

**Data Collection and Modeling Requirements for
Assessing Transportation Impacts
of Micro-Scale Design**

EXECUTIVE SUMMARY

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***Note** – The appendices are not available in this document. They will be furnished at a later date in a separate document called *Data Collection and Modeling Requirements for Assessing Transportation Impacts of Micro-Scale Design – Technical Appendices*

CHAPTER 1.0

INTRODUCTION TO MICRO-SCALE DESIGN

1.1 OVERVIEW

Up until the early 1990s, transportation planners used only macro-scale analysis for modeling travel behavior on major roads and transit systems. Macro-scale transportation features in the real world are major roadways, commuter rail, transit lines, and development at a scale that ignores non-motorized travel. Macro-scale travel forecasting, the prevailing model, relies on large transportation analysis zones using averaged demographic data.

“Micro-scale design” (MSD) is a term that has been coined recently by transportation and land use planners to describe the human-scale features of the built environment. This concept focuses on accessibility to desired activities rather than on mobility; the latter requires more transportation facility capacity. MSD describes the physical features of development at the level-of-detail of a neighborhood or a single building site.

MSD features are concerned with bicycle, pedestrian and transit access-oriented facilities such as:

- Sidewalks and other streetscape features;
- Bikeways;
- Building orientation and location;
- Parking facilities;
- Pedestrian and transit amenities and
- Other features that stimulate and support non-motorized travel activities.

The physical features of the neo-traditional neighborhood development (NTND), transit-oriented development (TOD), and the new urbanism contain elements that we would classify as MSD. For example, all three of these settlement patterns incorporate residential, commercial, and community land uses within walking distance of each other. In most cases, accessibility to a regional transit system is an important element or even the focal point of the design of the development. These same features may be found in new communities that are designed to be “sustainable” in the future, i.e., not dependent upon travel by fossil fuel-powered vehicles.

Frustration with suburban sprawl has led to a resurgence of pedestrian- and transit-oriented development and has raised questions about the impact of these new development patterns on travel behavior. Along with this has come the realization that the existing regional travel models were insensitive to the relationship between these

newer developments and travel behavior. For example, transit ridership varies greatly as a function of the difficulty of crossing streets at bus stops and the presence of waiting shelters and sidewalks, but these micro-scale design features are not recognized in most regional models.

“The longest journey begins with a single step”—this proverb succinctly describes the relationship between micro-scale design elements and regional travel. Settlement patterns and site design considerations play a central role in personal travel choice, frequently by acting as a constraint on the choices that might be available.

In response to questions about the true ability of NTNDs and TODs to reduce the need for automobile travel, planners and researchers have been exploring the influence of neighborhood development on vehicle use and have been searching for methods to model this micro-scale behavior in a satisfactory manner. The U.S. Environmental Protection Agency (EPA) and the U.S. DOT Federal Highway Administration (FHWA) are interested in how effectively these settlement patterns reduce mobile emissions and contribute to improving air quality. Many of these activities are in response to conformity with the requirements of the Clean Air Act Amendments of 1990, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), and the Transportation Equity Act for the 21st Century (TEA21).

Accomplishing the transportation system model-builder’s goal of an ideal travel model requires the collection and interpretation of more data than has been used in travel forecasting activities. The ideal level of detail is much finer than typically encountered in travel forecasting models in use today. In this context, MSD elements address the human-scale features of the transportation system and settlement patterns—sometimes classified as urban design or urban form—and focus on those site characteristics that enter into an individual’s decisions about activity selection and consequential travel choices.

The anticipated audience for this report is the group of transportation and land use planners who will be collecting travel behavior data or modifying their existing transportation models to incorporate MSD elements.

There are several hurdles to effective modeling of the influence of MSD features on travel behavior using regional models:

- **The scale of regional networks is too coarse** to include the pathways used by pedestrians and, even in some cases, bicycles.
- **In much of the suburban areas of a typical region, walking and biking trips are infrequent** because of the lack of facilities and nearby attractions. The result is that travel behavior surveys collect insufficient data on bike and walk trips in these areas for model development.

- **Planners lack an agreed-upon set of variables** to describe MSD. Therefore, researchers and model builders are still searching for ways to describe the micro-scale environment to give consistent estimates of travel behavior from one study to another. One goal of this project is to disseminate MSD research results that identify independent variables that describe micro-scale-related travel choices.
- **Decisions about regional transportation facilities are made at all levels** of government, including the state and federal levels. However, micro-scale development decisions are typically local and made by the local government or the private sector. Regional facilities are generally built to move traffic; local facilities focus more on access and quality-of-life issues.

MSD is highly visual and amenable to graphic presentation, and thus has been approached from the fields of architecture and landscape architecture as well as engineering and urban planning. There are numerous publications that present excellent graphics displaying settlement patterns that have worked and schemes that are predicted to provide a quality of life and an environment that fosters independence from the single-occupant automobile. More than 25% of the residents of the United States do not drive¹, and many more would prefer to not have to drive, particularly on high-volume roads. Therefore, it seems only natural to explore development methods that produce successful combinations of the MSD features.

1.2 PURPOSE OF REPORT

This report is not intended to present design guidelines for the implementation of TOD or NTND. Instead, it presents illustrations of the salient features of development that fosters non-motorized travel, and provides references for those who are planning the human settlements of the future. There have been attempts to rank streetscapes and urban design characteristics in terms of their transportation impacts, with some results presented in Appendix C.

The purpose of this report is to:

- Summarize the current state-of-the-art of methods that incorporate MSD elements in the computer models used to estimate travel behavior, land use patterns, and air quality impacts.
- Review the results of research on the interaction of land use, urban form, urban design, and personal travel behavior variables, and describe the effectiveness of each variable's influence on travel choices.

¹ Proceedings from the [Nationwide Personal Transportation Survey Symposium](#), Table 4, page 98, 1999, D. Pickrell and P. Schimek. "Trends in Motor Vehicle Ownership and Use: Evidence from the NPTS."

- Describe transportation modeling innovations being developed to enhance the current regional models to increase their sensitivity to changes at the MSD level of detail.

1.3 PROJECT PANEL

The study team assembled an expert panel for this report, representing both academic and practical perspectives. Panel members were: Elizabeth Deakin, University of California, Berkeley; Ronald Eash, Chicago Area Transit Study; Robert Dunphy, Urban Land Institute; and Robert Griffiths, Metropolitan Washington, DC Council of Government. The panel reviewed the progress of the project, modeling issues, and the research on MSD issues included in the appendix and offered feedback to the study team.

1.4 ORGANIZATION OF REPORT

Chapter 1 provides a brief description of MSD and the reasons for preparing this report.

Chapter 2 describes MSD parameters that have been investigated, tested, and reported in the literature. In this chapter the MSD elements are discussed in terms of both their quantitative and qualitative attributes. Also discussed are the issues surrounding each of the parameters and, where available, their impact on travel behavior.

Chapter 3 presents approaches being developed and used by metropolitan planning organizations (MPOs) to incorporate the MSD parameters in the travel demand models, recognizing that a number of MPO models in use today are at different levels of detail and precision. Descriptions of each of eight steps in the current travel forecasting process are given, from network development through trip assignment. The described work is either in progress or is being completed by MPOs and universities to extend the suite of travel demand models, so that the models become more sensitive to MSD features and their impact on travel decisions.

Appendices contain excerpts or summaries of various programs to support the material presented in Chapter 3. These appendices are designed for the practitioner who is interested in more detail on the measurement of MSD parameter values and modeling their impact on transportation.

Appendix A contains tables of MSD variables that have been postulated and/or tested in academic or MPO projects. The Appendix tables include descriptions of the variables, their source, and some characteristics of their makeup.

Appendix B contains a table summarizing a survey of MPO activities particularly in terms of their surveys used to calibrate and validate their model systems. It also summarizes the status of their modeling process with respect to non-motorized travel.

Appendix C, summarizes the methods and conclusions of an “Accessibility Measure and Transportation Impact Factor Study” prepared by J H K and Associates for the Oregon Department of Transportation and the Oregon Department of Land Conservation and Development. This excerpt describes major steps, grading and scoring systems, and the transportation impact factors from this major study. For purposes of this study, “accessibility” is a composite variable containing measures of proximity, pedestrian access environment and the attractiveness of the destination.

Appendix D summarizes a paper by Ryan and Han on Vehicle Ownership Models Using Family Structure and Accessibility. The important contributions of this work are the use of density as an indicator of auto parking costs and space availability, and the use of accessibility measures to estimate the relative importance of owning a motorized vehicle.

Appendix F summarizes transit-friendliness factors as used in the Research Triangle Study and similar to the pedestrian environmental factors implemented in Portland, Oregon by 1000 Friends and the Transit Serviceability Indices developed by the Maryland National Capital Park and Planning Commission in Montgomery County, Maryland. This study examines the ability of micro-scale factors to explain the variation in transit use among different zones in the region.

Appendix G presents a compilation of pedestrian and bicycle levels of service from various sources that represent the beginnings of bicycle compatibility variables and models that estimate non-motorized travel using the regional modeling process as a basis.

Appendix H summarizes a network development guideline prepared for Oahu, Hawaii. In this highway network, the links have been coded with characteristics that can be used in the future to estimate pedestrian and bicycle travel. Also in this modeling effort, transit networks and zones were structured and estimated in ways in which they could be used to evaluate pedestrian and bicycle friendliness.

Appendix J contains a review of modeling practice and the planning environment leading up to the present requirements to include land use and MSD variables in the model.

CHAPTER 2.0

MICRO-SCALE DESIGN VARIABLES

Although the transportation planning literature identifies more than 300 variables that could describe a certain aspect of micro-scale design (MSD), the variables can be grouped along several dimensions to create a manageable set. These variables can be grouped according to their physical properties, their statistical attributes, and their policy connections. Several of the commonly used classifications include:

- Variables that describe the density, diversity and design characteristics of a particular site or neighborhood (sometimes called the three D's of MSD);
- The mathematical and statistical attributes that include whether or not the variable is linear or non-linear, and whether or not the independent variable is ordinal, cardinal or binary; and
- Description of how we observe the variable, which includes whether our observations suggest that we see the variable subjectively or objectively, and whether we see it as a single element or as a surrogate for some other combination of characteristics, including composite variables.

These distinctions carry some weight in the development of travel behavior models since many modelers shy away from “subjective” variables and the so-called objective variables frequently are surrogates or only a partial measure of the impact of a subjective variable.

We are frequently concerned about the stability of subjective variables, although they can be well behaved if the evaluator is provided with clear direction. Researchers have also suggested that choices are based on personal, subjective responses to all MSD elements, even those that we call “objective.” Another category for MSD variables includes composites, such as transit-oriented design (TOD) or neo-traditional neighborhood design (NTND). These terms frequently come into use when we find it difficult to identify just which characteristics of the environment influence our travel choices.

2.1 MICRO-SCALE DESIGN ELEMENTS

Just what are MSD elements, and how do they affect travel behavior? For purposes of travel demand analysis, we are including those site-specific and urban design elements in the man-made environment that appear to affect travel choices, including the choices of when, where, how, and by what route to travel. These elements include sidewalks, pedestrian-oriented street systems with protected intersection crossings, location of structures relatively close to the sidewalks, and parking control and location that foster or support walking and transit use. A common thread running through all these elements is their relatively small, human scale and their association with individual building sites.

Transportation impacts of MSD and mixed-use development often result in conflicts between regional and local government regulations. Regional, state, and federal governments are interested in transportation impacts and the resulting congestion levels, often far from the particular site being developed. Local governments are concerned with the economic vitality of the development.

The desirable attributes of independent variables for travel models include simplicity, stability and their high correlation with dependent variables such as number of trips or choice of mode. Independent variables should also have a recognizable and statistically defensible correlation with the policies they represent. After identifying more than 300 variables it seemed important to classify them according to dimensions that will help us select the most efficient estimators for travel demand models.

The following sections describe the results of recent research on the most frequently analyzed MSD variables and the relationship of the MSD variables to travel behavior. Research often includes analysis of several variables at one time, making it difficult to isolate the impact of each element. There is no universal agreement on the significance of MSD elements. Therefore, the list of those most frequently cited has been arranged in alphabetical order.

2.2 ACCESSIBILITY AND CONNECTIVITY

Accessibility and connectivity are widely used in transportation planning to provide a measure of satisfaction and transportation system effectiveness, and as an integral means of establishing winners and losers when evaluating alternative transportation systems. Lacking a well-established lexicon, accessibility and connectivity have been used as the label for a number of different concepts regarding the ability to reach a satisfying number of activities.

2.2.1 Definition

Accessibility usually is defined as the number of destinations or attractions within a defined reach, either distance or travel time. Usually “more” is considered better. Actually “enough” is the appropriate target, although that seems to be somewhat elusive.

Connectivity refers more to the ease with which destinations may be reached because the locations are well connected and, hence, more accessible. High levels of connectivity imply smaller grid pattern networks and facilities that enhance pedestrian travel. In both these ways, accessibility is generally increased.

Most accessibility and connectivity measures use land use information such as households and employment, with zone-to-zone travel times. They differ, however, in their construction and, consequently, in their translation of policy into changes in travel behavior. Two example measures will be discussed here: Accessibility Measures 01 and 02.

2.2.2 Means of Measurement

Accessibility 01, a typical accessibility measure, is computed by estimating the number of jobs, households, or retail employment within a certain distance or travel time from the site in question. This measure (sometimes called the “cutoff accessibility,” which sums the number of households or jobs within a certain travel time) has probably been used more in travel demand studies than the other variables with the same name. It is fairly easy to calculate and quite easy to understand. Normally, the measure is stated in words such as, “the number of retail employees within 15 minutes of transit travel time.” Unfortunately, the measure is a “cliff” measure and it is possible that adjacent zones can have very different values. Cliff measures tend to be a creation of our techniques used to measure accessibility as a function of time or distance from a given traffic zone to other zones. It can occur when the number of the destination points lie just beyond the cutoff distance or travel time results in adjacent zones having disparate numbers of destination points.

Accessibility 02 is estimated by summing, for all destination zones, the product of the land use information and a function of travel time; in some cases, the function of travel time is time raised to a negative power (such as 2). This second accessibility measure, (sometimes referred to as total accessibility), is not a cliff variable, but it is not intuitively easy to visualize. For example, one study used the following to measure accessibility to employment:

$$\text{Accessibility (zone I)} = \text{Sum for all destination zones (employment * highway time}^{-2.0})$$

In this accessibility measure, employment located “far” from the origin zone is given a small weight, while employment close to the origin zone is given a large weight. For

example, a zone with 200 employees ten minutes from the origin zone would produce a value of 2.0 while a zone with 200 employees twenty minutes from the origin zone would produce a value of 0.5. When the product of land use and time function are summed, the close zones obviously provide the greatest contribution to the accessibility measure. This is an excellent measure of accessibility; its major deficiency is the lack of a simple description of the measure to the general public. This measure functions as a relative measure (i.e., zone x is twice as good as zone y).

The accessibility measure, of course, does not have to use employment as the size variable but can use any variable associated with the analysis. Transportation planners speak of trips being produced at their normal origin point, such as a home or a household, and attractions as the ends of trips that are attracted to non-home locations, such as retail or office spaces. The travel time for the accessibility measure does not have to be highway travel time, but it also can be transit time, non-motorized time (walk or bicycle time) or any other measure of zone-to-zone impedance. For example, a multi-modal accessibility might use the Log Sum measure from the mode choice logit model. The analyst may also wish to consider using some equivalent time measures. For example, the out-of-vehicle travel time might be weighted more (typically, 2.5 times) than the in-vehicle travel time.

Accessibility and connectivity may provide measures of compactness and decentralization. For example, Miller, E.J. and A. Ibrihim define the “combination of the physical distribution of activities and the activity patterns of people over time and space” as urban form. They propose simple measures of density, decentralization and structure to represent the physical component of urban form. Based on statistics for the greater Toronto area, regression models were developed to include the home-based work vehicle/kilometers per worker as a function of a set of urban structure variables. These included the distance to the central business district (CBD), the distance to the nearest high-density employment zone outside the central area, accessibility to rail or subway stations, the number of jobs within a 5-kilometer radius of the zone centroid divided by the population within that same 5-kilometer radius (a jobs/housing ratio surrogate), the number of jobs within 5 kilometers of the job centroid normalized to the largest observed value, and the zone population density in terms of thousands of persons per square kilometer.

Accessibility has sometimes been measured by a function of travel impedance, time, distance, or cost, and the amount of activity (the number of employees or square footage of activity space). (Handy, S.) We can think of the factors that contribute to accessibility in at least two sets. The first relates to the separation between activities, and the second relates to the nature of destinations within the available set and covers a wide range from the amount of activity to the quality of the shopping center design. Urban designers can suggest potentially important qualitative factors in the description of urban form.

2.2.3 Potential for Describing Travel Behavior

The previously discussed study by Miller and Ibrihim concluded that:

- Centralization or compactness matters (that vehicle miles traveled (VMT) per worker increased with distance from the center);
- A system of high-density employment/activity centers would appear to reduce travel when compared to sprawl (this supports the concept of a multi-nuclear city);
- Other than the impact of high-density employment centers in the suburbs, the job/housing balance was not found to have a significant impact; and
- “Population density appears to be more of an intermediate variable rather than a strong causal variable in the explanation of variations in VMT per worker across the urban area.”

Accessibility as a framework for characterizing urban form leads to the following conclusions:

- High levels of accessibility should be associated with shorter average travel distances.
- More activity should lead to greater variety in the range of options, therefore high accessibility.
- A travel budget is suggested where residents in low accessibility areas compensate for longer trip distances by taking fewer trips.
- Residents in high accessibility areas make more trips because they are easier and have a greater variety of potential destinations.
- In high accessibility areas, residents may have more viable options to walking.
- Walk trips may replace driving for some trips, or walk trips may be in addition to driving trips—high accessibility induces travel.

Accessibility has also been defined as the “intensity of the possibility of interaction” (Hansen, 1995, as quoted in Handy, *Understanding the Link*, etc., as above).

The research supporting the above accessibility concept involved case studies of four neighborhoods in the San Francisco Bay area. Their selection was based on three factors:

- Location within the region and accessibility to regional centers,

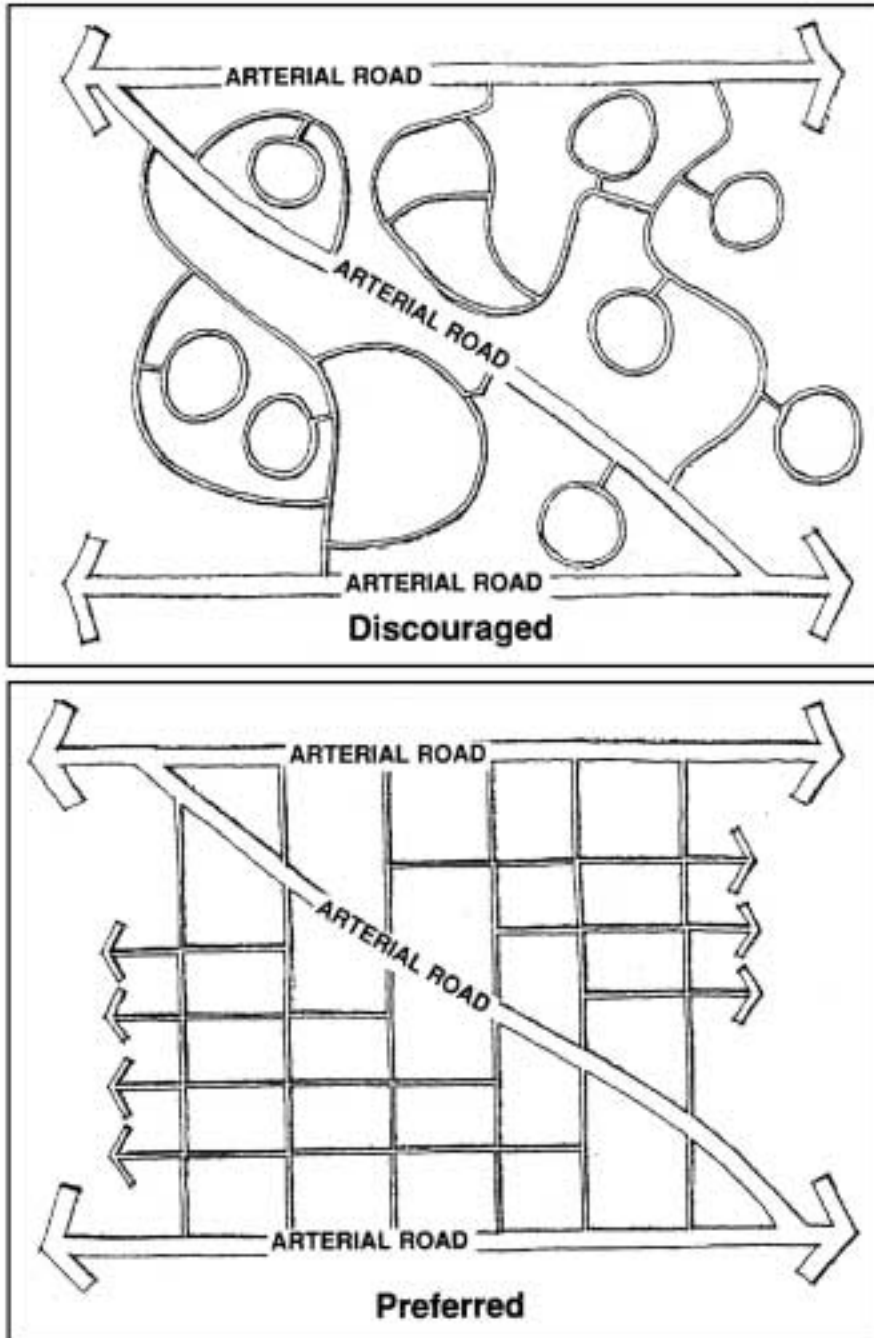
- One traditional and one typical neighborhood in each of two areas, and
- Socio-economic characteristics of the residents in the neighborhoods.

The research involved the following neighborhood features:

- Characterization and evaluation of urban form,
- A description of the neighborhoods based on urban design characteristics, including:
 - Sidewalk width/size of streets
 - Building setback
 - Variations in building materials
 - Orientation of buildings to the street
 - Building design
- The nature of human activity which, in turn, influences the perception of the pedestrian environment and thus influences the choice to walk.

Grid street patterns and small blocks encourage walking and transit use—but only if there are suitable destinations within acceptable maximum walk distance and/or attractive transit service. In this case, function does not always follow form. Grid-street patterns, as seen in Figure 2.2-1, provide connectivity superior to that of do cul-de-sac plans and reduce VMT (McNally, 1964).

**FIGURE 2.2-1
GRID VERSUS CUL-DE-SAC STREET PATTERNS**



Source: Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities. Prepared for the Federal Transit Administration. June 1994.

2.3 BALANCE

2.3.1 Definition

Within the MSD lexicon, balance suggests an ordered efficiency that minimizes travel as a part of daily activities. Since the reported research has not put forth a precise measure, balance is frequently expressed as the job/housing ratio.

2.3.2 Means of Measurement

Although the regional level of jobs per household may be 1.5 or slightly higher, the ratio for individual jurisdictions may vary dramatically. The ratio for the jurisdiction with the CBD may be considerably higher than for other counties because of the concentration of jobs in the CBD. On the other hand, counties (farthest from the CBD) may have considerably lower job/housing ratios, and even below 1.0. Values near the regional average (1.6 for Washington, DC, for example) should be reflected in the minimum commuting distances, on the assumption that the jobs match the household labor force.

2.3.3 Potential for Describing Travel Behavior

The reported research has been inconclusive, but the few existing studies report that regional travel decisions seem to be relatively insensitive to changes in the job/housing ratio. It is possible that this is partly due to the labor force skills not matching nearby job requirements.

2.4 DENSITY

2.4.1 Definition

Much of the popularity of using density to explain variation in transit and non-motorized travel is the ease of collecting and computing of data.

Density measures are used in travel studies as they tend to imply measures of urban “congestion.” For example, it could be inferred that a high population density would make it more difficult to garage an automobile, which would increase the implicit cost of owning an automobile. It could also be inferred that a high employment density would increase the cost of the land and therefore would increase the price of parking an automobile with a consequent increase in the use of transit.

2.4.2 Means of Measurement

The measure of density of development is widely used in relationships between MSD elements and travel behavior. It takes on a number of different forms:

- Persons per acre or square mile
- Households per acre or square mile
- Employment, employees, or jobs per acre or square mile

The land area used to calculate the density may be:

- Total area of zone or census area
- Office or retail development and/or zoned area
- CBD or other specified sub-region
- Transit station/stop area (physical boundary or psychological limit)

In the crudest sense, we may use U.S. Census data (for population and households) and select land areas from TIGER files. Employment data are generally less readily available; but in many models only the CBD density is needed, and an approximation can often be calculated from state or local employment statistics.

2.4.3 Potential for Describing Travel Behavior

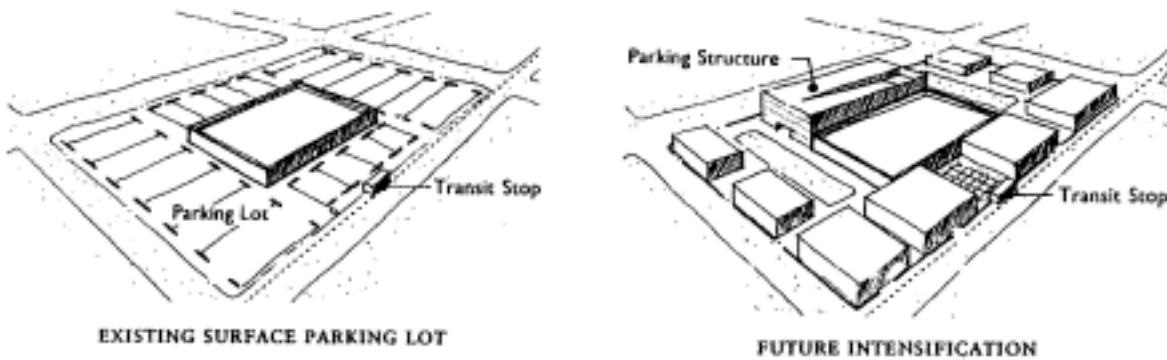
The density variable(s) has desirable properties. It is a useful, predictive variable, but not a causal variable: as it increases, so does transit use, walk and bicycle access to transit and increased non-motorized travel. Assertions that increased density increases transit use, walk access to transit trips and non-motorized travel must be accompanied, however, by carefully defined assumptions about the design features of the development and the transportation system performance (see Figure 2.4-1).

Research in Portland, Oregon (Sun, Wilmot & Kasturi, 1998) into the fundamental relationship between land use and transportation asserts that households in high-density locations will make fewer and shorter trips. However, many of the households in high density development areas are relatively small and generally make fewer trips. Another issue is that the surveys may only be counting vehicle trips. The Washington, DC area employment center data collected by Douglas & Evans (1998) found that workers in high density areas actually make more work-related trips than their colleagues in suburban work places, but their short walking trips were not always counted.

Research (Frank & Pivo, 1994) concluded that the relationships at the tract level between density and mode choice are relatively weak. Using data from the Puget Sound area (Seattle, Washington), the authors examined the relation between mode choice (single-occupant vehicle (SOV), transit and walking) for work trips and shopping trips versus urban form variables, which in this case refers to population and

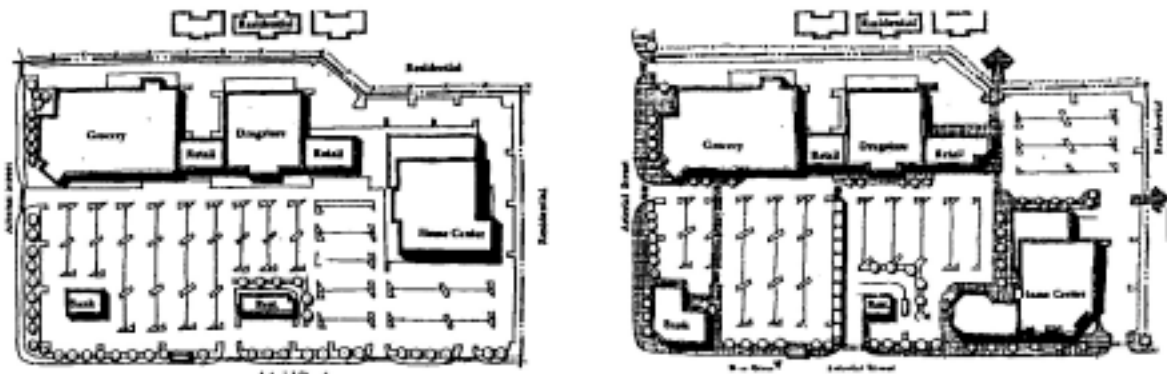
**FIGURE 2.4-1
RETAIL DENSITY AND IMPROVED ACCESS (CONNECTIVITY)**

Mall Intensified through the Addition of Outbuildings



Source: P. Calthorpe, *The Next American Metropolis - Ecology, Community, and the American Dream*, Princeton Architectural Press, New York, 1993, p. 111.

Shopping Center Redesigned to Connect to the Street



Source: Snohomish County Transportation Authority, *A Guide to Land Use and Public Transportation—Volume II: Applying the Concepts*, Lynnwood, WA, 1993, pp. 2-2 and 2-3.

Source: [Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities](#). Prepared for the Federal Transit Administration. June 1994.

employment density and land use mix. The density calculations used the gross area of the census tract. The mix of land uses was calculated using the entropy function described in Section 2.5, using seven land use types, which resulted in a maximum value of 0.794. The maximum population density was 47 residents per acre and the maximum employment density was 401 employees per acre. The study concluded that:

- The relationships between employment density, population density, land use mix, and SOV usage were consistently negative for both work and shopping trips.
- The relationships between employment density, population density, land use mix, and transit use and walking are consistently positive for both work and shopping trips.
- As employment density increases to more than 75 employees per acre, there is a significant shift from SOV use to transit and walking.
- The reduction in SOV travel was less significantly associated with population density than with employment density.

The study concluded that although the relationships can be measured at the census tract level, the relationships are relatively weak (see Table 2.4-1). This suggests that further research on land use mix of smaller geographic units would be more sensitive to the relationships with mode choice.

**TABLE 2.4-1
CORRELATION COEFFICIENTS BETWEEN
URBAN FORM AND MODE CHOICE VARIABLES**

WORK TRIPS			
Travel Behavior Variables	Employment Density	Population Density	Mixing of Uses
% SOV	-0.26	-	-0.13
% Transit	0.59	0.19	0.15
%Walk	0.43	0.34	0.21
SHOPPING TRIPS			
% SOV	-0.15	-	-
% Transit	0.44	0.16	-
% Walk	0.24	0.31	-

Source: L.D. Frank and G. Pivo, Impacts of Mixed Use and Density on Utilization of Three Modes of Travel: Single-Occupant Vehicle, Transit, and Walking. In *Transportation Research Record 1466*, Washington, D.C., 1994.

Another assessment of density impacts was based on research comparing five San Francisco Bay area communities with household densities ranging from 3.8 to 117 households per residential acre. Population densities range from 2 to 52 persons per total acre. Based on these statistics for 1998 auto use, Holtzclaw concluded that a 100% increase in density is associated with a 30% reduction in vehicle travel, both per capita and per household. While not actually measured, the reduction in VMT was attributed to accessibility to commercial and retail properties and transit service.

By itself, density does not appear to have a major impact on travel decisions. This is particularly true in a mono-cultural development such as a housing tract where the residents have walk access only to other residences. Residential density is frequently highly correlated with the transportation prevailing at the time of development. For example, many of the inner suburbs surrounding major cities were built in the early part of the 20th Century when walking and transit were much more important travel modes for everyday use. In an attempt to provide decent accessibility, lots were small, sidewalks were plentiful, and commercial areas were within tolerable walking distance from most houses. Such development is conducive to non-motorized travel and provides greater travel freedom for children, for teenagers who do not yet drive, and for elderly people who no longer drive.

It is important to recognize that it is not density that is driving these decisions, but the accessibility of destinations within tolerable walking distances and comfortable and attractive urban design for pedestrian and bicycle use. The use of area type and, in some cases, density, may depend on the assumption that increased density brings with it increased diversity and/or pedestrian and transit-oriented infrastructure. Older developments also carry with them different architecture, different construction and integrity, and a location closer to downtown where people go for dining and entertainment in a cultural and recreational atmosphere. A higher level of transit service is usually found in such areas.

2.5 DIVERSITY OR MIX OF LAND USES

Diversity of land uses and dense development often lead to reduced vehicle trip making, more walk trips, and attractive urban settings. A mixed-use development may provide the desired diversity and spatial arrangement of activities. Individuals with similar settlement patterns may differ in the activities they choose, the locations they choose for these activities, and the way they choose to travel to desired locations. This difference in behavior is attributed to some extent to differences in urban forms.

2.5.1 Definition

The Urban Land Institute has a structured definition of mixed-use development that describes some of the relevant attributes but does not satisfy all of the requirements for

predicting behavior patterns. Some of the mixed-use developments that fit one or more definitions include:

- A mix of commercial and retail spaces which, because of their operating times, can share parking spaces (such as hotels and offices) or share access roads
- A mix of retail and residential spaces
- A mix of residential, retail, commercial, and transportation facilities that produce a sustainable and somewhat enclosed community

Such mixed uses were incorporated in the “constructs” used in the MSM Study (Middlesex, Somerset, Mercer Regional Council, 1992). The purpose of the study was to develop settlement patterns that would combine future development in ways that would minimize vehicular traffic and/or optimize the satisfaction of activity needs with a minimum of motorized transportation.

2.5.2 Means of Measurement

Measuring the success, vitality or “health” of a mixed-use development is a challenge. On one hand, we are searching for surrogates, or simple indicators, such as temperature and blood pressure used in a medical exam, to indicate the vitality of a settlement. At the same time, we are looking for thresholds to give us some indication as to whether a development is healthy.

One scale for evaluating the mix of uses is whether a certain proportion of residents can fulfill a major proportion of their weekly shopping needs within walking distance of their residence. To determine this, we can measure the proportion of households that have to fulfill their shopping needs, and the proportion of shopping needs that have to be fulfilled in order to satisfy the neighborhood mixed-use concept.

Measurers would need to examine pedestrian friendliness and mixed-use character at each end of a home-to-work trip. In other words, both the home and work ends need to have facilities that result in a mixed-use development.

Two concepts that are used in evaluating mixes of use include assessment of parcel files, as a basis for analysis, and accessibility measures, which calculates the total employment or retail employment within one mile or within a particular time limit from the residence.

2.5.3 Potential for Describing Travel Behavior

The arrangement of diverse land use appears to have a strong influence on activity patterns and, thus, on travel patterns. Cervero, 1991, proposed a diversity function that is dimensionless, but little work has been reported on market response to the mixed-use developments. This early work related land use mix and suburban activity center characteristics relating the percentage of transit or carpool use as a function of parking

availability, mixed use (a dummy variable) or tenancy (another binary variable where 1=multitenant, and 0=a single tenant in a building). The most highly correlated variable was building height, the number of stories in office buildings that was highly correlated with the percent of work trips made by mass transit. The parking supply had a weak but noticeable effect on automobile and transit use; as parking availability increased automobile use went up and transit use declined. Data were not available for disaggregate modeling.

There are several methods for considering mixed-use areas. At a fairly macro level, this is the mix of residential units and employment within a short distance, e.g., less than 5 miles. At the more micro level, this could be mixing residential and commercial establishments in the same block. At the macro level, major policy decisions can affect land uses and have a major effect on travel. A macro level mixed-used policy would attempt to “match” workers and jobs in fairly small markets. This would reduce “bedroom” communities and increase areas with a reasonable “match” between labor force and employment. The separation of residential areas and commercial areas can increase trip length, change modal market shares, and substantially increase VMT.

In estimating the distribution of travel, the travel times between areas are considered a major variable in the determination of trip length. But the relative location of the productions (where the workers live) and the attractions (where the workers work) can affect the average trip length to a much greater degree than travel times. At the micro-level, the mixing of residential and commercial establishments can increase the propensity to walk and may also promote shorter non-work vehicle trips. A micro-level mixed-use policy would attempt to match residences with “convenient” type retail areas (including cleaners, grocery stores, bookstores, etc.) within a fairly small area (within walking distance). This type of policy is much more difficult to implement since it runs counter to new super-large and commercially efficient stores.

On the residential side, many people do not want commercial establishments close to their residences. Separating “mixed use” from some density measures and accessibility measures is difficult, since the density and accessibility measures make use of the mixed-use information. Therefore, many effects of mixed-use policies can be captured in the other measures, especially accessibility measures. But policies on mixed use can be an extremely effective method of reducing traffic and should be seriously considered both at the macro- and micro-scale levels.

2.6 NEIGHBORHOOD AND TRANSIT-ORIENTED DESIGN FACTORS

2.6.1 Definition

This section reviews the research into the impacts that neighborhood and transportation facility design factors may have on travel, including TOD, NTND, street geometry, and provisions for sidewalks and bikeways. The discussion identified the micro-scale effects of these elements on travel, in addition to the more macro-scale effects that

these design factors would have. For example, TODs and NTNDs might increase development densities and increase walk and transit accessibility.

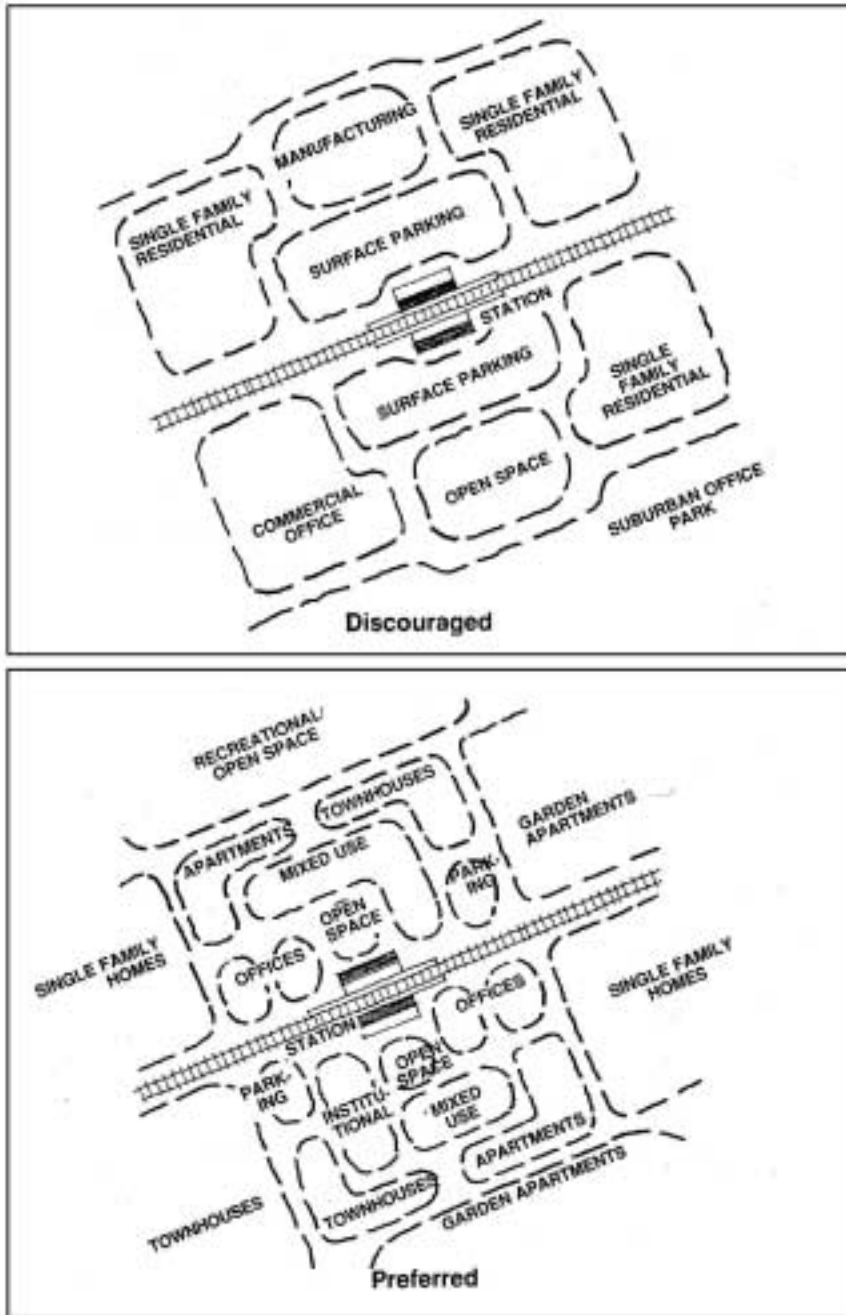
Since development patterns, either transit-oriented or neo-traditional neighborhoods, involve a combination of strategies, it is sometimes more effective to use illustrations. Figures 2.6-1 and 2.6-2 illustrate a discouraged and a preferred layout of development surrounding a major or minor intermodal transfer facility. Figure 2.6-3 illustrates the sidewalk orientation and parking locations suggested to provide transit-supportive and pedestrian-supportive development. These attributes of TODs and NTNDs are generally the result of research topics and should be revised as more research takes place.

TOD designs should incorporate land use configurations that minimize the impedance to access transit stops and stations in addition to increasing densities near stations. This might include placing parking lots behind buildings instead of in front of them, having covered and lit walkways at transit stops, and providing clear transit directions in easily identified locations. NTND would include micro-level mixed-use design coupled with good walk and bicycle access systems. In addition, the MSD of NTNDs is intended to promote walk and bicycle trips as well as increase visiting within the neighborhood.

2.6.2 Means of Measurement

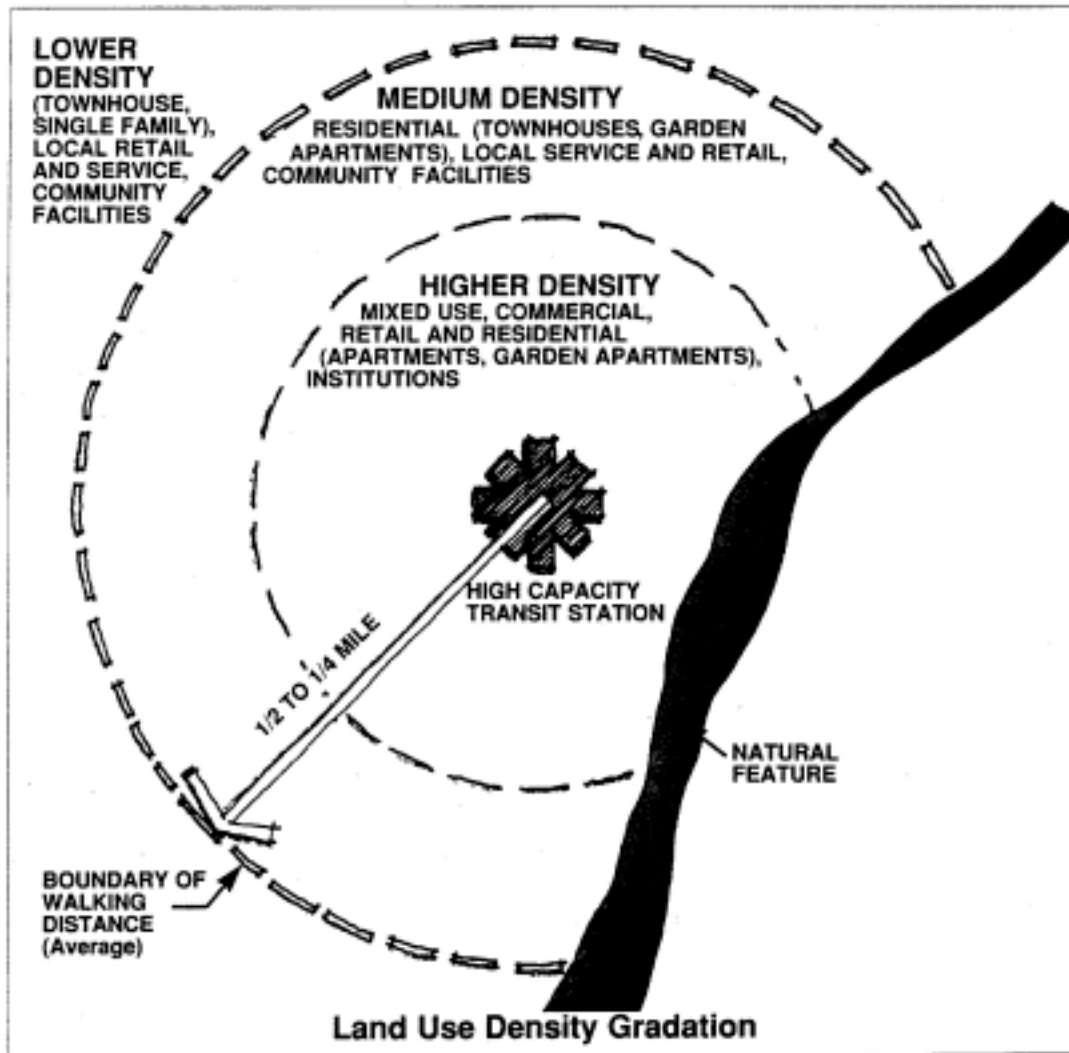
Design factors are difficult to measure for the base year and even more difficult to specify for future years. Most current evaluation procedures include weighting and rating schemes that require a fairly detailed on-site evaluation of the area with a great deal of subjective and professional judgment. Hopefully, the increasing use of GIS systems to store urban data will allow these procedures to become more objective and efficient. In both cases, either detailed on-site evaluation or GIS analysis, the most probable overall measure for design factors will be a rating system, ranging from a low number (such as 1) for a design that does not minimize travel or promote transit or walk trips, to a high number for a design that is instrumental in promoting use of transit and walk trips. With GIS systems, it may be possible to estimate the walk time to bus stops more accurately and identify whether these travel times can be made on enclosed walkways or sidewalks.

**FIGURE 2.6-1
TRANSIT-FRIENDLY STATION AREA DEVELOPMENT**



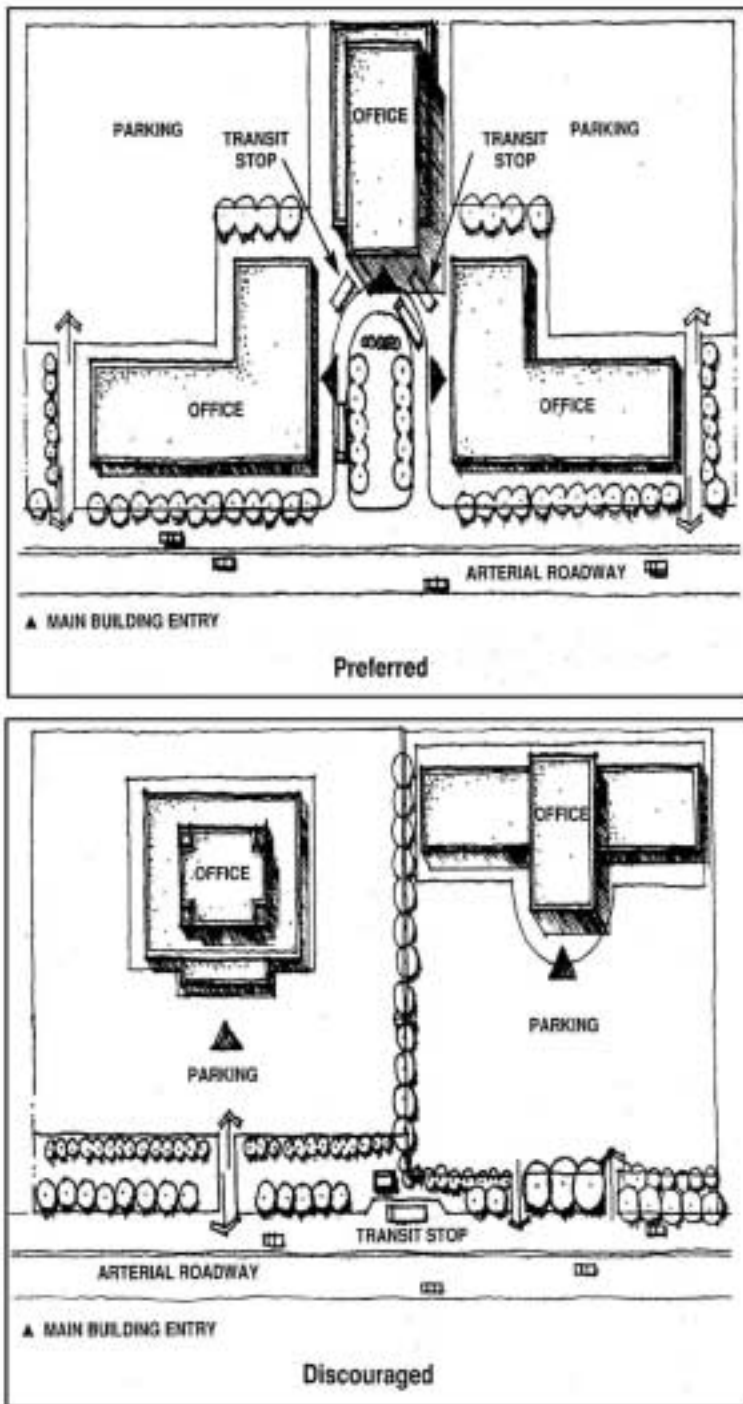
Source: Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities. Prepared for the Federal Transit Administration. June 1994.

FIGURE 2.6-2
TOD—DENSITY AND DIVERSITY



Source: Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities. Prepared for the Federal Transit Administration. June 1994.

**FIGURE 2.6-3
ELEMENTS OF PEDESTRIAN AND TRANSIT-ORIENTED DEVELOPMENT**



Source: Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities. Prepared for the Federal Transit Administration. June 1994.

2.6.3 Potential for Describing Travel Behavior

TOD variables tend to reflect those attributes of station area development that research has suggested contribute to transit attractiveness. Many of these measures are subjective in nature and composite in structure—that is, they describe an area as being friendly to transit, using judgement and descriptive indices.

In a study of access to rail station access in San Francisco and Chicago (Davis) were interested in the role of the built environment in explaining the mode of access. They summarized the distances to which walking predominates, as shown in Table 2.6-1 below:

**TABLE 2.6-1
SUMMARY OF THE INFLUENCE OF DISTANCE
ON MODES OF ACCESS AND EGRESS
AMONG CLASSES OF BART STATIONS**

Station Class	Distance Up to Which Walking Predominates		Mode of Access Beyond Walking Distance		Mode of Egress Beyond Walking Distance	
	Home-End Access	Work-End Egress	Dominant	Secondary	Dominant	Secondary
San Francisco Office Center	3,000 ft	4,000 ft	Transit	---	Transit	---
San Francisco Commercial/Civic Center	4,000 ft	3,300 ft	Transit	Kiss-n-Ride	Transit	---
Downtown Oakland	3,800 ft	3,600 ft	Transit	Kiss-n-Ride	Transit	---
Urban Districts	3,300 ft	3,600 ft	Transit	Drive-alone/ Kiss-n-Ride	Transit	Bicycle
Suburban Centers	2,700 ft	3,300 ft	Park-n-Ride	Transit/ Kiss-n-Ride	Transit	Passenger Pick-up
Low Density Areas	2,900 ft	2,900 ft	Park-n-Ride	Transit/ Kiss-n-Ride	Transit	Passenger Pick-up

Source: Davis, J., R. Cervero, and S. Seskin. *Mode of Access to Rail Transit*. Cooperative Research Program, Transportation Research Board, Washington, DC.

In their analysis they define the catchment area as one-half mile from the rail station. The independent variables included the households and employees per acre, the percent of land area in commercial and residential uses and the entropy index of land

use mixes. The study calculated the percentage change in probability in using each access mode associated with an increase of either one household or one employee per acre. The higher household densities give a higher proportion of walking trips to rail stations and a lower proportion by car. They found that an increase of one household per acre resulted in about two percentage points increase in the probability of walking, with a similar decrease in the probability of driving.

When looking at transit-oriented development, it is necessary to:

- Check the level of transit accessibility.
- Examine the level of service of transit, such as whether it's local bus or express bus.
- Examine whether or not there is neighborhood transit.

Using data from the BART Passenger Survey in the fall of 1992 Loutzenheizer, 1996, analyzed the reason for the variation in walking access trips among the various stations. The conclusion was that the variation was in great measure due to the design of the station and access facilities. At the time of the survey, walk access at shared individual BART stations varied from 3% to 74%. A series of analyses using logit models resulted in the following significant findings:

- Individual characteristics (income, age, education, job classification) influence walking more than urban design and station area characteristics.
- Walking distance is the most significant factor in the choice to walk.
- Males are more likely to walk than females.
- Population and dwelling density, while appearing significant when analyzing station area characteristics alone, are insignificant in a combined model taking into account individual characteristics.
- When stations are located in downtown corridor areas with office domination, there is a low incidence of walking to rail transit.
- Station areas with a strong retail-oriented environment produced the greatest proportion and incentive for walking.
- High incomes and the availability of a car are the strongest disincentives to walking, after distance and gender.

It will be noticed that the NTND and TOD developments circumvent this problem to some extent by presuming that the urban design guidelines employed during site planning provide a superior level of transit accessibility for the entire development. Today, actual implementation of these ideas has led to some mixed results, in part because the transit accessibility, while necessary, is not sufficient to ensure travel patterns that make use of the transit service and walking patterns provided by the development itself.

2.7 PEDESTRIAN-ORIENTED AND BICYCLE-ORIENTED DEVELOPMENT

The infrastructure elements required to support pedestrian and bicycle travel are emerging as we enter the 21st Century. Major elements are pathways, amenities, and safety-related fixtures that provide a secure and attractive series of paths in our urban areas.

2.7.1 Definition

Pedestrian- and bicycle-oriented development are the natural environment for MSD elements. The essential ingredients are a mixture of uses clustered together with acceptable pathways for walking or biking. Many of these attributes are implicitly included in the neo-traditional neighborhood and transit-oriented developments described in Section 2.6. In this section, the emphasis is more on complete trips made by non-motorized travel, principally walking and biking.

The initial infrastructure needed for bicycle commuting is relatively low-cost; provision of a few lockers, a few paths, and maybe a shower or two. Cyclists also need protection and safety, although the cyclists themselves may pick the fastest route, not necessarily the safest and most scenic.

2.7.2 Means of Measurement

Many transit-friendly factors are subjective with survey questions scaling from one to three or one to five. An agreed-upon definition of levels of pedestrian friendliness is crucial, so that ratings could be replicated if performed by different planners using the same definitions of service levels. There is an emerging consensus that a composite measure is probably needed and that research should concentrate on accurate definitions.

There is a wide range in the levels of some indicators. Developing local neighborhood travel would be easier if a parcel-level system were used. In the past, a network for pedestrian travel has been thought to be superfluous because of the short trips and the average size of the transportation analysis zone (TAZ). The need for pedestrian trip data is now more appreciated because of the tendency towards planning more expensive walk projects and congestion mitigation and air quality (CMAQ) programs. A walk origin-destination matrix could essentially be the major travel matrix with more trip ends occurring within cells on the main diagonal plus a few cells on either side of the diagonal.

The bicycle-oriented development variables describe infrastructure attributes that support bike use. They also may act as surrogates for community and employer attitudes toward bicycles and serious use for other than recreation trips. Bicycle planning and travel forecasting presents some unique challenges, partly because there are numerous small cyclist populations with characteristics and preferences that are still

not well understood by most urban and transportation planners. There are recreational cyclists, business/commuting cyclists, and daredevil, high-speed cyclists who take risks and travel along the fastest route. Although cyclists today make up a small proportion of the total regional trips, models of their choices can be calibrated. The EPA believes that cycling will be more important in the future, and bicycle facilities are eligible for CMAQ funds.

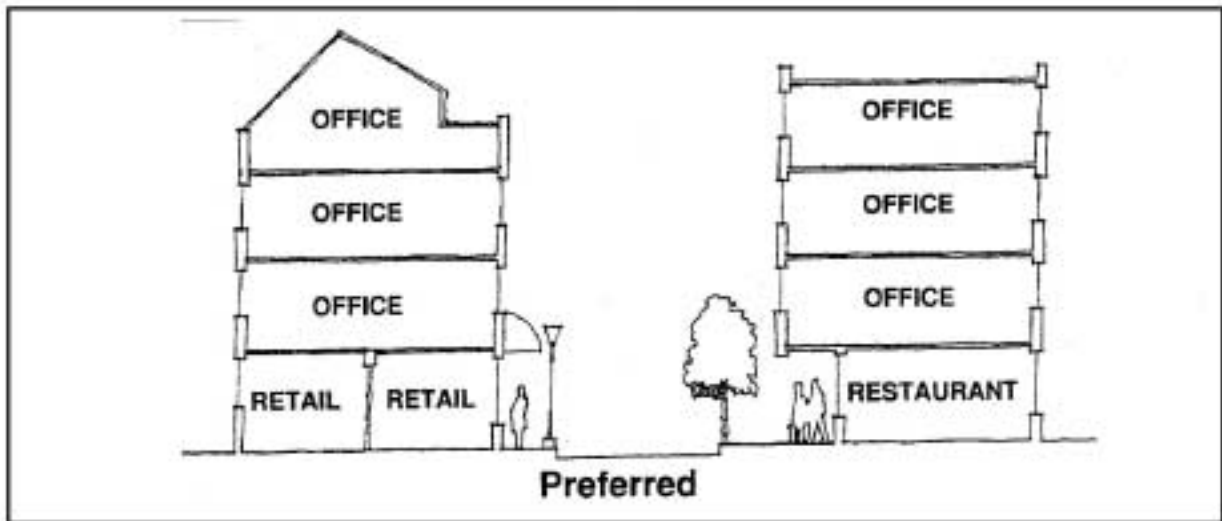
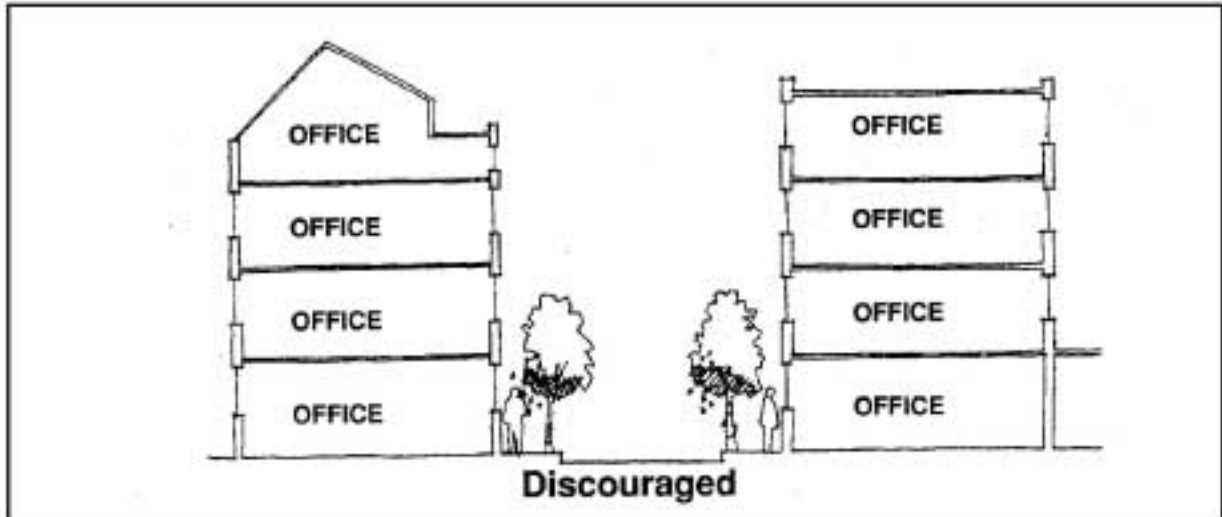
2.7.3 Potential for Describing Travel Behavior

Only a few MPOs include walk trips explicitly in their model process. Even those that estimate walk trips often use a model based on a crude relationship between trips and regional location, such as the CBD. In that process, the trip ends are discarded after the trip generation step, and are generally not traded for vehicle trips in response to policy changes.

Historically, home interview surveys either ignored short trips or explicitly directed the respondent to exclude trips of short duration (in minutes or blocks), thus under-counting numerous walk trips. One argument for this practice was the absence of a need for this information when planning roads and transit lines. Walkers were considered to be non-users. Likewise, those under 16 or over 70 years of age without driver's licenses were thought not to have a major impact on the auto driver trip pool. What is lost in this restricted type of data collection is the increased mobility and accessibility provided by urban environments.

This study recommends that current and future home interview surveys should collect as much non-motorized travel data as possible, even though their models might not use the information at the moment. If these surveys are to be the only source of household data for the study area for the next 5 to 10 years, then the details collected should be as complete as possible.

**FIGURE 2.7
PEDESTRIAN/TRANSIT-FRIENDLY STREETSCAPES**



Source: Planning for Transit-Friendly Land Use: A Handbook for New Jersey Communities. Prepared for the Federal Transit Administration. June 1994.

CHAPTER 3.0

INCORPORATING MICRO-SCALE DESIGN FACTORS

IN EXISTING TRAVEL MODELS

This section describes methods and programs that have been devised and developed to enhance the transportation planner's ability to assess the transportation impacts of micro-scale design (MSD) factors. We can categorize these methods and programs in a number of ways: aggregate vs. disaggregate; empirical vs. conceptual; in process vs. post process; probabilistic vs. deterministic; and behavioral vs. mechanistic. Most of these methods have been devised to refine the estimates of travel most important for evaluating policy actions such as those required by the Clean Air Act Amendments, the Intermodal Surface Transportation Efficiency Act (ISTEA) or the Transportation Equity Act for the 21st Century (TEA21). Many of the current models are insensitive, for the most part, to changes in policies of that nature.

3.1 IMPROVING SHORT-TERM TRAVEL DEMAND MODELS

Incorporating MSD elements into a metropolitan planning organization's (MPO) existing regional models may prove to be a unique process in each case. The work required to implement a change in a methodology or program to accommodate MSD elements will vary according to the current levels of detail in the networks and zone systems, the level of detail regarding travel behavior in the calibration data sets (and per force the background surveys used for calibrating the models) and the structure of the models themselves. Another major concern is the capability of the MPO to measure and describe the MSD features of a particular site in a way that will stimulate the model's sensitivities.

If design factor rating schemes are used in developing travel demand models, care should be taken to ensure that the ratings are applied fairly in the forecast year. But even if no forecast is made of the design factors, it may be better to include these schemes in the model structure and then carry the base year ratings to the future—at least the analysis will “acknowledge” present-day designs. These variables, some of which are quite creative, describe both the shape and texture of the neighborhood or transit station area infrastructure. Those that are subjective measures would benefit from consistency of definition. A first step would be to evaluate the design concepts recorded by Ewing, Calthorpe and other architects to arrive at a professional consensus on terms. While design factor rating schemes probably can be used to improve travel demand models, the cost of developing this data is substantial and therefore the use of this analysis should probably be given a low priority in the development of travel demand models, depending on the urban area.

3.1.1 Demands of Micro-Scale Design Implementation

Implementation of any of the methods or programs described in this report requires:

- A model that relates a stimulus to a response, typically a decision about travel
- Identification of variables that capture the stimulus and response and that can be shown to have a reliable nexus or connection
- A means to describe the variables to the program, typically performed with a network and spatial database

These requirements often spell disaster for the modeler who finds that the data are not available at a usable level of detail or that the connection that seems so clear turns out to be multi-colinear with several variables. The response to certain stimuli could appear to be based on non-travel factors (i.e., they might be highly correlated but not causally related).

Increasingly, as we expand the scope of personal and family data in our travel demand databases, we encounter reluctance on the part of those being surveyed to reveal private family decisions. Even though household data and travel behavior information require thoughtful and expensive surveys, it is in the area of MSD and land use data where we have made the least progress.

Thanks to the U.S. Decennial Census, the Bureau of Economic Activity forecasts, the Census Transportation Planning Package (CTPP), the Nationwide Personal Transportation Survey (NPTS), and the Public Use Micro-Sample Data (PUMS), we have a number of reasonable sources for personal information. The typical sources of travel behavior in larger urban areas is the household interview survey or the on-board survey supplemented by surveys on truck movements and other special generator effects. Until the 1990s, land use data were captured by surrogate measures such as at-place employment or at-place retail employment. Most of the attributes of the trip and the traveler were ascribed to the household or home end of travel.

The studies reviewed for this task link travel behavior with land use and MSD variables such as age of development, distance from the regional core (central business district (CBD)), block size, and neighborhood characteristics that correlate well with travel patterns. The causal relationship is less clear. In a number of recent cases, the development follows many TOD design rules but experience little transit use. Examples include Kentlands in Montgomery County, Maryland; Carnegie Center in Princeton, New Jersey; Metropark in Elizabeth, New Jersey; and Meisner Park in Boca Raton, Florida. In these developments, isolation from the rest of the region, limited and unattractive transit service, and unsupportive mixed use appear to offset the positive aspects of higher density and pedestrian-friendly urban design elements. A package of attributes is needed to describe a TOD adequately.

MPO travel forecasters have found it difficult to model TOD, since it is not a single measure. Some interesting avenues of approach, however, would be to examine:

- Development in Chicago, particularly downtown Chicago, and also its fringe neighborhoods. These could also be examined as good mixed-use developments.
- The East line in Portland, which was built with a pedestrian promenade.
- The BART stations in San Francisco, which demonstrated the need for enough people to make it work.
- Ballston in Arlington County, which some suggest could be more pedestrian friendly, because of the difficulty in crossing Wilson Boulevard.

The following categories of programs and methods represent the full suite of travel forecasting techniques, from off-line, relatively ad hoc post-processors, to concepts that include MSD elements throughout the full travel forecasting stream of programs. Since each MPO may use a slightly different travel demand analysis process with varying levels of detail and data availability, this report includes examples from each category—some of which seem quite mundane and others perhaps too complex for application in most areas.

Implementation of MSD-responsive techniques have taken place in four different ways:

- Post-processor programs
- Pre-processor programs
- Parametric changes to existing modules
- Radical change in the entire modeling process

Each approach has special needs and challenges. The last implementation approach would, in all likelihood, require scrapping a four-step or n-step sequential modeling process and may be thought of as more in line with the TRANSIM program, which is based on a different approach.

3.1.2 Post-Processor Techniques

For purposes of this study, post-processor techniques refer to models that modify or pivot off the results of the four-step model process. In most cases, it occurs either after the traffic assignment step or, in fewer cases, after the mode choice step. This approach includes the techniques most widely used to estimate vehicle emissions, vehicle miles traveled (VMT) and traveler response to travel demand management (TDM) actions and, perhaps, urban design options during the past decade. In this approach, vehicle trips and VMT estimates from traditional travel models are manipulated in order to estimate diversion from single occupant vehicles (SOVs), or automobiles in general to other modes or to estimate a reduction in vehicle use. The development of this approach was motivated primarily by the Clean Air Act Amendments and the search for ways to reflect TDM and other policy efforts, including growth management. The *Accessibility and Transportation Impact Study* (JHK, 1996) represents one of the more comprehensive post-processors that estimates reduction in

travel as a function of a large number of MSD factors. The impact factors that result calculate the percent reduction in trips by trip purpose by zone to reduce the number of trips. The change in VMT is derived from the number of trips and an estimated average trip length.

The JHK Accessibility Study is summarized in Appendix C to provide the reader with qualified assessments of parameters that describe MSD elements. The scoring system converts subjective values into numerical scores and then transforms the numerical scores back into qualitative indices; this makes it difficult to develop impact factors.

The advantages of the post-processor technique includes:

- It does not disturb the modeling process currently being used by the MPO
- The data requirements and the level of detail for the MSD impacts can be different from that used for the rest of the modeling process
- The existing models do not have to be re-calibrated or validated
- It can make use of the aggregate results from the research

The post-processor approach has some serious deficiencies that limit its usefulness. The impacts calculated as a result of the implementation of MSD features are generally not reflected in the intermediate steps of the sequential modeling process. For example, there generally is no feedback that would reflect the change in trip generation rates, distribution patterns and, consequently, traffic assignment levels reflecting policies about growth and travel behavior.

3.1.3 Pre-Processor Techniques

The term “pre-processor” in this case indicates an operation within the standard sequential modeling process, but before the mode choice stage. The pre-processor can be applied to the trip generation calculations or the trip distribution process as well as just before the mode choice process. The pre-processor also comes into play as part of the TDM process where the impact of particular TDM measures falls only on some small sub-population and where the sensitivity to TDM measures is not found in the four-step process in use in a particular region. An example of such a module is one that discards non-motorized trips, either after the trip generation or trip distribution step, and therefore precludes the need for inclusion of these trips in mode choice. This approach seems to be well-suited for instances where data are not available to recalibrate the mode choice model or the trip distribution model, and where the trips estimated from the re-calibrated trip generation model can be modified with the results “pruned” before proceeding into the downstream models. However, this technique, while allowing for analysis of motorized trips without having to determine the characteristics of the non-motorized travelers, also eliminates the possibility of analyzing walking and bicycle trips further in the process.

3.1.4 Modified Parameters in Traditional Process

The most appealing short-run techniques to measure the impact of MSD features involve the introduction of parameters that quantify MSD features into the existing models. The most common applications of this type involve auto ownership models, trip generation models, and mode choice models.

While the attractiveness of this approach is obvious, there are also some significant challenges. Modifying the trip generation model to estimate trips that are influenced by MSD features may require an additional re-calibration and re-estimation of the trip distribution and mode choice models. Previous research has reported problems with multi-colinearity when trying to estimate models with a number of parameters that involve urban design and urban form features, all part of MSD. Modeling issues are somewhat different if transit access enhancements are separate and distinct from trip generation and distribution issues. Examples of transit access improvement modeling is provided in Appendix F, which describes the development and application of transit-friendly factors.

3.1.5 Revised Travel Forecasting System

The most ambitious, expensive and time-consuming approach is to develop a new set of travel forecasting models that are more responsive to growth management and MSD issues. Such an approach would involve: (1) the establishment of a different planning environment that would include ways to express MSD elements, and (2) surveys to develop behavioral relations between these parameters and travel choices. In most cases, development of the model would involve new travel surveys with information or with questions involving choices that could be influenced by MSD parameters. Some pioneering work has been going on with the use of stated preference surveys and panel surveys such as the Seattle panel. While this approach is exciting, it appears to go beyond the scope of this report, except to mention the possibilities and to urge travel forecasters to plan ahead when setting up a travel survey work plan.

3.1.6 The Ideal Travel Demand Model

All the information used in travel demand analysis is stored either in networks or in polygons. The networks are the repository of information describing the impedance to moving between points in space, and the polygon is the cluster of attributes for a small or large geographical unit. If the ideal travel model reflects individual choices, then the site data need to be stored on a very small polygon, very much smaller than the typical TAZ. It also requires disaggregating demographic information. Ideally then, we could evaluate the available choices and travel decisions made by each individual in going through their daily activities.

In a like manner, through time we have tried to disaggregate the various components that describe the overall impedance to making a journey. In addition to travel times and

direct travel costs, we have tried to include safety, security, comfort, convenience, and other taste variables, all of which play a part in our travel decisions. The models in current use include only a small portion of the information described above, although we are making progress in some areas. Implementing a model change, hopefully an improvement, requires evaluation of a number of issues:

- What variable will serve as an indicator of the change in value of the MSD factor?
- How can we collect the data to support this particular variable?
- How difficult is it to predict future changes in the variable?
- What other models in the overall planning process will need to be calibrated?
- What else occurs in the models with a change in the utility function? (Are there unintended consequences?)

For each of the MSD variables and model improvements suggested in this report, we present several alternative approaches with increasing degrees of difficulty in data collection, manipulation, and model calibration. In this way, we can envision incremental improvements to the travel forecasting process, and the possibility of implementing changes to the existing model structure that would be within the grasp of the MPO or other agency performing the travel demand analysis.

Each model used in travel forecasting presents its own specific challenges when considering the incorporation of MSD variables.

3.2 ENHANCING THE CURRENT TRAVEL FORECASTING MODELS

Because a great many MPOs use a sequential modeling process with four or more distinct steps, sometimes with feedback and sometimes not, this section is organized in the sequential manner of a typical travel forecasting process:

- Step 1: Highway and Transit Networks
- Step 2: Transportation Analysis Zones
- Step 3: Household Vehicle Ownership
- Step 4: Trip Generation
- Step 5: Trip Distribution
- Step 6: Time of Day
- Step 7: Mode Choice
- Step 8: Trip Assignment

The implementation of MSD elements in the modeling steps of the travel forecasting process usually depends on the ease of use and the effectiveness in contributing to the decision-making process. Table 3-1 represents the various MSD elements discussed in Chapter 2 and compares them in terms of how well they address the more common transportation issues and how effective they appear to be in enhancing the precision and accuracy of the typical travel demand models. Each MSD element is graded from good to poor, or high to low, or from yes to no, in terms of ease of understanding by lay persons and in how complicated data collection tends to be. The ease of forecasting the various variables and estimating their impact on VMT reduction represent two of the driving forces in our desire to enhance the travel forecasting process. The remainder of the table presents a summary of how effectively each element contributes to each of the eight models presented in the table. In some cases, such as the time of day model, the preponderance of poor ratings indicates that we uncovered no current uses of the MSD elements in the time of day model or factor used by MPOs. Additional discussion of these relationships occur in following sections of Chapter 3.

**TABLE 3-1
EASE AND EFFECTIVENESS OF USE**

MSD Element	ISSUES				EFFECTIVENESS IN MODEL APPLICATION							
	Easily Understood	Data Needs	Easily Forecast	VMT Reduction	Networks	Zones	Auto	Trip Generation	Trip Distribution	Time of Day	Mode Choice	Assignment
Accessibility	G	G	G	F	F	F	F	F	G	N	G	N
Connectivity	G	F	F	G	G	F	F	N	G	N	F	G
Balance	F	F	F	P	N	F	F	N	G	N	N	N
Population/Household Density	G	G	F	F	F	G	F	F	G	N	G	N
Employment Density	G	F	G	G	N	F	N	F	G	N	G	N
Diversity/Mix	G	P	P	G	F	G	N	F	G	N	G	N
Design TOD/NTND	G	F	F	G	G	F	F	N	F	N	G	F
Pedestrian/Bike	G	G	G	G	G	G	F	F	F	N	G	F
Legend:												
G				F				N				
Good				Fair				Poor				
Yes				Maybe				No				
High				Medium				Low				

3.2.1 Improving Highway and Transit Networks

Computerized highway and transit networks provide the fundamental spatial relationship information used in travel forecasting. The earliest networks contained only information about highway travel time and, until very recently, networks contained information about motorized transit and roadway transportation. Recognizing that time and distance play major roles in our travel decisions, planners recognized the need for network data describing walking and bicycle trips as well as transit and highway trips.

Travel demand models have evolved in response to analytical and policy needs. Highway networks may contain bicycle infrastructure data, although infrequently. Description of the network development for Oahu is presented in Appendix H; area types calculated from population and employment density provide guidance on free-flow speed and capacity on each highway link as a function of the adjoining land uses implied by each area type. Transit network architecture has been refined to provide the information defining the difference between walk access to transit service and drive access to transit service.

One of the most widely recognized weaknesses in the early networks used for travel forecasting was the absence of a means to describe the variation of transit accessibility for the various points in a TAZ. It generally has become a matter of acceptable practice to have a means for describing walk access and auto access to transit services.

The general methods for achieving this delineation, listed in order of increasing elegance, include:

- Estimating the percentage of the total zonal population and employment within a defined walking distance of a transit system access point. This distance generally ranges between one-quarter and one-half mile, and is sometimes straight-line distance and sometimes actual walking distance. This method assumes uniform distribution of jobs and people throughout the zone.
- Subdividing total zonal data into several concentric rings or areas around the transit service (e.g., the percentage of trip ends within one-eighth mile, one-quarter mile, three-eighths mile and one-half mile from the transit station or stop).
- Using different percentages for trip productions and attractions to reflect a difference in the distribution of residential and commercial properties within the zone. (This helps to overcome a weakness in the above methods, which assume uniform distribution of population and employment throughout a zone, ordinarily an assumption made because of a lack of better information.)

The availability of more high-powered computing equipment now allows for subdividing the region into many more and smaller TAZs than in the past. For example, in

Honolulu, the new models now being developed will include zones that are small enough to be either totally within walking distance of transit or not. MPOs developing more disaggregated models for pedestrian and bicycle analysis in the Midwest are using quarter sections—as used in Chicago—or even quarter-quarter sections as their small area zone system, which they contend supports a network of sufficient detail to be used for pedestrian and bicycle trips.

For those regions with sufficiently detailed and public parcel files, it will be possible in the future (and now on a limited basis) to provide even finer detail about the environment around each point in the region. There is some inertia among model builders because of the expense of assembling and maintaining files at this level of detail. But the ability to evaluate the transit accessibility for each plot in the region has obvious interest. This level of detail would also allow the models to go directly from the venue at the parcel level to the transportation network, bypassing the zone aggregation and averaging assumptions about median or mean travel times between the zone centroid and the network.

The most disaggregate methodology of all is based on a geographic information system (GIS) where attributes of place can be developed at the raster cell level, using each of the geographic layers at whatever level of aggregation is required for the data being presented by layer. The calculation of distance and accessibility to transit service can then be estimated for each traveler. This last method for evaluating TOD or transit orientation of the geographic elements of a region may fall beyond the scope of assimilation into current modeling practice, but it has exciting potential.

The cost of the methods listed above relies on geographic and geometric assessments.

Uniform distribution throughout a zone assumes that the distribution of population, employment, and activities are uniform with respect to the location of transit and that the walking infrastructure (or bicycle access infrastructure) is uniform throughout the zone. If zones are small enough, this may not be too serious a problem; but larger zones commonly found in most suburban areas of medium and large regions do not have uniform development patterns. In some cases there may be large areas of low-density development with just a few high-density developments within one section of the zone. In others the clusters of commercial and residential developments may be located in areas that have either very good or very poor transit service.

Recent examples of this approach to network coding with attempts to include more detail about factors fostering walking or bicycle use include Delaware DOT; Oahu, Hawaii; and Portland, Oregon. The available data until recently have been vehicle travel times, sometimes with congestion effects, and transit travel times, sometimes reflecting congestion. Transit travel times also have included walk access and auto access travel times, but these have frequently been estimated for the average resident of a zone that is too large to be traversed on foot. Only in rare cases do the network

files contain information relevant to MSD attributes. Thus, walk access is assumed to be of the same quality at each transit stop or station area.

Very few forecasting models have dealt with walk access explicitly, other than to estimate the percentage of the zone that lies within walking distance. Models that used a network expression for walk access include Dallas and San Diego, which used a block system.

The MSD factors that affect highway and transit networks are found in two categories: those factors that are essential parts of the network configuration and those factors that represent wayside or roadside development. The elements that are generally used to describe attributes of network links include:

- Sidewalk ratio (either the presence of a sidewalk or the relative occurrence of sidewalks compared with the centerline miles of roads and streets)
- Bicycle compatibility—a relatively new and not widely tested concept and with relatively rare events on which to calibrate a model
- Curbside parking ability
- Crossing safety

These elements allow the model to estimate the difference in speed, capacity, and relative safety of the roadway and pedestrian networks. The pedestrian network, of course, has implications for transit access.

An approach providing more sensitivity to pedestrian and bicycle traveler's needs includes calculating the density of development, either population, employment, or households and perhaps accessibility and connectivity measures to provide information about the suitability of the network for pedestrian and bicycle travel. It would also be possible to prescribe smart growth policies and other development constraints and incentives to capture the relative attractiveness of different locations as affected by their proximity to desirable activities and transit facilities.

Responses to the challenge of capturing the variation in transit access impedance based on variation in MSD/urban form factors have usually included either creating micro-scale TAZs or stratifying the TAZ demographic data according to distance from a transit facility. Several applications of the methods used to split the TAZs—whether physically or logically—have been compiled into a TMIP publication, "Guidelines for Network Representation of Transit Access, State-of-the-Practice Summary," 1994.

3.2.2 Improving Transportation Analysis Zones

TAZ systems are usually based on census geography, either groups of blocks or census tracts. In most cases the zones and the associated networks are at too coarse a scale to reflect in any meaningful way most of the design features and policies that fall under the rubric of MSD. Given this state of affairs, the MPO planner is faced with

using either aggregate measures (usually in a post-processor format) or MSD measures requiring substantial modifications to the databases used for travel demand forecasting.

Current practice results in TAZs that increase in size with increased distance from the regional core. Through time the number of zones in many regions has increased due both to extension of the regional cordon line outward and to reduction in zone size in the most densely developed areas. Even so, the majority of regional models rely on zones of 1 square mile or greater.

To incorporate MSD features, the analysis zone should be as small as possible. There is consensus that small zones are better than large zones for modeling purposes, but there are weaknesses and strengths in both cases. One major weakness is that land use models, in particular, and land use planning, in general, deal with large zones, and so small zones are difficult for land use forecasting. Another problem, but one of diminishing importance, is the increased cost of models as the number of zones increases. This is becoming less of a problem because of high-speed small computers. One alternative is to use a windowing system, although not generally satisfying for transit analysis.

An example of an MPO using small zones is the OMPO zone system for Oahu, Hawaii, which takes advantage of the small size of the developed area (about 400 square miles) and advances in computing power to support a system of 767 TAZs, many of which are a single block in size. Advantages include specific transit access designation; e.g., walk access to transit is designated for each zone without the need for estimation and calculation of the proportion of the zone within walk distance of transit service.

3.2.2.1 Finer Level of Detail

Census blocks relate primarily to physical blocks in urban areas and tracts or polygons frequently delineated by natural features outside the urban area. The use of census blocks provide a richer variation in demographic and land use data than the use of zones or even districts, which are generally combinations of zones. The use of census blocks leads to questions of confidentiality, particularly when using U.S. census data since the Census Bureau is reluctant to present data that can be identified as coming from a single household. Even when using census blocks, we are forced to use averages of demographic and land use attributes.

An even more detailed analysis can be performed if data are stored by individual parcel. Parcel data indicate the exact land use since, in almost all cases, a single parcel will contain a definable, if not singular, use. Parcel data tend to be more expensive to collect since it has to be performed at the local level. What is perhaps more of a challenge is that forecasting parcel level data tends to be difficult and may not be politically correct. A further problem arises from the fact that private sector

activities frequently are kept secret and don't necessarily follow the time frame envisioned by planners.

An even smaller unit of geography is that defined by the raster cell, a very small unit of geography located at a particular point and, in some cases, defined by the size of a pixel. The assumed benefit from using these very small geographic units is the ability to minimize the equivalence problem caused by the different geographic bases used to assemble data. In this way, if we know the location of a single traveler, we can collect all the geographic, demographic and system attributes. It also obviates the need for dealing with averages, but it does not solve the problem of confidentiality.

Should the selected spatial system be relatively rigid, it is often possible to modify the access coding to reflect walking access conditions. Accessibility measures can be modal or multimodal, depending on the zone-to-zone impedances. When accessibility is associated with transit time, the analyst should be very careful in defining the measure. Many studies separate zones into walk-to-transit zones and drive-to-transit zones, while other studies disaggregate individual zones into walk-to-transit areas and drive-to-transit areas. When the accessibility measure is being calculated for these studies, care must be taken to separate out the information into the walk-to-transit time, the drive-to-transit time and the cannot-use-transit. This step is usually performed using the following steps for each zone-to-zone interchange:

- (1) Multiplying the destination zone size variable (such as employment) by the proportion of the destination zone within walk distance of transit, which is the new size variable
- (2) Applying the accessibility equation ($\text{employment} * \text{time}^{\text{factor}}$) using the walk-to-transit times and multiplying by the proportion of walk-to-transit for the origin zone
- (3) Applying the accessibility equation using the drive-to-transit times and multiplying by the proportion of drive-to-transit for the origin zone
- (4) Adding the values from steps 2 and 3 to obtain the total accessibility measure for the interchange

3.2.3 Improving Household Auto Ownership Models

Travel forecasting models use a variable reflecting household auto ownership. Numerous trip generation models also use auto ownership as one of the variables. In this way, one can observe that the presence of an automobile supports trip-making while absence of a motorized vehicle constrains the choices for trips to those that can be reached on foot or by transit.

Auto ownership is an important factor in travel choices. Appendix D describes the research and development of an auto ownership model by Ryan and Han for Hawaii, which uses MSD elements to define parameters in the model. The cost and convenience of auto storage at the home location and the “importance” of owning a vehicle are based on (1) development density and (2) the accessibility of attractions by transit or non-motorized travel.

3.2.3.1 Use of Density in Vehicle Ownership and Other Socioeconomic Models

Density measures have been used to estimate vehicle ownership, household attributes, parking cost, assignment, and mode choice. In vehicle ownership and household attribute models², density measures are usually used to imply urban congestion. In one vehicle ownership model, the dependent variable was the share of the households by automobile ownership and the model structure was a logit model. In this case, the population density was a continuous variable in the utility equation.³ The use of population or household density would appear to be an obvious variable in the estimation of household size (persons per household) and income.

3.2.3.2 Use of Accessibility in Vehicle Ownership and Other Socioeconomic Models

Accessibility measures can be very useful in developing automobile ownership models and other socioeconomic models. The automobile ownership model developed by Ryan and Han⁴ used a combination of the accessibility measures to develop a measure they called the “auto importance measure.” This measure was the highway time accessibility measure divided by the sum of the highway time accessibility plus the transit time accessibility plus the walk time accessibility.

$$\text{Auto Importance Measure} = \frac{\text{Highway Time Accessibility}}{\text{Highway time accessibility} + \text{transit time accessibility} + \text{walk time accessibility}}$$

The transit time accessibility measure was calculated using only the walk-to-transit portion of the transit accessibility calculations because the drive-to-transit accessibility required an automobile and, therefore, should not be included for the automobile ownership model. This auto importance measure could range from 1.0 (where no transit or walk accessibility is available) to 0.33 (where the three times—highway, transit, and walk—are equal). In extreme cases it might drop below 0.33 (where transit is considerably better than highway). The auto important measure was found to be an

² These are models which, given aggregate data and system data, estimate the number of households (or the market share of households) by various attributes of the household including household size, income, workers per household, etc.

³ “Vehicle Ownership Model Using Family Structure and Accessibility” by James Ryan and Greg Han, presented at the 1999 Transportation Research Board Annual Meeting. See Appendix D.

⁴ “Vehicle Ownership Model Using Family Structure and Accessibility” by James Ryan and Greg Han, presented at the 1999 Transportation Research Board Annual Meeting.

important variable in estimating car ownership; as auto importance increased so did automobile ownership.

3.2.3.3 Mixed Use in Vehicle Ownership and Other Socioeconomic Models

Micro-level mixed uses should provide increases in the walk accessibility measure. This, in turn, will lead to a reduction in the auto importance measure⁵ and therefore to reduced automobile ownership. At the macro level, closer home and work connections may increase transit accessibility faster than highway accessibility and therefore reduce the auto importance measure.

3.2.3.4 Role of Design Factors in Vehicle Ownership and Other Socioeconomic Models

Design factor ratings may be a reasonable variable in the estimation of vehicle ownership. It is anticipated that these ratings schemes could be used in the Ryan/Han vehicle ownership model as a “dummy” variable. That is, a variable that is either a 1 or a 0. Depending on the urban area, the model might have a couple of these variables—one to signify if the area had a high rating (perhaps above 8 on a scale of 1 to 10) and one to signify if the area had a low rating (perhaps below 3 on a scale of 1 to 10).

3.2.4 Improving Trip Generation Models

Trip generation models in current use tend to relate travel to household characteristics. These models are sometimes stratified, such as CBD versus non-CBD models. This stratification accounts for MSD features of the CBD, but in an aggregate manner, so that all parts of the CBD are deemed to be identical. This is obviously not the case. In many model structures, trip generation models predict fewer trip ends for CBD or dense urban sectors than in the less densely developed areas. This is because the primary focus is on vehicle travel, either private or public, totally ignoring pedestrian and bicycle modes.

Incorporating non-motorized travel into the traditional sequential model introduces additional requirements: the trips that have been introduced into the trip generation phase have to be distributed and, if they are not going to be incorporated into the mode choice model, they need to be dealt with at some point prior to that operation. If non-motorized trips are going to be dealt with in the trip distribution step of the sequential model, it is necessary to have zones and networks that can estimate the impedance for non-motorized trips in a way that makes them compatible with the estimates of travel by vehicle. CATS has developed non-motorized modeling capability using a walk network and small zones.

⁵ See the previous discussion on vehicle ownership and accessibility.

3.2.4.1 Use of Density in Trip Generation Models

The role of density in trip generation is difficult to quantify. Some studies have used density both as a continuous variable and as a cross-classification variable in both production and attraction models, with the density being inversely proportional to the trip rate (trips per household or trips per employee). But normally these models were used to estimate “motorized” trips⁶ rather than total trips and the density measures were surrogates for removing the walking trips. That is, as density increased, so did walk trips with a subsequent decrease in motorized trips. But state-of-the-practice travel demand models should include both motorized and non-motorized trips (walking and bicycling). In which case, density should probably not be extremely important in trip generation.

A possible exception to this is the non-home based trips made while at work. A state-of-the-practice model should, at least, identify non-home based trips (if present) as trips made while at work, to or from work, and non-work related. For the non-home based trips made while at work, the employment density measure might be useful. An area of high density might promote more trips since there are many more potential opportunities nearby, although many of these trips might be walk trips. Thus, a person might leave the office to go to lunch or walk over to another person’s office (instead of calling).

3.2.4.2 Use of Accessibility in Trip Generation Models

The use of accessibility measures in trip generation is difficult. Some studies have used the cutoff accessibility measure in the shopping attraction equation. In this case, the shopping attractions per retail employee increase as the number of households within the given time range increases. Similar cutoff accessibility measures have been used for non-home based trips, especially those associated with the work place. For shopping attractions and non-home based trips, the use of accessibility measures appears reasonable. These are discretionary trips and as the number of potential “customers” increases, so should the total number of trips per employee or per square foot of establishment space.

Studies that estimate travel stratified by the income of the traveler have used accessibility measures to help “split” the attractions into income groups. In New Orleans, accessibility was the number of households within 35 minutes by transit; this measure was used in the work attraction model to stratify the attractions by income group. Accessibility in this case was calculated as the ratio of the income group value to the value for all income groups. Essentially this variable said that as workers available in income group X increased, the number of jobs for income group X increased—a fairly reasonable result.

⁶ Motorized trips are trips made by a vehicle, either as an auto-drive, an auto-passenger, or as a transit passenger.

3.2.4.3 Mixed Use in Trip Generation Models

Mixed-use policies in trip generation may be more difficult to ascertain. The micro-level policy should increase the potential for the walk mode and this would reduce trip generation for a model estimating motorized trips. The decrease in automobile ownership would also tend to decrease the total travel. On the macro level, a policy of matching laborers and employment opportunities might increase some accessibility measures and therefore affect shopping trips and non-home based trips, but this is not necessarily true.

3.2.4.4 Role of Design Factors in Trip Generation Models

The effect of design factors is not known for trip generation, aside from the density and accessibility affects. But if a rating scheme has been developed, the analyst should be able to review the effects of this rating on trip productions by including the ratings as one of the variables in a cross-classification model or by using an analysis of variance. Similar analyses could be performed on trip attractions, depending on the observed data available.

3.2.5 Improving Trip Distribution Models

Trip distribution is the process of connecting trip productions (origins) and attractions (destinations), thus creating a web of travel throughout a region. The fundamental theory behind most trip distribution models in the past has been that people are attracted to large accumulations of trip ends and are reluctant to travel any farther than necessary. This theory is very similar to Newton's theory of gravitation, hence the name of the most widely used model, the gravity model. In the last decade, planners have recognized that other attributes of origins and destinations play an important role in the distribution pattern and they are still working on defining the nature and extent of these attractions.

3.2.5.1 Use of Density in Trip Distribution Models

Very little has been done in using density measures in trip distribution. In some cases, the terminal times (the travel times off the highway network, including parking the automobile) are modeled as a function of densities. Since terminal times usually range from 2 to 10 minutes (with the higher values being very rare) a cross-classification model using residential and employment density would be an adequate model. This type of model has been used in Atlanta to estimate terminal times. Density measures have an indirect impact on the distribution model, since they can be used to estimate capacity and free-flow times on the highway networks. These, in turn, would affect the travel times being used by the distribution model.

3.2.5.2 Use of Accessibility in Trip Distribution Models

Accessibility measures are very important in trip distribution models. The accessibility measure (defined as total accessibility) is the denominator in the gravity model where the travel time is defined using a set of F factors rather than by a power. In a logit distribution model, the log sum term is essentially total accessibility—again with a modification of the time function.

In Chicago, the distribution model is an intervening opportunity model. The calibration parameter for this type of model is the L value. The initial calibration of the L value was based on geography, but a later calibration effort related the L values to a cutoff accessibility measure—which was the number of attractions within a certain generalized cost⁷. This is a very interesting case where the accessibility measures modify the travel time function. Neither the F factors in the gravity model nor the coefficients in logit distribution models are made a function of the accessibility measure.

3.2.5.3 Mixed Use in Trip Distribution Models

Mixed-use policies have significant effects on trip distribution. The placement of the origins and destinations of trips has a major influence on the trip length distribution of travel. This, in turn, affects the person and VMT and, potentially, the market shares for the different modes. It is difficult to specify, even in general, the decrease in travel that mixed-use policy would generate, but it can be substantial. It is suggested that an interesting policy analysis would be to specify, for a land use forecast, that each additional worker (household) should be accompanied by an additional employment opportunity (job) no more than X miles from the resident—where X is a value between 1 and 5. Indeed, it should be possible to “program” this policy and build several future land use forecasts with different values of X. Using these land use forecasts, the travel demand models could then be applied and the change in VMT determined. This analysis would allow the analyst to provide policy makers with a measure of the efficiency of mixed-use policies for their specific urban region. Since the potential of mixed use (especially at the macro level) is so great, an analysis of the affects of mixed-use policy is highly recommended as one of the initial evaluation analyses for long range planning.

3.2.5.4 Role of Design Factors in Trip Distribution Models

It is probably difficult to include design factors in the trip distribution model with the exception of the ability to estimate transit walk access more accurately. The analyst might attempt to develop a separate set of F factors for the gravity model based on zones grouped by the ratings (perhaps three groups); or, if the distribution model's

⁷ Memorandum “Calibration and Application of the Intervening Opportunity Trip Distribution Model for the 1993-1994 Conformity Evaluation,” R. Eash, July 5, 1994.

structure is a logit model, the analyst might try using the rating schemes as a set of dummy variables in the utility expression.

3.2.5.5 Including Walk and Bicycle Trips in Trip Distribution

For most of the last three decades, travel models did not include walk and bicycle trips in their trip generation equations. The reason was actually quite simple: the trip distribution, mode choice, and assignment modules did not deal with walking and bicycle travel as primary modes. This meant that estimating walk and bicycle trips in the trip generation phase of the modeling process required removing those trips before proceeding with the analysis. The realization was that walking and bicycle use were, in fact, modes that could be substituted for auto and transit use, given the right infrastructure. For most modeling activities, acknowledgment of bicycle and pedestrian travel was accomplished in reverse; trips generated in walkable neighborhoods were generally reduced or lower in number than trips for the same purpose by households with the same composition but located in neighborhoods without pedestrian amenities.

3.2.6 Improving Time of Day Models

The time of day functions in use in most MPOs are relatively crude relationships between the proportion of trips and the time of day. The percentage in each time period is frequently determined from observations of ground counts. In general, the peak hour and/or peak period factors are regional or subregional, but rarely reflect the site design characteristics of the origin and destination zones. Investigation and further research into the time of day distribution of trips related to MSD features appears to be a most interesting research topic.

3.2.7 Improving Mode Choice Models

In the typical n-step travel-forecasting model, mode choice has received the greatest emphasis during the last decade. In part, this is due to long-standing observations that “transit works” where densities are above some threshold (for example, more than 10 dwelling units per acre). The following sections describe a number of interesting techniques used to increase the sensitivity of the mode choice models to MSD features. The influence of MSD on mode choice models appears to be stronger than on any of the other models in the travel demand forecasting process.

There are two examples of mode choice models calibrated on transit accessibility measures that include not only distance but also the amenities and security requirements necessary for attractive transit access (1000 Friends, 1992; Douglas and Evans, 1997). The weakness in these two methods is their reliance on subjective evaluation of transit and pedestrian environmental factors (PEFs) or transit-friendly factors (TFFs) resulting in replication and transferability issues. On the other hand, the development of subjective criteria, if carefully described and applied by local/regional planners with intimate knowledge of the region’s infrastructure and pedestrian and bicycle infrastructure attributes, can be a useful tool to explain some of the variation in transit use that’s not explained by service and demographic characteristics.

3.2.7.1 Use of Density in Mode Choice Models

Density measures have been used in mode choice models as direct variables; that is in the mode choice equations, and as in-direct variables, used as variables to estimate other measures used in the mode choice model. Some mode choice models have used density measures as continuous variables in logit utility equations, both residential and employment density. Other models have used indicators of density (such as area type) and a CBD as dummy variables so that the coefficient on the variable was in essence a modal bias coefficient. One common method is to have a CBD dummy (a 0/1 variable) as one of the utility equation variables with the CBD defined as having an employment density over a certain value. The use of these dummy variables, though, should be used with caution, because they contain the “cliff” feature previously discussed.

As a macro-scale measurement, density is usually estimated as an average density for a TAZ. The simplest method of making this calculation is to divide the population (or households or employment) by the area of the zone. In some cases, this can produce anomalies; for example, a park in the middle of the CBD might decrease a zone’s density to a low level, or a large building in a small zone might substantially increase the zone’s density. A better measure of density for a TAZ would be land use information (population, employment, etc.) and area within a certain distance of the center of the zone. For example, one-half mile and three-quarters of a mile have been used in some urban areas. This type of calculation becomes fairly easy with GIS systems. One

simple method of performing this calculation was in New York where the GIS system produced a data file of the percent of each zone within a specified distance of the centroid of the subject zone. These percentages were then multiplied by the population, employment, and area of the zones to estimate the density measures. More sophisticated GIS systems can estimate these density measures using more disaggregate data.

Density measures have been used in two different ways: as a continuous variable or as a cross-classification variable, with the density measure having several classes (ranges). If possible, using density as a continuous variable is preferred over using density as a series of discrete ranges. The models that use density as discrete ranges tend to have “cliff” problems, since each range has a set of precise limits. For example, if a density step function is used in a mode choice model, then two adjoining TAZs could produce very different transit shares because the density measure changes from one group to another. This is especially true when the density measure is a binary variable (the zone is either a high density zone or it is not). If discrete ranges are used, there should be more than seven ranges and they should have a fairly minor effect on the dependent variable.

Parking cost has long been a major cost component of mode choice models and some studies estimate the cost of parking based on employment density. The reasoning is that density is an indicator of the cost of the land and, therefore, the building rent; as the cost of rent goes up so must the actual cost of parking. Typically these models are either non-linear equations or piece-wise regression equations. For example, in Atlanta, the parking cost was estimated as follows:

- A null cost for under 5 employees per acre
- As a cost of 1.5 cents per employee per acre after 5 employees per acre
- Plus 50 cents for the next 45 employees per acre
- As a cost of 0.2 cent per employee per acre after the first 50 employees per acre

A travel demand model that includes non-motorized travel should have a method of estimating walk and bicycle trips in the mode choice model. The walk and bicycle model can be included as a separate mode(s) in a full share model, usually a nested logit model. In some cases, the non-motorized trips are removed from the universe of trips after trip generation:

- Reducing the productions and attractions to only motorized travel, or
- Reducing the person trips to only motorized travel.

If this type of procedure is followed, residential and employment density are possible independent variables in the model to remove the non-motorized trips. One method of using these densities would be to have a model similar to the area type model shown on Table 3.2.7-1 (except the residential and employment density combinations would be directed toward the estimation of non-motorized travel).

**TABLE 3.2.7-1
PRELIMINARY AREA TYPE DEFINITIONS FOR THE NEW YORK AREA**

		Employment Per Square Mile Between									
		0-100	100-500	500-1800	1800-3375	3375-6800	6800-10000	10000-22250	22250-48800	48800-211000	211000 and up
Population Per Square Mile Between:	0- 300	11	10	8	8	4	4	3	3	2	1
	300-1000	10	10	8	8	4	4	3	3	2	1
	1000-4675	9	9	9	8	4	7	3	3	2	1
	4675-9600	9	9	9	8	4	7	3	3	2	1
	9600-14500	6	6	6	6	4	7	3	3	2	1
	14500-20000	6	6	6	6	4	7	3	3	2	1
	20000-30000	6	6	6	6	6	6	3	3	2	1
	30000-70000	5	5	5	5	5	5	3	3	2	1
	70000-80000	5	5	5	5	5	5	5	3	2	1
	80000 and up	5	5	5	5	5	5	5	5	2	1

For example, a possible model structure would have a cross-classification similar to Table 3.2.7-1, with the independent variable being the percent of non-motorized trips (instead of a simple area type designation as in Table 3.2.7-1). This type of model would be used for the model structure that removed productions and attractions after trip generation.

For the model structure that separated person trips into motorized and non-motorized trips (simple model not a full nested logit), a similar set of cross-classification tables could be used but the model would have to include a distance component. For large

urban areas, a state-of-the-art travel demand model should include a mode choice model that contains a full set of modes, including non-motorized modes. The models that remove the non-motorized modes prior to applying a full mode choice model should be considered interim models and should be used only until a full mode choice model can be developed.

3.2.7.2 Use of Accessibility in Mode Choice Models

Accessibility measures are usually not used in mode choice models. However, there have been some exceptions. Early mode choice models in the Houston, New Orleans, Seattle and Washington, DC regions used the cutoff accessibility measures (number of attractions within a certain transit travel time) as independent variables. The reasoning for the accessibility measures in these mode choice models was that a person would be more inclined to use transit for a specific opportunity (attraction) if there were many transit opportunities available. An interesting reason for discontinuing the use of accessibility in these models was that it was difficult to explain to policy makers why alternatives had different patronage when the alternatives had similar times but different accessibility values. For example, the travel time difference between stops on a rail line and a busway, from suburban areas to the CBD, might be very similar but the rail line—because of the intermediate stations that provide the ability to travel within the route—tends to have a larger accessibility value (the busway goes directly from the subway to downtown).

There have been some suggestions that non-home based transit trips, especially those related to work, could be estimated using direct demand models, with a major variable being a cutoff accessibility measure, such as employment within 20 minutes of transit time.

3.2.7.3 Mixed Use in Mode Choice Models

Mixed-use policies may or may not increase the use of transit in an urban area. On one hand, it should allow workers to have a reasonable distance to travel to work places which, in turn, allows local bus service to be potentially competitive. On the other hand, the policies may decrease concentrations of employment which, in turn, would decrease the potential for high volume transit modes, such as heavy rail, with a subsequent decrease in the potential for transit. Micro-level mixed-use policies should increase the potential for walk trips, especially for non-work travel. Normally the effect of the micro-level mixed-use policies would be implemented—in the mode choice models—through the use of accessibility measures or some other variables that would specify the increased benefits and potential for walking.

3.2.7.4 Role of Design Factors in Mode Choice Models

One of the major positive points in design features should be the design of good transit access. Covered walkways, sidewalks and direct access should be elements of the

urban design, especially for TODs. The analysts preparing the travel demand models should take care to properly specify the walk impedances for “good” design areas and poor design areas. This would be in sharp contrast to the present procedures of estimating walk times based on spatial areas and assumptions of uniform densities. This type of analysis would probably rely on good GIS data sets and procedures and therefore may still be a few years in the future for many urban areas. Given that this information is available, it could be used to specify more accurate walk times and to separate the walk times into types of “walks” (e.g., covered walkways, separate walk paths, sidewalks on streets, no sidewalks). Each of these different walkways could be either assigned a different “weight” or be used in the statistical analysis to produce different coefficients. With the development of GIS data sets allowing the analyst to perform the above analysis in the future, it may be an extremely useful analysis in the estimation of market shares.

Design factor rating schemes can be used in mode choice modeling. In this case the rating schemes would be used as a set of dummy variables in the logit utility expression. The Maryland National Capital Park and Planning Commission performed such an analysis for the Washington, DC region and found that the design factor ratings were significant variables (Replogle, 1990, 1991, 1995).

3.2.8 Improving Traffic (Trip?) Assignment Models

Once travel patterns have been established and modes have been chosen, the final step in travel forecasting is assigning trips to the networks to determine where congestion levels will occur. The trip assignment models start with trips that have specified origins and destinations and select a path based on minimizing the generalized costs—usually a combination of time and money. The impact of MSD features on this process is not well documented and may not be a particularly strong relationship. For repetitive trips (e.g., work trips) and medium- to long-distance vehicle trips, the path choice of the vehicle is generally not seriously affected by the MSD features at either end of the trip. There may be some impact on the path chosen if the site design characteristics of the development along the right-of-way influence roadway or transitway capacity. As with the time of day models, the impact of various MSD factors on trip assignment procedures represents what we think is an interesting and critical research topic.

3.2.8.1 Use of Density in Trip Assignment Procedures

Density measures have been used in the assignment phase of travel demand modeling. Typically density measures are used as one of the variables in the determination of highway capacity and free-flow speed. Density measures represent urban congestion that impacts the design of highway and performance, which is difficult to measure in the base year and probably impossible to estimate in future-year forecasts. These are items like driveways, on-street parking, truck loading areas, and design standards. In this case, density measures are typically used in a cross-

classification model with density and the type of highway being the two independent variables, and the capacity per lane or the free-flow speed being the dependent variable.

Since residential density and employment density may have different, but related, effects on highway capacity, some studies have specified an “area type” that is developed as a cross-classification model. Here, residential density is used as one independent variable and employment density as the other dependent variable. In most cases, the transportation analyst classifies TAZs into a fairly wide range of “area” types; ranging from very commercial urban with substantial curbside interference to rural areas. The employment and residential densities are then reviewed to ascertain the cross-classification model that will estimate the area types accurately. An example of a cross-classification model to estimate area type is shown on Table 3.2.7-1.

The area type and a definition of the type of highway (facility type) are then used as indicators for free-flow speed and capacity. Some transportation planning packages allow this type of table to be directly input in the assignment procedure, while in other cases the analyst has to update the highway link records with the free-flow speed and capacities. An example of this type of model is shown on Table 3.2.8-1.

**TABLE 3.2.8-1
EXAMPLE OF FREE-FLOW SPEED AND CAPACITY TABLES
USING AREA TYPE AND FACILITY TYPE**

Area Type	Facility Type	Free-flow Speed	Capacity Vehicles per Lane per Hour
1	1	28	350
1	2	44	1850
1	3	44	1850
1	4	54	2250
1	5	52	2200
1	6	52	2200
1	7	47	2000
1	8	42	1800
1	9	50	1800
1	10	48	1700
1	11	42	1650
1	12	38	1300
1	13	33	1100
1	14	30	1000
1	15	29	900
1	16	25	800
1	17	42	1200
1	18	30	700
1	19	24	400
1	20	26	400
1	21	7	90000
2	1	28	400
2	2	45	1900
2	3	45	1900
2	4	56	2300
11	10	59	2250
11	11	57	2350
11	12	51	2150
11	13	46	1950
11	14	44	1900
11	15	43	1800
11	16	42	1750
11	17	55	1500
11	18	50	1050
11	19	44	750
11	20	32	850
11	21	45	90000

3.3 DATA NEEDS FOR MICRO-SCALE DESIGN

All the data used in travel demand modeling are stored either on networks or in polygons (called zones in most MPO models). With this information, we can describe the demographic and environmental characteristics of a point in space occupied by a single traveler and then the characteristics of a journey to another point in space. These two points are typically called “the origin and destination of trips,” or the “venue for activities,” or simply places. Ideally, for MSD purposes, we would like to be able to express the activity and travel-related information at the smallest practical area level, such as a single dwelling unit, plot of land, or commercial place. We also would like to be able to calculate and interpret all of the opportunities and constraints available to a traveler wishing to move from one place to another.

It is clear that each step in enhancing travel demand models leads to requirements for more data, not only a larger quantity of data, but also more kinds of data that include greater levels of intimacy. Adding stated preference surveys to the revealed preference surveys adds another level of complexity and uncertainty to the underlying data used to construct choice models.

Collecting the desired household interview survey (HIS) and site design data to include MSD features in models results in increased costs and, unfortunately, a certain level of intrusiveness into people’s lives. The results of this increased intrusion are likely to include omission of activities or trips that the respondent considers private, or even rejection of the survey by some households, leading to concerns about non-response bias and something we could call “mis-response” bias. Forecasting these variables may be the most daunting task of all. MPO staff members have frequently been attacked for what is seen as invasive.

As an alternative to household surveys, there is growing interest in using global positioning satellite (GPS) tracking. Some believe that this results in more precise locations, although the individual locations still need to be tied to the activities that are taking place. As a result, there would still be a need for a fair amount of diary collection, even using GPS.

Another data issue concerns those variables, particularly at the parcel level, that may provide spurious information since their current status may be quite different from their future status. This may be particularly true where future land use patterns depend upon private actions that are kept secret for fear of commercial or economic difficulties if they are made public. For example, a developer assembling parcels of land for a major shopping mall may be reluctant to divulge ownership (frequently hidden under dummy corporations) for fear that divulging the information may raise the cost of assembling the property. In a similar vein, detailed plans by central planning boards that pinpoint specific parcels for future development may create friction between the planners and the current owners of the property.

Planners have expressed concern about the TIGER file and its lack of accuracy and precision. Apparently the longitude and latitude values result in errors of one to several hundred feet. E-TAC files, which are developed at the county level, are considered to be superior. Several analysts in New York have suggested that we warn users about match problems and discuss which GIS regional consortia have used. The MPO or transit agency can coordinate the GIS work with the local jurisdictions, working at the lowest level of detail imaginable, since it's always easier to aggregate to larger land areas or polygons than it is to subdivide at some later date. A challenge for the GIS would be to provide highway and signal data, currently lacking in GIS at most jurisdictions.

GIS data seem to be a natural for use in MSD. We recommend starting with census data, particularly the TIGER line file, as the least expensive accessible data that could be used for MSD analysis. By manipulating publicly available data it is possible to develop indexes that distinguish among MSD features among different transportation planning zones.

3.4 NEW APPROACHES TO TRAVEL FORECASTING

3.4.1 Activity Versus Trip as the Unit of Analysis

One of the new approaches in travel forecasting is the use of activities rather than trips to describe a household's daily pattern. The use of activities leads to a need for better land use data and in fact is virtually meaningless without it. The major difference between activity analysis and trip analysis is the inclusion of trade-offs between in-home vs. out-of-home opportunities. Coupled with these activity trade-offs, we also are moving towards including walk trips and bicycle trips or other non-motorized modes in addition to autos and transit. Not only is the neighborhood pattern important in the home end of a home-to-work couple, but the land use pattern at the work place has a major impact on the set of activities and the tours that will be made by residents of the household.

The trip decision process asks the following questions:

- Is it possible to do what's needed at home?
- If not, can the objective be reached by walking or biking?
- Is an automobile available and can the desired location be reached by driving or by transit?
- If a vehicle is not available and there is nothing within walking distance, then the individual must stay home and not complete the desired interchange. If a vehicle or transit is available and there is nothing within walking distance, a motorized trip is essential.

In the past, trip generation models ignored trips that did not take place in a motorized vehicle such as an auto or a bus, thus giving no credit for settlement patterns or policies that reduced travel by increasing satisfaction through walk trips instead of auto trips.

The data required for activity analysis is quite similar to the data collected for travel or activity diaries. The essential ingredient for activity analysis is to have enough information to estimate the trade-offs between activities taking place in the home and out of the home. In general, household surveys do not include information about MSD features surrounding the venues listed in the survey itself. This information is readily available, although not always inexpensive, through GIS.

Activity modeling as opposed to trip analysis is the wave of the future according to planners in Portland, Oregon; Berkeley, California; and other fast-growing cities. This study will not deal in depth with activity modeling. Planners will continue to deal with trips until the activity models are ready. It is important to collect activity data sets today even if we don't include them in the models. This is because:

- In-home activities may take the place of activities away from home.
- Activity surveys are more likely to capture very short trips that are considered part of an activity but that seem insignificant.
- Activities by non-drivers (children, teens and elders) are often overlooked in urban centers but included in suburbs where "mom's taxi" is required.
- Chauffeured trips, and the "soccer mom" are included in trip diaries in the suburbs, but may be ignored in more urban "walking" and inner suburbs. (In these latter areas, teenagers may travel alone.)

It is essential that we recognize the value of activity data and associated data collection issues. Activity data surveys require more intrusive and probing questions that may increase the non-response rate and data collection costs (more interview time per household). There is also a trend towards multi-day surveys to capture trade-offs around activity schedules, and greater use of stated preference surveys to estimate traveler response to new, not previously experienced, stimuli. Each of these innovations and enhancements increases the costs of data collection, but since the next HIS may need to support 5 to 10 years of model development and application, careful survey design and aggressive collection seems imperative. Any other course appears to have serious long-range disadvantages.

Three prejudices exacerbate the phenomenon of overemphasizing vehicular trips and under-emphasizing the role of non-motorized travel as part of gaining satisfaction and fulfillment of needs and desires. First, travelers tend to be students, young teen and elderly demographic groups that are not considered as important as vehicle-using workers and shoppers. Second, short trips that don't consume roadway space for vehicles are seen as less interesting and of less importance; reductions in costs are not viewed with the same importance as increases in costs and, consequently, saving a trip lacks the impact of causing an additional trip. Third, trips that begin and end at home

with no intermediate stops registered, such as a walk around the block, are not considered trips at all, in spite of the fact that they may be providing an important benefit. An alternative would be driving to a health club, which would be considered a trip and another activity.

Concurrently with the interest in reflecting MSD issues and attributes in the modeling process, a number of efforts are under way to enhance various components of the modeling process and to transform it from the essentially n-step sequential models used for the last several decades. Several of these efforts are critical to the incorporation of land use and MSD variables in the planning and travel forecasting modeling process. In particular, efforts should be increased in the area of activity-based models and the development of GIS capabilities for describing the environmental and cultural attributes of any given point in the region based on evaluation of a number of data layers or coverages that include infrastructure, environmental, and cultural information.

3.4.2 Micro-Scale Design and Residential Location Choice

The neighborhood or settlement pattern around a residence has been seen to have a major influence on travel and the activities undertaken by residents. For purposes of this discussion, we divided households into five cohorts that influence the type of residential neighborhood chosen and the type of accessibility to jobs, shopping, and entertainment that are needed or desired:

- Single young people or young married couples without children
- Young families with children at school and living at home
- Empty nesters
- Retirees still able to drive
- Elderly who are no longer mobile by SOV

Each of these cohorts has different requirements for space, costs, educational facilities, cultural activities, accessibility to jobs, and walkability and safety, both personal and security. The mix of attributes of different settlement patterns or neighborhoods is important because location of a residence in an outer suburb may preclude a number of activities and decrease accessibility by foot or bicycle. As a result, this type of residential location may not be attractive to young people or retirees. On the other hand, educational facilities are not of great importance to young families without children, whereas they are extremely important to families with school age children. These phenomena have two significant ramifications:

- A decision on residential location made when a household is a member of one cohort may be quite different than the decision made within the timeframe of the current cohort.

- The settlement pattern in which a residence is located will have a significant impact on the activities in which that household can engage and the transportation necessary to fulfill the particular activities selected. What this really means is that a household's choice of activities may be determined by a decision about residential location made many years earlier. What is particularly important for MSD issues is that certain residential locations preclude activities when they are not accessible, leading to a strong argument for analyzing activities rather than trips when compiling data bases for travel analysis.

It is important to recognize the interactive nature of the transportation and land use models even though the changes may be difficult to represent in travel forecasting models. Long-term residential locations may be chosen as a function of short-run visions. This is another way of saying that the choice we make may not be applicable very far into the future. It may be that a life event such as a birth, death, divorce or marriage raises the question of whether a household will move or stay or experience a job change. The decision may frequently revolve around friends or other members of the family cohort and the location of that cohort in the life cycle. For example, a decision to move or stay when the household is composed of adults and children who are within a year of leaving for college or their own life may be quite different than the same family's decision made when the children were pre-school age. The residential location and the location of job and other activities will have a major influence on short-term or daily decisions.

In the short term, we deal with decisions that may include impulse or habitual patterns. A number of retail choices, such as fast food restaurants, non-prescription drug stores, and other relatively ubiquitous retail establishments attract customers who are making other journeys and include a stop on impulse. A number of travel decisions are the result of habitual patterns; for example, the route taken on the way to work that may or may not be the least congested on a particular day but is chosen on the basis of historical data and habit. This choice may be "efficient" in terms of the energy needed to make decisions on alternate paths.

MSD features will influence whether or not an activity will take place at home. Certain activities must take place at home or be foregone if the only other alternative requires automobile use (too far to walk and no transit available). If the only transportation alternative is auto, then to reach the activity out of the home will involve a journey that is part of a longer tour. MSD features at the origin or production point determine the modes that are available for the first journey and whether or not autos are available for the rest of the tour. Likewise, they determine whether or not child care requires a diversion from the typical path, and whether or not it is located near the home or workplace. The mix of land uses, another MSD feature, will also be important in setting up the sequence of trips within a tour or journey.

We see that MSD features play an important role in making long-term residential and job location decisions, that in turn have important and, in fact, critical impacts on short-

term (daily) or impulse decisions. Another impact of this process is that life style changes that tend to take place slowly may mean that neighborhoods respond in a slow fashion to changes in MSD or urban design features. Therefore, introducing good transit service and sidewalks may not show impressive benefits or changes in lifestyle for as much as a decade, principally because the residents have organized their lifestyle around different patterns.

Another factor in the choice of residential location appears to be the neighborhood and its visual and structural components, how close the houses are to each other, how walkable it is, how well the houses and surrounding grounds are tended, and how attractive the walkways are. These may be appealing to individual family taste more than to economic decisions about transportation. In examining decisions and models, it would appear that travel time or commuting distances are more a constraint on the other choices than a real element in the residential location decision. Put another way, any location within a tolerable commuting distance is a candidate and is not significantly more attractive because it's closer rather than farther from the center of employment. Of course, it appears that urban dwellers would prefer to be closer to their jobs and not have to deal with traffic congestion

