saturday. Researchers usually single out travel information on Saturdays and information on Sundays to compare with the rest of weekday travel characteristics. More data summary is presented in the following section of this Technical Memorandum.

Survey asked the MPO staffs to compare weekend travel and weekday travel in its region. Most survey respondents emphasized that the traffic condition on weekends is based on their own experiences rather than collected data or analysis. MPO staff observed different travel patterns on weekends and weekdays, even without solid data backup. For example, one of the MPOs in Illinois reported that shopping and other major destinations attract higher volumes/ridership on weekends, depending on the facility and time of day. One of the MPOs in the northwest region found that weekday and weekend congestions have different locations, some of the facilities are more heavily congested over the weekend. Another MPO in northeast observed different functions of highways, such as commute oriented highways and more vocational oriented highways. For the commute oriented highways, volumes are lower on weekends. However, depending on the time of the year, the more vocational highways can expect more volume on weekends, such as I-495. This is used by many New York and New Jersey people traveling to Maine in the summer.

Weekend traffic congestions also raises concerns for air quality. One of the MPO in Texas “deals” with Saturday and Sunday travel by applying time-of-day factors to weekday travel numbers for air quality purposes. The responses from the survey further confirm the observations in the literature that the travel characteristics and dynamics of weekdays and weekends are likely to differ and there is a need to develop new models that more accurately predict travel needs on weekends.

Based on different traffic demand on weekends, planning organizations show different levels of interest about weekend travel demand modeling. For regions where traffic on weekends is low, planning agencies have no plan to include weekend travel information in the data collection process in the near future. The planning agency for a region such as SCAG, where traffic in many corridors is as heavy on weekends as on weekdays, is moving forward to develop a weekend demand modeling to incorporate into its weekday module. Weekend travel demand is also driven by air quality concerns. One of the MPOs on Texas mentioned that air quality breaks often on weekends. Another MPO in Texas plans to figure out a more sophisticated way of factoring our weekday model so that it can represent weekend conditions for its air quality work. However, interest in weekend travel model development is also constrained by funding available and policy concerns. One of the MPOs in Texas reported that traffic volume on weekends in some of the corridors within its planning region, is heavier than volume on weekdays. However, because of funding restrictions, a proposal to assign half of the samples on weekends in the next round of household survey was turned down. Also, one of the MPOs in California observed several busy corridors on weekends, but, the respondent added: “they are not policy concerns right now.”

In terms of mode split, only a few agencies answered. The low response rates on this particular question might be driven by the dominate mode share in most areas being automobiles, therefore, the neglect able impact of other modes, and eventually lack of data. However, the overall impression from those who responded is that transit use is less on weekends, while shared ride is more. Some responses mentioned that transit design is usually CBD oriented, serving work or school trip purposes, instead of recreational trips. The transit mode share from those who responded ranges from 1.5% to 2.5%, except New York City. One of the MPOs in the west coast mentioned that weekend trips involve a lot less transit shares, but a lot more shared ride. Transit services in the region do not serve the nature of the trips on weekends. The only exception is during the football game on weekends, when extra commuter cars are put into service to transfer people from remote parking. Another MPO in the southern region mentioned that transit usage is much heavier on weekdays for school and work, recreational trips do not use transit much. Transit ride share also depends on its level of service. A MPO in the mid-east mentioned that “transit access is not very good. The light rail is downtown oriented, so it serves mostly weekday work travel. On weekends, it serves with very limited headways.”

Future Plans for Weekend Travel Demand Forecast

Most agencies, except SCAG who is ready to initiate a RFP, do not have a plan to incorporate weekend travel into their current travel demand forecast mode/split models in the near future. They do not have a clear plan for developing weekend models either. However, further probing indicates that more and more agencies, especially those in large metropolitan areas, are confronted by various congestion problems that occur in non-traditional, outside of peak commuting periods. Some of the agencies, such as Houston Galveston Area Council, has developed factors to reflect the air quality conditions, While others, such as Maricopa Association of Governments, is contemplating the options of incorporating the weekend travel by capturing recreational behaviors.

On the other hand, most MPOs have put the weekend travel demand forecast model on the back burner. For example, a staff from SEMCAP mentioned that we may consider it after this round of RTP process. Another staff from Sacramento Area Council of government mentioned that they are currently developing an activity based model and hoping that it will be a better base for weekend travel demand forecasting.

The responses mentioned a wide variety aspect for factors that affect weekend travel characteristics, which are consistent with the factors we have discussed in the Technical Memorandum I. The most recognized difference between weekend and weekday travel is the trip purpose. A number of respondents mentioned more non-working, recreational trips on weekend, more trip training and higher occupancy rate on weekend. Another frequently mentioned characteristic of weekend travel is the temporal distribution. Most responses emphasized the seasonal changes of weekend travel, differences between Saturday and Sunday, and peaking characteristics of each weekend day, which are different from weekday traffic distributions. An example from the west coast demonstrated that ferries are more congested in summer season. Other factors suggested by the survey participants include trip purposes, travel length, life style, current traffic, and auto occupancy.

The consensus is clear that the first step to understand people's behavior over the two weekend days is a household travel behavior survey to capture the entire period from Friday afternoon to early Monday morning. However, as demonstrated by one New Jersey respondent, a local household travel behavior survey may not provide enough data since recreational attractions might also attract people from out of states, so he suggested that an external cordon survey might need to be included.

The suggestions for the modeling structure, ranged from applying a simple factor to complex four step models, to tour or activity based models. The majority responses are along the line of traditional four step models with emphasis on trip generation and mode split steps. A number of responses identified activity or tour based and also recognized the increased cost and effort to develop such models. Is there a consensus? It has largely to do with questions that are to be answered, as rightly pointed out by one respondent. For example, weekend congestion around regional shopping centers or tourist destinations could be analyzed by assigning estimated trip tables from traffic counts. Analysis of weekend regional air quality concerns could require traditional four step models.

The Roles of Special Generators

As directed by the project client, New Jersey Transit, we have added a question on special generators to the MPOs that we have surveyed in the later stages. As expected, a number of land use types have been modeled by various travel demand forecast models, ranging from airport, medical centers, colleges, ports, stadiums, retail malls, science centers, and downtown centers. One of the MPOs in Texas included non-residential adjustment by factoring hotel room occupancy rates. Another MPOs in Arizona estimated trip generation rate for airport and universities using gross factors. The Puget Sound Regional council actually modeled three major exhibition locations not for their sporting functions, such as football, baseball but when they were used for exhibition purposes. The gross factors for trip generation based on exhibition function are derived from regional population bases. The same MPO also modeled ports for heavy truck traffic since over the years, port volume has increased twice fast as fast as the population.

To obtain a general trip generation rate for various land use types, the research team has compiled a trip generation table with both weekday and weekend characteristics based on ITE trip generation manual (ITE, 1998). As a result, different trip generation rates for weekend and weekdays are observed and collected for various ports and terminals, industrial, agricultural, residential, lodging, recreational, institutional, medical, office, and retail establishments.

A general analysis revealed that a few selected categories, such as church, Cemetery, Beach Park, State Park, National Monument, nursing home, motel and military base all have higher trip generation rates for at least one weekend day than weekdays. On the other spectrum, warehouse, industry park, office park, daycare center, general light industrial park, business park, high school, truck terminal, manufacture, and library all have significant lower weekend trip generation rates than weekdays. A mixed picture has been observed for other categories, such as hotels, Universities, hospitals, and planned unit residential development, where the weekend attractions can be anywhere between 50 to 120 percent of weekday volume.

Given the ranges of the modeling structures suggested, the research team concluded that the factor approach is probably the least expensive and easiest to accomplish. However, it will not capture the differences between weekday or weekend travel behavior and unique spatial and temporal distributions of each. The activity and tour based model may be expensive and time consuming to accomplish, however it will provide the most comprehensive understanding of weekend travel and produce reliable travel demand forecast for the future. But it demands extensive data collection and may encounter difficulties to be incorporated within the routing modeling structures in New Jersey MPOs.

New Jersey Transit is concerned that the weekend mode split may be different from the generally perceived patterns observed in other places. The focus of this project is to capture the true differences in mode share between weekday and weekends, the research team is suggesting an approach to start with a basic four step modeling structuring with emphasis on special generators, which have the potential to attract more weekend travel than weekdays, and more non-working trip than commuting trips. Another emphasis of this approach would be placed on mode share on weekend. A series of surveys and analyses should be included to prove or disapprove that mode share on weekend is different from weekdays, and the actually patterns and magnitude of each.

Weekend Travel Data

As mentioned repeatedly in both surveys presented in last section, household surveys are important resources that provide us with valuable information about travel preferences and demographic information across the population. This section described two major series of data that directly deal with weekend travel and are available to the research team.

Household Travel Surveys

In order to store, preserve, and make the resources more publicly available, Bureau of Transportation Statistics and the Federal Highway Administration have funded a project at the University of Minnesota to develop a Metropolitan Travel Survey Archive. The databases along with relevant documentation for many regions were posted at http://www.surveyarchive.org. Presently there are over 60 surveys from 28 metro areas and states together with documentation and reports available on the project web site. Among these data sets, the research team has identified five set of surveys that have weekend travel data since 1990s, as listed in Table 22.

Table 22. Household travel surveys including weekend data

Agency	Major City	State	Year
Southern California Association of Governments	Los Angeles	CA	2001
Metropolitan Transportation Commission-Oakland	San Francisco	CA	2001
Atlanta Regional Commission	Atlanta	GA	2001
City of Calgary	Calgary	Canada	2001
Metro	Portland	OR	1994

Four of the five sets of household travel surveys were conducted in 2001 and one in 1994. The four surveys in the United States used similar format, travel dairies for two consecutive days of the week and City of Calgary used a one day dairy. That is a “two-day activity diary” was collected by each of the survey. Each individual in the households was required to submit a complete diary records of all travel made for a 48-hour period. For example, households might be assigned to record their travel information on Sunday and Monday or Monday and Tuesday. However, each individual provided information on only one weekend day in the survey (i.e. an individual was surveyed on either Friday and Saturday or Sunday and Monday, but not on Saturday and Sunday).

Atlanta Household Travel Survey, conducted in 2001, was to be used in calibrating travel demand models for travel forecasting, land use planning, and air quality planning for the 13 counties in the Atlanta region. A total of 8,069 Atlanta households, representing 0.5% of total households in the metropolitan area, participated in the survey, which included 18,326 persons, 15,050 vehicles, and 151,401 places visited during the 48-hour travel period.

A typical format used in two day travel diary was used in 2001 Atlanta Household Travel Survey. The information collected in the survey includes type of activities, the type of activity participation locations, departure and arrival times of activity participation, and the geographic locations of activity participation, as exhibited in Table 23. The survey also collected data on individual and household socio-demographics, individual employment status, dwelling type and household vehicle ownerships.

San Francisco Bay Area Travel Survey (BATS) conducted in 2000. This survey was designed and administered by MORPACE International Inc. for the Bay Area Metropolitan Transportation Commission. The survey collected information on all activity and travel episodes undertaken by individuals from over 15,000 households in the Bay Area for a two-day period

The information collected on activity episodes included the type of activity (based on a 17-category classification system), the name of the activity participation location (for example, Jewish community center, Riverpark plaza, etc.), the type of participation location (such as religious place, or shopping mall), start and end times of activity participation, and the geographic location of activity participation. Travel episodes were characterized by the mode used, and the start and end times of travel. Furthermore, data on individual and household socio-demographics, individual employment-related characteristics, household auto ownership, and Internet access and usage were also obtained.

Two major efforts were undertaken to conduct the Portland survey. First the four MPO areas were surveyed in 1994-95 with a few extra surveys conducted in Marion, Polk, and Yamhill counties. Eight additional counties scattered across the state were surveyed in 1996. In all, the surveys covered 16 counties and included nearly 15,000 households, among which 11,762 were conducted in 1994 in the first round, and 3,193 in the second round. The total resulting data base includes over 250,000 person trip records. The participating households committed to providing: two day diaries of all activities lasting more than 30 minutes or requiring travel, the location of all of their activities, such as home, work, school, university, shop, recreation, daycare, and other. The survey also collected household demographics, persons, workers, age, income, autos, etc.

Table 23. Data types covered in travel dairies in Atlanta household survey

Types of Activities	Activity Locations	Travel Modes
1 Eating/preparing meals at home/Dining out/Drive thru	1 Home	1 Auto/Van/Truck - Driver
2 Entertainment	2 Work	2 Auto/Van/Truck - Passenger
3 Visit friends/relatives	3 School (Daycare-12th)	3 Transit - MARTA bus
4 Working	4 College/Vocational school	4 Transit - CCT bus
5 Work related business sales call, conference, errand)	5 Already used	5 Heavy rail - Marta
6 School (attending classes)	6 New place	6 Dail-a-ride/paratransit
7 Incidental shopping (groceries, gas, meds)	9 Out of area	7 School bus
8 Major shopping (furniture, clothes, auto, etc)		8 Taxi, shuttle bus, limousine
9 Watching children		9 Motorcycle/moped
10 Household work/Outdoors work		10 Bicycle
11 Fitness/Exercising		11 Walk
12 Outdoor recreation (vacation, camping, sightseeing, etc.)		12 Intercity bus (greyhound,Trailways)
13 Medical/Dental (appointment, treatment, procedure)		13 Airplane
14 Community meetings, political/civic events, public hearing		14 Intercity train (Amtrak)
15 Worship/religious meeting		
16 ATM, banking, post office, bill payment		97 Other
17 Waiting for transportation		
18 Drop off/Pick someone up		
19 Sleep		
21 Rest/Relax		
22 Pick up something/Drop something off		
23 Personal (bath, shower, get dressed)		
24 Personal Business		
25 Volunteer work		
26 Getting Ready		
27 Other at home activities (homework, reading, playing)		
28 Work related from home/doing work from home		

The survey result is presented in three major files, household information, person information, and activity information. The household file contains household physical address and phone number; type, own/rent, years of residence; household size; vehicle information and household income. Personal information includes names of the person, relationship with the household head, gender, age, licensed, employment status/occupation, telecommute, education, ethnic, and disabilities. Finally, the activity file contains detailed information on each activity lasting more than 30 minutes or requiring travel: activity type, place where the activity took place, start and stop times (duration), whether the activity involved a trip, if yes, the trip duration, mode of transportation, vehicle availability, specific vehicle used, pay to park if by car, and number of people in the vehicle.

Southern California Travel and Congestion Survey was conducted in 2001. It is a major survey of travel patterns in the Southern California Association of Governments (SCAG) region. The study occurs once every 10 years to gather detailed information on where people travel, why they travel, and how they travel. However, the data set is unavailable on the internet. Attempts to obtain it from MPO was not successful, thus no further information was obtained.

Another source of data may be difficult to access due to different data share protocols from different countries and culture. According to Stopher (2006), The Sydney Household Travel Survey (HTS), a continuous survey, collects data on weekend travel, as did the last Adelaide HTS. The Victoria Activity Travel Survey (VATS) also collected data on weekends throughout its duration of a number of years. However, it is not clear whether any weekend model has been built from the weekend data collected there.

On-Board Transit Surveys

In recent years, there has been a growing awareness of the need to enhance public transit services to relive congestions on the roads. As a result, it has become very important for public transit agencies to carefully evaluate the services so as to provide the more efficient and desirable transit services to the community that it serves. Public transit customer surveys can play an important role in the evaluation of current and planned public transit services. Table 24 presents the most recent transit on board surveys we have access to.

As a regionally focused survey, the Atlantic Regional Council (ARC) On-board Transit Survey was conducted among fixed route riders including both bus and rail in the Metropolitan Atlanta Regional Transit Authority (MARTA), Cobb Community Transit (CCT), Clayton County, and Gwinnett County transit systems. The data collection period began Saturday, October 13, 2001 and continued through Sunday, December 9, 2001. The survey did not include paratransit or demand-responsive service or special event shuttles. It collected origin and destination data, demographic characteristics including household size, vehicle availability, access and egress modes, and public transit use.

The primary objective of the ARC on board survey is to update input for the regional travel demand models. The transit on-board survey was designed to provide critical information on travel patterns, demographics, transportation options, and mode choice for transit-using residents of the 13-county Atlanta region. The survey has collected information on 25,522 trips during weekday and 5,722 trips during weekend, roughly equating to an 80% and 20% split among weekday and weekend trips respectively. The split of sample size matches the region's local transit service split.

Interesting findings are highlighted in the survey summary report (ARC, 2002). Similar to other metropolitan areas, public transit in the Atlanta region is mainly used, during the week, for non-discretionary trips, such as work or school, rather than for discretionary trips, such as shopping, social or recreation. Weekend respondents are slightly younger than weekday respondents with 31% weekend and 26% weekday respondents between the ages of 16 and 24.

Table 24. Transit on board surveys

Survey	Survey Date	Sample Size	Weekday	Weekend
Atlantic Regional Council On Board Survey	2001	31,244	25,522	5,722
Hudson Bergen LRT On Board Survey	2005	2,682	Frequency*	Frequency*
River Line Full OD Survey	2004	6,111	3621	2490
PATH Survey	2004	15,850	10922	4928

*Frequency – see Figure 30 below

The Hudson Bergen LRT on board survey was carried out in 2001 and 2005. The 2001 survey consists of 1,213 survey responses and the 2005 survey 2, 682. Information contained in the survey includes on and off board stations, detailed origin and destination locations, access and transfer mode, trip purpose, return trip information, ticket payment method, and service satisfaction rate. The survey does not indicated day of week of each trip, but it asked for the frequency of using Hudson Bergen LRT on a typical day, including weekend.

As shown in Figure 30, the majority of the survey respondent, about 70%, uses Hudson Bergen Light rail twice a day on weekday. About 75% of the survey respondents use the facility at least once a day on any typical weekdays.

However, most of the survey respondent, 77% on Saturday and 86% on Sunday, does not use the facility during the week at all. Trip frequencies on Hudson Bergen Light rail is the lowest on Sunday, with only 10% of the respondent taking the trip twice.

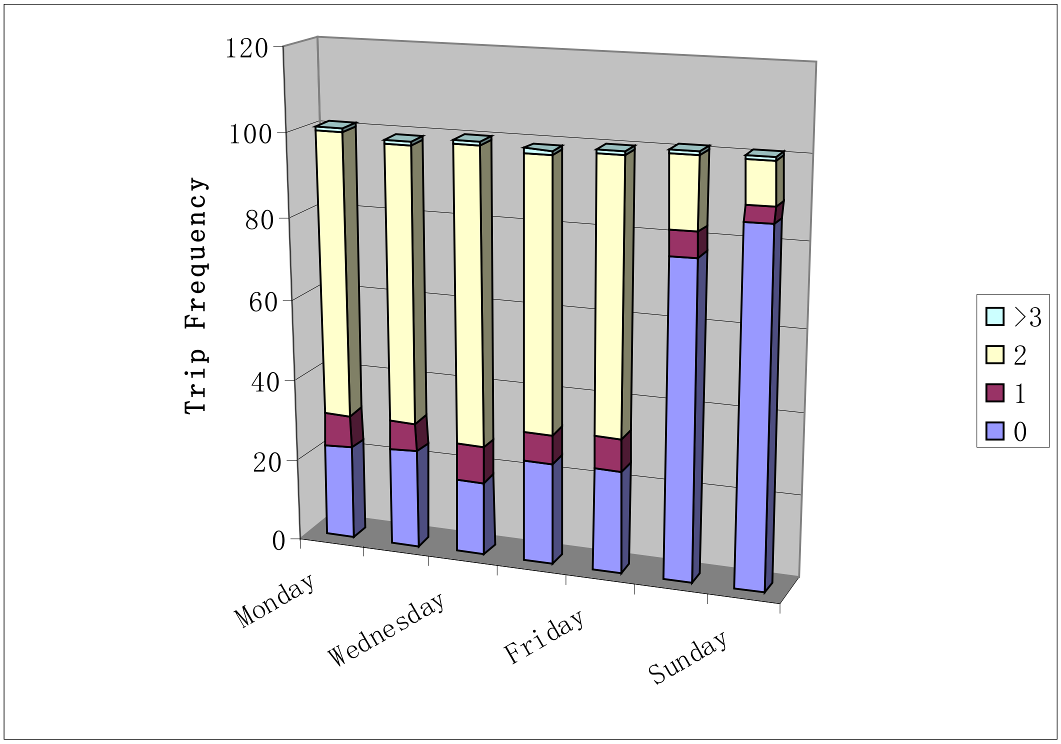


Figure 30. Typical one-way trip frequencies
Hudson Bergen Light Rail Transit

The 2004 River Line Survey, a customer satisfaction survey, was conducted for River LINE in fall 2004 after its launch in March. Altogether 6,111 interviews were collected, with 3,621 weekday interviews and 2,490 weekend interviews. Information collected in this survey include on and off station, connection mode, detailed address of OD, trip purpose, trip frequency, transit fare payment method, number of people traveling, and travel experience on River Line. Demographic information includes age, gender, household income, and race.

2004 PATH survey -- PATH survey was carried out in 1996, 2001, and 2004. The 1996 and 2001 survey questions were distributed at PATH stations and then mailed back to central office. The 2004 survey was a platform-intercepted with passengers interviewed at stations while awaiting trains. The survey form was programmed into a hand-held Palm Personal Digital Assistant (PDA). The main questions asked at each station includes boarding and lightening station, detailed address of OD, access and transfer mode, time of boarding, trip purpose, time of day, and trip frequency. A total of 15,850 interviews were conducted in 2004 PATH survey, among which 10, 922 contain weekday travel information and 4,928 contain weekend travel information.

Other Surveys Conducted In New Jersey

There are two other surveys conducted in New Jersey that may lend some useful data or methodology to this particular study. Both surveys were conducted in 2002 by NJ Transit and both of them address trip frequencies in the survey but via different audiences.

- Rail ePanel Survey 2002
- Interstate Bus Survey 2002

The Rail ePanel survey was launched in 2002 as the internet-based Rail Customer Satisfaction Survey, the most ambitious market-research endeavor in its 23-year history. An independent research firm was hired to handle recruitment and data collection. Patrons were recruited at rail stations and onboard trains. Recruited customers were asked to fill out a brief survey online four times -- once every quarter for a 12-month period. When taking subsequent surveys, participants will be given their responses from the previous survey. Quarterly surveys will allow NJ Transit to track trends, changes and improvements in satisfaction throughout the year. The first wave consists of three panels and 122,471 responses.

Rail transit users were asked to rate their parking experiences, conditions of boarding and destination stations, conditions of trains, schedule, performance during service disruptions, and finally the overall experience with NJ Transit. A list of drill down questions was designed to follow the change of customer's ratings. The rail users were also asked to rate how well NJ Transit handles complaints. The survey also collects information on how frequently the interviewer traveled by NJ Transit rail on weekdays and weekends, as shown in Figure 31. The survey also classifies the users as frequent or infrequent weekday or weekend user.

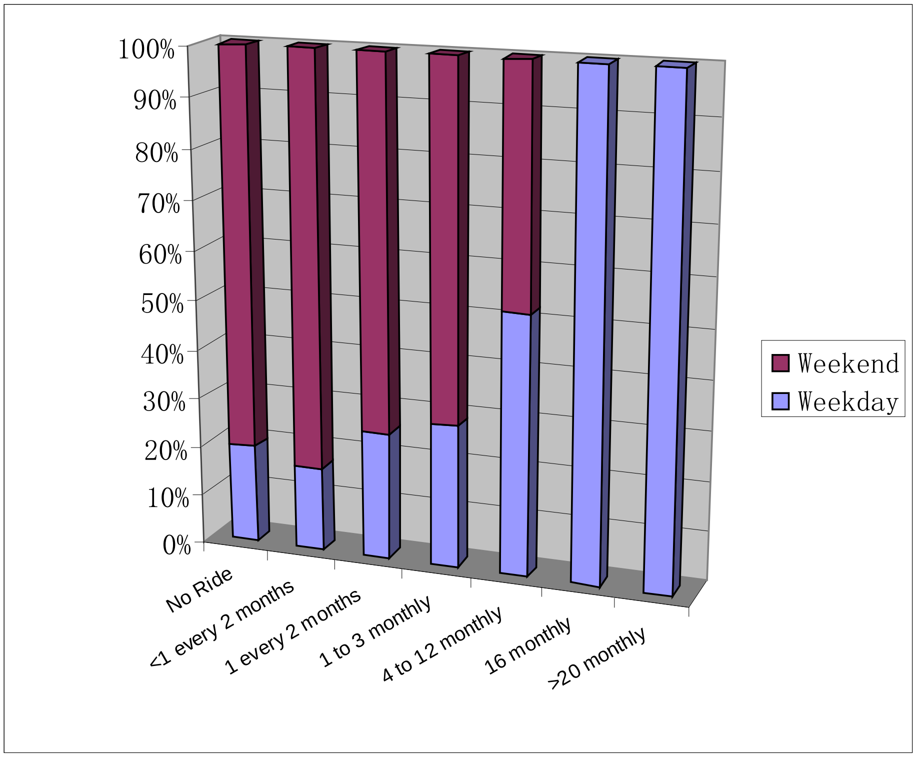


Figure 31. Typical round trip frequencies on NJTRANSIT

The 2002 Interstate Bus Survey was distributed to bus passengers departing the Port Authority Bus Terminal, Lower Manhattan and the George Washington Bridge bus terminal for an entire day. The survey was distributed to both NJ Transit and private bus operators.

This survey records travel information on origin and destination, boarding and de-boarding station, departure time, connection/transfer mode, bus route, and customer satisfaction rate. Demographic information includes age, gender, language, household size, and number of employees in the household. The survey does not have trip characteristics on weekday and weekend, but has trip frequencies on each day of the week made by the respondents.

Figure 32 presents the result from the interstate bus survey. The majority of the surveyed people, about 70%, take two trips a day by the interstate buses during weekdays. About 85% of the survey respondent will use the bus services at least once everyday during the weekday. However, the majority of the survey respondents on weekend, about 77% on Saturday and 87% on Sunday do not use the bus services at all.

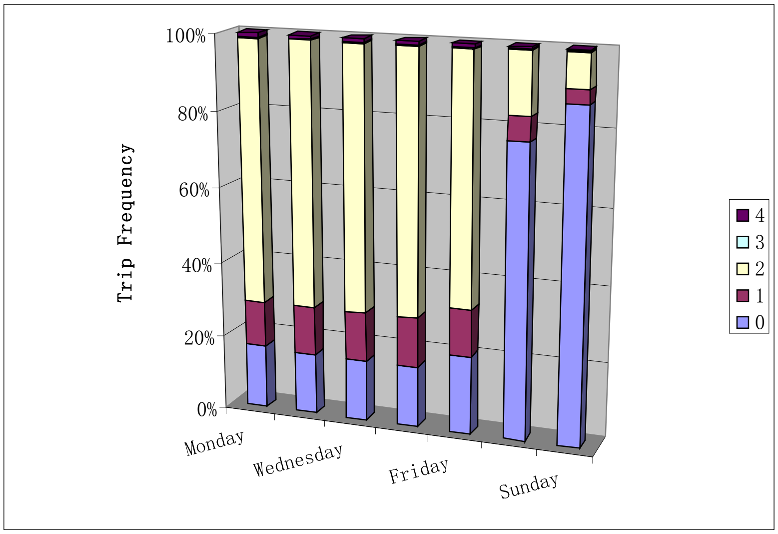


Figure 32. Trip frequencies by interstate bus survey

Summary

Both MPO and TMIP list server surveys conducted in this task confirmed our anticipation that systematic or general methodology for estimating travel demands, and mode choice in particular, do not exist for weekend travel analysis. The research team have identified potential major special generators during weekend period, especially those that significantly exceed weekday trip generation knowing that weekend travel is dominated by non-work travel as well as very specific peak and off-peak periods quite different from weekdays,.

Travel behavior refers to a number of different choices that people make regarding how they get from one place to another. Primary among these is the total time spent traveling each day; but it also includes the mode used, speed, the total number of trips per day, and whether to travel at all in a given day. A number of household travel survey and transit on board survey data sets are included in this document, which will serve the starting point for the development of weekend travel demand forecast and mode choice models.

As the immediate next step, a model development strategy will be mapped out to incorporate the findings of this task and that from evaluation of existing travel demand models used in New Jersey. A model specification or pilot modeling structure, if possible, will be developed in the next phase of this project.

APPENDIX 4. BUS SURVEY INSTRUMENT

An Official survey of NJ TRANSIT, Coach USA and
the Port Authority of New York and New Jersey

Weekend Bus Customer Survey

NJ TRANSIT and Coach USA are conducting this survey to better understand your travel needs. Please take a few minutes to complete this survey and return it in the collection envelope provided on-board your bus or drop it in any U.S. mailbox, postage free. To show our appreciation we will enter your name in a drawing to win **a $100 cash prize. Please be assured that all responses will be kept confidential.**
Thank you for your participation.

For Your Trip Today...

1. What is the scheduled departure time of this bus?

☐☐ : ☐☐ ❍ AM ❍ PM

Hour *Minute* *(Please select AM or PM)*

2. How did you get to the Port Authority Bus Terminal? *(Please select primary method only)*

- ❍ Walk only
- ❍ NYC Subway ____________________ *(please specify lines used)*
- ❍ NYC Bus ________________________ *(please specify route)*
- ❍ Other Bus _____________________ *(please specify carrier & route)*
- ❍ Taxi
- ❍ Car – dropped off
- ❍ Other _______________ *(please specify)*

3. Where are you coming from? *(Please select one)*

- ❍ Work
- ❍ Home
- ❍ Recreational/Entertainment
- ❍ Other

4. What is that address...?

____
Number & Street OR Intersection OR Landmark

____
Town/Boro *State* *ZIP Code*

5. Where will you get off **this bus** *(bus stop/terminal)*?

____
Street, Intersection, Location, Park/Ride OR Terminal (your bus stop)

____
Town/ Municipality *State* *ZIP Code*

6. Where are you going *(your **final destination**)*? *(Please select one)*
   - ❍ Work
   - ❍ Recreational/Entertainment
   - ❍ Home
   - ❍ Other

7. What is that address...?

____
Number & Street OR Intersection OR Location

____
Town/ Municipality *State* *ZIP Code*

8. How will you reach your final destination after you get off this bus?

(Please select primary method only)

- ❍ Walk only
- ❍ Car, drive parked car
- ❍ Car, picked up
- ❍ Carpool
- ❍ Taxi
- ❍ Another bus ____________________ *(please specify carrier & route)*
- ❍ Other ____________________ *(please specify)*

9. What time did you (will you) reach your final destination?

☐☐ : ☐☐ ❍ AM ❍ PM

Hour *Minute* *(Please select AM or PM)*

For the other half of your round trip earlier (or later) today...

10. How did you (will you) travel for the other half of your round trip today? *(check all that apply)*

- ❍ Same bus route
- ❍ Different bus route(s) ______________________ *(please specify carrier & route)*
- ❍ Train ________________ *(please specify)*
- ❍ Auto/Van
- ❍ Other ________________________ *(please specify)*
- ❍ Not making a round trip

11. If you selected **bus** for the other half of your trip, what was (will be) the scheduled arrival time of the bus in New York City?

☐☐ : ☐☐ ❍ AM ❍ PM

Hour *Minute* *(Please select AM or PM)*

12. What is the main purpose of this trip?

- ❍ Going to/Coming from work
- ❍ Company business (e.g., attend seminars/sales calls)
- ❍ Personal business (e.g., medical/visiting)
- ❍ Social (e.g., meeting friends/family)
- ❍ Shopping
- ❍ Recreation (e.g., dining/entertainment/vacation)
- ❍ School
- ❍ Other ________________ *(please specify)*

13. What type of ticket are you using for this trip? *(check one)*
❍ One-way/Cash ❍ Monthly ❍ Senior Citizen/Customer with disability
❍ Round Trip ❍ Multi-trip ❍ Other ______________ *(please specify)*

14. Why did you **not use a car** for this trip?
❍ A car was not available
❍ A car was available, but it was not the best choice for this trip

15. Why did you **not use a train** for this trip?
❍ A train was not available
❍ A train was available, but it was not the best choice for this trip

16. Are there any other reasons why you are making this trip **on a bus**?
❍ No
❍ Yes _______________________ *(please specify)*

In general...

17. How many times per month do you travel to New York **by public transportation on weekdays**?

☐☐ times per month

18. How many times per month do you travel to New York **by public transportation on weekends**?

☐☐ times per month

19. How many times per month do you travel to New York **by auto on weekdays**?

☐☐ times per month

20. How many times per month do you travel to New York **by auto on weekends**?

☐☐ times per month

21. Are you making this trip alone or with others in a group?

- ❍ I am traveling alone
- ❍ I am traveling in a group of _________________ people
  (please specify number in group, including yourself)

22. In the chart below, please provide us with the information about **each of the other persons** who may be traveling together with you as a group – their age, gender, how they paid the fare today, and about how often each month they make a transit trip like this to or from New York?

Other Persons in your group:

Other Person	Age	Gender	Paid with Monthly:	*How many **Weekdays** travel this route*	*How many **Weekend** days travel this route*
		M or F	*Yes or No*	*# days per month*	*# days per month*
1					
2					
3					
4					
5					

Please tell us about yourself…

23. Are you…? ❍ Male ❍ Female

24. What is your age?
    - ❍ Under 18 years
    - ❍ 18 - 24 years
    - ❍ 25 - 34 years
    - ❍ 35 - 44 years
    - ❍ 45 - 54 years
    - ❍ 55 - 64 years
    - ❍ 65 years and over

25. In which occupational group do you place yourself?
    - ❍ Sales/Retail
    - ❍ Student
    - ❍ Homemaker
    - ❍ Clerical/Secretarial
    - ❍ Management/Professional
    - ❍ Non-Office Worker
    - ❍ Not currently employed
    - ❍ Retired
    - ❍ Other _________________________ *(please specify)*

26. How many people including yourself, live in your household?
    - ❍ 1
    - ❍ 2
    - ❍ 3
    - ❍ 4
    - ❍ 5
    - ❍ 6 or more

27. How many children under 18 years of age, live in your household?
    - ❍ 1
    - ❍ 2
    - ❍ 3
    - ❍ 4 or more

28. How many people in your household are currently employed?

- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ 6 or more

29. What is your annual household income?
- ❍ Under $15,000
- ❍ $15,000-$24,999
- ❍ $25,000-$34,999
- ❍ $35,000-$49,999
- ❍ $50,000-$74,999
- ❍ $75,000-$99,999
- ❍ $100,000-$149,999
- ❍ $150,000-$199,999
- ❍ $200,000-$249,999
- ❍ $250,000 and over

To enter our drawing for a $100 cash prize, please include your home address:

Name_________________________________ Day phone # ___________________

Street Address ____

Township/Municipality ______________________ State _____ Zip ___________

Email Address ____

Please return completed surveys to the collection envelope or survey agent on the bus, or drop it in any U.S. mailbox (postage is paid).

All responses will be kept confidential.

Thank you for participating in the survey!

APPENDIX 5. RAIL SURVEY INSTRUMENT

Weekend Rail Customer Survey

NJ TRANSIT is conducting this survey to better understand your travel needs. Please take a few minutes to complete this survey and drop it in the collection boxes at Newark or New York Penn Station, or in any U.S. mailbox, postage free. To show our appreciation we will enter your name in a drawing to win **one of five $100 cash prizes. Please be assured that all responses will be kept confidential.**
Thank you for your participation.

Thank you!

ABOUT YOUR TRAIN TRIP TODAY . . .

1. At what station did you board this train today?

- ❍ Hamilton
- ❍ Princeton Junction
- ❍ New Brunswick

2. What was the scheduled departure time for this train?

☐☐ : ☐☐ ❍ AM ❍ PM

Hour *Minute* *(Please select AM or PM)*

3. How did you get to the train station? *(Please indicate your primary mode and select one circle)*

- ❍ Walk only
- ❍ Drove alone and parked
- ❍ Carpooled and parked
- ❍ Passenger in carpool
- ❍ Car-Dropped off
- ❍ Bus/Shuttle ______________________________ *(Specify carrier/bus route)*
- ❍ Shuttle ______________________________ *(Specify operator/ route)*
- ❍ Princeton Dinky
- ❍ Other ______________________________ *(Specify)*

5. Where did you begin this trip today?

❍ Home ❍ Work ❍ Other

______________________________ *(Please specify)*

6. What is that address *(not your boarding station)*? ***(Please print clearly)***

____

Company Name/Business/School/Landmark

____

Street Address (or nearest intersection/landmark)

________________________ ☐☐ ☐☐☐☐☐-☐☐☐☐

Borough/Town/City *State* *Zip Code*

7. At what station will you get off the NJ TRANSIT train *(If you switch to another NJ TRANSIT train in New Jersey, tell us where you will finally exit the railroad)*?

- ❍ NY Penn Station
- ❍ Newark Penn Station
- ❍ Newark Liberty International Airport Station
- ❍ Other ______________________________ *(Please specify)*

8. Where is your final destination?

❍ Home ❍ Work ❍ Other ________________________ *(Please specify)*

9. What is that address *(not your exiting station)*? ***(Please print clearly)***

____

Company Name/Business/School/Landmark

____

Street Address (or nearest intersection/landmark)

________________________ ☐☐ ☐☐☐☐☐-☐☐☐☐

Borough/Town/City *State* *Zip Code*

IF GOING TO NEW YORK . . .

10. How will you complete your in-bound trip to New York today? *(Select your primary mode only)*

- ❍ Stay on this train to New York Penn Station
- ❍ At Newark Penn switch to PATH __________ *(Please specify your deboarding station)*
- ❍ Other ____________________________________ *(Please specify)*

11. Once in New York, how will you reach your final destination? *(Select primary mode only)*

- ❍ Walk only
- ❍ NYC Subway ______________________ *(Specify the first line used)*
- ❍ NYC Bus ______________________________ *(Please specify)*
- ❍ Taxi
- ❍ Auto
- ❍ Other __________________________________ *(Please specify)*

Skip to Question 13

IF GOING TO NEW JERSEY . . .

12. How will you travel to your final destination from your NJ TRANSIT exiting station? *(Select all that apply)*

- ❍ Walk only
- ❍ Auto drive
- ❍ Auto pick-up
- ❍ Taxi
- ❍ PATH _________________________ *(Please specify station you deboard)*
- ❍ Bus/Shuttle ______________________ *(Please specify carrier and route)*
- ❍ Newark City Subway _________________________ *(Please specify station you deboard)*
- ❍ Hudson-Bergen Light Rail ____________________ *(Please specify station you deboard)*
- ❍ Switch to another commuter train at _____________ *(Please specify station you switch)*
- ❍ Other ____ *(Please specify)*

FOR ALL CUSTOMERS, FOR THE OTHER HALF OF YOUR TRIP . . .

13. **How do you usually travel for the other half of your trip?**

- ❍ Take the train, but in the opposite direction
- ❍ Take a bus ↓ _________________ *(Please specify)*
- ❍ Auto
- ❍ Other ____________________ *(Please specify)*

14. What will be(was) the scheduled departure time for this train? ↓

☐☐ : ☐☐ ❍ AM ❍ PM

Hour *Minute* *(Please select AM or PM)*

FOR ALL CUSTOMERS, FOR YOUR TRIP TODAY . . .

10. What time did you (will you) reach your final destination?

☐☐ : ☐☐ ❍ AM ❍ PM

Hour *Minute* *(Please select AM or PM)*

11. Why did you **not use a car** for this trip?
- ❍ A car was not available
- ❍ A car was available, but it was not the best choice for this trip

12. Why did you **not use a bus** for this trip?
- ❍ A bus was not available
- ❍ A bus was available, but it was not the best choice for this trip

13. Are there any other reasons why you are making this trip **on a train**?
- ❍ No
- ❍ Yes ________________________ *(please specify)*

15. What is the main purpose of this trip? *(Select one circle only)*
- ❍ Work
- ❍ Company business (e.g., attend seminars/sales calls)
- ❍ Shopping
- ❍ Social (e.g., meeting friends/family)
- ❍ Recreation *(e.g., dining/entertainment/vacation)*
- ❍ Personal business *(e.g., medical/visiting)*
- ❍ Other ____*(Specify)*

16. What type of train ticket are you using for this trip?
- ❍ Monthly
- ❍ Senior citizen/Customer with a disability
- ❍ 10-Trip
- ❍ Student Monthly Pass
- ❍ Off-peak Round trip
- ❍ Other ________________________ *(Specify)*
- ❍ One-way

17. How likely are you to recommend this service to a friend or relative?

❍	❍	❍	❍	❍
Very Likely	Somewhat Likely	Do not Know	Somewhat Unlikely	Very Unlikely

18. Are you making this trip alone or with others in a group?

❍ I am traveling alone

❍ I am traveling in a group of _______________ people

(please specify number in group, including yourself)

19. In the chart below, please provide us with the information about **each of the other persons** who may be traveling together with you as a group – their age, gender, how they paid the fare today, and about how often each month they make a transit trip like this?

Other Persons in your group:

Other Person	Age	Gender	Paid with Monthly:	*How many **Weekdays** travel this route each month*	*How many **Weekend** days travel this route each month*
		M or F	*Yes or No*	*# days*	*# days*
1					
2					
3					
4					
5					

20. How many times per month do you travel to New York **by public transportation on weekdays**?

☐☐ times per month

21. How many times per month do you travel to New York **by public transportation on weekends**?

☐☐ times per month

22. How many times per month do you travel to New York **by auto on weekends**?

☐☐ times per month

TELL US ABOUT YOURSELF . . .

23. **Are you ... ?**

❍ Male

❍ Female

24. **What is your age?**

- ❍ Under 18 years
- ❍ 18 - 24 years
- ❍ 25 - 34 years
- ❍ 35 - 44 years
- ❍ 45 - 54 years
- ❍ 55 - 64 years
- ❍ 65 years and over

25. In which occupational group do you place yourself?

- ❍ Clerical/Secretarial
- ❍ Student
- ❍ Homemaker
- ❍ Sales/Retail
- ❍ Non-Office Worker
- ❍ Management/Professional
- ❍ Not currently employed
- ❍ Retired
- ❍ Other ______________ *(please specify)*

26. What is your approximate annual household income? *(Please select <u>one</u> circle.)*

- ❍ Under $15,000
- ❍ $15,000-$24,999
- ❍ $25,000-$34,999
- ❍ $35,000-$49,999
- ❍ $50,000-$74,999
- ❍ $75,000-$99,999
- ❍ $100,000-$149,999
- ❍ $150,000-$199,999
- ❍ $200,000-$249,999
- ❍ $250,000 and over

27. How many people including yourself, live in your household? ___________ *(please specify)*

- ❍ One
- ❍ Two
- ❍ Three
- ❍ Four
- ❍ Five
- ❍ Six or more

28. How many children under 18 years of age, live in your household? ___________ *(please specify)*

- ❍ One
- ❍ Two
- ❍ Three
- ❍ Four or more

29. How many people in your household are currently employed? __________ *(please specify)*

- ❍ One
- ❍ Two
- ❍ Three
- ❍ Four
- ❍ Five
- ❍ Six or more

30. Do you own or rent your current home?

- ❍ Own
- ❍ Rent

If you would like to enter our drawing for ONE OF TEN PRIZES FOR A FREE NJ TRANSIT MONTHLY RAIL PASS OR TWO TICKETS TO A BROADWAY SHOW OF YOUR CHOICE, **please give us your name, address, phone numbers and email address *(Please print clearly)*.**

____
Your name

____
Mailing Address

____________________ ☐☐ ☐☐☐☐☐-☐☐☐☐

Borough/City/Town State Zip Code

Day phone number: Evening phone number:

☐☐☐-☐☐☐-☐☐☐☐ ☐☐☐-☐☐☐-☐☐☐☐

____
Your email address

May NJ TRANSIT contact you for future research? ☐ Yes ☐ No

Your comments are important to us. If you have any specific comments, please...

Call Customer Service: 1-800-772-2222, press '5' for Customer Service
Visit our website: www.njtransit.com
Write: Customer Service, NJ TRANSIT, One Penn Plaza East, Newark, NJ 07105

Thank you for participating in the survey!

Please be assured that all information you provide is strictly for

NJ TRANSIT The Way To Go.

Research

One Penn Plaza East, Newark,

APPENDIX 6. WEEKEND MODEL USER DOCUMENTATION

The NJIT Weekend model Interface and implementation is done in Excel Spreadsheet
(MS Office 2007). It is a nested logit model with eight modes: SOV, HOV, Bus-walk egress, Bus- transit egress, Bus-Taxi egress, Rail- walk egress, Rail- transit egress and Rail-taxi egress. This model includes a policy analysis toolbox.

Below is an explanation of sheets in the model spreadsheet. The set of sheets that should not be altered by user are:

1. **Base**: the consolidated survey records from auto, bus and rail surveys for the corridor are located in this sheet along with Base year level-of-service (LOS) variables.
2. **Policy**: similar to "Base" sheet but the LOS variables are for the policy such as increase in auto toll, improvement of transit service etc, to be analyzed.
3. **Coeff (Work):** Model coefficients for purpose 1, i.e. Work, company business and personal business.
4. **Coeff (Recr):** Model coefficients for purpose 2, i.e. Recreation, Social and Others.
5. **Utility (Base):** Mode Utilities for Base Scenario.
6. **Utility (Policy):** Mode Utilities for Policy Scenario.
7. **Probability**: Mode choice probabilities for both base and policy scenario
8. **Model Structure**: this spreadsheet shows the nested logit model structure
9. **Summary**: comparison reports of mode summaries by purpose for base and policy.

The other sheets, which are part of the policy analysis toolbox, can be altered by the user to define a policy scenario. There are three adjustments types available for users to make to the LOS variables – multiply a factor, add a value or override a value. The adjustment factors can be applied to the following LOS variables-

1. **Auto** - free flow travel time, congestion delays, auto toll;
2. **Bus** – In-vehicle travel time, fare, initial wait time, transfer wait time, walk time, number of transfers, egress transit IVTT, egress taxi travel time, egress taxi fare;
3. **Rail** – In-vehicle travel time, fare, initial wait time, transfer wait time, walk time, number of transfers, egress transit IVTT, egress taxi travel time, egress taxi fare;

These adjustments can be defined by origin and destination districts.

1. **Tazdist:** in this spreadsheet, user can define a TAZ (NJTDFM) to district correspondence. Currently, a maximum of 10 districts can be defined.
2. **Labels:** The district names are defined in this spreadsheet corresponding to label numbers. Also, user can choose the districts to use for analysis. If a district is not chosen, then adjustment factors are not multiplied for these districts. If the user has only five districts defined which cover the whole survey area then district# 6 to 10 will have value 0 in "Use" field. Currently, labels are defined for our survey corridor, i.e. New Jersey and Pennsylvania to Manhattan.

District Name Labeling

District	Name	Use
1	Lower Manh	1
2	Valley	1
3	Midtown	1
4	Upper Manh	1
5	New Jersey	1
6	Pennsylvania	1
7	Other NYC	0
8	Long Island	0
9	NY State	0
10	CT	0

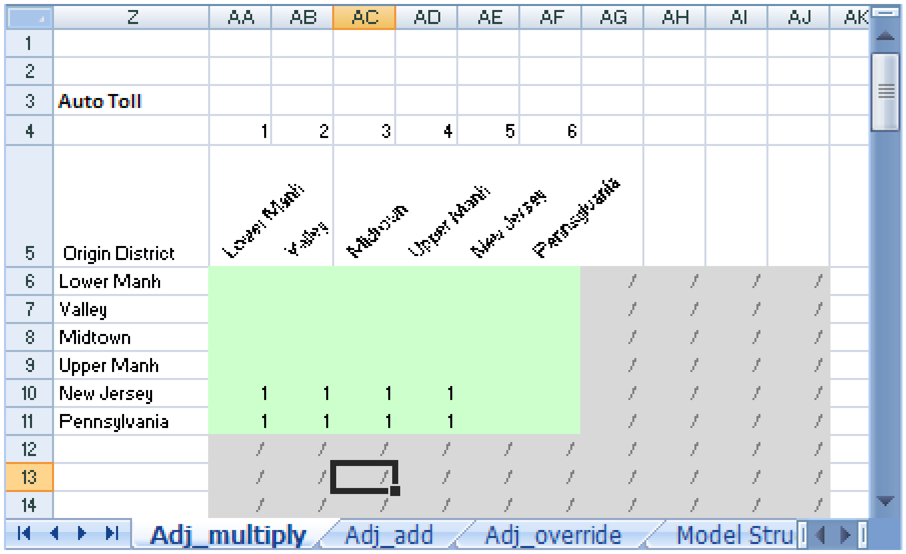
Policy | **Labels** | tazdist | Adjustment

How to Apply Adjustments for Policy Analysis

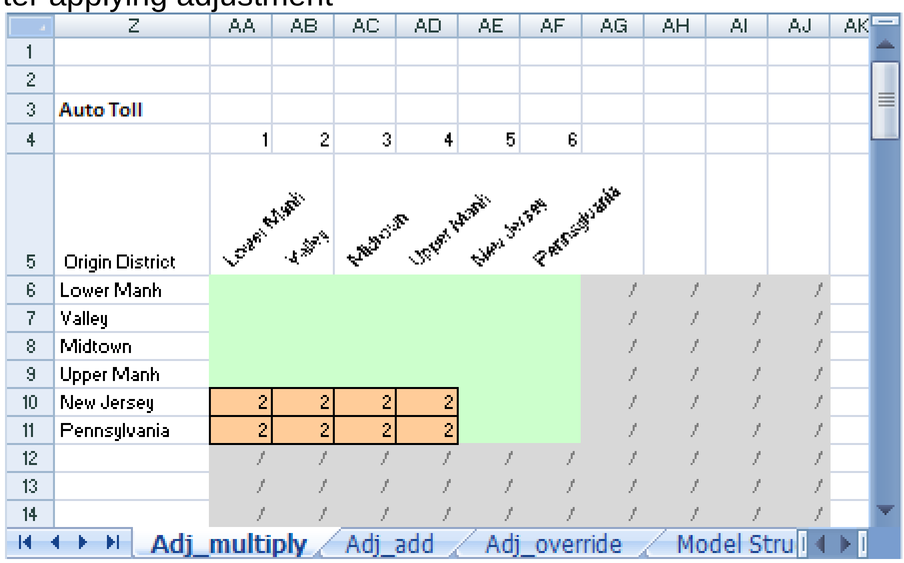
1. **Adj_multiply:** In this sheet, the user can define an adjustment factor which will be multiplied to the base LOS variable to calculate the policy LOS variable. The default value is 1.

   Example: *Setting up Policy scenario using multiplicative factor: Double the Auto Toll*

   Before applying adjustment



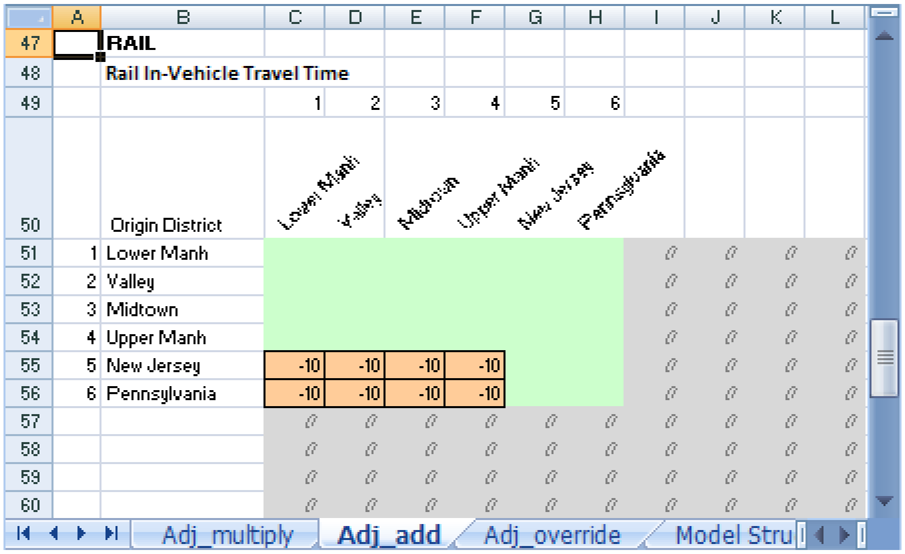
After applying adjustment



Note: when a cell in any of the adjustment sheet is filled with a value other than default, the cell is highlighted in different color. This helps user to quickly check the edits made to the sheet.

2. **Adj_add:** In this sheet, the user can define an adjustment factor which will be added to the base LOS variable to calculate the policy LOS variable. The default value is 0.

   Example: *Setting up Policy scenario using additive factor: Improvement in Rail IVTT by 10 minutes.*



	A	B	C	D	E	F	G	H	I	J	K	L
47		**RAIL**										
48		Rail In-Vehicle Travel Time										
49			1	2	3	4	5	6				
50		Origin District	Lower Manh	Valley	Midtown	Upper Manh	New Jersey	Pennsylvania				
51	1	Lower Manh							0	0	0	0
52	2	Valley							0	0	0	0
53	3	Midtown							0	0	0	0
54	4	Upper Manh							0	0	0	0
55	5	New Jersey	-10	-10	-10	-10			0	0	0	0
56	6	Pennsylvania	-10	-10	-10	-10			0	0	0	0
57			0	0	0	0	0	0	0	0	0	0
58			0	0	0	0	0	0	0	0	0	0
59			0	0	0	0	0	0	0	0	0	0
60			0	0	0	0	0	0	0	0	0	0

3. **Adj_override:** In this sheet, the user can define a policy LOS value to override existing base scenario value. The default value is 0. If override option is used then multiplicative and additive factors are ignored for the LOS variable. This could be used for analyzing transit service extensions etc.

Adjustment factors can be applied for specific origin and destination district pairs. In the above examples, adjustments were applied for all available OD pairs because example policies affected everyone.

4. **AdjustbyOrigin:** This sheet has multiple option adjustment options at origin location:

   a. ***Adjustment for Population Growth***- A factor can be applied to account for change in total number of travelers along the corridor with change in population of origin locations. This factor is multiplied to the weights to get change in total number of trips.

Adjustments by Origin Zones

Changes allowed to these cells

1. Adjustment for Population Growth

SI No.	COUNTY	Base Trips		Population Growth Factor	Trips with Growth Factor	
		Work and Related	Recreation and Others		Work and Related	Recreation and Others
1	Mercer, NJ	1,369	4,023	1.01	1,382	4,063
2	Middlesex, NJ	1,548	3,250	1.00	1,548	3,250
3	Southern Somerset, NJ	283	958	1.10	311	1,054
4	Western Monmouth, NJ	401	914	1.00	401	914
5	Northern Burlington, NJ	171	307	1.00	171	307
6	Eastern Bucks, PA	26	181	1.00	26	181
	Total	**3,798**	**9,633**		**3,840**	**9,769**

Adj_add | Adj_override | **AdjustbyOrigin** | Summary | Model Struc

b. ***Adjustment for Household Income, Age Group Category or Car Availability distribution by Origin Location***- changes can be applied to one of three (income, age group and car availability) variables at one time. However, these changes can be applied with population growth factor.

The base scenario distribution of these variables by County and variable categories provides the default variables. The percentage distribution can be changed for the policy scenario such that the total is 100 percent for each county. Figures below show before and after adjustment of Income group categories in Southern Somerset, NJ. Similarly, adjustments can be applied for Age group category and Car Availability.

Before Adjustment:

2.1 Change in HouseHold Income Distribution

SI No.	COUNTY	Base HH Income Distribution					Policy HH Income Distribution				
		*Unknown***	<50K	50-150K	>150K	Total	*Unknown***	<50K	50-150K	>150K	Total*
1	Mercer, NJ	*12%*	4.3%	51.4%	32.0%	100%	*12%*	4%	51%	32%	100%
2	Middlesex, NJ	*8%*	18.1%	61.1%	13.1%	100%	*8%*	18%	61%	13%	100%
3	Southern Somerset, NJ	*4%*	19.0%	44.3%	33.0%	100%	*4%*	19%	44%	33%	100%
4	Western Monmouth, NJ	*10%*	7.1%	46.7%	35.8%	100%	*10%*	7%	47%	36%	100%
5	Northern Burlington, NJ	*29%*	5.8%	54.3%	11.0%	100%	*29%*	6%	54%	11%	100%
6	Eastern Bucks, PA	*4%*	6.4%	72.5%	17.5%	100%	*4%*	6%	73%	18%	100%

Adj_add | Adj_override | **AdjustbyOrigin** | Summary | Model Structure | Probability | Utility(Policy) | Base Calibr

After Adjustment:

2.1 Change in HouseHold Income Distribution

SI No.	COUNTY	Base HH Income Distribution					Policy HH Income Distribution				
		*Unknown***	<50K	50-150K	>150K	Total	*Unknown***	<50K	50-150K	>150K	Total*
1	Mercer, NJ	*12%*	4.3%	51.4%	32.0%	100%	*12%*	4%	51%	32%	100%
2	Middlesex, NJ	*8%*	18.1%	61.1%	13.1%	100%	*8%*	18%	61%	13%	100%
3	Southern Somerset, NJ	*4%*	19.0%	44.3%	33.0%	100%	*4%*	15%	44%	37%	100%
4	Western Monmouth, NJ	*10%*	7.1%	46.7%	35.8%	100%	*10%*	7%	47%	36%	100%
5	Northern Burlington, NJ	*29%*	5.8%	54.3%	11.0%	100%	*29%*	6%	54%	11%	100%
6	Eastern Bucks, PA	*4%*	6.4%	72.5%	17.5%	100%	*4%*	6%	73%	18%	100%

Adj_add | Adj_override | **AdjustbyOrigin** | Summary | Model Structure | Probability | Utility(Policy) | Base Calibr

After adjustments are applied, go to Summary Sheet for comparison of Base and Policy summaries.

Things to Remember:

1. For level of service variables, if a negative adjustment factor is used and base value + factor is less than zero then policy LOS value is set to 0.
2. If the In-vehicle time for any of the transit modes =0, then the mode becomes unavailable.
3. Multiplicative and additive factors can be used together in one policy scenario.
4. Do not use negative values for multiplicative and override adjustments.

Base Calibration:

Base calibration has to be done once for given set of base scenario inputs to match the observed counts. Currently, in the model spreadsheet the base is calibrated and the final adjusted constants and coefficients are located in the *Coeff* sheets. It would be required to redo calibration if the base year level-of-service variables are changed by the user.

"Base Calibration" sheet summarizes observed share and base scenario and calculates adjusted calibration constants and coefficients for base model run. The calibration is done for the following:

1) Mode Specific Constants
2) Car Availability
3) Destination Dummy – Lower Manhattan, Valley, Midtown, Upper Manhattan
4) Frequency of Travel
5) Gender

6) Age Group

At the top of the sheet, the two factors are defined which can be altered during calibration. The first factor is applied to the adjustment for mode specific constants and the second is applied to all other adjustments (i.e., destination constants, car availability etc.). These factors scale down the adjustment applied to constants/coefficients to help reach convergence. With calibration rounds, the second adjustment factor can be reduced further to refine calibration. Please refer to final report for calibration details.

BASE CALIBRATION SHEET

Factor for Mode Constant	0.5
Factor for all other	0.33

(This factor is applied to adjustment before adding to the Coefficient.)

1. MODE SPECIFIC CONSTANTS

	Work and Related			Recreation and Others			Mode Specific Constants	
Mode	Observed	Base Modeled	% Diff	Observed	Base Modeled	% Diff	Work	Recreation
SOV	735	763	4%	573	578	1%	4.2291	2.8337
HOV	2,741	2,697	-2%	7,502	7,486	0%	6.9446	4.8862
Bus -Walk Egress	40	42	5%	116	119	2%	-1.2635	1.6153
Bus -Transit Egress	10	11	6%	24	23	-1%	-3.2738	0.7131
Bus -Taxi Egress	85	90	5%	109	107	-2%	-1.4180	1.4076
Rail -Walk Egress	125	130	4%	505	512	1%	-6.3030	-1.9599
Rail -Transit Egress	55	58	5%	687	688	0%	-6.8350	-1.7018
Rail -Taxi Egress	6	6		119	119	1%	-8.3281	-3.2709
Total	3,798	3,798		9,633	9,633			

Adj_add / Adj_override / AdjustbyOrigin / Summary / Model Structure / Probability / U

For each variable, the summaries are done by purposes and percentage difference is calculated between observed and base modeled. The percentage change is ignored for very small cell values.

BASE CALIBRATION SHEET

Factor for Mode Constant	0.5
Factor for all other	0.33

(This factor is applied to adjustment before adding to the Coefficient.)

1. MODE SPECIFIC CONSTANTS

	Work and Related			Recreation and Others			Mode Specific Constants	
Mode	Observed	Base Modeled	% Diff	Observed	Base Modeled	% Diff	Work	Recreation
SOV	735	763	4%	573	578	1%	4.2291	2.8337
HOV	2,741	2,697	-2%	7,502	7,486	0%	6.9446	4.8862
Bus -Walk Egress	40	42	5%	116	119	2%	-1.2635	1.6153
Bus -Transit Egress	10	11	6%	24	23	-1%	-3.2738	0.7131
Bus -Taxi Egress	85	90	5%	109	107	-2%	-1.4180	1.4076
Rail -Walk Egress	125	130	4%	505	512	1%	-6.3030	-1.9599
Rail -Transit Egress	55	58	5%	687	688	0%	-6.8350	-1.7018
Rail -Taxi Egress	6	6		119	119	1%	-8.3281	-3.2709
Total	3,798	3,798		9,633	9,633			

Adj_add / Adj_override / AdjustbyOrigin / Summary / Model Structure / Probability / U

Revised constants and coefficient are calculated based on observed and base modeled values as shown in the equation below. The base modeled values change for every round of calibration.

$$\overline{C} = C + \mu \times \log\left[{}^{observed}/_{base\ modeled}\right]$$

Where,

$\overline{C}$ is the revised constant or coefficient,
C is the starting constant or coefficient,
μ is the scaling factor and log term is the adjustment.

BASE CALIBRATION SHEET

Factor for Mode Constant	0.5
Factor for all other	0.33

(This factor is applied to adjustment before adding to the Coefficient.)

1. MODE SPECIFIC CONSTANTS

	Work and Related			Recreation and Others			Mode Specific Constants	
Mode	Observed	Base Modeled	% Diff	Observed	Base Modeled	% Diff	Work	Recreation
SOV	735	763	4%	573	578	1%	4.2291	2.8337
HOV	2,741	2,697	-2%	7,502	7,486	0%	6.9446	4.8862
Bus -Walk Egress	40	42	5%	116	119	2%	-1.2635	1.6153
Bus -Transit Egress	10	11	6%	24	23	-1%	-3.2738	0.7131
Bus -Taxi Egress	85	90	5%	109	107	-2%	-1.4180	1.4076
Rail -Walk Egress	125	130	4%	505	512	1%	-6.3030	-1.9599
Rail -Transit Egress	55	58	5%	687	688	0%	-6.8350	-1.7018
Rail -Taxi Egress	6	6		119	119	1%	-8.3281	-3.2709
Total	3,798	3,798		9,633	9,633			

Adj_add / Adj_override / AdjustbyOrigin / Summary / Model Structure / Probability / U

Similarly, these adjusted coefficients are updated in the Base Calibration sheet for all the six variables discussed above. Then, the user has to copy revised coefficients and constants to the Coeff (Work) and Coeff (Recr) sheets for the two purposes, respectively, for the next round of calibration. This process is repeated till the results are within an acceptable range of observed share. For coefficients (other than mode specific constants), the difference between observed and base modeled for transit modes were compared for all egress modes combined. The cells highlighted in yellow (see figure below) show percentage change in all bus and all rail trips between modeled base and observed.

2. AUTO AVAILABILITY (DUMMY)

	Work and Related Auto Available				Work and Related Not Available			
Mode	**Observed**	**Base Modeled**	**% Diff**		**Observed**	**Base Modeled**	**% Diff**	
SOV	735	763	4%		-	-		
HOV	2,741	2,697	-2%		-	-		
Bus -Walk Egress	34	36	7%		6	6		
Bus -Transit Egress	10	11	2%	3%	-	0		19%
Bus -Taxi Egress	79	81	2%		6	9		
Rail -Walk Egress	101	105	4%		25	25	2%	
Rail -Transit Egress	39	45	15%	7%	17	13	-22%	-7%
Rail -Taxi Egress	6	6			-	0		
Total	**3,744**	**3,744**			**53**	**53**		

Adj_add | Adj_override | AdjustbyOrigin | Summary | Model Struct