NEW JERSEY'S LINKS TO THE 21ST CENTURY: MAXIMIZING THE IMPACT OF INFRASTRUCTURE INVESTMENT

Working Paper No. 2

Discussion of Alternative Modeling Frameworks

By:

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Preface

The University Transportation Research Center (UTRC), as part of the *New Jersey's Links to the 21st Century* project, has requested the different members of the research team to produce working papers on the different facets of the analysis. These working papers are intended to provide an initial basis for discussion and analyses of ideas, and to stimulate discussion and analysis on the part of both team members and New Jersey Department of Transportation representatives.

In this context, rather than being an official expression of the research team, the working papers represent a starting point for discussion. The research team is extremely interested in receiving comments and suggestions from the readers and reviewers. Constructive comments and suggestions will enhance the quality of the final product, ensuring the New Jersey Department of Transportation receives a product of the highest quality representing the state of the art of transportation science.

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Introduction

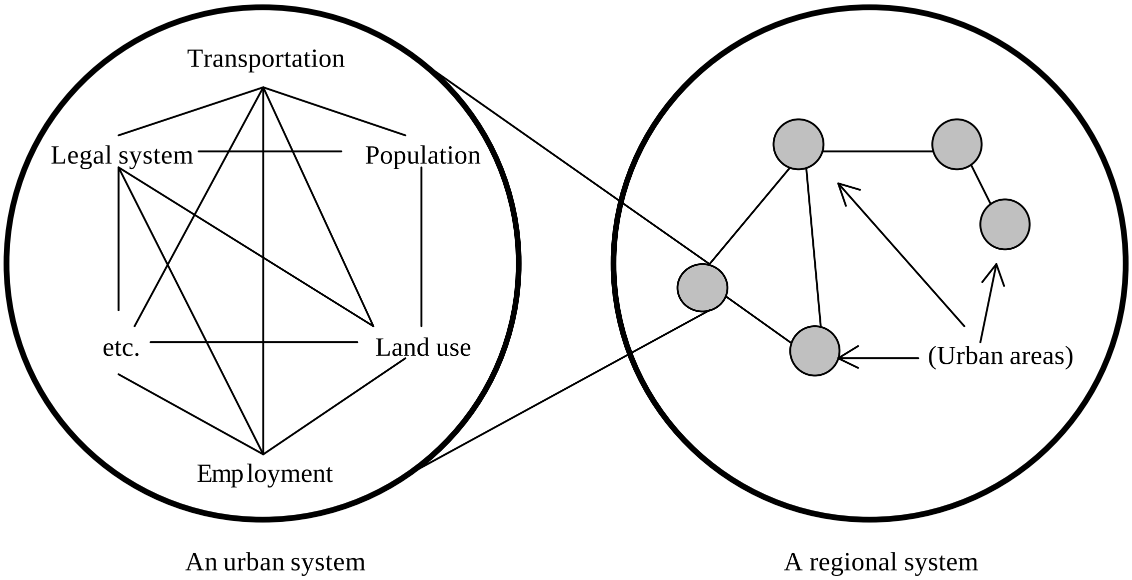
The main objectives of this paper are to briefly discuss the alternative modeling frameworks and address some of the key questions in anticipation to the modeling components of the *New Jersey's Links to the 21st Century* project. This report reviews the spectrum of modeling options seeking to balance the needs of the New Jersey Department of Transportation, the practicality of the different approaches, their conceptual validity, and the corresponding potential for research contributions. The report focuses on the following elements: *a) definition of scope, b) level of specification (network and zoning), c) modeling options and computer tools,* and *d) data needs*.

Definition of scope: system and environment

The first major decision that the research team must tackle is to determine the scope of the modeling effort. This decision will have a direct impact upon the magnitude of the work to be done, and the modeling tools that will be required. An under-specified system will fail to provide a meaningful depiction of the major interactions between transportation flows and land use, while an over-specified system will significantly increase the amount of data required, as well as the corresponding efforts in both calibration and forecasts. For these reasons, it is crucial for the success of the modeling effort to define an appropriate scope of the system to be modeled.

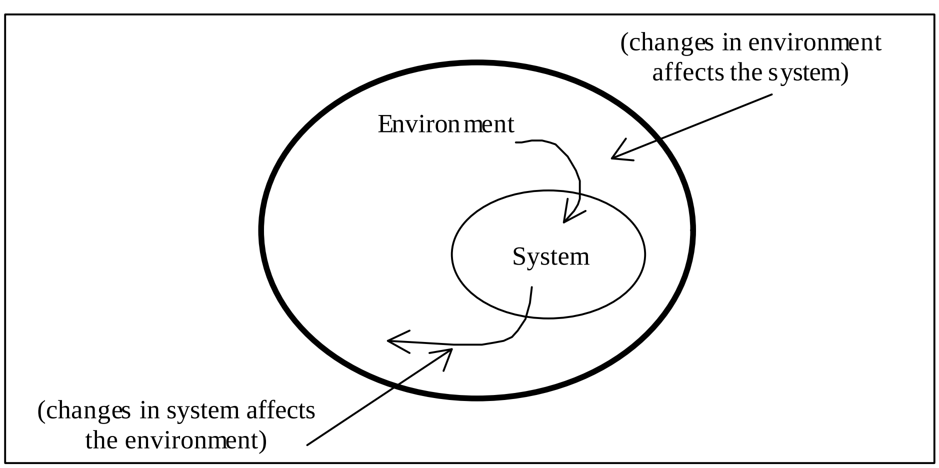
At this stage, it is important to provide some basic definitions to ensure the consistent use of the technical terms used throughout this document. For the most part, these definitions follow the works of Hall (1968) and von Bertalanffy (1968). In simple terms, *System* will refer to a set of entities collaborating in the pursuit of a given set of objectives and following a certain set of self-regulation rules. Implicit in the definition of system is the concept of *sub-system*, i.e., a sub-set of the entities. In this context, an urban area may be considered a system comprised of subsystems, such as transportation, land use, employment, etc. (systems in their own right). By the same token, the urban area is a subsystem of a higher level system, i.e., the regional system. As can be seen, the definition of systems and subsystems are relative to the scope of the work. Figure 1 depicts a schematic of a system.

Figure 1: Examples of urban and regional systems



Environment refers to the set of entities that, while not being part of the system, may be conditioned by the system's performance and/or that may have the potential to condition system behavior. Figure 2 exemplifies the relationship between system and environment. While the concept of environment is used to define the "external" boundaries of the system, the concept of *Black box* is used to specify the lowest level of dis-aggregation, beyond which the analyst is not interested in the internal dynamics.

Figure 2: System and environment



While for the vast majority of the modeling projects, practitioners seldom explicitly define the *system* and the *environment* that they model, in modeling projects of great complexity such as *New Jersey's Links to the 21st Century* providing explicit definitions of system, environment, and the lowest level of dis-aggregation (i.e., the black boxes) will help both the modeling team and the client, New Jersey Department of Transportation, to achieve a common understanding of the scope of the work to be done. For that reason, the research team will attempt to define, in as much detail as possible, the system and the environment that will be modeled as part of the *New Jersey's Links to the 21st Century* project.

The definitions of system and environment for the modeling component of the *New Jersey's Links to the 21st Century* project need to be consistent with the project's objectives, which are related to the assessment of economic development impacts of transportation investments. These definitions are multidimensional in nature encompassing geographic and economic considerations, among many others.

The geographic definition of the system could be based upon different criteria. The first alternative is to define the system based upon the economic interactions among the different counties. In this context, counties will be included as part of the system to be modeled based upon the economic interactions with adjoining counties. This definition could be supported by analyses of commuter travel patterns, interviews with transportation industry representatives, etc. An alternative way to specify the system is simply as the set of counties comprising the administrative/political jurisdiction of Northern New Jersey, as defined by the North Jersey Transportation Planning Authority (NJTPA). It is important to highlight that each approach would lead to a different definition of the system to be modeled, and the corresponding modeling environment. This, in turn, will have significant implications in terms of the corresponding data and calibration efforts.

As a starting point for discussion, this paper will focus on what can be considered an administrative definition of Northern New Jersey (the project team does not have yet data, to attempt the definition of the system based upon economic interactions). The main advantage of using an administrative definition of Northern New Jersey is that this definition fits the scope of the study objectives. However, such definition may eventually over-specify the system by including counties with no significant interaction with the counties along the West side of the Hudson River that are the main focus of the project, or in contrast, may leave out counties or communities that have important interactions with the focus area. However, it seems that the definition of the system based upon the economic interactions will result in a smaller geographic area that, in turn, will may (significantly) reduce data collection and data processing costs.

Because of the critical nature of the geographic specification, input is needed from New Jersey Department of Transportation regarding NJDOT's interpretation of the modeling scope of this project. This decision has to take into account, among other things: a) data collection and data processing costs; b) the consistency of such definition with project objectives.

Geographic definition of the system (based on the administrative/political definition of Northern New Jersey)

From the geographic standpoint, the system –for modeling purposes– would be comprised of the counties of: Sussex, Passaic, Bergen, Hudson, Essex, Morris, Warren, Union, Hunterdon, Somerset, Middlesex, Monmouth and Ocean (see Figure 3a). However, since the main interest seems to be on the economic development impacts of transportation projects along the Hudson River, the level of specification of both the transportation system and land use will be higher in the counties of: Bergen, Hudson, Essex, Union and the Northern section of Middlesex (see Figure 3b). The environment will be comprised of the counties of: Richmond, King, Queens, Nassau, Manhattan, Bronx, Westchester, Rockland, Orange, Sullivan, Pike, Monroe, Northhampton, Bucks and Burlington.

Figure 3a: Geographic definition of *System*

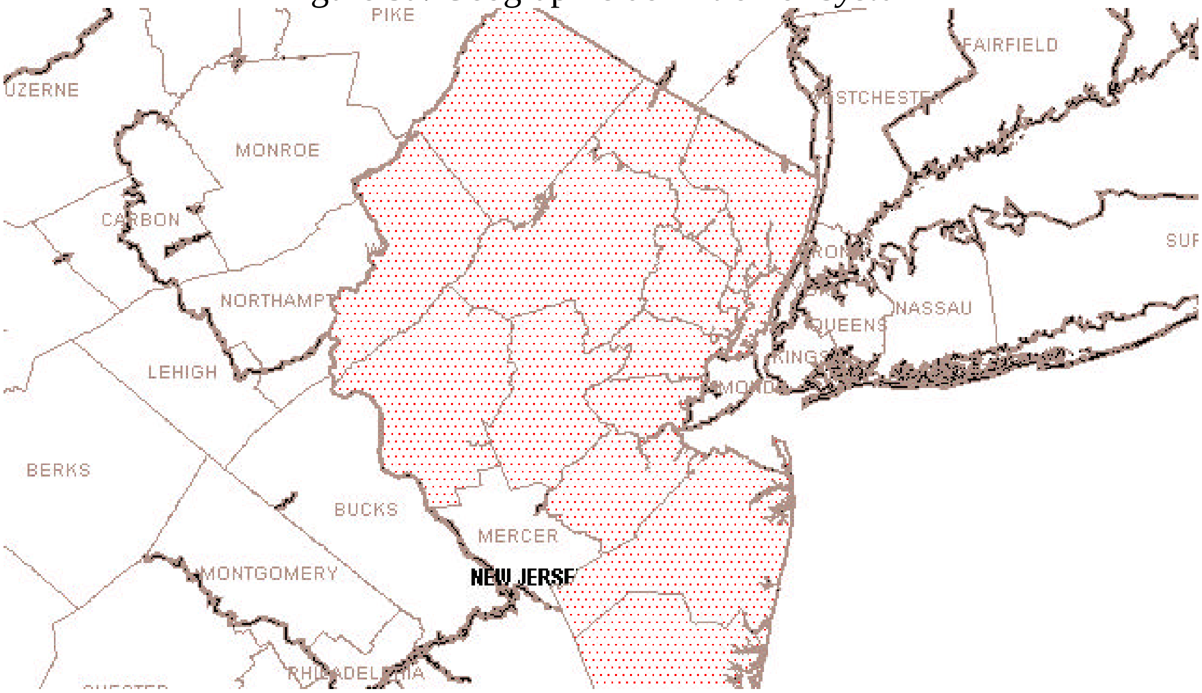


Figure 3b: Section of the *system* with higher level of specification

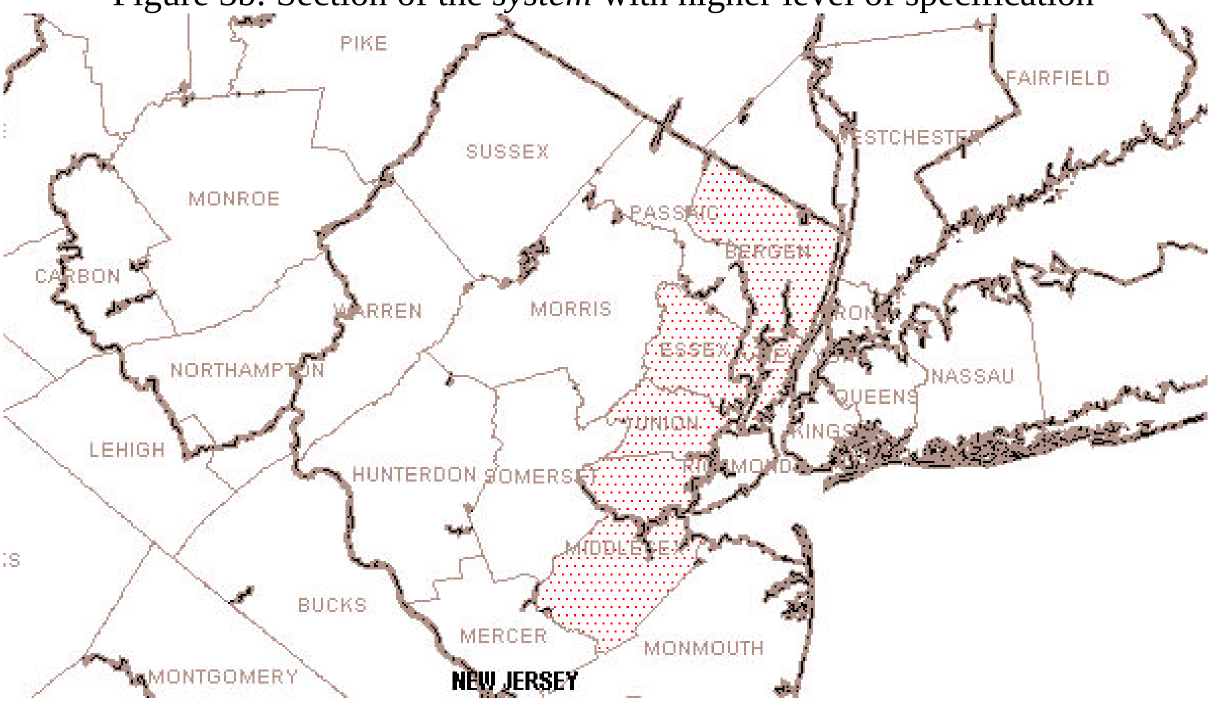
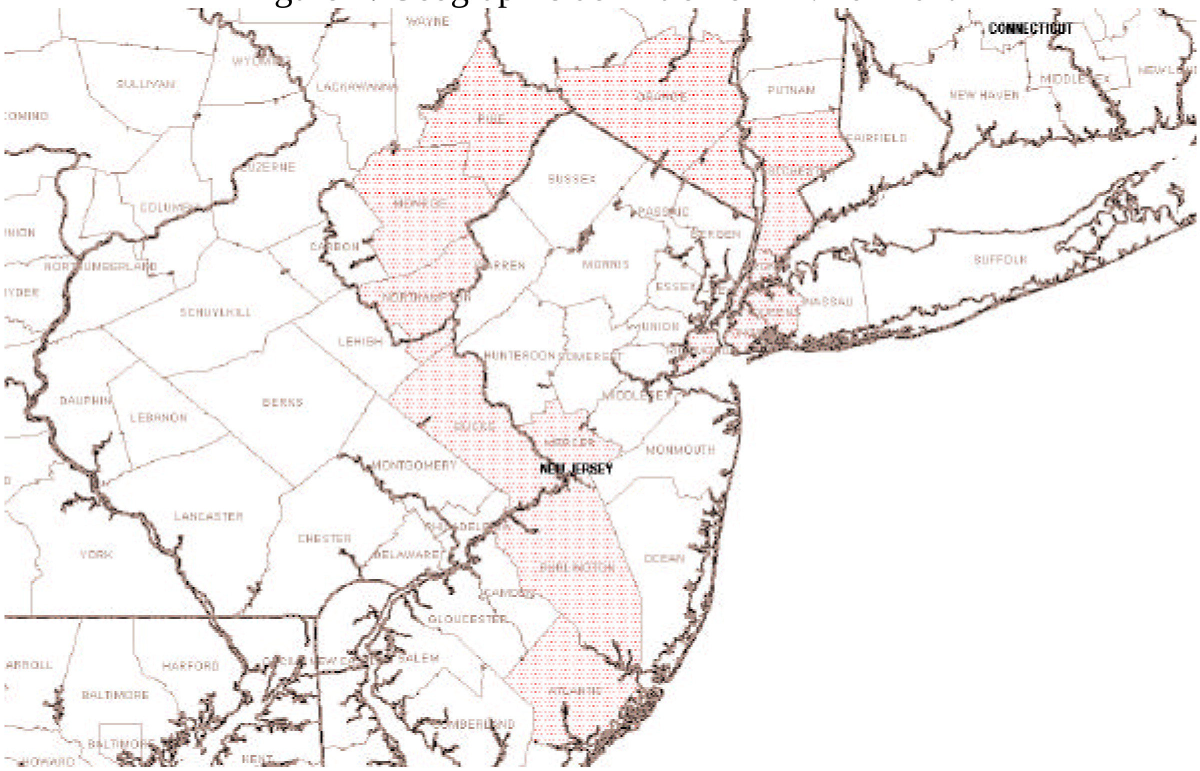


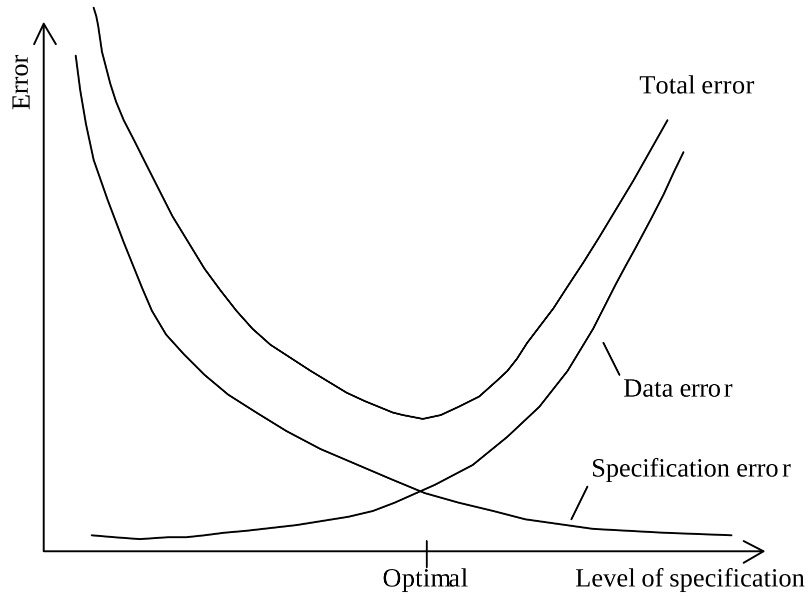
Figure 4: Geographic definition of *Environment*



Level of specification

The level of specification, which will implicitly determine appropriate parameters for modeling, deserves careful consideration because of its implications for data needs and calibration efforts. A highly disaggregated system could have the potential to capture the interactions among the modeling units, though the calibration effort and data needs will increase significantly. At the other end, a very coarse system, though simpler to calibrate and model, may not be able to capture the fundamental economic relationships. The optimal level of specification is usually found in between the two extremes, as depicted in Figure 5.

Figure 5: Specification and data errors



In transportation modeling, the level of specification is of critical importance when specifying the transportation network and the corresponding zoning system. Given the regional scope of the proposed modeling approach, the research team anticipates that in the five counties with the higher level of specification (with an area of roughly 600 square miles and a population of 3.3 million), the transportation analysis zones (TAZs) on average will be in the range of 2-5 square miles each. According to this plan, the system could be specified with roughly 150-250 TAZs; the environment could require approximately 100-150 TAZs. This level of specification would be consistent with standard modeling practices for regional transportation studies such as the Anillo Metropolitano project (Guatemala, José Holguín-Veras, 1999), Panamá's National Transportation Plan (Panamá, José Holguín-Veras for Frederic R. Harris Inc., 1989). Table 1 shows the number of zones for a variety of transportation studies (after Ortúzar and Willumsem, 1994).

Table 1: Number of zones for typical transportation studies

City	Population	Number of zones	Comments
London (1972)	7.2 million	2252	Fine level subzones
		1000	Normal zones at GLTS
		230	GLTS districts
		52	Traffic boroughs
Montreal Island (1980)	2.0 million	1260	Fine zones
Ottawa (1978)	0.5 million	120	Normal
Santiago (1986)	4.5 million	260	Zones, strategic study
Washington (1973)	2.5 million	1075	Normal zones
West Yorkshire (1977)	1.4 million	1500	Fine zones
		463	Coarse
Guatemala City (1999)	2.1 million	186	Regional study
Santo Domingo (1982)	1.3 million	40	Zones, strategic study
Extension of Caracas Metro	4.5 million	25	Regional study
La Victoria (1986)	0.12 million	30	Zones, strategic study
Curacao (1981)	0.15 million	30	Regional study

The specification of the network will focus on the major components: highways, arterials, major transit routes, and rail links. It must be kept in mind that the specification of the transportation network must be consistent with the geographic specification of the system, in terms of TAZs.

Modeling options and computer tools

The selection of the modeling approach is a function of the project's objectives and project constraints and resources. In this section the different methodological options are briefly discussed, highlighting the corresponding pros and cons. The main methodological options identified are: a) Random Utility Models; b) Microeconomic models (e.g., of accessibility and economic development); b) variants of the Urban Transportation Planning System, i.e., the Four-Step Model; c) Integrated Land-Use Transportation Models. Table 2 shows a summary of their features.

Table 2: Summary of features of main modeling options

~~Variable:~~	**Random Utility Models**	**Micro Economic**	**Variants of UTPS**	**Land Use Transportation Models**
Level of aggregation	Disaggregated	Both	Aggregated	Aggregated
Data requirements:	Choice data Attributes of alternatives	Choice data Attributes of alternatives Land Use data	Network data Land Use data	Network data Basic employment data
Consistency among model components	Within each model	Within each model	Consistent	Consistent
Calibration process	Moderately difficult	Moderately difficult	Moderately difficult	Difficult
Consideration of Land Use	Exogenous	Exogenous	Exogenous	Endogenous
Ability to assess economic development	Marginal	Able	None	Able

As can be seen, only two of the modeling approaches capable of assessing economic development impacts. Given the fact that this project is specifically concerned with economic development, modeling approaches deemed not able to assess economic development must be disqualified from further consideration. This leaves only two alternatives: "Microeconomic Models" and "Land Use Transportation Models;" these are further discussed in what follows.

The *Microeconomic Models* option would attempt modeling the interactions between transportation, land use, and economic development on the basis of a set of independent models (of accessibility, land use, etc.) based upon microeconomic and economic development theory. Current and past data could be used to express land use as a function of transportation accessibility, for instance. Different models, calibrated independently, would address the different facets of the problem, i.e., accessibility, land use, and economic development.

Land Use Transportation Models are based upon the assumption that transportation flows and land use changes are so intertwined that it is not possible to separate them. In this context, urban areas are modeled as a system comprised of a land use sub-system and a transportation subsystem. Basic employment is assumed to drive the economic development, as well as the geographic distribution of the service employment and the population (together with accessibility). By their very nature, they ensure consistency between accessibility and land use.

Though easier to calibrate, a modeling approach based upon Microeconomic Models would not ensure consistency among the different models. This is a consequence of the fact that each model is independently specified and calibrated, for the most part, with no formal relationships with the other models (such relationships could be build with other models). In this context, there is no formal way to ensure, for instance, that the output of accessibility models will be consistent with the output of land use models, or economic development models; though micro economic models are useful to gain insights into the fundamental relationships driving these processes.

Land Use Transportation Models do have the benefit of a consistent theoretical foundation on which land use and transportation flows are the two sides of the urban equation. However, these models are difficult to calibrate, though once this hurdle is overcome, they provide great insights into the impact of transportation policies upon land use, and vice versa. Given the long term nature of this research project, this author recommends the use of Land Use Transportation Models because of the potential payoff for the New Jersey Department of Transportation. However, the research team will also investigate the use of some economic models that are expected to provide insights and help assess the overall consistency of the results provided by the Land Use Transportation Models.

In terms of the corresponding computer tools, the research team anticipates the use of the following computer packages:

a) TRANSCAD (www.caliper.com): A leading transportation modeling software based on Geographic Information Systems (GIS). TRANSCAD will be used to conduct GIS analyses, most likely related to the specification of the transportation network, in anticipation of the use of the Land Use Transportation Model.

b) TRANUS (www.modelistica.com): A Land Use Transportation Model developed by Professor Tomas De la Barra. TRANUS has been successfully applied in a number of different countries, in Europe, Latin America and the United States. Descriptions of TRANUS, its economic foundation, and papers can be found at the above web site and De la Barra (1989).

c) Statistical Software Tools (SST) and Statistical Package for the Social Sciences (SPSS): Both SST and SPSS will be used for statistical and probability modeling, the estimation of parameters, and data analysis.

Data needs

Should the New Jersey Department of Transportation and the research team decide to use Land Use Transportation Models, the data requirements would not be significantly different to those required by the more traditional UTPS applications. For the most part, the information required will be comprised of employment (categorized by economic sector), population (subdivided by income group, for instance) and land use characteristics such as space available and an indication of prices.

Land Use Transportation Models do have a more involved calibration process than the traditional UTPSs. However, the research team has experience using and calibrating this type of model and, in addition, has strong relationships with Professor Tomás De la Barra, the developer of the TRANUS system. Professor De la Barra and his staff will assist the research team, should the need arise.

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