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A Gis-based decision support for travel demand analysis

Sandeep Burli
University of Nevada, Las Vegas

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A GIS-BASED DECISION SUPPORT SYSTEM FOR TRAVEL DEMAND ANALYSIS

by

Sandeep Burli

A thesis submitted in partial fulfillment of the requirement for the degree of

Master of Science

in

Civil Engineering

Department of Civil and Environmental Engineering
University of Nevada, Las Vegas
December 1995
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Abstract

Transportation related problems have become one of the most pressing and visible concerns of urban life. Growing traffic congestion increases the pressure on the transportation system and results in deterioration of both the mobility and quality of transportation service provided. Although the transportation problem is multifaceted, a very important transportation issue in the mind of the public is congestion. Limited resources and insufficient transportation capacity aggravate the problem. This necessitates optimal allocation of existing and new resources. The objective of this research is to develop a decision support system to facilitate transportation planning and policy development. The system is designed to help identify travel demand characteristics in urban areas and to evaluate key variables which influence these characteristics. In turn, this will assist policy development for better allocation of existing resources, deployment of new resources, enhancement of urban mobility and payment for access to transportation services in metropolitan areas. An urban travel demand forecasting model (TRANPLAN) and a Geographic Information System (ARC/INFO) program are used to support the analysis. The decision support system is a user friendly, menu driven analytical system. Specifically, it helps identify the spatial distribution of travel demand at the Traffic Analysis
Zone level for various trip purposes. It also helps perform simple statistical analyses and incorporates Boolean algebra based analysis. Among the most powerful features of the system are its user friendly interface and its graphical display capabilities. The Las Vegas metropolitan area is used as a case study for demonstration of the application of the decision support system.
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CHAPTER 1

INTRODUCTION

Traffic congestion has become a disruptive fact of life in most metropolitan areas in the U.S.A. The astonishing increase in both the number and use of automobiles for commuting has caused traffic problems in many metropolitan areas. The number of cars and trucks increased almost 50 percent nationwide between 1975 and 1990, a period when it had become difficult to expand highway capacity [Fielding and Klein, 1993]. In most parts of the United States, vehicle ownership as a proportion of population is approaching one car per adult of driving age. The ratio of passenger vehicles to population between ages 15 and 74, rose steadily from a value of 0.30 in 1940 to 0.95 in 1989 [Genevieve, 1994]. Between 1975 and 1985, population and employment grew by around 18 percent and 30 percent, respectively, in the 32 largest metropolitan areas in the U.S. Over the same period, traffic volumes in these areas increased 12 percent, while highway mileage grew by a little over one percent [Cevero, 1991]. These statistics show that increased demand coupled with a stagnant supply of road facilities adds up to congestion. Fiscal pressures have also taken a toll. Inflation has devalued construction dollars and eroding
gas tax revenues and government-imposed spending limits have drastically curtailed spending.

Motivation

In metropolitan areas traffic congestion has increased and is likely to continue increasing to some degree. In turn, increasing traffic congestion problems increase the pressure on the transportation system. Generally, there is enough highway capacity in American cities to comfortably handle traffic volumes on any given day. The problem, of course, is that most of the travel demand is concentrated over short time periods during the day and along relatively few corridors. Thus, our challenge is to make better use of the capacity already in place by redistributing demand either by mode, by time, or over space. With supply of transportation services unable to keep pace with increases in demand, traffic congestion is a major problem faced by major metropolitan areas in the USA. This has a direct impact on the mobility afforded and the quality of service provided by the surface transportation system. The availability of limited resources necessitates reevaluation of existing mechanisms for providing access to existing transportation facilities and developing new services.

Hopes that wise transportation investments will improve the quality of life, revitalize the central city, spur rural development, support economic growth and competitiveness, reduce environmental degradation, and improve social equity are matched by fears that transportation also causes great and possibly irreparable harm. The most commonly considered options are charging tolls, "congestion pricing" mechanisms, and
providing preferential service to select groups of users such as high occupancy vehicles (HOV) and transit vehicles. Each approach has associated costs and benefits. The development of successful strategies requires accurate identification of these costs and benefits. These are in turn based on identification and quantification of travel demand, its distribution and factors affecting the same.

**Objective and Scope of Work**

Although the urban transportation problem is complex, one of the most important transportation issues in the mind of the public is congestion. Limited resources and transportation capacity aggravate this problem. Addressing and alleviating such a problem requires the optimal allocation of existing and new resources. The objective of this research is to develop methodologies to assist policy development for better allocating existing resources, deploying new resources, enhancing urban mobility and paying for the access to and use of transportation services in metropolitan areas. The focus of the research is to develop a decision support system that would help identify travel demand characteristics and evaluate the spatial distribution of travel demand and key variables which affect travel demand. The methodologies incorporated in the system could be used to support policy development, planning, design and operations of transportation systems in metropolitan areas.

An urban travel demand forecasting model (TRANPLAN) and a Geographic Information Systems (ARC/INFO) program are used to support the analyses of the system.
developed in this research. The Las Vegas metropolitan area is used as a case study to demonstrate the applications of the methodology to evaluate policy options. This region has experienced tremendous growth and large scale development over the last decade. This has resulted in a significant strain on street and highway systems which were designed for much lower levels of activity. In turn, there has been a pressing demand for major transportation system infrastructure enhancement and development.

The Las Vegas valley is one of the fastest growing urban areas in United States. Due to new development in the region there are signs of an increase in real estate values. This increase will have an effect on disposable income and housing choices. With an increase in real estate value, many may find it increasingly difficult to find suitable housing near their place of employment. It is anticipated that, in future, a large number of trips will be made to developments that are yet to be built today. Thus, there is still time to make planning decisions that will help to avoid severe traffic problems in some developing areas. At the same time, existing areas are clamoring for relief from traffic problems and for better strategies to manage such problems. The task of the research is to develop a system that will help in identify appropriate strategies and develop new policies which will help alleviate transportation problems in this region.
Outline of Thesis

A review of the literature is presented in chapter 2. This review focuses on congestion and different methodologies and policies developed and followed in different parts of the U.S. to address congestion related problems. The methodology used for the study and the procedure followed are discussed in Chapter 3. Details of the study area and sources of data under consideration and analysis of the study area are described in Chapter 4. Results obtained using the system are presented in Chapter 5. Chapter 6 includes a brief summary and recommendations for future work.
CHAPTER 2

LITERATURE REVIEW

One of the most important urban transportation issues in the mind of the public is traffic congestion. Congestion has become common place in most urban areas throughout the country. Today, urban mobility has become one of the key issues facing transportation professionals. A large component of the travel demand in many metropolitan areas is provided by freeways and arterial streets. High congestion on these facilities has affected mobility in urban areas. The problem is worsened by the fact that travel demand is increasing continuously while there has been a decline in new highway construction. Several factors contribute to this decline in new construction: budget cuts, increased construction costs, public resistance to new construction, environmental impacts, and acute right-of-way problems. Thus, as demand increases and supply does not keep pace, the level of service provided deteriorates.

An objective of this research is to develop methodologies to assist policy analysis for enhancing urban mobility by better allocating existing resources, deploying new resources and paying for the access to and use of transportation services in metropolitan areas. Several efforts have addressed similar concerns. Some of the pertinent works cited
in the literature are reviewed in this chapter.

Giuliano and Small [1993] discuss congestion policies in the Los Angeles area, review several alternative policies including inaction, land use intervention, highway capacity expansion, low technology mass transit, and pricing. They state that the severity of today's urban traffic congestion interferes with the role of the transportation system. Productivity is diminished from what it could be. Coping mechanisms such as trip rescheduling and greater decentralization are to some degree inefficient, in part because they reduce the close inter-connectedness of activities that fuel the agglomeration economies of a healthy urban area. Attempts to lure people into other modes by providing subsidized systems are insufficient to draw them from convenient individualized motor vehicles, and they are overwhelmed by latent demand on the part of people immune to the particular incentive being offered. Capacity expansion creates significant benefits, but is often too expensive and too damaging to the environment. Some of the policies proposed by Giuliano and Small such as parking pricing and congestion pricing are effective but they are negative incentives to a large portion of peak-hour users. Other policies proposed by the study are specialized transit and paratranist services, HOV lanes, and privatization of some transit services.

Deakin [1991] states that there are two reasons for the increase in congestion: shortage of public funds for transportation and lack of coordination of land use planning and development decisions with available and planned transportation capacity. Currently a number of local governments in California have adopted different policies such as
utilizing development exactions and impact fees to finance transportation improvements and are implementing transportation systems management and TSM-oriented site design requirements. But, in the long run these strategies may not be sufficient to resolve traffic problems. According to Deakin, some strategies which might help to alleviate traffic congestion are: local transportation plans and investment programs; regional and areawide plans and programs; strengthened requirements for consistency between land use and circulation elements; improved subdivision and zoning regulation; and investment programs and additional financing for transportation. There are some barriers to the strategies such as local prerogatives, taxpayers' resistance, other funding uncertainties, and staffing problems.

Cervero [1991] identifies four major factors that have fueled today's congestion problems: continued population and employment growth during a period when highway systems are reaching maturity; powerful demographic shifts, in particular the trend toward a smaller, dual-wage-earner household; the decentralization of jobs brought on by post-industrialization; and widening jobs/housing imbalances. His options to potentially improve mobility are better land use planning and an increase in vehicle occupancy rate by encouraging people to consider vanpool and carpool or take mass transit by offering generous travel allowances. If expansion of highway capacity is required, he suggests that funds for such projects be generated from gasoline taxes, sales taxes, impact fees and tolls. He says that land use actions are long-term propositions, however, and thus these are not favored by political parties which demand short-term payoffs. He says that the biggest
obstacle ahead may very well be less of gridlock and more one of mindlock.

Fielding and Klein [1993] say that a consensus is emerging among the transportation economists that the best way to deal with freeway congestion is to charge for driving during peak hours. They proposed implementation of congestion pricing by phasing in congestion pricing over a period of many years. According to them, current HOV lanes are not very effective at reducing traffic; 43 percent of car-poolers are members of the same household. HOV lanes cost everyone, but serve few drivers. They propose replacing HOV lanes with High Occupancy/Toll lanes (HOT). A HOT lane would give free passage to three-occupant vehicles but would permit others to pay a peak-hour toll for access. This would utilize more of the lane’s capacity, demonstrate congestion pricing on a wide scale, and generate revenues to pay for HOT lane construction. As and when existing HOT lanes reach capacity and if there was demand for more of its service, the adjacent lane would be converted to an additional HOT lane. Advanced technologies have made it easy to price highways. They say that the main barrier to its implementation is political. One of the drawbacks of the HOT lanes is it might affect ridesharing programs.

Anderson [1991] describes how Geographic Information Systems (GIS) can be applied to transportation planning. The planning support branch of FHWA’s office of Environment and Planning, with transportation planning division of the Maryland-National Capital Park and Planning Commission (M-NCPPC) in Montgomery County, Maryland, conducted a 3-month case study examining M-NCPPC’s application of the GIS Spatial
Analysis System software (SPANS) to its transportation planning activities. SPANS was used to disaggregate the county’s TAZs into smaller subzone components to produce finer-grained modeling data. They did a comparison of current and planned housing and employment with prescribed development ceilings. Future scenarios can be created based on the amount of remaining legally developable land, as well as the future demand for transportation by mode. The author says that using GIS-produced disaggregate socioeconomic data with travel demand modeling techniques improves the planner’s ability to model both trip generation and modal choice.

Burns [1994] discusses how Geographic Information System (GIS) can be used in a trip reduction program. Travel-demand management policies are the focus of a national debate on ways to limit the growth of local highway congestion and improve urban air quality. Trip reduction requires changes in travel behavior of individuals, which can be achieved by increasing vehicle occupancy, limiting travel miles, and eliminating travel. The locational nature of many transportation planning activities makes GIS an attractive application.

Arnold [1993] discusses congestion-reducing measures used in Virginia. A total of 53 measures used to reduce congestion were identified in the literature. He states that, traditionally, supply measures have been used more often than demand measures to reduce congestions for years. But, it appears that demand measures appear to offer more reduction in congestion than supply measures.
Prevedouros and Schofer [1989] state that major cause of suburban congestion is the changing transport behavior of people. The change in transport behavior is due to changes in social, economic, technological, and cultural factors. He suggests that useful solutions to the suburban congestion problem must be based on a more fundamental understanding of the underlying life-styles and transport behavior of suburban residents.

Douglas, Deakin, Hooper, Pratt, Dunphy, Lockwood and Howes [1990] discuss the episodic nature of activity in the field of transportation planning and attempts to deal with suburban congestion.

Ghanem [1994] discusses how Geographic Information System (GIS) can be used in transportation planning. The paper illustrates applications of GIS in short and long range transportation planning such as identifying projects on the network, preparing network link tables for travel demand planning, and identifying future areas of congestion.

Williams [1992] discusses transportation planning and a methodology developed to integrate a GIS software program (ARC/INFO) with a mainframe traffic forecasting model and other regional data bases. The paper also illustrates problems, solutions and policies associated with the integration of Dallas-Fort Worth Regional Travel Model and GIS.

Bell [1993] discusses ways of reducing demand for road space in urban environments without building more roads or widening existing ones. Some of the suggested policies are: incorporation of parking facilities in new office buildings; provision of car parks for shoppers; use of park and ride facilities; upgrading public transport system;
implementation of toll systems and road pricing; and introduction of dynamic route
guidance systems.

Most of the previous studies discuss factors affecting congestion, solutions to some
of the congestion problems, and different tools used to address and solve congestion
problems. However, one of the major limitations faced by practitioners and decision makers
is the lack of a good computerized tool or system which provides a graphical interface.
The objective of this research is specifically to develop such a system to facilitate
quantifying the spatial and temporal distribution of travel demand, and communicate
results effectively. Previous studies were reviewed to identify factors affecting congestion
and identify key variables that could be used in the system to identify travel demand
characteristics of urban areas.
CHAPTER 3

METHODOLOGY

Quantifying the spatial and temporal distribution of demand for transportation services is a key step in the development of strategies to improve urban mobility by means of re-allocating existing resources and development of new resources. This would facilitate identification of major activity centers in terms of their share of trip productions or attractions both as number of trips or as vehicle miles of travel in metropolitan areas.

An activity center may be an aggregation of one or more proximate traffic analysis zones (TAZs) used in traditional urban transportation modeling. A detailed study of the land-use developments, spatial and temporal distribution of demand, and socio-economic characteristics of an area is needed in order to develop a tool or methodologies which assist in developing policies or strategies for transportation system planning, operations and management.

Transportation Planning Process

The objective of the transportation planning process is to provide information necessary for making decisions on when and where improvements should be made in the
transportation system, promoting travel and land development patterns that are in keeping with community goals and objectives. A general framework for urban transportation planning that reflects the need for a decision-oriented approach is shown in Figure 3.1 [Meyer and Miller, 1984]. Transportation planning studies have been conducted in a large number of urban areas throughout the world during the past few decades. The planning process most commonly used at present, called the Urban Transportation Planning Process (UTPP), has its origin in studies performed in several cities in United States during the 1950-1960 period, particularly in Detroit and Chicago [Hutchinson, 1974; Weiner, 1992].

The UTPP is a formalized planning methodology designed to provide guidelines and priorities for future transportation investment, and construction of urban transport infrastructure and facilities. An integral part of the UTPP is travel demand forecasting, which consists of four distinct steps: Trip Generation, Trip Distribution, Modal Split, and Traffic Assignment. Each of these steps is discussed briefly next.

In order to achieve a conceptually and analytically tractable formulation of the travel demand problem, it is necessary to work at a more aggregate level of the system representation than that of the individual trip maker. Aggregation of characteristics of a group of people will tend to present common trends that are representative of the group. Aggregate values are required in planning process as opposed to predictions of individual activities or experiences. For that reason, in the traditional UTPP, spatial aggregation is performed by dividing the urban area into a set of transportation analysis units. The transportation analysis units are known as traffic analysis zones (TAZs). TAZs are the
Figure 3.1: Steps in an Urban Transportation Planning Process
(Source: Meyer and Miller, 1984, Chapter 1)
basic spatial units of analysis. Some of the key criteria used to develop TAZs for a metropolitan area include achieving homogenous socio-economic characteristics for each zone’s population, minimizing intra zonal trips, recognizing major physical (rivers, transportation infrastructure), political and historical boundaries and census blocks/tracks, and maintaining contiguous zones and avoiding “zone-within-a-zone” (donut). The TAZs vary in size depending on the density or nature of urban development. An important consideration in establishing TAZs is their compatibility with the transportation network to be used. Generally, transportation network elements should form the boundaries of the TAZs.

Trip Generation is the process by which measures of urban activity are converted into numbers of trips, i.e., number of trips that will begin or end in each TAZ within the study area. Trip ends are classified as either a production (defined as the home end of home-based trip or the origin of a non-home-based trip) or an attraction (the non-home end of a home-based trip or the destination of a non-home-based trip). Trips are further described in terms of trip purposes such as Home-Based Work, Non-Home Based and Home Based Other. Some of the most commonly used methods for trip generation analysis are cross-classification method and multiple linear regression [Dickey, 1984; Meyer & Miller, 1984; Khisty, 1990; Garber & Hoel, 1988].

Separate models are used to predict trip productions and attractions. Typically variables used in trip production models include number of households, auto ownership, household size, number of workers per household, household income, residential density,
and distance of the zone (TAZ) from the central business district (CBD). Similarly, typical variables used in trip attraction models include zonal employment levels, zonal floor space, type and density of land use, and accessibility to the work force [Meyer and Miller, 1984].

The outcome of the trip generation step is the total trips produced and attracted to each zone. However, this step does not provide any information on the distribution of trips that originate at each origin TAZ. Trip distribution analysis is a process to estimate where the trips produced from a zone will go and how they would be divided among all other zones in the area, i.e., to predict the flow of trips \( T_{ij} \) from each production zone \( i \) to every other attraction zone \( j \). The most widely used trip distribution model is the gravity model, which states that the number of trips \( T_{ij} \) between two zones \( i \) and \( j \) is directly proportional to trip production in the origin zone and to the attraction in the destination zone, and inversely proportional to the separation between the zones as a function of the impedance (travel time or distance) between the two zones. Table 3.1 summarizes trip interchange matrix which shows the total trips from zone \( i \) to zone \( j \). Estimation of total trips produced or attracted to a TAZ may be calculated by using the following equations. The total sum of the trips from an origin zone to each destination zone should be equal to the total trips produced in the zone, \( P_i \):

\[
\sum_{j=1}^{n} T_{ij} = P_i
\]
Likewise, the sum of the trips attracted to a TAZ from all origins should be equal to the total trips attracted to the TAZ $A_j$:

$$\sum_{i=1}^{n} T_{ij} = A_j$$

**Table 3.1: Trip Interchange Matrix**

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>j</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$T_{ij}$</td>
<td>$P_i$</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$A_i$</td>
<td>$\sum A_i = \sum P_i$</td>
</tr>
</tbody>
</table>

The gravity model is used to perform trip distribution and it provides trip interchange matrix. Mathematically, the gravity model is expressed as follows:

$$T_{ij} = \frac{P_i A_j F_{ij} K_{ij}}{\sum_{j=1}^{n} A_j F_{ij} K_{ij}}$$

Where

$i =$ origin zone
\( j = \) destination zone

\( T_y = \) number of trips produced in zone \( i \) and attracted to zone \( j \)

\( P_i = \) total trips produced from zone \( i \)

\( A_j = \) total trips attracted to zone \( j \)

\( F_{ij} = \) friction factor for interchange \( ij \) (based on travel time or impedance between \( i \) and \( j \))

\( K_y = \) socio-economic adjustment factor for interchange \( ij \)

\( n = \) number of zones in the study area

Since \( F_y \) is used to quantify the separation (impedance) between zones \( i \) and \( j \), it is inversely proportional to the travel time \( t_y \) between \( i \) and \( j \).

The trip interchange matrix provides an estimate of the number of trips produced from each zone and attracted to every other zone in the study area. The distribution of trips produced in a zone, \( i \) to zone \( j \) depends on the relative attractiveness of zone \( j \) and the relative accessibility of zone \( j \), i.e., zone \( j \) gets a portion of the zone \( i \)'s trip productions according to its characteristics as compared to the characteristics of all other zones in the study area. The trip interchange matrix provides information on the number of person trips between all TAZs.

In order to estimate the travel demand in terms of the number of vehicles on the transportation system, it is necessary to convert the person trips to an equivalent number of vehicle trips. Modal split or mode choice models are used to predict the percentage of trips using each of the modes available to the given trip maker. Mode usage analysis can be done at various points in the forecasting process. The most common point is after trip
distribution. The factors that affect mode usage are characteristics of the trip maker (family income, automobile ownership, family size, residential density), characteristics of the trip (trip distance, time of day), and characteristics of the transportation system (riding time, excess time), and costs associated with various modes. Examples of methods include direct generation methods, trip end models, trip interchange models and choice models [Garber & Hoel 1988]. This step of the UTPP facilitates obtaining estimates of the number of vehicle trips between TAZs.

Traffic Assignment is the final step in the travel demand forecasting process. This is used to determine traffic volumes on the transportation system segments or links. The procedure used to determine the expected traffic volume is known as traffic assignment. Examples of algorithms used for this purpose include all-or-nothing, incremental, or equilibrium assignment techniques.

Estimation of Travel Demand

One of the primary objectives of the travel demand forecasting process is to support the development of policies, plans, operations and management strategies for the transportation system. The process entails identification of the demand for transportation - in particular the spatial and temporal distribution of the demand. The long lead times required for any significant modifications or additions to the supply component of the system necessitate early and accurate estimation of future demand patterns. This is necessary for an efficient deployment of resources so as to best serve the transportation
demands on the system.

The demand on a transportation system can be quantified and characterized in many ways. Two possible measures of such demand are the number of person trips and number of vehicle trips. However, when considering overall mobility issues, the number of trips is not the sole criterion that needs to be taken into account. Other factors of importance include the trip length and travel speeds (or times). Trip lengths are particularly important in quantifying travel demand, whereas travel speeds reflect system conditions as a function of demand and supply. Since the main focus of this thesis is towards demand analysis, the major factors addressed will be limited to the number of trips (in particular, vehicle trips) and trip length. In quantifying total demand, trip length can be accounted for as an element of the term “vehicle miles of travel” (VMT) or “vehicle kilometers of travel” (VKT). VMT can be defined and estimated as follows:

\[
VMT = \sum_{i=1}^{N} d_i
\]

\[
= N \sum_{i=1}^{N} \left( \frac{d_i}{N} \right)
\]

\[
= N \cdot \bar{d}
\]

where

\[ N = \text{total number of vehicle trips} \]
\[ d_i = \text{trip length of } i\text{th trip (in miles)} \]
\( \bar{d} = \text{average trip length (in miles)} \)

When evaluating the spatial distribution of demand, the demand exerted on the transportation system by various TAZs could be estimated in terms of the number of trips produced or attracted. This is the basic tenet for the methodology and tools developed in this thesis. Next, the methodology developed to estimate travel demand is discussed, following a brief description of the computer tools that will be used in the research.

**Computer Models**

Travel demand forecasting for metropolitan areas can be accomplished using the four step UTPP methodology discussed earlier. However, it is a very complex task that requires a vast amount of data and the use of sophisticated analytical routines. Thus, several computerized models have been developed to facilitate travel demand forecasting. Examples of such models include EMME2, MINUTP, QRS, TMODEL and TRANPLAN. Data capture, analysis and management is one of the most demanding elements of performing analysis using such models. The advances in computing technology (both hardware and software) have resulted in the development of tools to assist such activities. Specifically, Geographic Information System (GIS) programs are particularly useful in this context. This section consists of discussions of TRANPLAN, a travel demand forecasting model, and ARC/INFO, a GIS program. These two specific tools have been selected because of their widespread acceptance by professionals and because they are the tools
adopted by various agencies in the Las Vegas metropolitan area. These were important considerations for developing the case study presented in this thesis.

**TRANPLAN**

TRANPLAN is a travel demand forecasting software based on the four step urban transportation planning process (UTPP) (Urban Analysis Group TRANPLAN: A User Manual, 1993). TRANPLAN is developed to perform analysis of multimodal transportation systems efficiently and economically. TRANPLAN is structured as a dynamic tool. The program consists of forty modules, referred to as "functions," each of which has specific capabilities. These include networks, modal choice model, paths, loading, matrix utilities, reporting, plotting, and trip generation. TRANPLAN is designed as a computerized analytical tool to aid the planner in the planning process. It is available for various hardware platforms. For this study the program was run on a IBM compatible personal computer platform in the DOS operating system environment. The basic data required for forecasting using TRANPLAN include zonal land use and trip generation rates data, friction factors for the calibration process, and the highway and transit networks. Figure 3.2 summarizes the TRANPLAN modeling process.

The first step of the process is to build highway network. In TRANPLAN, this can be accomplished by using the BUILD HIGHWAY NETWORK module. Next, the TRIP GENERATION module can be used to estimate the number of trips (by purpose) produced by or attracted to a traffic analysis zone as a function of the demographic,
socioeconomic, locational, and land use characteristics of the zone. The trip distribution step is used to distribute all trips produced in a zone to all possible attraction zones. The product of trip distribution is a set of zone-to-zone person trips. Next, mode split separates the person trips into various alternative modes. Finally, the traffic assignment model is used to assign the various modal trips to alternative paths or route available.

**Geographic Information Systems**

A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information [Environmental System Research Institute, 1993a]. GIS can also be viewed as an analytical tool that is a combination of an information system and spatial analysis tools with graphical display capabilities. A major advantage of a GIS is that it facilitates the visualization and identification of spatial relationships. A typical GIS includes a database. The database concept is central to a GIS and it is the main difference between a GIS and any other mapping system which can only produce good graphic output. Database systems provide the means of storing a wide range of information and updating them without the need to rewrite programs.
ARC/INFO Software

ARC/INFO is a set of automated GIS software for efficiently capture, store, update, manipulate, analyze and display spatially oriented data [Environmental System Research Institute 1993a]. In ARC/INFO, ARC handles the spatial referencing of the features, while the INFO component handles the feature description database and how each feature is related to others. Within ARC/INFO there are different modules including ARCEdit, ARCPLOT, INFO, NETWORK, and DATA CONVERSION. Each of these modules has its own unique capability in performing certain tasks. In digital maps, spatial relationships among different features such as points, arcs and polygons are depicted using topology. The three major topological concepts of ARC/INFO are connectivity, area definition, and contiguity.

ARC Macro Language (AML) is an interpreted language. AML is a part of the ARC/INFO software. AML provides the user with programming capabilities and a set of tools to tailor the user interface of ARC/INFO applications. AMLs can be used to build interactive menus, enhance native ARC capabilities, to implement complex task, and to perform modeling. The AML increases productivity by creating user interface for any application, automates database access and the most important of all it provides managers with display and query capabilities [Environmental System Research Institute, 1993b]. In developing specific application tools AML programming can be used extensively to enhance efficiency, effectiveness, and automation.
Estimation of Vehicle Trips

Trip generation models provide estimates of the number of trips (by purpose) produced by or attracted to a traffic analysis zone (TAZ) as a function of the demographic, socioeconomic, locational, and land use characteristics of the zone. Trip productions are defined as the number of trips produced in a TAZ; trip attractions are the number of trips attracted to a TAZ.

Typical inputs to trip generation models include socio-economic data and data from household travel surveys. This information is typically used to generate person trip productions and attractions based on specific trip purposes. Some of the commonly used trip purposes are home-based-work, home-based-school, home-based-shopping, home-based-other, and non-home-based. This classification scheme is used for the travel demand forecasting model for many metropolitan areas including the Las Vegas valley. For the Las Vegas valley model for internal trip purposes, only trips with both origins and destinations within the planning area are included [BRW, 1991a]. Figure 3.3 provides a graphical description of the process for development of trip interchange matrix and partial application of TRANPLAN model.

The first step of the process is to build interzonal skims (minimum paths) and intrazonal impedances for the transportation network. In TRANPLAN, this can be accomplished by using HIGHWAY SELECTED SUMMATION and BUILD INTRAZONAL IMPEDANCES modules respectively. Next, the gravity model is used to estimate the distribution of person trips between origins and destinations. The gravity
Figure 3.3: Development of Trip Interchange Matrix
model module in TRANPLAN performs trip distribution using the gravity model algorithm and it provides a production-attraction trip interchange table. Person trips are converted into vehicle trips by taking into account average vehicle occupancy rates. This is done by using the matrix update function in TRANPLAN. The total auto vehicle trip matrix is derived by using matrix manipulation function in TRANPLAN. Since all the output files are in binary format, the "report matrix" function is used to convert them into ASCII trip interchange matrix format. This information is used as the basis to obtain a $t_p$ matrix. Using essentially the same procedure, with a slight modification of TRANPLAN control files, trip interchange matrixes ($t_p$) can be created for all the five purposes. The TRANPLAN control files used in this research are presented in Appendix A.

The trips produced from a TAZ, can be represented by using the following equation

$$t_i = \sum_{k=1}^{n} t_{ik}$$

where $t_{ik}$ = trips from TAZ, to TAZ$^k$.

The trips attracted to a TAZ, can be represented by using the following equation

$$t_j = \sum_{k=1}^{n} t_{bj}$$

where $t_{bj}$ = trips from TAZ$^k$ to TAZ$^j$.
These equations merely indicate the closure conditions that need to be attained in the forecasting process.

The trip purposes stratify travel behavior into activities such as work, school, shopping and other. Productions and attractions can thus be estimated for all the trip purposes and the data may be stored in any desired format. ASCII data can be imported into the GIS environment to support GIS based analysis.

Estimation of Distance

In order to quantify demand in terms of VMT, it is not only necessary to estimate the trip interchange matrix, but also to estimate the corresponding distances between origins and destinations. Therefore, the next step is to calculate the distances \( d_{ij} \) between TAZ pairs. In ARC/INFO, the NETWORK module facilitates the modeling of spatial networks. NETWORK analysis provides tools to find the shortest path or minimum impedance path through a network. The \( d_{ij} \) between TAZ pairs is estimated using NETWORK Module. In order to use network module, it is necessary to develop an understanding of the NETWORK data model and its different elements.

Network Data Model

The network data model is an abstract representation of the components and characteristics of real-world network systems. The model consists of network links, network nodes, stops, centers and turns. The key to producing successful network models
is in understanding the relationship between the characteristics of physical network systems and the representation of those characteristics by the elements of the network model [Environmental System Research Institute, 1993c]. Network links form the framework of the network model. They are modeled as arcs in ARC/INFO. Network links are used to represent real-world transportation network structures such as highways, railways, and shipping lanes.

Network nodes are the endpoints of network links. Network links are always connected at network nodes. Nodes may represent intersections or interchanges in a road network. Stops, Centers, and Turns are not true ARC/INFO features. These elements have properties and attributes unique to each and they are stored as descriptive data.

Centers are discrete locations at which there exists a resource supply or some type of attraction. Centers may represent shopping centers, schools, airports, and centroids of TAZs. In our model centers are representation of centroids of the TAZs. Centers are used in allocation and spatial-interactions analysis.

**Network Analysis**

Figure 3.4 shows a flow chart summarizing the network analysis. To start with, two different feature type coverages are needed for network analysis. One is a point coverage, i.e., CENTERS coverage, which contains the centroids of the TAZs. The second coverage is the network coverage, i.e., NETCOVER, which is the actual transportation network coverage area (the street centerline coverage for the Las Vegas
Figure 3.4: Network Analysis: Process of Development of Trip Distance Matrix
area presented in the case study). This network is different from the network used in the TRANPLAN model in that it has a much greater level of detail.

In the transportation network, a centroid is defined as a node for each TAZ. For the transportation modeling, all the trips within a TAZ are assumed to be generated at the centroid. Each centroid is connected to the transportation network by “dummy links” called centroid connectors which represent the local streets feeding traffic to the major streets. In the real world, centroid connectors may be or may not be a physical network elements.

To perform network analysis there should be continuity between the centroid, i.e., CENTER, and the street network, i.e., NETCOVER. However, this does not exist because centroid connectors are not always a part of the actual transportation network but they are parts of the TRANPLAN network. The TRANPLAN network is an abstraction (subset) of the actual network. To accommodate this setback ARC/INFO is used to estimate the distance \( d_i \) between a centroid and the closest node on the actual transportation network. Then, network analysis is used to estimate the distance \( d_{ij} \) between a pair of TAZs. Figure 3.5 illustrates the case discussed above. The actual distance between the pair of TAZs \( d_y \), is estimated by the following equation.

\[
d_y = d_{ix} + d_{ij} + d_{xy}
\]

where

\[
d_y = \text{distance between TAZ } i \text{ and TAZ } j
\]
\[ d_{ij} = \text{distance between a centroid of TAZ } i \text{ and closest node on the arc} \]
\[ d_{ij} = \text{distance between a centroid of TAZ } j \text{ and a closest node on the arc} \]
\[ d_{ij} = \text{distance between the closest node on the arc at TAZ } i\text{'s centroid and the closest node for TAZ } j\text{'s centroid.} \]

There are three ways of estimating the distance \( d_{ij} \) by using network analysis. These are the network distance, Manhattan distance, Euclidean distance. Figure 3.6 shows the three measures of distance estimation by network analysis. Network distance is the shortest path along the actual street network between the two points (the quickest path between the two points may also be obtained in a similar manner). Euclidean distance is the distance ‘as the crow flies’ and is measured as the distance of the straight line connecting the two points. It is estimated using the following equation.

\[
    d_{12} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}
\]

Where

- \( x_1, y_1 \) and \( x_2, y_2 \) are Cartesian coordinate locations of two nodes
- \( d_{12} \) is the distance between the two points

Manhattan distance is the sum of the length of the change in the x (horizontal) direction and the change in the y (vertical) direction [Environmental System Research Institute, 1993c]. The following equation is used to estimate Manhattan distance.
Figure 3.6: Three Measures of Distance Estimation
\[ d_{12} = |x_1 - x_2| + |y_1 - y_2| \]

For all the three-distance estimation techniques, distance (length of the arc) is used as impedance. For the estimation of vehicle miles of travel (VMT), which will be discussed in the following pages, network distance is considered as \( d_y \). Thus, the \( d_y \) can be computed for each \( i, j \) pair (all TAZ combinations) and used to build the \( d_y \) matrix.

**Estimation of Vehicle Miles of Travel (VMT)**

Vehicle miles traveled (VMT) is a function of both travel distance and traffic volume. Estimation of \( VMT_y \) contributions for productions and attractions of individual TAZs may be calculated by using the following equation.

\[ VMT_y = t_y \times d_y \]

Production end VMT is calculated using the following equation

\[ VMT_i = \sum_{j=1}^{n} (t_y \times d_y) \]

Attraction end VMT is calculated by using the following equation

\[ VMT_j = \sum_{i=1}^{n} (t_y \times d_y) \]
where

\( VMT_i \) = vehicle miles traveled at an attraction end of TAZ \( i \)

\( VMT_j \) = vehicle miles traveled at a production end of TAZ \( j \)

\( t_{ij} \) = trips produced or attracted between TAZ pair \( i \) and \( j \)

\( d_{ij} \) = distance between TAZ pair \( i \) and \( j \)

\( n \) = total number of TAZs

To quantify demand, VMT production and attraction are computed as described above for each TAZ and for each trip purpose. These results can then be transferred into the GIS environment by using AML capabilities of ARC/INFO.

**Decision Support System**

Analysis is only one component of the planning and travel demand forecasting process, and, in fact, demand estimation is only one component of analysis. Analysis provides input into the planning and decision-making process [Meyer and Miller, 1984]. A key consideration for all analyses of the demand for transportation services is the fact that this demand is a derived demand.

Thus, trip purpose is an important factor in estimating demand. Transportation demand analysis can be performed accurately with aggregation of data. Aggregation is performed in at least three dimensions: spatial, temporal, and socioeconomic. Spatial aggregation is performed by dividing the urban region into a set of zones (TAZs) and then treating these zones as the basic units of analysis. Thus, rather than dealing with trips
made by individuals from point to point, the analysis is concerned with total flows of people from zone to zone. Zonal characteristics used to explain these flows typically take the form of zonal totals or zonal averages. In this study aggregation of data is done at TAZ level.

Temporal aggregation is performed by grouping travel flows into discrete time periods. Typical time periods include the weekday peak period (morning and evening), weekday offpeak, weekend period, the weekday and the year. In this study, total traffic flow per day between TAZs is considered for analysis. Socioeconomic aggregation occurs whenever one categorizes individuals into homogeneous groups. It is common, for instance, to group households according to their income level, auto-ownership level, and family size for the purpose of trip generation analysis. It is assumed that behavior of the members of a group is similar or at least the variance in their behavior is small relative to the differences in behavior observed between their group and other groups.

After estimating the number of trips (by purpose), and vehicle miles traveled the next task is to evaluate key factors that influence the distribution of travel demand. Such an evaluation would be based on the data needs and data availability. Principal sources of pertinent data include local data bases and data collected by the U.S. Bureau of the Census (including the census transportation planning package, CTPP) data.

The foundation of effective transportation planning, at any level of analysis, is a good data base. Data are used to determine the existing conditions of the transportation network, for calibration and application of travel forecasting models, for evaluating the
overall performance of system operations, and for gauging the degree to which planning goals and objectives are achieved. Collecting and processing these data consumes a substantial percentage of the planning study budgets, in some cases more than 50 to 60 percent of the total funds available [Meyer and Miller, 1984].

**CTPP Data**

The CTPP is a collection of summary tables that have been generated from both the 1990 census short and long forms. These data are available for major urban centers from U. S. Bureau of the Census. The data set contains information about population and household characteristics, worker characteristics and characteristics of the Journey-to-Work [Rasas and Sathisan, 1995]. Some of the key variables that are extracted from the CTPP data are: number of households, household income, and number of vehicles. The data contained in the CTPP cannot be disaggregated; however, they can be combined to conduct a variety of analyses. In fact, the CTPP data have been designed specifically for transportation planning analyses based on extensive input from transportation professionals. CTPP data are available only for 1990.

**Local Data Sources**

Since the CTPP data are based on the decennial census, the use of the CTPP data may be limited. This would be a particularly important consideration if the analyses were being conducted several years after the time when the data were originally conducted or
if the urban area was experiencing rapid growth. Either of these two reasons necessitates augmenting the CTPP data with efforts to obtain local data that are more current, detailed or accurate. Such efforts are also necessary to obtain data projections for future years.

An example of efforts to develop local data sources to support travel demand forecasting is the “planning variables” program at the Regional Transportation Commission of Clark County in Las Vegas, NV. The planning variable database contains final estimates and projections developed from a larger set of demographic, economic, and land use information [Coopers and Lybrand, 1992]. Estimates are available for all the TAZs for the Las Vegas valley. The planning variables included in this study include population, employment, number of households, household size, and average income.

**Spatial Distribution of Travel Demand by TAZ**

The spatial distribution of travel demand can be evaluated at the TAZ level. Demand could be estimated at the TAZ level in terms of trip productions or attractions both as the number of trips and for vehicle miles of travel. Table 3.2 summarizes the principal measures that could be used to quantify the spatial distribution of demand at the TAZ level. This would then facilitate analyses to evaluate the relative contributions of individual TAZs. Demand contribution could be quantified for individual TAZs based on activity units such as transportation demand per person, household, or employee. These results help characterize and quantify the spatial distribution of travel demand. The results of such analyses would be particularly important for the development of policies and plans
based on identifying the relative demand exerted on the transportation system by various TAZs.

Table 3.2: Travel Demand Estimation at the TAZ Level

<table>
<thead>
<tr>
<th></th>
<th>PRODUCTION</th>
<th>ATTRACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERSON TRIPS</td>
<td>$P_i$</td>
<td>$A_j$</td>
</tr>
<tr>
<td>VEHICLE TRIPS</td>
<td>$t_i$</td>
<td>$t_j$</td>
</tr>
<tr>
<td>VMT</td>
<td>VMT$_i$</td>
<td>VMT$_j$</td>
</tr>
</tbody>
</table>

The estimation of trips by purpose should also be considered because home base work trips and work related trips contribute up to 32 percent of the total trips [Meyer and Miller, 1984]. As discussed in previous sections the five trip purposes included in the model are home-based-work, home-based-school, home-based-shopping, home-based-other, and Non-home-based. The number of trips by production and attractions for each TAZ can be represented as follows:

$$P_{ik} = \text{number of trips produced for trip purpose } k \text{ zone } i = \sum_{j=1}^{n} t_{jk}$$

$$A_{ik} = \text{number of trips attracted for trip purpose } k \text{ to } j = \sum_{i=1}^{n} t_{jk}$$

where

$$i = 1 \text{ to } n, \text{ TAZ-ID numbers and } k = 1-m \text{ trip purpose}$$
j = 1 to n, TAZ-ID numbers and k = 1-m trip purpose

t_{ijk} = trips from zone i to zone j for trip purpose k

Table 3.3 shows how the data may be quantified at the individual TAZ level.

<table>
<thead>
<tr>
<th>TRIPS</th>
<th>NUMBER</th>
<th>VMT</th>
<th>VMT</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCTION</td>
<td># PER HOUSEHOLD</td>
<td>P_i</td>
<td>VMT_i</td>
<td>VMT_{ik}</td>
</tr>
<tr>
<td></td>
<td># PER INDIVIDUAL</td>
<td>P_i</td>
<td>VMT_i</td>
<td>VMT_{ik}</td>
</tr>
<tr>
<td></td>
<td># PER AUTO</td>
<td>P_i</td>
<td>VMT_{j}</td>
<td>VMT_{ik}</td>
</tr>
<tr>
<td>ATTRACTION</td>
<td># PER HOUSEHOLD</td>
<td>A_j</td>
<td>VMT_{j}</td>
<td>VMT_{jk}</td>
</tr>
<tr>
<td></td>
<td># PER INDIVIDUAL</td>
<td>A_j</td>
<td>VMT_{j}</td>
<td>VMT_{jk}</td>
</tr>
<tr>
<td></td>
<td># PER AUTO</td>
<td>A_j</td>
<td>VMT_{j}</td>
<td>VMT_{jk}</td>
</tr>
<tr>
<td></td>
<td># PER EMPLOYEE</td>
<td>A_j</td>
<td>VMT_{j}</td>
<td>VMT_{jk}</td>
</tr>
</tbody>
</table>

This section has summarized procedures that could be used to quantify the spatial distribution of travel demand. It is important to note that travel demand changes over time. Recognition and evaluation of such changes are of paramount importance for proper transportation system planning and development activities.
Change in Travel Demand

Travel demand in urban areas vary spatially and temporally. These variations could be significant. The preceding section addressed the spatial variation of travel demand. This section addresses the temporal variations of travel demand.

Travel demand could vary by the hour of the day, day of the week, week, month and year. It is important to recognize each of these elements of the temporal change in travel demand. However, for transportation system planning activities an important aspect of temporal changes in travel demand is the change over a period of years. It is necessary to estimate the magnitude of such changes, and the spatial distribution of the same, in order to plan for system enhancements and modifications.

As discussed previously, key variables affecting travel demand could be used to estimate the spatial distribution of travel demand. This could be done for various scenarios that address current and future planning needs, e.g., scenarios for the present year (baseline) and for a future model “horizon year.” Two aspects of the change in travel demand that need to be evaluated are the absolute change and the relative change. These are defined as follows:

\[
\text{absolute change} = \text{horizon year travel demand (TD)} - \text{baseline travel demand (TD)}
\]

\[
\text{relative change (Percent)} = \frac{\text{horizon year TD} - \text{baseline TD}}{\text{baseline TD}} \times 100
\]

\[
= \frac{\text{absolute change}}{\text{baseline TD}} \times 100
\]
where

\[ TD = \text{travel demand} \]

The absolute change and the relative change in travel demand will help quantify the needs for transportation system supply with reference to the baseline conditions. In turn, this would help policy development and the development of system deployment strategies.

System Design

The preceding sections have presented and discussed methodologies that could be adopted to quantify and evaluate travel demand in urban areas. The main elements of such analyses include data bases, travel demand forecasting models, and analytical processes. Also discussed were the need for computerized tools to support analyses. The design and development of an integrated system - one which links many of the individual elements - to support travel demand analysis, transportation planning and decision making is presented in this section.

The design of a computer-based decision support system takes into consideration several factors such as the analytical engine, support databases, user interfaces for input and output. The analytical engine consists primarily of the various analytical routines and methodologies discussed previously. The support databases have also been addressed previously. The system design introduces several enhancements to the analytical engine - enhancements which are intended to assist data visualization, statistical analyses of data and problem formulation. The user interface is designed to be menu driven so as to make
the system as user friendly as possible. The computing hardware and software selection is one of the critical decisions in the development of the system. The system is developed using a Unix based workstation platform (DECstation). The GIS software is ARC/INFO and it is supported by programming using ARC/INFO's AML capabilities and C programming language. The system also integrates outputs from the TRANPLAN modeling software package which is a PC based program. It is to be noted that this link between the system and TRANPLAN is not interactive. The flow of information is unidirectional from TRANPLAN to the decision support system. A schematic representation of the system design is presented in Figure 3.7.

System Applications

The system permits simple statistical analyses of the data to obtain maximum, minimum, mean, and standard deviation for any variable in the data. These statistics help identify the upper bounds and lower bounds to be used for analyses depending upon criteria supplied by the user. It also enables identification of outliers in the data. This will help in future data collection efforts by identifying areas or TAZs for which the level of accuracy of the data may be compromised. This would depend on the impact of the variable in these areas or TAZs. This tool will not only enable the use of a single variable for analyses but also the use of a combination of variables. These combinations could be in the form of Boolean expressions, using Boolean operators such as “and,” “or,” and “not,” and comparison expressions, using relational operators such as “less than,” "greater
Figure 3.7: Structure of the Decision Support System
than," “equal to,” “not equal to,” etc. The system also has the built in capability to obtain the percentile distribution of any data in the database. The percentile distribution is presented in terms of the number of TAZs that contribute to the specified percentile value of the variable. Once again, this would be particularly useful in supporting future data gathering efforts. The graphical representation of the information also helps in visualization.

The system will help identify the relative productiveness or relative attractiveness of TAZs. To identify the TAZs based on these two criteria a rank matrix is created using the trip interchange matrix by a ranking scheme based on the $t_y$ value. The largest (lowest) rank in a row or column will be the number of unique $t_y$ values in that row or column. In any column or row, TAZs with same $t_y$ will get same rank. To identify the attractiveness of a TAZ, the rank of all TAZs in the column are summed and the column with smallest sum will be the “most attractive” TAZ. Similarly, summing up rowwise will help identify the “most productive” TAZ.

The above analyses will help identify high transportation demand corridors, various strategies for providing improved access and mobility, as well as mechanisms for financing the required improvements could be developed and evaluated. Other strategies would include reallocation of the existing facilities by identifying the potential corridors for the HOV lane, operation of new transit routes, and payment and financing mechanisms for the provision of access to and utilization of transportation services such as congestion pricing.
CHAPTER 4

LAS VEGAS: A CASE STUDY

Applications of methodology and decision support system developed in this research are demonstrated using a case study. It is necessary to use a case study so as to obtain data and scenarios for a realistic evaluation and analysis. The Las Vegas valley is selected for this purpose. The case study illustrates only some of the potential applications of the system developed. This chapter provides a discussion of the urban transportation system status in the Las Vegas valley. The purpose of this chapter is also to examine sources of data to be used in the demonstration of the decision support system developed.

Study Area

The Las Vegas valley is located in Clark County, Nevada. Gaming and tourism activities engines that support the economy of the region. The 1980s was a period of dramatic changes for the Las Vegas valley. During the last decade, tourist volumes increased by 50 percent and more than 22,000 hotel rooms were added. Approximately 168,000 new residents moved to the Las Vegas area resulting in an increase in resident population of more than 33 percent between 1980 and 1990. The effect on the local
economy has been significant. Per capita income increased by 10 percent, retail sales
doubled, retail space grew from 9.5 million to over 19 million square feet, and construction
nearly tripled in valuation [BRW, 1991a].

The first half of the 1990s has seen these growth trends continue unabated. The
population has since increased by 26 percent between 1990 and 1994 [Regional
Transportation Commission of Clark County, 1994]. The Las Vegas valley remains
apparently insulated from national economic fluctuations. Growths in population,
employment, retail sales, and gaming revenues have all contributed to making Clark
County the nation's fastest growing county. Figure 4.1 shows the historic and projected
population and employment values for the metropolitan area. The figure projects the
county's population to be under one million in 1995. However, it is to be noted that the
Las Vegas valley's population alone has already exceeded one million. The accelerated
urban growth rate has placed extreme pressures on the local authorities that are
responsible for the provision of urban services. One of the most visible areas of such
pressures on urban services is the urban transportation network. In particular, problems
related to the highway system are amongst the most visible to the general public and to
policy makers.

Data for the Case Study

Data for the study were obtained from different sources. The travel demand
forecasting model (TRANPLAN), variables used by the TRANPLAN model and the TAZ
Figure 4.1: Population and Employment Trends for Clark County, Nevada
(Source: Regional Transportation Plan, RTC, 1994)
coverage used in the study were obtained from Regional Transportation Commission (RTC). The street center line coverage used for estimation of distances was obtained from Clark County GIS Management Office. Other data used in the study are 1990 Census Transportation Planning Package data obtained from the U.S. Department of Transportation.

**TAZ System**

TAZs are used in travel demand modeling to partition the model study area into geographic units for which socio-economic data can be collected. The Las Vegas region is divided into 749 TAZs including 10 external zones, as shown in Figure 4.2. There are some problems with the GIS coverage for TAZs. The GIS coverage contains only 731 TAZs. Several TAZs are missing because they are not closed polygons. These include TAZ #85 in the northeast, TAZ #560 in the south, and TAZ #741 to 749. Therefore, these TAZs are eliminated from data sets for all calculation purposes. The external TAZs are also not included in the data set. Another problem is that the CTPP data set does not have information for all the TAZs.

**Travel Demand Characteristics**

The valley’s rapid growth has been paralleled by increases in travel demand (as measured by VMT) and congestion on roadways (as measured by vehicle delays and hours traveled). The growth in visitor volume has greatly increased the observed levels of
Figure 4.2: TAZs in the TRANPLAN Model for the Las Vegas valley
average daily traffic flow on the principal highways leading to and within the Las Vegas valley. Approximately 45 to 50 percent of all visitors arrive in Las Vegas by automobile [Regional Transportation Commission of Clark County, 1994].

Population and employment growth beget increased travel demands. Travel demands are projected to increase slightly faster than population growth because of the projected increase in employment and disposable household income. As a result of the growth in tourism and population, making provisions for adequate transportation facilities and services is becoming an increasingly difficult task for the local and state governments. Tables 4.1 and 4.2 display the RTC’s regional person-trip and vehicle trip assumptions for the scenario years 1990 and 1995. The tables summarize person trips, transit trips, external trips and vehicle trips by five different trip purposes. These tables show that there is approximately 27 percent increase in the metro population, 25 percent increase in employment, and 28 percent increase in total daily vehicle trips from year 1990 to 1995. A constant vehicle occupancy rate is considered for both years.

Transportation Supply Characteristics

An understanding of the supply side of transportation is clearly fundamental to planning and operating transportation systems. The Las Vegas valley can be compared to other metropolitan areas by considering the land use pattern. The downtown and strip corridor would be analogous to a CBD, Summerlin in the west, North Las Vegas in the north, Green Valley, and Henderson in the southeast would be considered as
<table>
<thead>
<tr>
<th>TRIP PURPOSES</th>
<th>TOTAL DAILY VEHICLE TRIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro Area Population:</td>
<td>709,876</td>
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<tr>
<td>Metro Area Employment:</td>
<td>359,200</td>
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<tr>
<td>Work Home Based</td>
<td>623,196</td>
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<td>Shop</td>
<td>166,454</td>
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<td>Other</td>
<td>411,806</td>
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<td>Non-Home</td>
<td>1,138,833</td>
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<td>Total</td>
<td>2,831,783</td>
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<td>Internal Person Trips Home Based</td>
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<tr>
<td>Internal Person Trips Non-Home</td>
<td>4,311</td>
</tr>
<tr>
<td>Home Based Transit Trips</td>
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<tr>
<td>Home Based Transit Trips</td>
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</tr>
<tr>
<td>Auto-Person Occupancy Rate</td>
<td>1,42</td>
</tr>
<tr>
<td>Vehicle Occupancy Rate</td>
<td>1,47</td>
</tr>
<tr>
<td>Internal Vehicle Trips</td>
<td>552,633</td>
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<tr>
<td>Internal Vehicle Trips</td>
<td>307,937</td>
</tr>
<tr>
<td>External Internal Vehicle Trips</td>
<td>110,351</td>
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<tr>
<td>External Internal Vehicle Trips</td>
<td>382,763</td>
</tr>
<tr>
<td>Misc. Internal Vehicle Trips (taxi, commercial truck)</td>
<td>115,158</td>
</tr>
<tr>
<td>External - External Vehicle Trips</td>
<td>75,346</td>
</tr>
<tr>
<td>External - External Vehicle Trips</td>
<td>6,983</td>
</tr>
</tbody>
</table>

(Source: RTC Planning Division, Planning Variables Report Update: 1992)
Metro Area Population: 904,950  
Metro Area Employment: 447,970

<table>
<thead>
<tr>
<th>TRIP PURPOSES</th>
<th>Work</th>
<th>School</th>
<th>Shop</th>
<th>Other</th>
<th>Based</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Person Trips</td>
<td>819,409</td>
<td>228,639</td>
<td>572,425</td>
<td>674,635</td>
<td>1,419,265</td>
<td>3,714,373</td>
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<tr>
<td>Home Based Transit Trips</td>
<td>9,126</td>
<td>2,596</td>
<td>8,076</td>
<td>8,254</td>
<td>0</td>
<td>28,052</td>
</tr>
<tr>
<td>Auto-Person Trips</td>
<td>810,283</td>
<td>226,043</td>
<td>564,349</td>
<td>666,381</td>
<td>1,419,265</td>
<td>3,686,321</td>
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<tr>
<td>Vehicle Occupancy Rate</td>
<td>1.12</td>
<td>1.50</td>
<td>1.42</td>
<td>1.47</td>
<td>1.30</td>
<td>1.31</td>
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<tr>
<td>Internal Vehicle Trips</td>
<td>723,515</td>
<td>150,697</td>
<td>397,422</td>
<td>453,333</td>
<td>1,091,703</td>
<td>2,816,670</td>
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</tbody>
</table>

Misc. Internal Vehicle Trips (taxi, commercial truck) 141,902  
External — Internal Vehicle Trips 104,851  
External — External Vehicle Trips 9,237  

TOTAL DAILY VEHICLE TRIPS 3,072,660

Table 4.2: 1995 Daily Trip Demand Summary  
(Source: RTC Planning Division, Planning Variable Report Update:1992)
predominantly as residential areas. So, typically traffic will flow from these residential areas to the CBD. Figure 4.3 shows the Las Vegas valley street network. The street network is a combination of grid network and radial network type. The GIS coverage for the street network is fairly complete and representation of the physical system. It consists of approximately 45,000 links and 20,000 nodes, whereas the TRANPLAN network consists of only 10,000 links and 2,500 nodes. Thus, the TRANPLAN model's highway network is a simplified and abstracted version of the physical network. The network is classified under different functional types which include expressway, Freeway, Interstate, Arterial, Major Arterial, Minor Arterial, Collector, Ramp, External, and Centroid Connector.

Each jurisdiction, such as the cities of Las Vegas, North Las Vegas, and Henderson, the Clark County and the Nevada Department of Transportation, within the region has tried to keep pace with the fast growth. The rate of increase of transportation demand continues to outstrip the rate of increase in the supply of street and highway capacity. Regionally, daily vehicle miles of travel have increased at a faster rate than the increase in roadway capacity. Because travel demand has exceeded available roadway capacity, the transportation system operations have experienced significant problems such as congestion. Congestion has resulted in travel delays, increased fuel consumption, and decreased air quality as a result of carbon monoxide and other pollutant emissions from automobiles.

It is estimated that since 1982, travel time has increased approximately 15 minutes
Figure 4.3: Las Vegas valley Street Network Coverage
per day or 80 hours annually for the average person, and approximately 45 minutes per day or 240 hours annually per household [BRW, 1991b]. The number of congested signalized intersections increased from 19 to 73 in the valley for the same period.

The existing transportation conditions in the Las Vegas valley are deteriorating rapidly toward unacceptable levels in many corridors. Without significant and immediate improvements to facilities and services, the transportation system will not be able to meet the mobility and accessibility requirements associated with a growing a dynamic metropolitan area. Limited resources preclude deployment of extensive systems to alleviate such problems. So, policies should be developed for optimal allocation of existing and new resources, by identifying demand characteristics such as VMT, and number of trips with regard to spatial and temporal distribution. Such comparative analyses of demand in terms of VMT and trips per household, per individual, and per auto should also be considered for planning, designing, financing, operating and managing the transportation system.
CHAPTER 5

ANALYSIS

As discussed in chapter 3, a GIS based tool is developed to support policy development and planning, design, financing, operations and management of the transportation system evaluation of key variables influencing urban travel demand. The sources of data and their incorporation into the GIS environment have been discussed in previous chapters. The system developed is interactive to provide a user friendly interface. It allows the user to perform a variety of tasks, enhance native GIS (ARC) capabilities, and implement complex applications. It also provides the user with display and query capabilities, automates database access of TRANPLAN and C program outputs, and it has been designed for users who may not have any significant experience in using ARC/INFO. This chapter presents a discussion of the results of the case study and demonstrates potential applications of the tool to support policy making and decision making.

Growing traffic congestion increases the pressures on the transportation system. In turn, this deteriorates the mobility afforded and the quality of transportation service provided. To understand and propose some solutions to the congestion problem it is important to know answers to questions such as who is contributing what and how much?
Distribution of P's, A's and VMT

As mentioned previously the data used for the Las Vegas valley are aggregated at TAZ level. The system is designed to provide answers to some of the questions of interest to policy makers and decision makers in quantitative and graphical formats. The system has the capability to identify areas of high transportation demand such as TAZs with high productions and TAZs with high attractions. Figure 5.1 shows graphical illustration of the distribution of total vehicle trips produced per TAZ. It is categorized in various groups such as TAZs whose production is less than 10 vehicle trips per day, TAZs whose production is between 10-1000 vehicle trips per day, TAZs whose production is between 1000-3000 vehicle trips per day, TAZs whose production is between 3000-4000 vehicle trips per day and TAZs whose production is greater than 4000 vehicle trips per day. Figure 5.2 is a graphical illustration of the distribution of total vehicle trips attracted to a TAZ. This is also broken down into different groups as shown in the figure. Figures 5.3 and 5.4 show the distribution of the total vehicle miles of travel per TAZ at the production end and attraction end respectively.

Normalization of Variables

Other applications include identification of potential transit routes. The tool allows the user to select more than one variable for analysis or evaluation. This option would provide the user more flexibility in identifying TAZs which are most critical under the combination of different variables. Identification of potential transit routes should start
with an analysis of the potential market for ridership. Two types of riders need to be considered: choice riders and captive riders. Focussing on the captive riders, typical characteristics of such riders can be identified. It is to be noted that these measures of travel demand do not account for variability of causal factors among the TAZs. For this purpose, these measures used to be normalized for measures of exposure or explanatory variables such as population, automobile ownership, and employment. These characteristics can then be represented using key variables such as household size, household income, automobile ownership, number of employees per household etc. Others include land use density such as number of households per TAZ. Similarly employment based characteristics may also be evaluated. Figure 5.5 shows graphical illustration of the distribution of total vehicle trips produced per household. Figure 5.6 shows total vehicle trips produced per employment. Figure 5.7 shows population distributions in each TAZs. Figure 5.8 shows number of households per TAZ, Figure 5.9 illustrates average number of autos per TAZ and Figure 5.10 illustrates average household income per TAZ. Figure 5.11 illustrates average household size per TAZ. For example potential transit corridors could be routes between areas with low auto ownership, large household sizes and low income and areas with high employment. Queries facilitated by the system allow identification of such areas. Figure 5.12 illustrates a graphical display of such analysis where average household income per TAZ, auto ownership, and household size are the key variables considered for the analysis.
Absolute and Percentage Change in Travel Demand

Travel demand in urban areas varies spatially and temporally. These variations could be significant. Figures 5.13 through 5.20 present graphical illustration of change in travel demand over a period of five years, i.e., change in travel demand from 1990 to 1995. Figure 5.13 illustrates the absolute change in total trip productions. Figure 5.14 illustrates absolute change in total trip attractions. Figure 5.15 illustrates absolute change in total VMT produced. Figure 5.16 illustrates absolute change in total VMT attracted. Figure 5.17 illustrates percent change in total trips produced. Figure 5.18 illustrates percent change in total trips attracted. Figure 5.19 illustrates percent change in total VMT produced and Figure 5.20 illustrates percent change in total VMT attracted.

Percentile Distribution of Variables

The contributions of TAZs to the total travel demand could be presented in terms of the number of TAZs that contribute to the specified percentile value of the variable. Figures 5.21 through 5.29 presents graphical illustration of percentile distribution for different variables. For example, in figure 5.21 indicates that about 430 TAZs contribute to the top 10 percentile of total travel demand in terms of trips productions. Figures 5.21, 5.22 and 5.23 illustrate percentile distribution for productions. Figures 5.24, 5.25, and 5.26 illustrate percentile distribution for attractions. Figures 5.27, and 5.28, illustrates percentile distribution for VMT produced. Figure 5.29 illustrates percentile distribution for VMT attracted. Table 5.1 summarizes total vehicle trips ($t_p$) greater than 900 trips per
Information such as presented in the figures could serve as the first step in identifying TAZs or districts (aggregation of TAZs) potential for Transportation Demand Management (TDM) programs. Reevaluation of taxation strategies such as “fair-share payment” and “fair-share compensation.” Examples of strategies include potential trip production or attraction based payment schemes such as traffic impact fees or taxes at hotels, employment centers and land parcels. Fair-share compensation examples include deployment of HOV or transit facilities which relieve pressure on the highway system. Other policies could include incentives such as tax rebates to reduce vehicle miles of travel.
Table 5.1: O-D Pairs with greater than 900 total trips/day

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<th>Zone (i)</th>
<th>Zone (j)</th>
<th>Trips</th>
</tr>
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<tbody>
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<td>367</td>
<td>730</td>
<td>4081</td>
</tr>
<tr>
<td>433</td>
<td>612</td>
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<td>333</td>
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<td>2181</td>
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<td>367</td>
<td>731</td>
<td>2064</td>
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<tr>
<td>328</td>
<td>663</td>
<td>1948</td>
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<tr>
<td>183</td>
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</tr>
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<td>431</td>
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<tr>
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<td>900</td>
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Figure 5.1: Las Vegas valley: Total Vehicle Trips Produced per day per TAZ (1990)
Figure 5.2: Las Vegas valley: Total Vehicle Trips Attracted per day per TAZ (1990)
Figure 5.3: Las Vegas valley: Total VMT produced per day per TAZ (1990)
Figure 5.4: Las Vegas valley: Total VMT attracted per day per TAZ (1990)
Figure 5.5: Las Vegas valley: HBW Vehicle Trips Produced per day per household (1990)
Figure 5.6: Las Vegas valley: Total Vehicle Trips Attracted per day per employment (1990)
Figure 5.7: Las Vegas valley: Population distribution (1990)
Figure 5.8: Las Vegas valley: Number of Households per TAZ (1990)
Figure 5.9: Las Vegas valley: Auto Ownership (1990)
Figure 5.10: Las Vegas valley: Distribution of Average Household Income (1990)
Figure 5.11: Las Vegas valley: Average Household Size per TAZ (1990)
Figure 5.12: Illustration of Relationship between Average Household Income, Number of Autos and Household Size (1990)
Figure 5.13: Las Vegas valley: Absolute change in Total Trip Productions from 1990 to 1995
Figure 5.14: Las Vegas valley: Absolute change in Total Trip Attractions from 1990 to 1995
Figure 5.15: Las Vegas valley: Absolute change in Total VMT Produced from 1990 to 1995
Figure 5.16: Las Vegas valley: Absolute change in Total VMT Attracted from 1990 to 1995
Figure 5.17: Las Vegas valley: Percent change in Total Trips Produced from 1990 to 1995
Figure 5.18: Las Vegas valley: Percent change in Total Trips Attracted from 1990 to 1995
Figure 5.19: Las Vegas valley: Percent change in Total VMT Produced from 1990 to 1995
Figure 5.20: Las Vegas valley: Percent change in Total VMT Attracted from 1990 to 1995
Figure 5.22: Las Vegas valley: Percentile Distribution of Home Based Work Productions
Figure 5.27: Las Vegas valley: Percentile Distribution of Home Based Work VMT Produced
CHAPTER 6

SUMMARY AND RECOMMENDATIONS

This chapter contains a brief summary of the research efforts documented in this thesis. Further, some recommendations for future work are also presented.

Summary

The primary contribution of this research effort has been the development of a decision support system for travel demand analysis. The system development is based on the use of existing models and software in conjunction with analytical methods and programs developed in the research. This decision support system is developed to facilitate transportation planning and policy development. It is designed to help identify travel demand characteristics in urban areas and evaluate key variables influencing them. The system could be used to assist policy development, planning, financing, designing, and operations and management of urban transportation systems.

Currently, there is a clear lack of integrated computer models available to permit travel demand analysis and graphically display results. The procedure and the system developed in this thesis integrate a travel demand forecasting model (TRANPLAN) and
a GIS program (ARC/INFO). The output from TRANPLAN, which runs on a DOS operating system, is linked to ARC/INFO, which runs on a UNIX operating system. The menu driven system also includes routines and tools to facilitate simple statistical analyses and other analyses to identify and evaluate the spatial distribution of travel demand. Travel demand is quantified in terms of vehicle trips and vehicle miles of travel. Additionally, the system also provides tools to quantify the relative travel demands exerted in terms of demand normalized for key variables affecting the demand. Further, it permits evaluation of change in demand over time. One of its most powerful capabilities is its ability to present results of analyses in graphical formats (in addition to the traditional tabular or text based outputs). The results obtained using the tool could be used for preliminary studies or to provide better understanding or feel for the problem and alternative solutions. Quantitative and graphical formats of the results could be used as a first step in policy making, developing plans, operations or management strategies for transportation system.

**Future Recommendations**

The system developed in this thesis facilitates model linkages, data transfer, quantitative analyses and graphical representation of results. It is a macroscopic level tool based on productions and attractions aggregated at the TAZ level. It could be enhanced by adding microscopic level capabilities which would facilitate analyses at the trip interchange matrix level. Such analyses are necessary to be able to better evaluate travel demand characteristics and patterns at the link level on a network. These analyses would
be particularly useful in developing transportation network operation and management strategies and identifying critical links on the network.

In terms of the Las Vegas valley case study there are geo-reference matching problems with the coverages. For example, the TRANPLAN network and street centerline coverage do not match exactly and this may be due to the fact that they are developed and maintained by different organizations and on different operating systems. Another coverage that needs to be integrated is the parcel level land use coverage. It too does not match the TRANPLAN network or the street centerline coverage.
APPENDIX I

TRANPLAN CONTROL FILES FOR ESTIMATION OF TOTAL TRIPS
$HIGHWAY SELECTED SUMMATION
$FILES
   INPUT FILE = HWYNET, USER ID = $LV90N.NET$
   OUTPUT FILE = HWYSKIM, USER ID = $LVTEM.SKMS$
$HEADER
   LAS VEGAS 1990 NETWORK INTERZONAL SKIMS
$PARAMETERS
   IMPEDANCE = TIME 1
   TURN PENALTIES = (3-4,10) (4-1,10) (1-2,10) (2-3,10)
                  (3-2,50) (4-3,50) (1-4,50) (2-1,50)
$DATA
   TABLE = TIME 1
$END TP FUNCTION

$BUILD INTRAZONAL IMPEDANCES
$FILES
   INPUT FILE = IZIN, USER ID = $LVTEM.SKMS$, UNLOAD
   OUTPUT FILE = IZOUT, USER ID = $LV90.SKMS$
$HEADER
   LAS VEGAS 1990 NETWORK INTRAZONAL SKIMS
$OPTION
   ~ PRINT DETAIL
$PARAMETERS
   NUMBER OF ADJACENT ZONES = 2
$END TP FUNCTION
$GRAVITY MODEL
$FILES
  INPUT FILE = GMSKIM, USER ID = SLV90.SKM$
  INPUT FILE = GRVDATA, USER ID = $NEWPA90$
  OUTPUT FILE = GMVOL, USER ID = $LV90A.PAS$
$HEADER
  LV90 NETWORK & 1990 TRIPS
  GRAVITY MODEL OUTPUT -- FIVE PURPOSES
$OPTIONS
  GRVDATA
  MERGED PURPOSE FILE
  ~ PRINT TRIP LENGTH STATISTICS
$PARAMETERS
  MAXIMUM TIME = 75
  MAXIMUM PURPOSE = 5
  ITERATIONS ON ATTRACTIONS = 5
$END TP FUNCTION

$MATRIX UPDATE
$FILES
  INPUT FILE = UPDIN, USER ID = $LV90A.PAS$, UNLOAD
  OUTPUT FILE = UPDOUT, USER ID = $NEWLV90A.VOLS$
$HEADER
  LV90 NETWORK PERSON TRIPS TO VEHICLE TRIPS
  (AVG. 1.32 PERSONS PER VEHICLE)
$OPTION
$DATA
  P1, 1-751, 1-751, *0.8929
  P2, 1-751, 1-751, *0.6666
  P3, 1-751, 1-751, *0.7042
  P4, 1-751, 1-751, *0.6803
  P5, 1-751, 1-751, *0.7692
$END TP FUNCTION
$MATRIX MANIPULATE
$FILES
  INPUT FILE = TMAN1, USER ID = $NEWLV90A.VOL$, UNLOAD
  OUTPUT FILE = TMAN3, USER ID = $NEWLV90A.DATS$
$HEADER
  LV90 NETWORK TOTAL VEHICLE TRIP TABLE
$DATA
  TMAN3,T1 = TMAN1,T1 + TMAN1,T2 + TMAN1,T3 + TMAN1,T4
  + TMAN1,T5
$END TP FUNCTION

$REPORT MATRIX
$FILE
  INPUT FILE = RTABIN, USER ID = $NEWLV90A.DATS$
$HEADERS
  REPORT MATRIX (REPORTING -- PAGE 8-2)
$OPTIONS
  PRINT TRIP ENDS
  PRINT TABLE
$PARAMETERS
  SELECTED PURPOSES = 1
  SELECTED ZONES = 10-751
$END TP FUNCTION
APPENDIX II

TRANPLAN CONTROL FILES FOR ESTIMATION OF HOME BASE WORK (HBW) TRIPS
$HIGHWAY SELECTED SUMMATION
.FILES
INPUT FILE = HWYNET, USER ID = $LV90N.net$
OUTPUT FILE = HWYSKIM, USER ID = $LVTEM.SKMS$
$HEADER
LAS VEGAS 1990 NETWORK INTERZONAL SKIMS
$PARAMETERS
IMPEANCE = TIME 1
TURN PENALTIES = (3-4,10) (4-1,10) (1-2,10) (2-3,10) (3-2,50) (4-3,50) (1-4,50)
(2-1,50)
$DATA
   TABLE = TIME 1
$END TP FUNCTION

$BUILD INTRAZONAL IMPEDANCES
.FILES
   INPUT FILE = IZIN, USER ID = $LVTEM.SKMS$, UNLOAD
   OUTPUT FILE = IZOUT, USER ID = $LV90.SKMS$
$HEADER
LAS VEGAS 1990 NETWORK INTRAZONAL SKIMS
$OPTION
~ PRINT DETAIL
$PARAMETERS
   NUMBER OF ADJACENT ZONES = 2
$END TP FUNCTION
$GRAVITY MODEL

$FILES
INPUT FILE = GMSKIM, USER ID = $LV90.SKMS$
INPUT FILE = GRVDATA, USER ID = $NEWPA90$
OUTPUT FILE = GMVOL, USER ID = $LV90HBW.PAS$

$HEADER
LAS VEGAS 1990 NETWORK & 1990 TRIPS
GRAVITY MODEL OUTPUT -- HOME BASED WORK(HBW) TRIP PURPOSE

$OPTIONS
   GRVDATA
   MERGED PURPOSE FILE
   ~ PRINT TRIP LENGTH STATISTICS
$PARAMETERS
   MAXIMUM TIME = 75
   MAXIMUM PURPOSE = 5
   SELECTED PURPOSE = 1
   ITERATIONS ON ATTRACTIONS = 5
$END TP FUNCTION

$MATRIX UPDATE
$FILES
INPUT FILE = UPDIN, USER ID = $LV90HBW.PAS$, UNLOAD
OUTPUT FILE = UPDOUT, USER ID = $HBWLV90.VOLS$

$HEADER
LAS VEGAS 1990 NETWORK PERSON TRIPS TO VEHICLE TRIPS THE VEHICLE
OCCUPANCY RATE FOR HOME BASED WORK TRIPS IS 1.12
$OPTION
$DATA
P1, 1-751, 1-751, *0.8929
$END TP FUNCTION
$MATRIX MANIPULATE
$FILES
INPUT FILE = TMAN1, USER ID = $HBWLV90.VOLS, UNLOAD
OUTPUT FILE = TMAN3, USER ID = $HBWLV90.DATS
$HEADER
LV90 NETWORK TOTAL VEHICLE TRIP TABLE
$DATA
TMAN3,T1 = TMAN1,T1
$END TP FUNCTION
BIBLIOGRAPHY


