To the Graduate Council:

I am submitting herewith a thesis written by Barbara Grim Hatcher entitled "Travel Demand Forecasting - Use of Quick Response System II Software." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

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TRAVEL DEMAND FORECASTING - USE OF QUICK RESPONSE SYSTEM II SOFTWARE

A Thesis
Presented For The

Master of Science
Degree

The University of Tennessee, Knoxville

Barbara Grim Hatcher

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DEDICATION

This thesis is dedicated to my husband,

Martin L. Hatcher, for his understanding,

encouragement, and love which allowed me

to complete this assignment, and to our

daughter, Emily, for taking long naps.

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There are many people to whom I would like to thank for helping me accomplish this thesis. The first is Dr. Fred Wegmann, my major professor and friend, for his encouragement for my graduation and for his sending me all of the information that I requested. The second is Kim Henry Begg, a friend and former colleague, for her putting up with my calls for data and information. And lastly, Jeff Welch, a friend and former boss, for his allowing me time to work with the Quick Response System II software.

ABSTRACT

This thesis will outline the four step travel demand forecasting process, discuss how to use Quick Response System II Software to develop and manipulate a model, and demonstrate by specific examples how the Quick Response Sytem II software was applied to the Blount County case study. By knowing how to gather and forecast data and develop a model, a transportation professional can estimate future traffic volumes on roadways in a planning area. This thesis deals with developing a model for a small urban area which does not have a transit system.

The methods for gathering and forecasting data are based on local experience and nationally accepted documents. The model development is based on the quick response system II that was developed by AJH Associates. The case study for developing a model for Blount County Tennessee is based on work performed by the Knoxville Urban Area Metropolitan Planning Organization.

When good local data is used along with the Quick Response System II Software, reasonable current and future traffic volumes can be estimated. Nationally accepted values can be used for predicting future traffic volumes as long as the base model can be calibrated to mimic current traffic volumes.

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Chapter 1 - General Overview

Introduction

The travel demand forecasting part of the transportation planning process is used to determine where improvements need to be made to the transportation system, to determine the impacts of land use developments on the utilization of the transportation system, and to evaluate the performance of the current transportation system. Another reason to analyze the performance of the current and future transportation system is to be able to estimate air quality conformity. There are four steps to the travel demand forecasting process. They are 1) trip generation, 2) trip distribution, 3) mode choice, and 4) trip assignment. Trip generation forecasts the number of trip ends that will be made into and out of an area. Trip distribution determines where those trips will go and how trip ends will be linked. Mode choice predicts how the trips will be divided among the available modes of transportation. Trip assignment predicts the routes that the trips will take (United States Department of Transportation, p. 1-22). This thesis only considers the highway portion of the transportation system and does not include mode choice because it may not be appropriate for smaller urban areas. Various software packages have been developed to conduct the four traffic forecasting process. Among them are MINUTP, TRANPLAN, EMME/2, TransCAD and Quick Response System II (QRS II). For the purpose of this thesis, QRS II, developed by AJH Associates, was selected to highlight the application of the four step travel demand forecasting process to a smaller urban area. The Quick Response System II software is split into two programs, the General Network Editor and the Quick Response System. The network is built by using

the General Network Editor program and is run in the Quick Response System program. Before using the model for forecasting, it must be calibrated. Calibration deals with ensuring the final results of the model that is built are representative of the current transportation system. That is, the calculated volumes of traffic on the roadways is within a certain percentage of the existing volumes of traffic.

Objective

In the transportation planning process, engineers and/or planners are asked to recommend where transportation improvements are needed to alleviate congestion, improve air quality, etc. They also might be asked to prioritize highway projects based on the volume to capacity ratio of the roadways. To be able to make effective decisions, one must first have an unbiased way to evaluate the highway system objectively and without political or other influences. Unfortunately developing a model of the highway system for a small area using a conventional travel demand forecasting software requires a substantial amount of data collection and knowledge of the local area and the software.

The objective of this thesis is to provide for the novice engineer and/or planner a manual for developing a travel demand forecasting model for a small urban area using the Quick Response System II travel demand software. The purpose of using travel demand forecast software is to estimate average daily traffic along roadways or corridors and determine how a transportation improvement or major land use development will ultimately affect the utilization of the current or future roadway system.

At the current time, there are no comprehensive manuals for the travel demand forecasting process, especially as it applies to small communities. Several documents exist that show where and how to collect data and forecast this data. Other documents show how to use software, but there are none which show how to do both. Small communities may not have resources available to accomplish the task of gathering data, building a network, and modeling the network. This document is a technology transfer reference that can be used by the small community to model the highway network.

The key steps include defining the planning area, gathering of socio-economic data, network development, and calibration and running of the model. Specific recommendations of how to manipulate and forecast the data and data sources are given. Where appropriate, specific examples will be given. Chapter 5 is a case study for the development of a transportation plan for Blount County, Tennessee. The examples are based on the transportation study of Blount County, Tennessee conducted by the Knoxville Urban Area Metropolitan Planning Organization.

The objectives of this thesis will be to:

1. Outline the four step travel demand forecasting process;
2. Discuss how to use QRS II to develop a model to perform the four step traffic forecasting process; and
3. Demonstrate by specific examples how QRS II was applied to the Blount County case study.

Chapter 2 - The Four Step Traffic Forecasting Process

Prior to beginning the four step travel demand forecasting process, current and future urban activity needs to be documented. Current urban activity includes determining where people live and work. The urban activity forecasts include determining or projecting where development will take place in the future and at what intensity. The socio-economic data chapter discusses urban activity in more detail. The four step traffic forecasting process is outlined in Figure 1.

The key steps in conducting a traffic forecast include the following:

1. The planning area needs to be defined based on the purpose of the study. This area could be a metropolitan area that includes more than one county, a small city, or several blocks within a city. "The boundary of the planning area is known as the cordon line"(United States Department of Transportation, p. 2-2). This cordon line should intersect with a minimum number of roadways so that data requirements are cut to a minimum.

2. After the planning study area is determined, it must be further subdivided into smaller units called traffic analysis zones. The United States Census Bureau defines traffic analysis zones as a division of a study area represented by a centroid and used for traffic assignment purposes. These

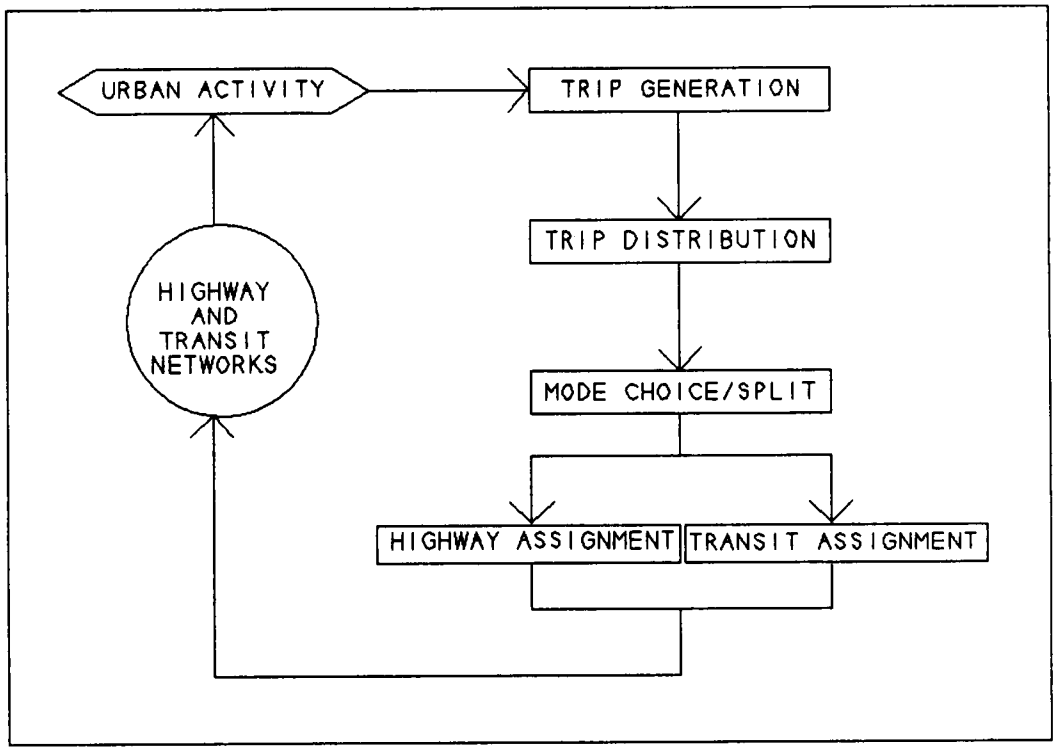


Figure 1 - Output from Four Step Traffic Forecasting Process

zones can vary in size depending on the population density or the land use of the area. The boundaries of zones most commonly are the transportation network, that is roadways. Other types of boundaries include waterways, powerlines, railroad tracks and mountain ridges.

3. The network created in a transportation model is a representation of the transportation system in an area. The network can include roadways from the interstate system to the local road system or major functional classified roads that carry region wide traffic. Included with the roadways are intersections, both signalized and unsignalized and ramps to limited access facilities.

4. Before and after creating a network, thought must be given to data that is needed to complete the modeling process. The socio-economic data include the number of dwelling units, income level, auto ownership and retail and non-retail employment. These key data items are used to estimate current and future travel. This data needs to be collected on a traffic analysis zone basis or at a minimum, the data needs to be aggregated to a zone basis. Dwelling units are the number of households available in a given area. The income level is defined as the average income in a zone. Auto ownership represents the average number of automobiles, cars, motorcycles, vans, and passenger trucks per dwelling unit in an area. Employment is the total number of jobs available in an area. Employment must typically be stratified into retail and non-retail. Retail employment includes

individual employees at shopping centers, restaurants, car dealerships; while non-retail employment includes individual employees with other types of jobs such as industrial, government, institutional, and etc. In addition to the required data, it may important and necessary to have secondary data to serve as a check and balance system or so that future estimates can be made. An example is having the number of persons per dwelling unit and the forecasted population so that number of dwelling units forecasted can be checked. Some major employment centers should be kept separate from the traditional employment figures because they may generate more trips than would be predicted by the generalized zonal model. Major activity centers are called special generators and need to be considered separately.

5. Average daily traffic counts on major roadways are used to establish the number of trips that enter and exit the network at external stations and for model calibration. There are three types of external trips, external to external, external to internal, and internal to external. The external to external trips pass through the area with only short stops such as to refuel and dine. Internal to external trips have their origin within the area and the destination outside of the area. The external to internal trips have their origin outside the area and the destination outside of the area. External to internal and internal to external trips will be used interchangeably in the remainder of the text.

6. After the planning area is established, the transportation network determined, traffic analysis zones defined, and other data collected, the network must be built and run.

The key aspects of the four step traffic forecasting process will be described in the next four sections.

Trip Generation

Trip generation involves determining the number of trip ends that are made in a traffic analysis zone. "A trip end is defined as the beginning or ending of a trip; therefore, a trip from home to work has two trip ends" (United States Department of Transportation, p. 3-1). Trip generation is based on urban activity. That is the number of trip ends can be estimated by the number of dwelling units, income, auto-ownership, and employment. Estimates of trip productions and attractions are made for each zone. A production is based at the "home" end of a trip. The number of productions can be calculated by using a cross classification table. These tables correlate the number of dwelling units, income and/or auto ownership with the number of trips per zone. An attraction is based at the non-residential end of a trip. The number of attractions can be calculated from equations that relate to the number of retail and non-retail employees and dwelling units. "For example, if a person went from home to work in the morning, and then went from work to home in the evening, the traveler would have generated two productions at the home zone and two attractions at the work zone" (Barton-Aschman Associates, p. 30).

Equations have been developed to calculate the number of productions and attractions for a traffic analysis zone by trip purpose. Two sources of equations for productions and attractions are the NCHRP Report 187 - *Quick-Response Urban Travel Estimation Techniques and Transferable Parameters* and its replacement, NCHRP Report 365 - *Travel Estimation Techniques for Urban Planning*. Trip purposes for a small urban area typically include home-based work, home-based other, and non-home-based. A home-based trip has one end at the home zone and the other at the work (where person is employed) zone. The home-based other trip has one end at the home zone and the other in a zone other than the work zone. An example of a non-work trip would be when the trip end is at a school, day care, or shopping center. A non-home-based trip would be when neither end of the trip takes place at home. An example would be when a trip begins at a school and ends at a restaurant.

Trip Distribution

The trip distribution process determines the linkages between productions and attractions that were generated in the first step. "Each zone's trip productions are connected to all the zones to which they are attracted" (United States Department of Transportation, p. 4-1). The most widely method used to distribute trips is the gravity model.

The gravity model is based on Isaac Newton's law of gravity that states that the attractive force between any two bodies is directly related to the masses of the bodies and inversely proportional to the distance between them. "Similarly, in the gravity model, the number

of trips between two areas is directly related to activities in the area represented by trip generation and inversely related to the separation between the areas represented as a function of travel time. Therefore, areas with large amounts of activity tend to exchange more trips and areas farther from each other tend to exchange fewer trips" (United States Department of Transportation, p. 4-2). The gravity model formula is:

$Tij = [PiAjF(t)ij]/[\Sigma AjF(t)ij]$, where;

Tij = the number of trips produced in zone i and attracted to zone j

Pi = the trips produced to zone i

Aj = the trips attracted to zone j

F(t)ij = the friction factor for interchange ij (based on traveltime between i and j)

$\Sigma AjF(t)ij$ = the summation of trips attracted to all zones times their friction factors

The friction factors are calibrated to replicate the trip length frequency curve. There are several documents that discuss the gravity model in detail (i.e. NCHRP Report 187 - *Quick-Response Urban Travel Estimation Techniques and Transferable Parameters* or NCHRP Report 365 - *Travel Estimation Techniques for Urban Planning*). See these documents for further clarification and friction factors.

After these trips are distributed by trip purpose, they must be balanced. That is across the study area, the number of productions must equal the number of attractions. An example

of trip balancing is shown in the external trip section.

Mode Choice

The mode choice step is used to determine the mode of transportation that will be used for trips. There are several factors that determine what type of transportation will be used.

> The first two factors that come to mind are the relative costs and travel times of the available modes -- certainly, a fast, inexpensive mode is more attractive to travelers than a slower, more expensive one. But, there are other factors that may be important and should be considered in the mode usage analysis. These factors, including time and cost, can be grouped into three broad categories.

1. characteristics of the traveler -- the tripmaker;
2. characteristics of the trip; and
3. characteristics of the transportation system (United States Department of Transportation, p. 5-3).

As mentioned earlier, this step in the travel demand forecasting process will not be included in this instruction manual because it is not usually appropriate for small areas because a transit system is non-existent or carries mostly captive riders.

Trip Assignment

The end product of trip assignment is the simulation of average daily volumes of vehicles on the highway system. There are three techniques available for highway trip assignment, 1) all or nothing minimum path, 2) minimum path with capacity constraint, and 3) multi route probabilistic assignment. The first step in any of these techniques is to find the path that the trips will likely take from one zone to another zone. After the paths

are identified, the total time, cost, distance, or impedance it takes to go between two points on a link by link basis are determined. The trips from the trip table, which is output from trip distribution, are then loaded onto the network by assigning them to those paths (United States Department of Transportation).

The all or nothing minimum path technique is based on the assumption that the traveler desires to use the minimum impedance route between two points. That is, all vehicles use the same path regardless of the number of other vehicles on the link. The impedance is typically travel time. This technique does not consider capacity and may cause links to be overloaded because there is no incentive to use another link. This method could also be referred to as the "all or nothing" technique.

The minimum path with capacity restraint begins with finding the minimum path, but also considers the other traffic utilizing the links. "Capacity restraint attempts to balance the assigned volume, the capacity of a facility, and the related speed" (United States Department of Transportation, p. 6-17). The volume to capacity ratio is taken into consideration with this method. When a link is at capacity, then other vehicles will use another link.

"There are several methods of utilizing capacity restraint in a trip assignment. The most common method is simply to load the network and adjust assumed link speeds after each loading to reflect volume/capacity ratio. These loadings and adjustments are done

incrementally until a balance is obtained between speed, volume, and capacity" (United States Department of Transportation, p. 6-17).

The multi route probabilistic assignment recognizes that there are several routes between two points that have nearly equal impedances. Some routes may be longer than others but have equal use. Using this approach, trips are assigned to reasonable paths between zones as a function of the path's relative impedance. Therefore, paths of equal impedance would receive equal traffic and longer paths less traffic.

Prior to beginning the four step traffic forecasting process, socio-economic data needs to be collected to define the activity within a zone which can be translated into trip ends.

Chapter 3 - Data Requirements

The Planning Area

The first step in the planning process is to determine the planning area that will be used. If future forecasts are going to be made, then both developed and undeveloped land needs to be included. This area could be a whole metropolitan area that includes farmland and wooded areas and is several counties large. It should include land that will be developed within the planning time period, twenty to fifty years into the future. The planning area may be defined by federal transportation legislation for areas that have population greater than 50,000.

Traffic Analysis Zone Boundaries

Traffic analysis zones are sub areas within a larger planning area. The size of the zones can be as small as a city block in a central business district or as large as many square miles. The size should depend on the population density in residential areas and the land use. The zones should be fairly homogeneous in land use (North Bannock Metropolitan Planning Organization). Zones should represent origins and destinations of travel activity within the planning area (Barton-Aschman Associates). Land use maps, major transportation facilities maps, aerial photos, and local knowledge should be used to identify the zones. The zones should fit into census tract boundaries that are set by the Census Bureau. Census tracts are small statistical subdivisions of a county that usually consists of 2,500 to 8,000 persons. Waterways, railroads, and high functionally classified roadways (interstate, arterial, and collector) serve as good zonal boundaries. When

determining the zones, consideration should be given to data that can be easily acquired. New and historical data for the zone should be available if projections will be made. Figure 2 shows an example of traffic analysis zones developed in Blount Count case study.

The area of each traffic analysis zone needs to be estimated in square miles to be able to determine the time for intrazonal travel. The estimate can be made by use of a computer if a geographic information system is available or can be measured by hand with a planimeter. The following two equations may be used to estimate intrazonal travel time:

Intrazonal Time = 0.5 * [Zonal Area] + Intrazonal Speed [area type] (Barton-Aschman Associates, p. 63), where

Intrazonal Time = total intrazonal time in minutes

Zonal Area = area of traffic analysis zone in square miles

Intrazonal Speed (area type) = intrazonal speed in miles per hour (varies by area type - for example use 15 mph for the central business district and 30 mph for rural areas)

Intrazonal Time = 45 * [1/speed]* zonal area (Comsis Corporation), where

Intrazonal Time = total intrazonal time in minutes

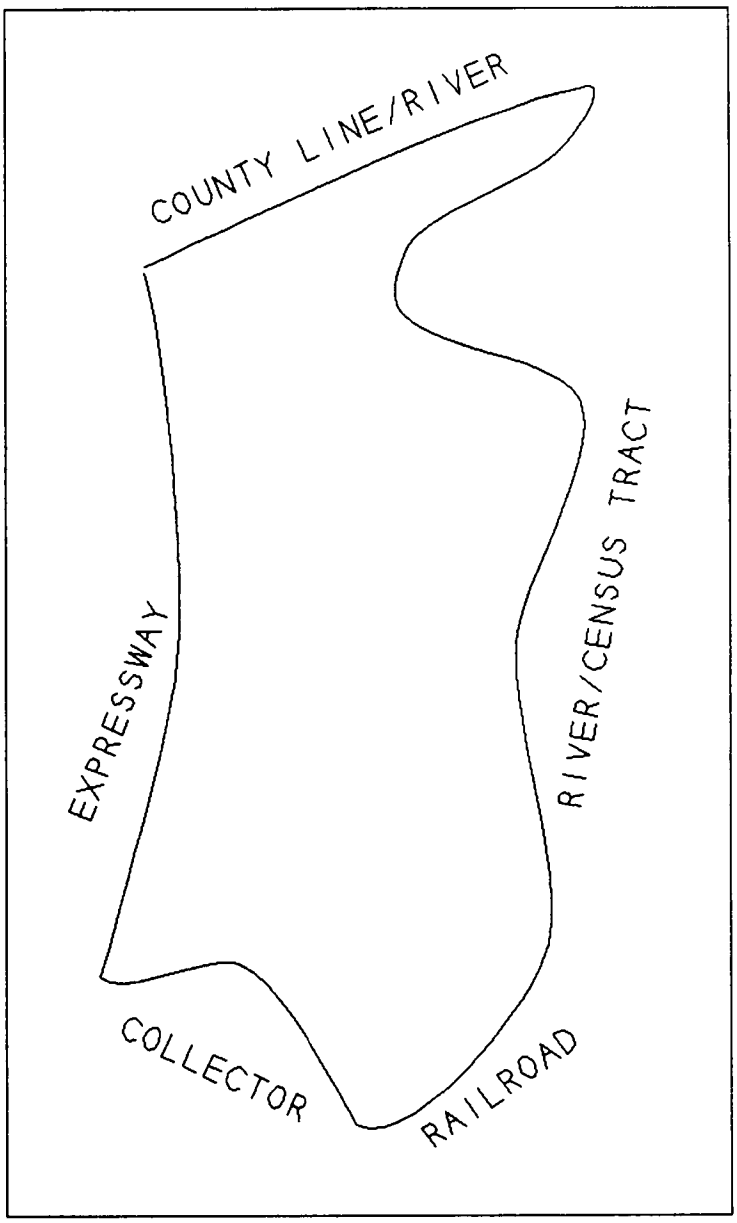


Figure 2 - Traffic Analysis Zone Example

Speed = intrazonal speed in miles per hour

Zonal Area = area of traffic analysis zone in square miles

Centroids

"Since it is not computationally feasible to represent every household, place of employment, shopping center, and other activity as a separate trip origin and destination, these entities are first aggregated into zones and then further simplified into a single node called a centroid" (Barton-Aschman Associates, p. 16). A centroid is a point that represents all travel origins and destinations in a zone. Zone centroids should be placed in the center of trip activity of the zone, using land use maps, aerial photographs, and local knowledge. Unique special generators, especially when surrounded by a different land use (such as a college campus in a predominantly residential area) should be isolated a separate zones. The center of activity is not necessarily the geographic center of the zone -- it is the midpoint of trip activity. Oftentimes judgement is more useful than measurement technique in determining where the zone centroid should be located (Barton-Aschman Associates, p. 16). Figure 3 shows a centroid within a traffic analysis zone.

The trips that are added to the network will be assumed to start and end at the centroid. The trips move from the centroid to the centroid connector to the roadway system (network) to another centroid connector and then to the centroid of another zone. The

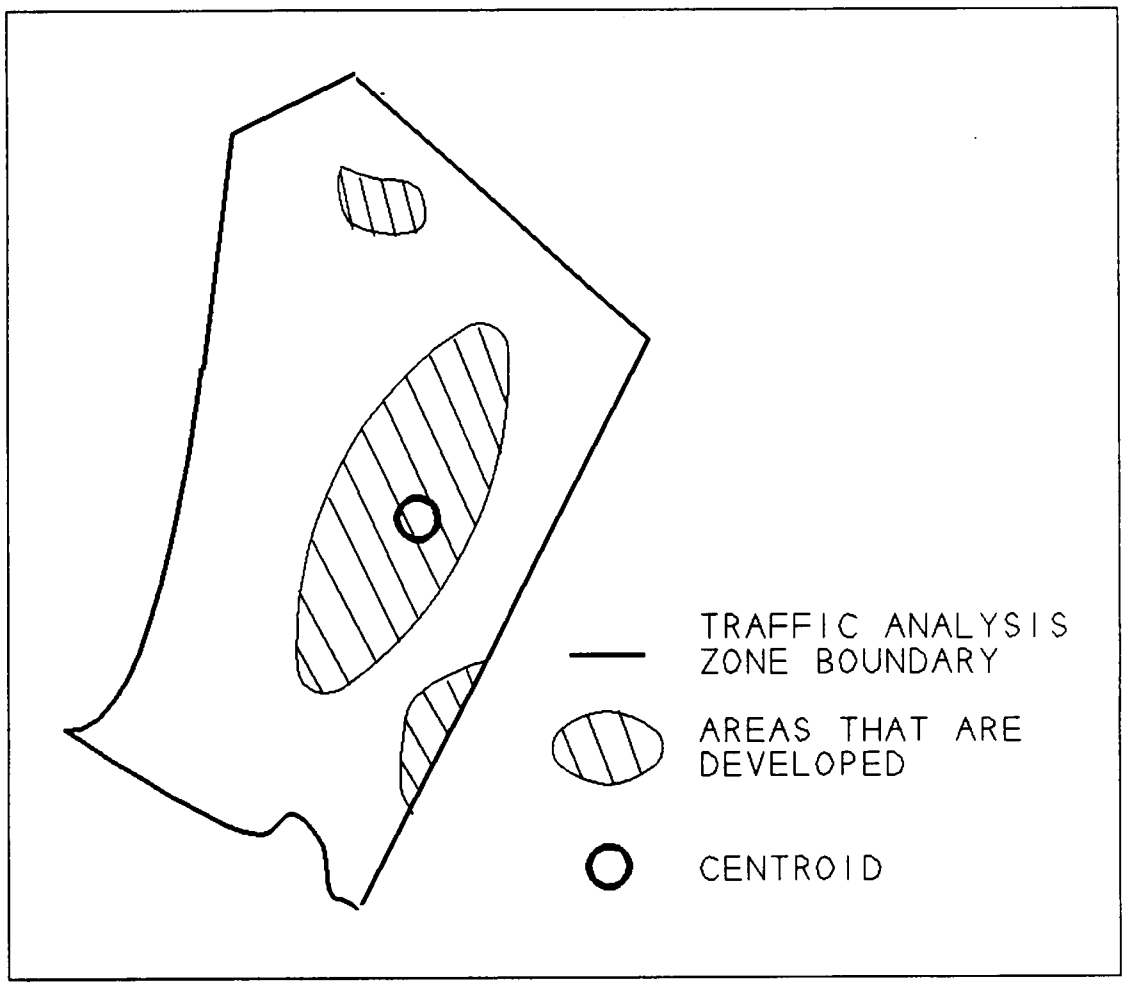


Figure 3 - Example of Centroid in a Traffic Analysis Zone

estimated number of trip ends added to a network are based on the socio-economic data that is discussed later.

The travel demand forecasting software will require the development of a network including the location of each of the centroids. Since trips are assigned to the minimum travel time route, the precise location of the centroid will be important. See the *Highways to Include* section that details how to find and record the coordinates.

Centroid Connectors

Centroid connectors connect the centroid of a traffic analysis zone to the roadway network. These connections should not cross boundaries of the zone and should not be connected at intersections. The connectors are representative of where connections are likely to occur as trips access the major roadway system. Figure 4 shows how to place centroid connectors.

The travel demand forecasting software requires the coordinates of the intersection of the centroid connector and highway network. See the *Highways to be Modeled* section that details how to find and record the coordinates.

Roadways to be Modeled

The highway network should represent the major roadway system including: the

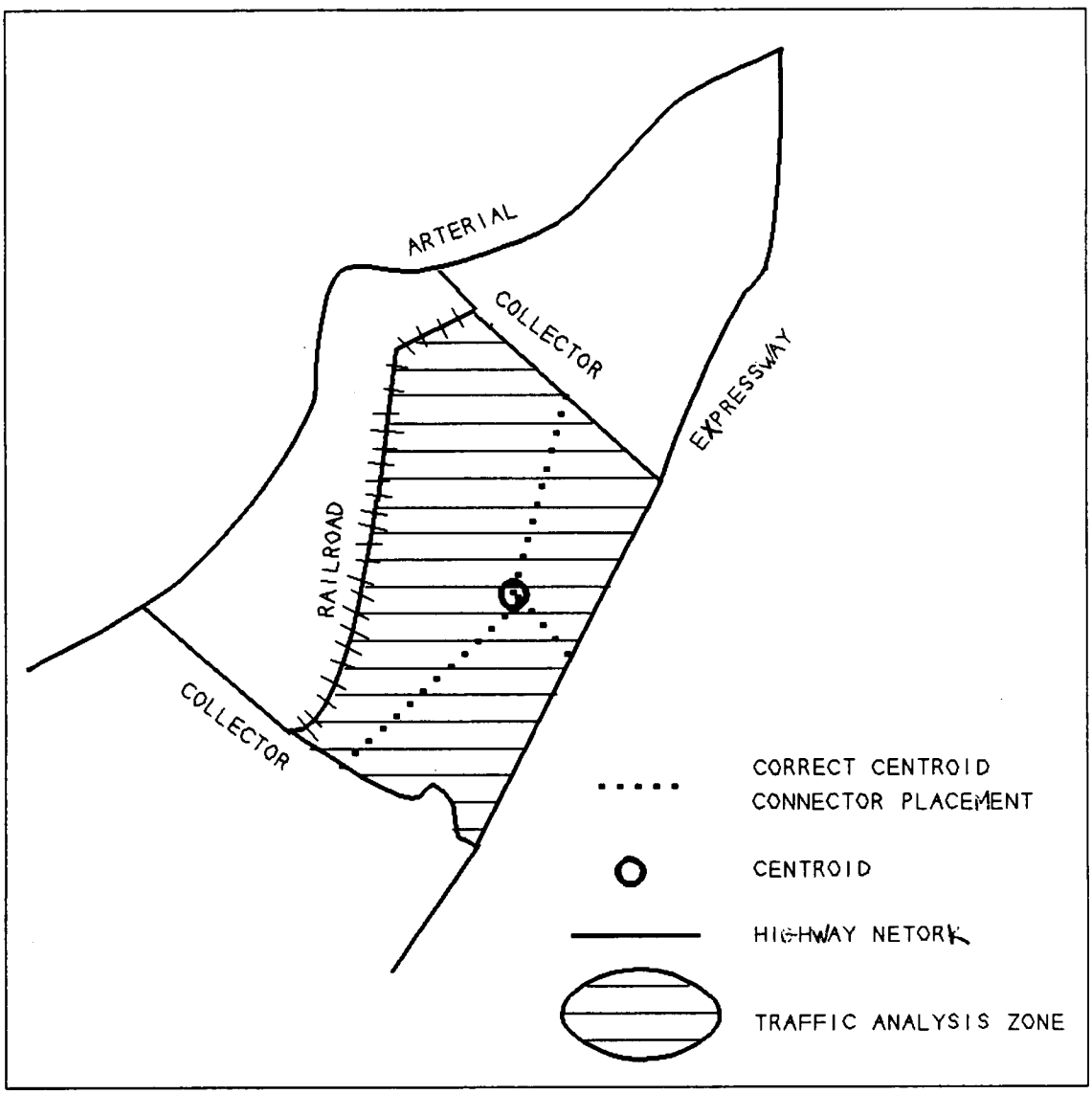


Figure 4 - Centroid Connector Placement

interstate system, major/principal arterials, minor arterials, major collectors, and selected minor collectors depending on the purpose of the study requirements. If the planning area is a subarea involving only a few blocks, then all the roads surrounding those blocks would be appropriate to use. It the planning area is a whole county or large city, then it would be most appropriate to use the higher functionally classified roads and only add minor collectors and local roads if they have high volumes or provide critical connectivity.

Highway Data Requirements

There are several roadway attributes that need to be defined, specifically, the functional classification, capacity, speed or travel time, number of lanes, geometry at intersections, and type of traffic control at intersections. All of this information should be known prior to building the network. Figure 5 represents an example of the data that is required for all approaches at an intersection.

Along with the physical attributes, the "location of the nodes" that define the roadway links also needs to be known. The nodes represent intersections of roadways or the roadways and centroid connectors, or represent the curvature of the roadway. Figure 6 represents various examples of nodes and links. There are several ways to acquire the coordinates of each node. They could be acquired via digital methods or by hand using graph paper. If the network is as large as a city or county, then obtaining the coordinates digitally would be the most practical if the digital format is available geographic

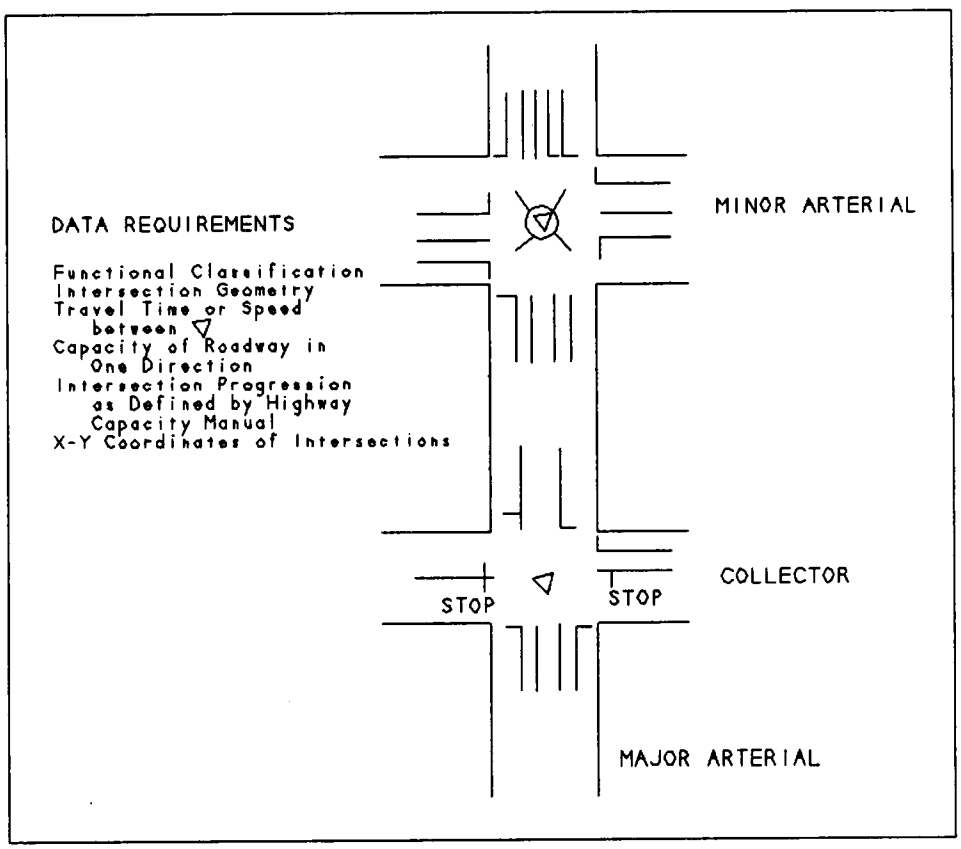


Figure 5 - Required Data for the Highway Network

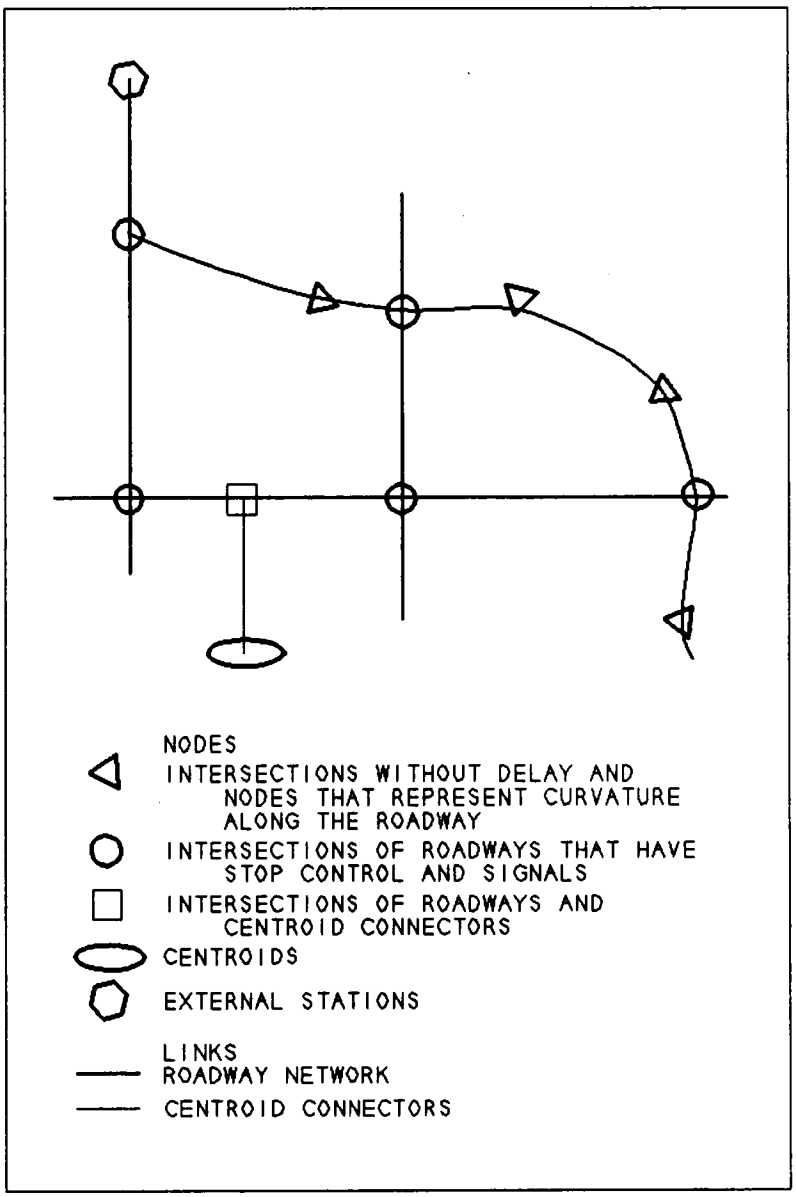


Figure 6 - Nodes and Links along a Roadway

information system. For smaller areas a TIGER File might be available from the United States Census Bureau. Manually abstracting the coordinates from a base map could be time consuming, but may be practical for smaller networks. One method to obtain these coordinates is to overlay a map of the highway network with graph paper and mark all nodes that are to be included. Other items to mark would be where the number of lanes increase or decrease and any representation of horizontal curvature. After all markings are made, they should be numbered or labeled and the X and Y coordinates established (see Figure 7).

Intersection Data Requirements

Traffic control needs to be identified for all intersections that will be included in the highway network. These include signalized, STOP controlled, freeway ramps, intersections where U-turns are permitted and are significant in number, and all intersections that have large delays. Intersections with minor roads that are not included in the network , need not be included.

If the intersection is controlled by a traffic signal, then the cycle time needs to be defined. If the intersection is STOP controlled, then the placement of signs must be known (i.e. 2-way or 4-way). Other types of data that can be used are adjustments for movements (delay) and the minimum unsignalized capacity. The minimum unsignalized capacity is important only to one-way and two-way STOP controlled intersections. This is the minimum hourly capacity of a signed approach, regardless of the amount of

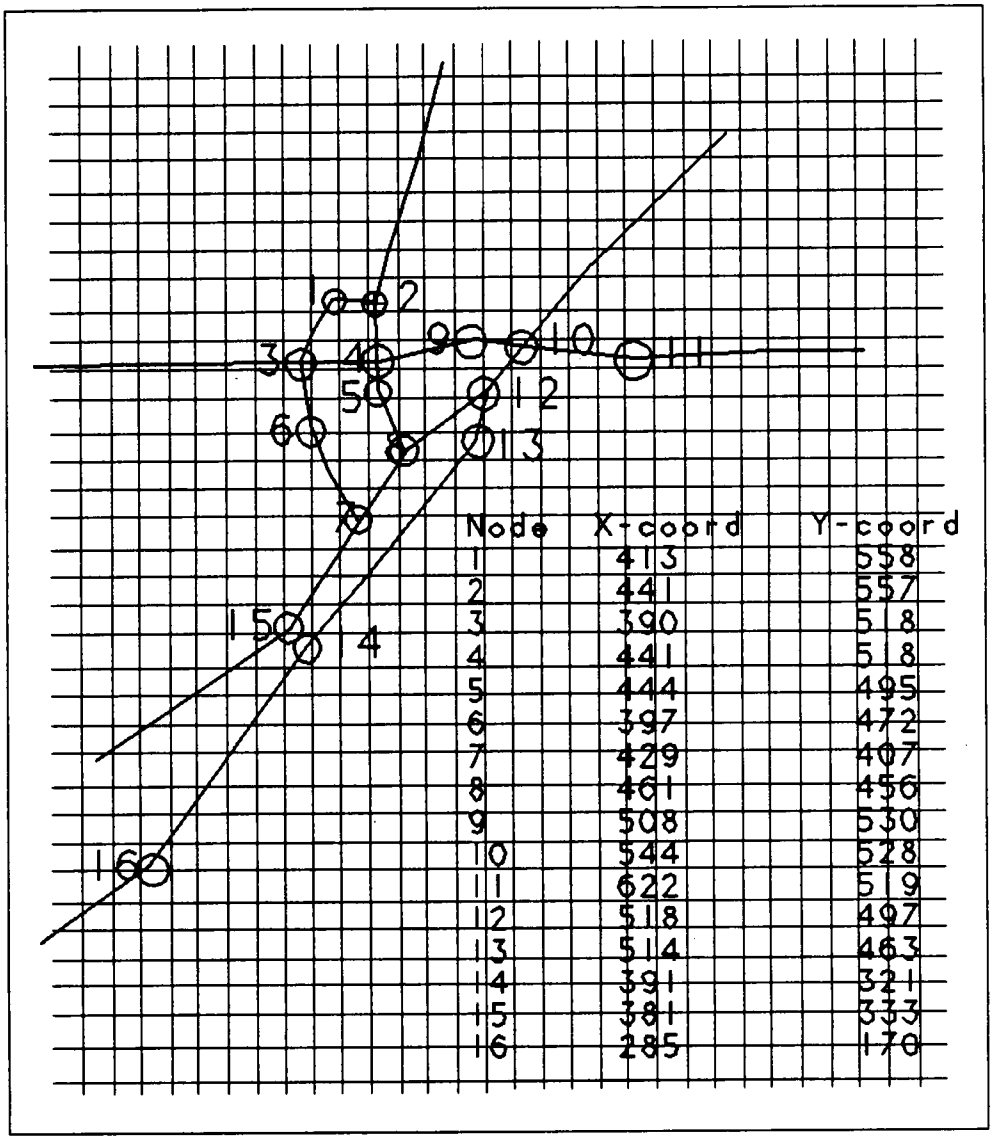


Figure 7 - Establishment of a Coordinate File

conflicting traffic.

Current Socio-Economic Data

Socio-economic data is utilized in the modeling process so that traffic models can generate the number of trip ends that will be produced at and attracted to each traffic analysis zone. A production is a trip end based on household characteristics such as the number of dwelling units, income, and/or auto ownership. An attraction is a trip end based on work or other non-home characteristics such as retail and non-retail employment. The socio-economic data represents the urban activity that is ultimately translated into trip ends as part of trip generation, the first step in the four step traffic forecasting process.

The types of socio-economic data that are required by Quick Response System II are: dwelling units, income or auto ownership, retail employment and non-retail employment. Each of these types of data are in the following sections.

Socio-economic data should be recorded on a traffic analysis zone basis. See Table 1 for an example of how data can be recorded in an appropriate spreadsheet.

It is advisable to keep track of this data with a spreadsheet on a traffic analysis zone basis. Also, keep all sources of information in a file so that it is easily found when needed.

Table 1 - Socio-economic Data Example

TAZ	Population	Dwelling Units	Income ($1,000)	Auto-Ownership	Retail Employment	Non-retail Employment
1	746	400	18.794	1.7	64	10
2	1261	712	18.794	1.7	50	508
3	1296	553	15.517	1.7	20	408
4	495	193	15.517	1.7	0	137
5	342	178	18.794	1.7	450	1187
6	858	330	18.794	1.7	250	471
7	477	205	18.794	1.7	0	15
8	1336	583	18.974	1.7	0	85
9	499	241	18.794	1.7	15	15
10	196	77	18.794	1.7	75	4160

Sources for Gathering Socio-economic Data

There are many sources from which to gather the socio-economic data. It is best to use sources that are reliable and professionally accepted and recommended. The following list shows sources of data for socio-economic data:

1. United States Census - The decennial census offers the best source for population and the required companion characteristics data (dwelling units, auto ownership, and income). These data are available at block level and can be aggregated to traffic zones. Although the census documents employment in the form of labor force, it is a household-based count rather than a count of employment by location. Labor force statistics provide counts of employment in various areas where residential population is located, but do not specify employment by employer or location. The Census Transportation Planning Package provides sums of resident employment at the traffic analysis zone; therefore, the census can be used for some general cross-checks for employment, but cannot be used to compile employment data for small geographic areas.

2. State Employment Commission (Employment Commission) - The State Employment Commissions generally document all employees for tax purposes. Each employer is identified by a federal identification number, number of employees, and an address usually keyed to where the payroll is prepared for the specified number of employees. The State Employment Commission data are significant because the address can tie the employer, and therefore the number of employees, to a specific geographical area. One consideration with the employment commission data is that often up to half the employers list Post Office boxes as the address of record. In addition, employers with more than one location are not always desegregated; that is, the headquarters of a firm may be listed with the total employees combined for all franchises.

3. Market Research Listings - Many market research firms offer commercial listing of all (or major) employers and number of employees by county and city. All the listings show business locations by street addresses, as well as Post Office boxes. Commercial listings offer these data on a subscriber basis with a range of access and purchase options.

4. Local Area Population and Employment Data - Many areas collect and record some type of population data. But few areas record employment data other than a broad listing of the employers with the highest number of employees locally. Chamber of Commerce often publish lists of member businesses.

5. Aerial Photography and Existing Land Use - Often aerial photographs can be used to update existing land use. The resolution of the photography is good enough to differentiate many residential and non-residential areas. When compared with the aerial photographs, each land use can be associated with a particular land use type (retail, industrial, etc.) for each building.

6. Telephone Directory - the telephone directory is a rich database that lists residential units and businesses by street address for any planning area; however, the rate of unlisted residential numbers is rising and may influence the use of telephone directories.

7. Polk Directory - the Polk Directory is a comprehensive list of household and employment data sorted by name and address. For households, such information as occupation and employer can be ascertained. For business establishments, type of business - including associations, libraries, and organizations that may not be on the tax file - can be determined (Barton-Aschman Associates, pp. 19-20).

The following deficiencies for the previously listed sources exist:

1. Population - The only data source acceptable to initially establish a residential database is the U.S. Census. All of the other data sources identified above do not provide comparable population statistics by specific area.

2. Employment - Each of the above data sources has some deficiencies specifying employment for small geographic areas. The census provides total labor force by traffic analysis zone; however, this represents only employment location of residents and not total employment. The employment commission data provide accurate employment for each business but only partially list street addresses (with the remaining having Post Office box listings). Commercial listing have all employers by street address. Although these listings are extensive, the accuracy is controlled internally and often cannot be considered comprehensive (because of the lack of information regarding collection methodology), but offers a check for other data sources. The aerial photography only assists in determining potential nonresidential areas. The land use data obtained from aerial photography provide a geographic location of businesses, but do not provide employment numbers.

A similar condition exists with the telephone directory. The directory covers most businesses and provides addresses for most of them. Several multi-use areas, such as shopping centers, do not provide numbered street addresses (Barton-Aschman Associates, pp. 20-21).

The United States Census Bureau performs the census every decade. These population,

dwelling unit, labor force, income, and auto ownership data can be interpolated for the years between censuses. Frequently in a small community, employment data, can be utilized from a windshield survey.

Dwelling Units

Dwelling units are defined as the total number of living quarters. These include houses, apartments, dormitories, etc. The total number of dwelling units in a particular traffic analysis zone, census tract or block group can be found in the decennial census. It is almost impossible to have an exact number of dwelling units at any given time in areas that are quickly developing or are being vacated.

The base data used should be taken from a reliable source such as the decennial census. In some instances, a government may to decide to take a special census. This data may then be used as the base data. There are several methods to determine the development activity in the traffic analysis zones including counting building permits, recording plats for subdivisions, and utility hookups. In instances where a government entity requires building permits, a fairly accurate count can be made. From there building permit data should be sorted by traffic analysis zone and summed. Recorded plats of subdivisions may be used where the vast majority of development is single family residences. The lots can be counted and aggregated by traffic analysis zone. The only problem with using this data is that some lots may have never been developed and others may have been developed with more than one dwelling unit. Data for commercial properties should not

be added in the this category but should be recorded as a source of employment data. The method of counting utility hookups can be used to determine the number of new residences if the data is easily accessible by traffic analysis zone and if it is coded for new residences only. If counting utility hookups is found to be an acceptable method for determining growth, then the data should be aggregated by traffic analysis zone. After the data is compiled, it should be added to the base data on a traffic analysis zone basis.

Auto Ownership and Income

Quick Response System II requires data for either auto ownership or income. It is best to use the data that is most accurate or most easily accessible. Auto ownership per traffic analysis zone is defined as the average number of automobiles owned per dwelling unit. The average auto ownership in a particular census tract or block group can be found in the decennial census. The borders of the census tracts should not be split by traffic analysis zones as several traffic analysis zones fit into a census tract. This means that auto ownership data for a particular traffic analysis zone should be equal to the auto ownership in the census tract within which it lies.

Income for each traffic analysis zone is defined as the average income for the traffic analysis zone. This data is available in the decennial census by census tract. QRSII requires that the data either be in 1980 dollars or an inflation index be provided for the particular year so that it can be converted to 1980 dollars. Similar to auto ownership data, income is only available by census tract. The data for the traffic analysis zone

cannot be differentiated for the census tract in which it lies. An example of how the 1990 income can be converted to 1980 income based on the consumer price index is as follows:

1980 Income = 1990 Income*(1980CPI)/(1990CPI), where:

1980 Income = Average income in 1980 dollars

1990 Income = Average income in 1990 according to Census data

1980 CPI = Consumer Price Index in 1980

1990 CPI = Consumer Price Index in 1990

Example:

Given: The 1990 average income for census tract 103 was $29,805. The 1980 and 1990 Consumer Price Indices were 246.8 and 391.4, respectively.

Solution:

1980 Income = $29,805*246.8/391.4

1980 Income = $18,794

See Appendix A for the Consumer Price Index for 1971 to 1997. A more complete source for the consumer price index is from the United States Bureau of Labor and Statistics' web site, STATS.BLS.GOV\CPIHOME.HTM. When using the consumer

price index, care must be taken to ensure that the base number used is the same.

Employment

Employment defined for a traffic analysis zone is the total number of jobs within the zone, not the total number of people who have jobs. QRSII requires that employment be subdivided into retail and non-retail. A revised quick response approach requires that employment be stratified into four categories, retail employment in central business district zones, retail employment in non-central business district zones, service employment, and other employment (Barton-Aschman Associates, 41). Employment categories or codes are used to define the employment groups.

Data seems to be lacking in this category especially on a traffic analysis zone basis. The reason for this problem is that the information is proprietary and is not always disseminated to the public. There is limited data available in the decennial census in the Census Transportation Planning Package. In Tennessee, the Department of Employment Security accumulates employment data on a county-wide basis and refers to it as "Annual Covered by Unemployment Insurance" (Grant). This employment data is compiled on a yearly basis. A local chamber of commerce or industrial board may have figures from the larger employers, such as airports, shopping centers, businesses in industrial parks, large corporations, and manufacturers in the area. Also, local governments and school systems have figures on their number of employees. The local newspapers in the area may be a source of information because they report new development and the number of

persons who will be employed. The property assessor's office may also have the square footage of buildings which could be used to project the total number of employees.

Fieldwork may be a way to estimate the number of employees in a traffic analysis zone. The total number of jobs in an area can be estimated with a drive-by. That is, while driving along a road, use a tape recorder or other device to record each place and type of business as well as cross roads. The cross roads are recorded so that the traffic analysis zone can be verified. Each business is then placed into its respective traffic analysis zone. Estimates can be made for each business for the total number of employees based on prior experience or by calling certain businesses, such as a car dealership, grocery store, hotel and small businesses. These businesses should be split into retail employers and non-retail employers. After all estimates are made, then each category should be summed on a traffic analysis zone basis. The total should be compared with the area, such as county-wide, totals.

Sometimes the major employment centers, such as airports, large hospitals, large manufacturing plants, should not be included in the employment data. Instead, they should be considered as special generators.

Special Generators

A special generator is defined as "major activity facilities that have a rate of activity greater or less than predicted by the standard equation" (National Highway Institute, p. 3-

19). Examples of special generators are regional shopping centers, airports, military bases, hospitals, and colleges or universities. The attraction rates of these types of employment centers may be significantly greater to or less than the typical zonal attraction rates used in travel demand software. Judgement should be used when determining what should be classified as a special generator.

The production and attraction rates for these special generators are calculated from outside sources, such as the current edition of the Institute of Traffic Engineer's *Trip Generation Manual*. The *Trip Generation Manual* contains equations for hundreds of land uses for the number of trips into and out of the business. The equations given for a particular land use typically include the average weekday trips and the A.M. and P.M. peak hour of adjacent street traffic. Also, the percentage of trips entering and exiting the land use are also given. The following equation, from the *Trip Generation Manual* for an industrial park for a weekday A.M. peak hour of the adjacent street, is a typical equation:

$Ln(T) = 0.86\ Ln(X) + 0.18$, where;

T = the number of trips entering and exiting the facility (by a time period)

X = the number for the variable that is used (i.e. acres, square feet, rooms, employees, and etc.)

To find the number of trips for this type of equation, use the following equation:

$$T = e^{(0.86 \text{ Ln}(X) + 0.18)}$$

The time period for the number of trips entering and exiting the facility may be for 24 hours, one hour in the A.M. or P.M. peak of the adjacent street, the A.M. or P.M. peak hour of the generator, or a time period on the weekend. Care must be taken when using the equations to make sure the trips generated are for the same time period as the area wide analysis.

The trip generation step estimates the number of vehicle trip ends which need to be converted to person trips and classified as productions and attractions. The productions and attractions then have to be split into trip purpose. An example of calculating the trips for a particular land use is as follows:

Given: A commercial airport lies in TAZ 310, it has an average of 165 flights per day. Find the number of trip ends for the airport. What are the number of productions and attractions that would be shown for this special generator? The average auto occupancy of the area is 1.2 persons per vehicle. Remember that the trip ends generated in the Institute of Transportation Engineers' *Trip Generation Manual*, Fifth Edition are vehicle trips not person trips.

Solution: The *Trip Generation Manual*, Fifth Edition, lists Commercial Airport as a land use and has the average rate of trip ends per average flights per day. It also contains a

range of rates. The average rate of trip ends on a weekday is 104.73 vehicle trips per flight.

A. The total trip ends would be: 104.73*165 = 17,280 vehicle trips per day

B. Because this special generator is not a residential location, all of the trips would be attractions. However, the number of trip ends would have to be multiplied by 1.2 because attractions must be given in person trips. Therefore, the total number of attractions would be: 17,280*1.2 = 20,736. These attractions need to be split into trip purpose (home-based work, home-based non-work, and non-home based). A source for estimating trip purpose could not be found for this type of special generator. Therefore, the trips may be split equally among the three trip purposes. That is, 6,912 of the trips will be used for each trip purpose. In QRSII these daily person trips would be represented with a Production/Attraction Tag attached to a special generator centroid with a piece of string. See the QRSII Chapter, the General Network Editor Section for more details. If the A.M. or P.M. peak hours are used, then care must be used as to the values placed in the production/attraction tags because the values in the tag are multiplied by the HRATES.txt file which is the percentage of trips for that hour.

Socio-Economic Data Projections

When it is necessary to predict traffic on the roadways in the future, projections for

socio-economic data must be made. These projections should be based on past trends and future plans and correlated with planning studies. The projections should be compared to those made by reputable sources such as Woods and Poole.

Dwelling Units

Projections for dwelling units can be made by combining past and present building trends and available land. After a trend is established on a year by year basis using building permits, utility hookups, and/or lots created, a projection can be made. A projected year must be established, such as five, ten, twenty years from the base year.

One method is to determine the yearly average of additional dwelling units and multiply that number by the number of years and add it to the base year. The equation is:

DUfuture = DUbase+(YEARfuture-YEARbase)*(DUav/year), where:

DUfuture = number of future year dwelling units

DUbase = number of base year dwelling units

YEARfuture = future year (i.e. 2000)

YEARbase = base year (i.e. 1998)

DUav/year = average number of dwelling units "built" per year

Example:

Given: There were 45 lots created in TAZ 59 from 1987 to 1993, inclusive, in 1993 there were 2,300 dwelling units, and the future year is 2018.

Solution:

DU av/year = 45/7

6.43 du/year

DU future = 2,300+(2018-1993)*6.43

2,300+161

2,461 dwelling units in TAZ 59

Another method to use would be to take two known years' data and project a straight line. If the 1980 and 1990 data is known from the decennial census on a traffic analysis zone basis, then a straight line could be used to determine a future year. The equation is:

DUfuture = [(YEARfuture-1990)/(1980-1990)]*(DU1980-DU1990)+DU1990, where:

DUfuture = number of future year dwelling units

YEARfuture = future year (i.e. 2000)

DU1980 = number of dwelling units in 1980

DU1990 = number of dwelling units in 1990

Example:

Given: In 1980 there were 2,000 dwelling units in TAZ 49, in 1990 there were 2,300 dwelling units in the same TAZ, a year 2010 projection is required.

Solution:

DU future = [(2010-1990)/(1980-1990)]*(2,000-2,300)+2,300

[20/-10]*(-300)+2,300

600+2,300

2,900 dwelling units in 2010

This method may not be as accurate as the previous method because the building activity rates may be over or under the current trend. However, this may be the best method if there is no data on the current trends available. Trend extrapolation must consider the period being considered and if these trends will project into the future.

Another method of determining future dwelling units is from population projections. When a population projection is made by a reliable source such as the census bureau, a consultant, regional planning agency, and etc. it can be used to project the number of dwelling units. The population for the base year must also be known to make the projection. The equation for the projection is the following:

DU(TAZ)future = DU(TAZ)base*POPULfuture/POPULbase, where:

DU(TAZ)future = future number of dwelling units for a traffic analysis zone

DU(TAZ)base = base number of dwelling units for a traffic analysis zone

POPULfuture = future year population projection

POPULbase = base year population projection

Example:

Given: Base year population = 90,000

Future year population projection = 100,000

Base year number of dwelling units = 5,000

Solution:

DU(TAZ)future = 5,000*100,000/90,000

5,556 dwelling units

This type of projection should be made when development activity can not be tracked in any way and when population projections are made by a reliable source or model.

After the projections are made, time should be taken to confirm that the projected year's data is acceptable. A look at the available land and the current and future land use of the traffic analysis zone should be compared to the projection. That is, if there was a very high rate of growth and the area is currently built-out, the projected data may to too high, and vice versa. Also, if the future land use of an area is zoned to be industrial, commercial or anything non-residential, a great change in dwelling units should not be

expected. A look at future sewer or other type utility expansion may make a low rate of growth area more susceptible to a high rate of growth.

Auto Ownership/Income

Auto ownership is a function of the number of dwelling units in the base case. Future projections may be based on the same proportion if no additional data is available. Income projections are a difficult to determine because of the uncertainties in economic conditions. Also, income levels may change dramatically in traffic analysis zones that are undeveloped now. That is, if high end housing or low income housing is built in the zone, the income level could increase or decrease, respectively.

Employment

Employment projections are more difficult to make on a zone by zone basis because current trends may not be indicative of the future. A total employment trend can be found by using the county-wide type data that was mentioned previously. The trend can then be used to determine a county-wide projection using a straight line or any other acceptable statistical model. The future year data can be determined on a traffic analysis zone basis by the following equation:

FEMPtaz = BEMPtaz*(TOTEMP/BASEEMP), where:

FEMPtaz = future year employment of a traffic analysis zone

BEMPtaz = base year employment of a traffic analysis zone

TOTEMP = total future year employment

BASEEMP = total base year employment

Example:

Given: In 1998 there were 300 employees in TAZ 29, 24,000 employees total, and the future total projected employment is 36,000. Find the number of employees in TAZ 29 in the future year.

Solution:

FEMPtaz = 300*(36,000/24,000)

300*1.5

450 Employees in TAZ 29 in the future year

The projections for non-retail and retail employment should be prepared the same way. These projections should be checked by traffic analysis zone and compared to future land uses and any plans by major employers, industrial boards, local and state governments. If a traffic analysis zone is completely built-out with an employment center, then employment should remain constant and not change in the future. However, if there are large farms in areas where the future land use plans call for industrial parks or heavy commercial development, employment figures should be increased dramatically, possibly being based on an employees by acreage figure from a source such as *Urban Land Use*

Planning by Kaiser, Godschalk, and Chapin. It is best to discuss any future plans with everyone involved in the process prior to making projections to eliminate the guesswork, to satisfy the politicians, and to cover oneself.

The employment projections process may be very subjective and care should be taken when making changes to any projections. The only time these types of adjustments should be made is when there is obvious reasons to make changes. If these changes are made, they need to be documented very well because questions may be asked. It is best to document any changes in projections on a traffic analysis zone basis so the data is readily available. These changes can be documented on a traffic analysis zone map as well as in text form. After making any changes on a zone by zone basis the total projected employment should always remain constant.

Special Generators

Projections for special generators may need to be made if a major employment center is planned for the future. The projection should be made by the same method as discussed in the *Socio-economic Data* section. Also, if there are special generators in the current network, they should also be used in the future network, if appropriate. If growth is anticipated in the current major employer, then this growth should be forecasted in the future model.

External Trips

"External trips are trips that have at least one end outside the study area defined by an encircling cordon line" (Barton-Aschman Associates, p. 77). The external trips are based on ground counts or average daily traffic at the cordon line. The ground counts can be found from the local planning department, city or county traffic engineering departments, or the state department of transportation. External stations are located where major roadways intersect or cross the cordon line. At these stations, trips enter and exit the network. If both trip ends of the trip are outside the cordon line, then the trip is considered to be an external to external or through trip. If one trip end of the trip is inside the cordon line, then the trip is considered to be an internal to external trip or an external to internal trip. See Figure 8 which shows how to determine if the trip is external to external or external to internal.

Determining the proportion of trips that are external to external or external to internal can be a difficult process due to the fact that external origin and destination information is generally not readily available. There are several methods that can be used depending on the amount of time

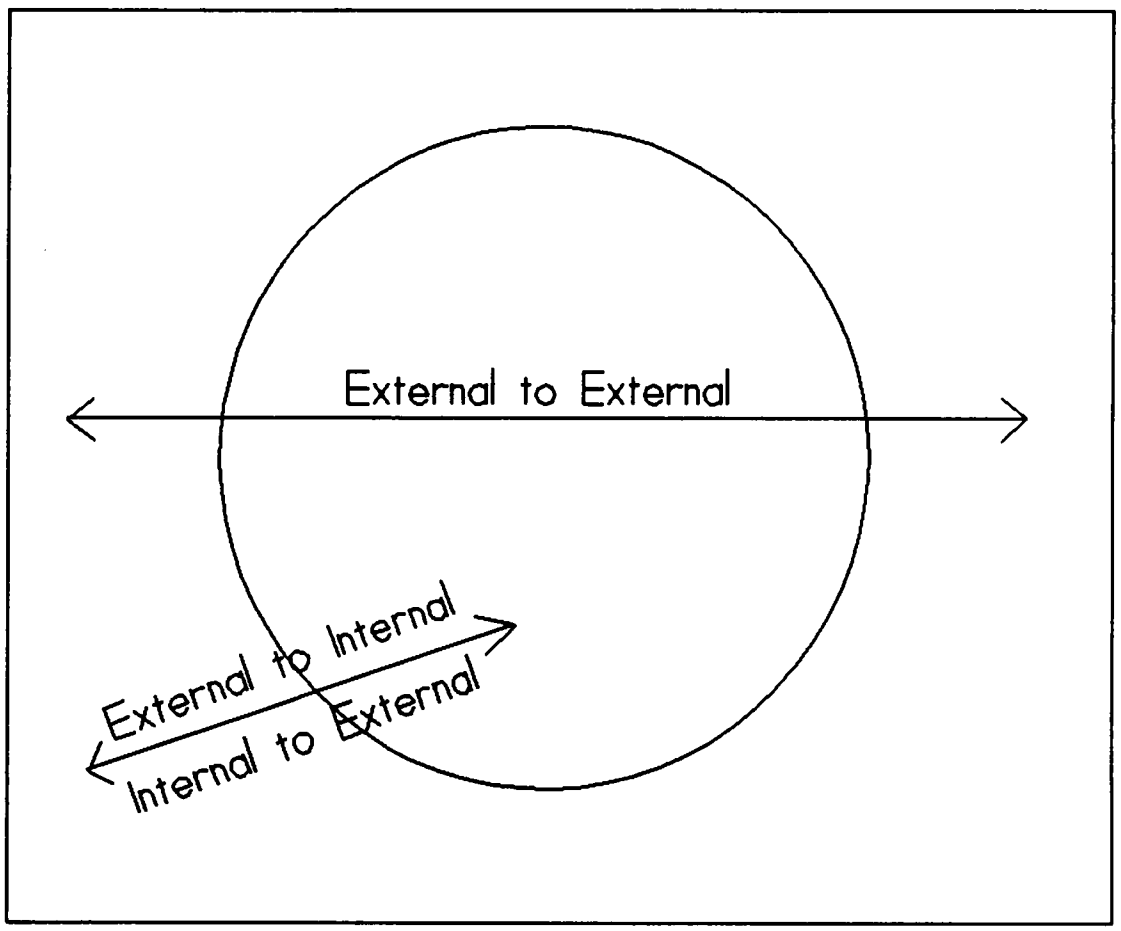


Figure 8 - External Trip Type (External to External or External to Internal)

and resources that are available. Methods of collecting this data and problems associated with the collection procedures are the following:

> Historically, the most popular method for collecting external travel data is to conduct a roadside intercept survey at the regional cordon. Very few roadside surveys have been conducted in recent years, primarily because of the concern that stopping vehicles on the highway would be perceived as an unacceptable intrusion on the motorist. Poorly conducted roadside surveys have resulted in unnecessary delays and extended queues of vehicles. Alternative, nonintrusive survey methods have been used to collect external survey data. These include:

1. The recording of license plate numbers (either through the use of videotape, direct reading of the plates into a tape recorder, or direct entry into a notebook computer by a survey recorder) and matching plate numbers at the cordon to obtain through trip tables; or

2. The recording of license plate numbers (using one of the above methods), matching the number with Department of Motor Vehicle registration, and mailing out a survey form to the registered owner of the vehicle.

> The first method only provides data on through travel and does not allow for the estimation of observed external to internal or internal to external travel. The second method, although providing data on all external travel, has the disadvantage of a definite time lag between the time the trip is actually made and the time the survey form is received by the driver. Even the direct entry of the plate number into a computer and overnight matching of numbers to registrant, it is at least three days (and more likely four to five) before the registrant receives the survey forms. The registrant may not recall exactly where the trips was made, or in some cases was not the driver of the vehicle. For these reasons, the roadside intercept is still the most cost-effective method for obtaining external travel data (Barton-Aschman Associates, pp. 77-79).

External to External Trips

External trips are trips that pass through a network without stopping. An example would be a trip on an Interstate highway where there are no stops or are only minor stops to refuel or dine. "Although the through trips are a minor portion of total vehicle trips in a region, the external to external volumes have a significant impact on facilities crossing

the cordon line and passing entirely through the study area" (Barton-Aschman Associates, p. 89). In areas where there is a lack of origin-destination data, external to external trips can be determined from locations at the cordon lines that have traffic counts. NCHRP Report 187 recommends that total through trips at external stations be based on a percentage of ground counts by area population. NCHRP Report 365 lists six cities and the percentages of trips that are through trips. The report also shows an equation that was used for a study in Asheville, North Carolina. See Table 2 for the recommendations of the NCHRP Report 187 and Table 3 for the percentages listed in the NCHRP Report 365.

The case study for Asheville, North Carolina uses an equation that calculates the proportion of through trips at an external station by using the functional classification of the roadway, the average daily traffic at the external station, the percentage of trucks excluding vans and pickups at the external station, the percentage of vans and pickups at the external station and the population inside the cordon line. This equation to estimate the number of through trips at an external station is:

Yi = 76.76 + 11.22*I + 25.74*PA - 42.18*MA + 0.00012*ADTi + 0.59*PTKSi - 0.48*PPSi - 0.000417*POP, where:

Yi = Percentage of ADT at external station I, that are through trips

I = Interstate (if the roadway is an interstate, then I = 1 and PA and MA = 0)

Table 2 - Recommendations for Through Trips in the NCHRP Report 187

Urban Area Population	% of All External Trips that are External to External
50,000 - 100,000	21
100,000 - 250,000	15
250,000 - 750,000	10
750,000 - 2,000,000	4

Table 3 - Through Trips as a Percent of External Trips from the NCHRP Report 365

Place	1990 Population	External to Internal Internal to External	External to External (Through)
Chicago	6,070,000	95%	5%
Twin Cities	2,464,000	93	7
San Diego	2,498,000	88	12
Phoenix	2,122,000	86	14
Reno	255,000	87	13
Wausau	37,000	80	20

PA = Principal Arterial (if the roadway is a principal arterial, then PA = 1 and I and MA = 0)

MA = Minor Arterial (if the roadway is an minor arterial, then MA = 1 and I and PA = 0)

ADTi =Average daily traffic at external station I

PTKSi=Percentage of trucks excluding vans and pickups at external station I

PPSi =Percentage of vans and pickups at external station I

POP = Population inside the cordon area (Barton-Aschman Associates, pp. 81-82).

As can be seen with the many variables, caution should be taken if using this equation as it is based on traffic patterns in Asheville, North Carolina. Also, the use of this equation could be very labor intensive because it requires vehicle classification counts taken at each of the external stations.

The following example shows how Table 2 from the NCHRP 187 Report is used to estimate external to external trips:

Example:

The 1996 population is estimated to be 110,000 therefore, the through trips should be 15% of the total average daily traffic at the external station. Table 4 shows the average daily traffic at the external station and the number of trips that are estimated to be through trips.

Table 4 - External to External Trips for Example Problem

External Station	Average Daily Traffic	Estimated Through Trips*
91	8,800	1,148
92	8,100	1,057
93	22,400	2,922
94	49,500	6,456
95	5,900	770
96	3,000	391
97	5,800	757
98	5,500	717
99	600	78

* ADT = External Trips* [1+proportion of through trips] (Comsis Corporation, p. 18)
External Trips = ADT/[1 + 0.15]
External Trips = ADT/1.15
External to External Trips = External Trips * 0.15

After the number of through trips at each external station is estimated, these must be distributed to the other external stations. The NCHRP Report 365 demonstrates the usage of the trip distribution equations from the Asheville, North Carolina example. There are three equations based on the functional classification of the origin external station. These equations are the following:

Interstate: $Yij = -2.70 + 0.21*PTTDESj + 67.86*RTECONij$

Principal Arterial:

$$Yij = -7.40 + 0.55*PTTDESj + 24.68*RTECONij + 45.62*(ADTj/\Sigma ADT)$$

Minor Arterial:

$$Yij = -0.63 + 86.68*(ADTj/\Sigma ADT) + 30.04*RTECONij, \text{ where}$$

Yij = Percentage distribution of through-trip ends from origin station I to destination station j

ADTj = Average daily traffic at the destination station j

ΣADT = Total average daily traffic of all external stations

RTECONij = Route continuity between station I and j: 1 = Yes, 0 = No

PTTDESj = Percentage through-trip ends at destination station j

An example in the NCHRP Report 365 demonstrates how to use the equations presented in an example of five external stations. The next seven tables and the following text show the Asheville, North Carolina method of determining external to external trips. The

steps include determining the number of through trips at each station, distribution of the trips from the origin station to the destination station, and balancing the trips.

In this example, stations 101 and 103 are two points on a continuous route, and stations 102 and 104 are two points on another continuous route. Table 5 shows the data for this example.

The estimated proportion of through trips for each station are computed using the equation:

$$Yi = 76.76 + 11.22*I + 25.74*PA - 42.18*MA + 0.00012*ADTi + 0.59*PTKSi - 0.48*PPSi - 0.000417*POP$$

For example, the percent through trips for station 101 would be:

$$Yi = 76.76 + 11.22*0 + 25.74*1 - 42.18*0 + 0.00012*15{,}000 + 0.59*5 - 0.48*10 - 0.000417*50{,}000$$

$$Yi = 30$$

The resulting through trips are presented in Table 6. The trips have been rounded to the nearest 100 trips.

Table 5 - Example Data for Through Trip Estimation (Barton-Aschman Associates, p.84)

Station	Functional Classification	Average Daily Traffic	Percent Trucks	Percent Vans and Pickups
101	Principal Arterial	15,000	5	10
102	Interstate	25,000	10	10
103	Principal Arterial	10,000	7	10
104	Interstate	20,000	10	10
105	Minor Arterial	5,000	3	10
Total		75,000		

Table 6 - Through Trips

Station	Average Daily Traffic	Percent Through	Through Trips	External to Internal Trips
101	15,000	30	4,500	10,500
102	25,000	71	17,800	7,200
103	10,000	31	3,100	6,900
104	20,000	71	14,100	5,900
105	5,000	11	600	4,400
Total	75,000		40,100	34,900

The next step is to estimate the distribution of the through trips between the external station. The equations presented previously are used and the results are normalized in order for the sum of the distribution percentages to be equal to 100 percent. For example, the distribution of trips from station 101 to the other four stations is presented in Table 7.

The through trip distributions are computed for each of the four remaining external stations. Table 8 contains the normalized percentages of through trip distributions among the five station. The percentages sum to 100 percent down each column.

The percentages presented in Table 8 are applied to the through trips presented in Table 6 for each external station. Table 9 contains the initial through-trip table.

Note that the row totals of trips do not equal the desired number of trips for each external station and that the table is not symmetrical about the intrastation diagonal. For example, the trips form 101 to 102 equal 2,736 trips while the trips form 102 to 101 equal 790. Because the trips represent average daily trips, the table should be symmetrical. The trip table is averaged to produce a table symmetrical about the diagonal. This symmetrical trip table is presented in Table 10. At this step in the process, the row and column totals are equal; however, they are not equal to the desired number of through trips at each external station. This difference is presented in Table 11.

Table 7 - Distribution of Through Trips for External Station 101

Origin Station	Destination Station	Calculated Percent	Normalized Percent
	102	12	18
	103	40	58
101	104	12	17
	105	5	7
	Total	70	100

Table 8 - Through-Trips Distribution Percentages

	Origin Station				
Destination Station	**101**	**102**	**103**	**104**	**105**
101	-	15	59	16	31
102	18	-	17	67	21
103	57	13	-	13	27
104	17	67	17	-	21
105	7	4	7	4	-
	100	100	100	100	100

Table 9 - Initial Through Trip Table

	Origin Station					
Destination Station	**101**	**102**	**103**	**104**	**105**	**Total**
101	-	2,736	1,837	2,165	188	6,926
102	790	-	524	9,483	126	10,924
103	2,595	2,329	-	1,843	160	6,927
104	782	11,965	519	-	125	13,391
105	332	770	220	609	-	1,932
Total	4,500	17,800	3,100	14,100	600	40,100

Table 10 - Averaged Through-Trip Table

	Origin Station					
Destination Station	**101**	**102**	**103**	**104**	**105**	**Total**
101	-	1,763	2,216	1,474	260	5,713
102	1,763	-	1,426	10,724	448	14,362
103	2,216	1,426	-	1,181	190	5,013
104	1,474	10,724	1,181	-	367	13,746
105	260	448	190	367	-	1,266
Total	5,713	14,362	5,013	13,746	1,266	40,100

Table 11 - Difference Between Calculated and Desired External Station Through Trips

External Station	Calculated Trips	Desired Trips	Ratio Desired/Calculated
101	5,713	4,500	0.79
102	14,362	17,800	1.24
103	5,013	3,100	0.63
104	13,746	14,100	1.03
105	1,266	600	0.47
Total	40,100	40,100	

The most common procedure for adjusting a trip table to match desired row and column totals is the matrix balancing or FRATAR technique. The major use of the technique is to produce future-year trip tables that are growth factored. Table 12 contains the balanced or FRATAR adjusted external through-trip table.

The FRATAR distribution is a method of distributing trip ends based on the growth factor of the origin and destination and on the given trip interchanges (United States Department of Transportation).

> The growth factor method takes a known trip distribution data set, or trip table, and projects it to a future time period by applying adjustment factors. These factors affect the origins and destinations of the trips, and therefore change the distribution of travel. The growth factors are based on changes in land use and socio-economic characteristics of the study area zones (National Highway Institute, p. 6-5).

The growth factors can be based on historical growth in 24 hour traffic volumes at the external stations.

Another method of distribution of trips from the origin station to the destination station is to factor them by the proportion of average daily traffic at the destination station to the total average daily traffic of all external stations. See the following equation:

$Yij = ADTi * (ADTj/\Sigma ADT-ADTi)$, where:

Table 12 - Balanced Through-Trip Table

	Origin Station					
Destination Station	**101**	**102**	**103**	**104**	**105**	**Total**
101	-	2,781	794	662	83	4,500
102	2,781	-	1,684	12,952	383	17,800
103	794	1,684	-	397	45	3,100
104	662	12,952	397	-	89	14,100
105	83	383	45	89	-	600
Total	4,500	17,800	3,100	14,100	600	40,100

Yij = Percentage distribution of through-trip ends from origin station I to destination station j

ADTi = Average daily traffic at the origin station I

ADTj = Average daily traffic at the destination station j

ΣADT = Total average daily traffic of all external stations

See the following example of this type of distribution:

Given: 5 External stations

Station 301 - ADT = 1,200

Station 302 - ADT = 2,000

Station 303 - ADT = 800

Station 304 - ADT = 3,000

Station 305 - ADT = 1,500

Find the number of trips from station 301 to 303 and develop a trip table but do not average or balance the trip table.

Solution:

ΣADT = 1,200+2,000+800+3,000+1,500

= 8,500

ADTi = 1,200

ADTj = 800

Yij = ADTi * (ADTj/ΣADT-ADTi), where

= 1,200*[800/(8,500-1,200)

= 132 trips from station 301 to station 303

See Table 13 which shows distribution of through trips

After the trip table is developed, as in the example from Asheville, North Carolina, it would be averaged and balanced. Time must be taken to ensure that this distribution is logical and feasible or appropriate. That is, if there are two parallel roads that make up external stations and they both carry a high amount of traffic compared to the other external stations, then it would be expected that there would be a high amount of traffic exchanged between those two stations. See Figure 9 which shows an example of where this situation must be considered.

External to Internal Trips/Internal to External Trips

External to internal trips are those trips that enter the network from an external station and stay within the network. The external to internal trips and internal to external trips are considered to be the same within this text. These trips account for the remaining percentage of the average daily trips at the external station after taking into account the through trips (FHWA).

Table 13 - Trip Table for External to External Trip Distribution for Example

	Origin Station					
Destination Station	**301**	**302**	**303**	**304**	**305**	**Total**
301	-	369	125	655	257	1,406
302	329	-	208	1,091	429	2,056
303	132	246	-	436	171	985
304	493	923	312	-	643	2,371
305	247	462	156	818	-	1,682
Total	1,200	2,000	800	3,000	1,500	8,500

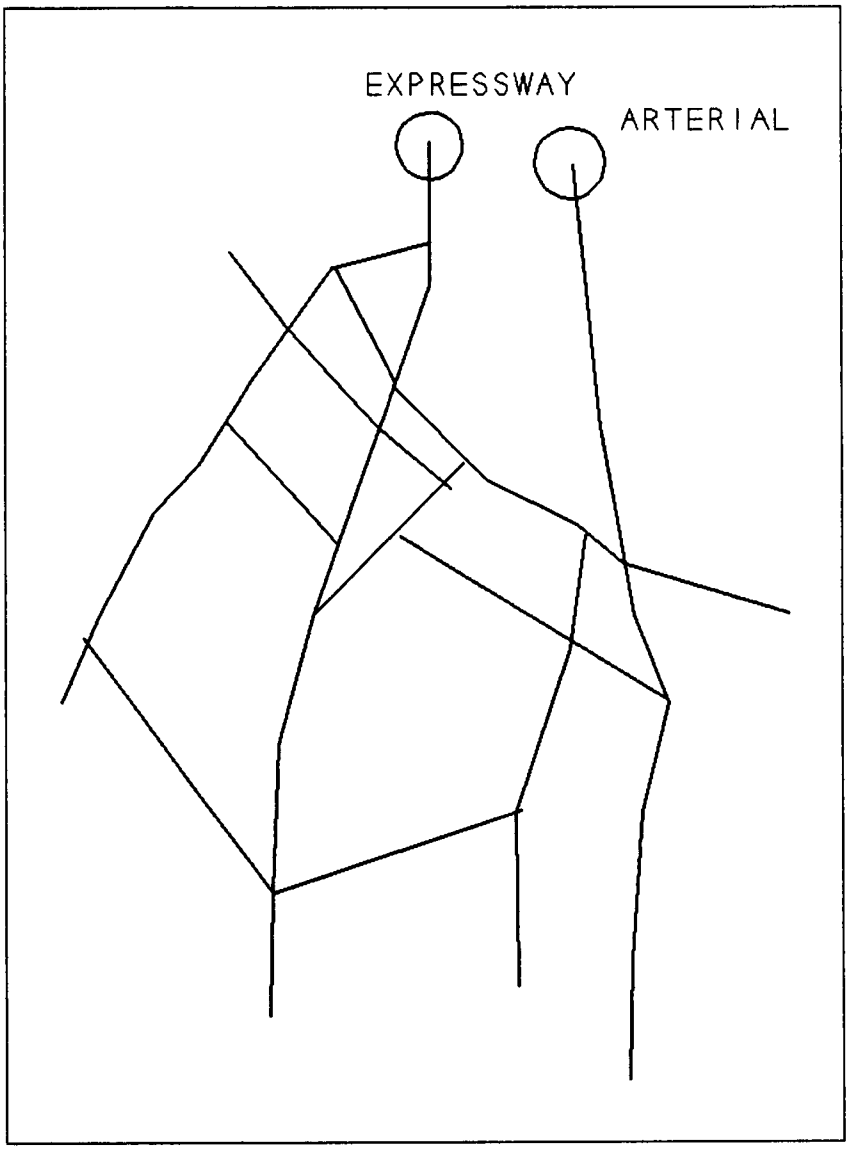


Figure 9 - Where Problems are Likely to Occur in the Distribution of External to External Trips

These trips need to be converted to productions and attractions by trip purpose. This can be accomplished by using origin and destination data for the study area, locally accepted equations or by other sources.

There are several steps to estimate the productions and attractions for external to internal trips at the external stations.

1. Summarize the through-trip matrix by direction and station and subtract these totals from the station counts. The remainders represent the overall control totals by station for external to internal trips. While the counts conducted at the external stations might show differences in the number of vehicles traveling into and out of the study area on a particular route, the directional differences are ignored. This assumption, that the total trips entering the study area equals the total trips leaving the study area on a typical day, simplifies the process used to estimate external to internal travel.

2. Separate the external trips by purpose and resident status. The resident totals by purpose become the attractions at each station. Nonresident totals by purpose become the productions at each station .

   While the external travel characteristics of cities and metropolitan areas can vary significantly, a few common variables exist. The size of a region, in area, and socio-economic characteristics, along with its proximity to other urbanized and suburban areas, are other factors that also affects the purpose and residency status of external to internal trips. The existence of a strong employment center within the study area will tend to pull more nonresidents into the region to seek employment. In areas where trip attractions such as employment and shopping are distributed more evenly between the areas inside and outside the cordon, the split between resident and nonresident trips at the cordon becomes relatively equal. Alternately, a region that is mostly suburban in nature may have a shortage of overall employment opportunities and a surplus of service and retail employment. In such a community, the flow of trips across the cordon could reflect a net export of work trips and a net import of other trips.

   Tables 14 and 15 show the split of internal to external trip totals by purpose and resident status for an area with a centralized activity center - San Juan, Puerto

Table 14 - External Trip Purpose/Residency Factors for Centralized Areas (San Juan, Puerto Rico 1990 External Cordon Survey)

Trip Purpose	Resident (Productions)	Non-Resident (Attractions)	Total
Home-Based Work	12%	34%	46%
Home-Based Other	9	23	32
Non-Home-Based	11	11	22
Total	32	68	100

Table 15 - External Trip Purpose/Residency Factors for Evenly Distributed Areas (San Diego Region)

Trip Purpose	Resident (Productions)	Non-Resident (Attractions)	Total
Home-Based Work	15%	10%	25%
Home-Based Other	27	23	50
Non-Home-Based	8	17	25
Total	50	50	100

Rico - and an area with a more even distribution of activities on either side of the cordon - San Diego, California (Barton-Aschman Associates, pp. 89-90).

The following example demonstrates the use of these tables:

Example:

Given: An urbanized area that has hospitals, industrial parks, an airport and shopping centers. The population is 300,000 and the ADT at external station 503 is 25,000. Find the productions and attractions by trip purpose at this external station.

Solution:

Because the data given is limited, the current NCHRP Report 187 will be used to determine the total number of external to internal trips. For areas of 250,000 to 750,000 population, 10% of all external trips are external to external.

ADT Count = External Trips * (1+proportion of through trips)

= External Trips * (1+0.10)

External Trips = ADT/(1+0.10)

= 25,000/1.1

= 22,727

Internal to External Trips = 22,727*0.90

= 20,455

Since the area has many jobs, Table 14 - External Trip Purpose/Residency Factors for Centralized Areas will be used. See Table 16 which shows the productions and attractions by trip purpose for the example.

It is best to do estimate productions and attractions with local data from origin and destination studies. However, if they are not available, these tables could be used with caution.

If there are no established strategies in the local area and/or the above mentioned methods or tables do not fit the local area, then a more simplified approach may be considered. It is to assume that the productions and attractions are equal (50/50), and that 33% of the trips are home- based work and 67% of the trips are home-based non-work (Horowitz, 1998).

These productions and attractions for the external to internal trips are vehicle trips. They need to be converted to person trips. The auto-occupancy rate of the area needs to be known. This data is available from the census. The auto-occupancy rate is the average number of people per automobile in an area. See the following example for converting vehicle trips to person trips.

Example:

Given: The trip table from the previous example

Table 16 - Vehicle Trip Productions and Attractions by Trip Purpose for External to Internal Trips Example

Trip Purpose	Productions Vehicle Trips	Attractions Vehicle Trips	Total
Home-Based Work	2,455 (12%)	6,955 (34%)	9,410 (46%)
Home-Based Other	1,841 (9%)	4,704 (23%)	6,545 (32%)
Non-Home-Based	2,250 (11%)	2,250 (11%)	4,500 (22%)
Total	6,546 (32%)	13,909 (68%)	20,455 (100%)

The average auto-occupancy rate for the area is 1.2 people per automobile

Create a person trip table for the external to internal productions and attractions

Solution:

Multiply each of the productions and attractions by trip purpose by 1.2. See Table 17 which show the number of person trips by trip purpose for the example.

External Trip Projections

Projections for external trips need to be made if future analyses of the highway system are going to be made. The traffic volume projections can be estimated by using the straight line extrapolation method. The only way to utilize the straight line method is to have traffic counts at every station for more than one year.

The steps in making projections by using the straight line method are as follows:

1. Retrieve all the historical average daily traffic count information that is available for each external station.
2. Perform a linear regression analysis to determine the slope and y-intercept by using a spread sheet, calculator, or by hand.
3. Determine the future years of analysis, if this has not already been done.
4. Estimate the future average daily traffic counts at each station by using the slope and y-intercept variables.

Table 17 - Person Trip Productions and Attractions by Trip Purpose for External to Internal Trip Example

Trip Purpose	Productions Person Trips	Attractions Person Trips	Total
Home-Based Work	2,946	8,346	11,292
Home-Based Other	2,209	5,645	7,854
Non-Home-Based	2,700	2,700	5,400
Total	7,855	16,691	24,546

See the following example for details on using these steps to estimate the future traffic at each external station:

Example:

Given: External station 110 has average daily traffic counts for the past 5 years, they are

Year - ADT

1993 - 2,489

1994 - 2,690

1995 - 3,023

1996 - 2,987

1997 - 3,148

Estimate the average daily traffic at this station for 2000, 2010, and 2020

Solution:

From regression analysis: Slope = 161.5

Intercept = -319,325

ADT(Year) = Slope * Year + Intercept

ADT(2000) = 161.5 * 2000 - 319,325

= 3,675

ADT(2000) = 161.5 * 2010 - 319,325

= 5,290

ADT(2000) = 161.5 * 2020 - 319,325

= 6,905

After all the average daily traffic is estimated for the future, all of the same calculations for external to external trips and external to internal trips can be made.

Check List

This manual is set up so that the user is able to collect data, forecast data, build a highway network and run the network. The *Reference Manual - Quick Response System II - Version 4* lists requirements and procedures in Chapter 4 for getting started building the network. The first thirteen steps include all data collection that is necessary for input into the software. The fourteenth step is the first step to building the network. These procedures are given as a check list to make sure that all of the data requirements are met. The instructions are as follows:

Requirements and Procedures

1. Determine the impact and study areas. The impact area should include all places where traffic will be significantly affected by the project. The study area normally encompasses the urbanized area.

2. Determine any sources of traffic from outside the urbanized area that may contribute to traffic volumes within the impact area. The locations of these sources will become external stations.

3. Draw a zone map. Zones should be small (just a few blocks) within the impact area, larger elsewhere. For site developments, a zone could be a single building or parking lot. The map should show external stations. When possible, zone boundaries should be consistent with the boundaries of census tracts or of any existing traffic analysis zones (TAZ's).

4. Assemble the necessary demographic data. For every zone you will need the number of occupied dwelling units, the number of retail employees, the number of non-retail employees and either the average household income or the average number of automobiles per household. These will be entered in the Centroid Attributes dialog box in GNE.

5. Measure the gross area of each zone. You will need this information for determining the intrazonal travel time (with the Intrazonal Time Worksheet in GNE, found from the Centroid Attributes dialog box).

6. Determine the number of person-trips that are entering or leaving the study area from each external station. If possible, do this separately for each trip purpose.

7. Draw the highway network for the impact area. Include all local streets that may carry traffic to and from the project, all freeways, arterials and collectors.

8. Draw the highway network for the rest of the study area. This portion of the network normally would include only freeways and arterials.

9. Identify all traffic-controlled intersections, all intersections with turn prohibitions, all intersections with significant U-turns, and all intersections that have unusually large delays. You will use Intersections with Delay nodes to designate these intersections.

10. Estimate the speeds on all streets that are represented in the network. Since it is normal practice not to penalize through movements at intersections, the speed estimates should account for usual delays at red lights and stop signs (if traffic control is not explicitly shown on the network).

11. Find a suitable location for each zonal centroid (typically near the center of urban development of a zone).

12. Estimate the amount of time that it takes to get from a typical location in a zone to the closest link in the highway network. Also, determine if there are any

destination charges (e.g., parking fees) in the zone. Destination charges should be evenly split between those trips that enter the zone and those trips that leave the zone. (The Travel Time Worksheet for centroid connectors may be used to combine time and cost.)

13. For each zone (or centroid) determine the points of access to the highway network.

14. Draw the network on GNE. Be sure to first load QRS40.DTA or QRS404.DTA. Maintain a careful scale. Designate all the entities, enter all the data, set the system attributes, and save the finished network (Horowitz, 1995, pp. 74-75).

After it is determined that the first thirteen steps are accomplished, fill in the checklist that is provided. The checklist that is given should be consulted prior to beginning work with the Quick Response System II software. This checklist includes a list of all of the data that will be required to build the network. See Figure 10 for the checklist. After the checklist is completed then it is time to start using the Quick Response System II software.

Calibration

After all error messages are eliminated and variables for the parameters are set in the QRS program, it is time to run the network. After running the network, it must be compared to actual data of the roadway. The item to check is traffic volumes on the roadways. That is, compare the link volumes to the actual ground counts. Calibration is

Item	Type of Media	Where Located	Source
Planning Area	Map		
Traffic Analysis Zones	Map		
Centroids	Map/Coordinates		
Centroid Connectors	Map/Coordinates		
Highway Network	Map/Coordinates		
Intersections	Map/Coordinates		
Traffic Signal Cycle Times	Map		
Socio-economic Data			
Dwelling Units	Spreadsheet		
Auto Ownership	Spreadsheet		
Income	Spreadsheet		
Retail Employment	Spreadsheet		
Non-retail Employment	Spreadsheet		
Special Generators	Map/Spreadsheet		
Socio-economic Data			
Dwelling Units	Spreadsheet		
Auto Ownership	Spreadsheet		
Income	Spreadsheet		
Retail Employment	Spreadsheet		
Non-retail Employment	Spreadsheet		
Special Generators	Map/Spreadsheet		
Traffic Counts (ADT)	Map/Spreadsheet		
External Trips			
External to External Trips Distribution	Spreadsheet		
External to Internal Trip Productions and Attractions by Trip Purpose	Spreadsheet		
External Trip Projections			
External to External Trips Distribution	Spreadsheet		
External to Internal Trip Productions and Attractions by Trip Purpose	Spreadsheet		

Figure 10 - Checklist

only done to the current roadway system. After the current system is calibrated then the network can be modified for future conditions. There are two ways to view the computed traffic volumes, by looking at the output network in GNE or by looking at output text files in a spreadsheet or word processor.

One of the ways to compare the calculated volumes with the actual volumes is to view the output data in GNE. To do this, go to GNE and open the OUTPUT.DTA file. Then open the links that have existing ground counts. Then open the attribute menu. Look at the VOLUME A TO B and VOLUME B TO A attributes or view these volumes by using the view labels menu.

The other way to view calculated volumes on a spreadsheet or word processor. Open the LINKVOLS.TXT file. The links are defined by nodes and link names. Find the links which have existing ground counts. After finding the needed volumes, compare them with the actual ground counts. If they are within a locally accepted range (i.e. 10%) then that link can be considered good enough. There are other ways to compare the volumes, they are to look at the volumes across cut lines or screen lines. See Figure 11 for an example that shows a screenline and cutline. For more information on screenlines and cutlines, see a document such as, *Calibration and Adjustment of System Planning Models* published by the United States Department of Transportation, Federal Highway Administration.

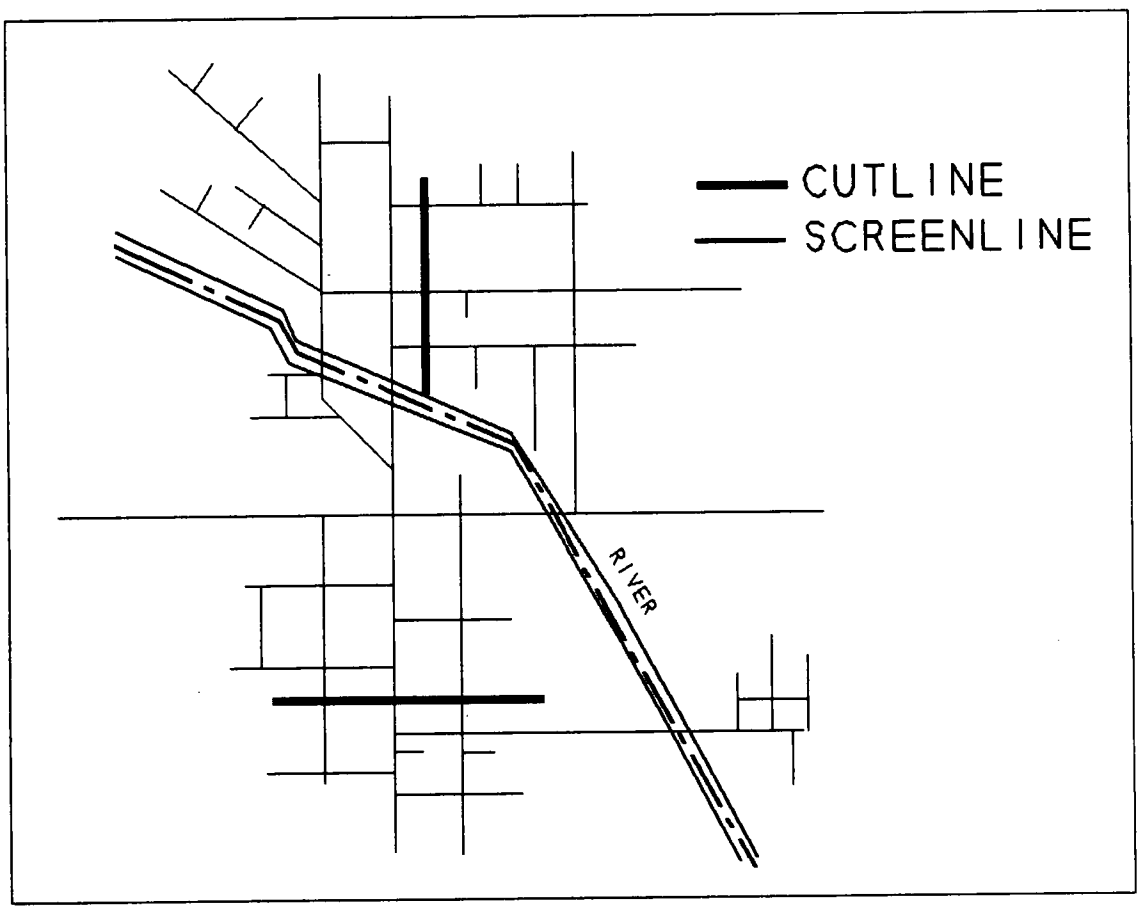


Figure 11 - Example of Screenline and Cutline

If the calculated traffic volumes are not within the specified percentage of the actual ground counts, then the network will need to be calibrated. There are many things that can be done to calibrate the network, such as making sure the network is coded correctly and accurately, having good data for trip generation, and have good distribution and assignment parameters. The *Calibration and Adjustment of System Planning Models* lists the following items to modify so that the traffic volumes can be raised or lowered:

1. Network Characteristics
    a. Centroid Connectors
    b. Roadway Speeds and Capacities
2. Trip Generation Rates
    a. Socio-economic Data
    b. Household Income
    c. Production and Attraction Rates
    d. Special Generators
    e. Trip Balancing Factors
3. Auto Occupancy
4. Trip Distribution
    a. Mean Trip Length
    b. Estimating Trip Length
    c. Employment Distribution
    d. Non-work Trip Purposes

5. Traffic Assignment

   a. All-or-Nothing

   b. Capacity Restraint

   c. Equilibrium (FHWA, p. 3)

It is best to save the "original" network and then save any modified networks as other names so that results can be compared. Whenever QRS is run, a new output file is created. It is advisable to save the output files as a name similar to the input file. Also, document all changes that are made so that it is easy to backtrack if necessary.

For more information concerning calibration, see the document *Calibration and Adjustment of System Planning Models* or any other reputable document.

Prior to calibrating a model, it has to be created and run. The next chapter will outline instructions for network building and analyzing.

Chapter 4 - The Quick Response System II Software

This chapter will outline the process of building and running a network. The Quick Response System II software is split into two separate programs, the General Network Editor (GNE) , and Quick Response System (QRS). The network is "built" in the GNE and is "run" in the QRS.

The first activity involves drawing the network using the GNE. After the network is drawn and all the attributes added, then it is time to run the network using QRS.

At this time make sure that the Quick Response System II software is loaded onto the computer. Both the GNE and QRS icons should be available from the desktop. It is assumed that the operator is familiar with using Windows 3.1™ or Windows95™ programs.

The General Network Editor

The instructions that are given are for drawing the network manually from a list of coordinates. It is also possible to draw the network using a digital file of coordinates for links and nodes. There are instructions in the user manual for setting up a network with digital files. The person(s) using the software should have the *Reference Manual - Quick Response System II* handy for more information on any of the steps if needed. The reference manual is set up in two sections, QRS and GNE.

1. Open the GNE program from the QRSII group.

2. Open the QRS40.DTA or QRS404.DTA from the File menu depending on which is needed. See Figure 12 which shows where the file is located. QRS40.DTA has schema that is appropriate to a network that has only three trip purposes (home-based work, home-based non-work, and non-home-based). QRS404.DTA has schema that is appropriate to a network that has 4 trip purposes (home-based work, home-based non-work, home-based ?, and non-home-based). A screen will pop up that asks if you want your file to be saved as the name of the file that you opened. Make sure your answer is no. Then save the file as a name that is appropriate for your network. Make sure to save the file often during the network building process.

3. Plot the nodes using the coordinates of the points (intersections, centroids, and etc.) that were established for centroids, centroid connectors, and highways. Nodes are all intersections of roadways, centroids, special generators and external stations. To do this, go to the Mode menu, click on the Node Actions, then Node Plot. See Figure 13 which shows the node plot menu.

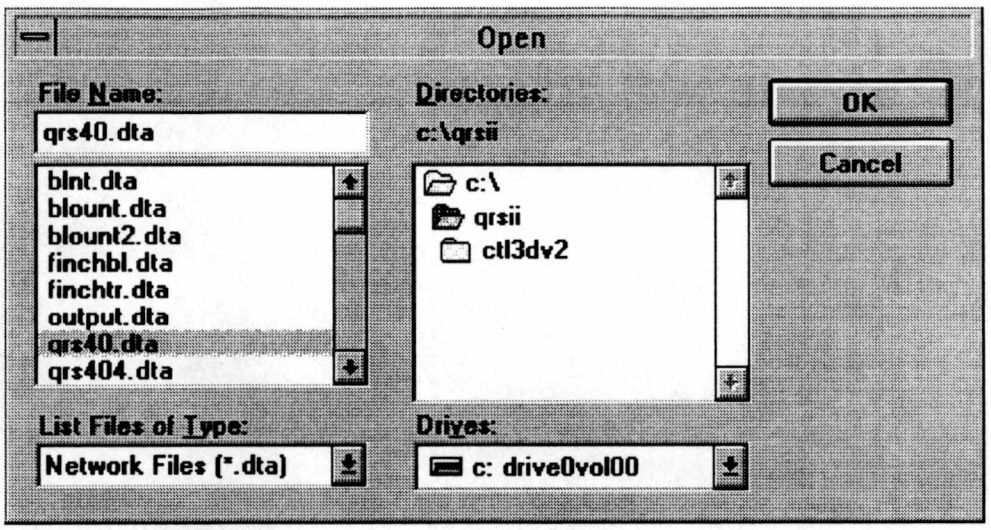


Figure 12 - QRS File Open Menu

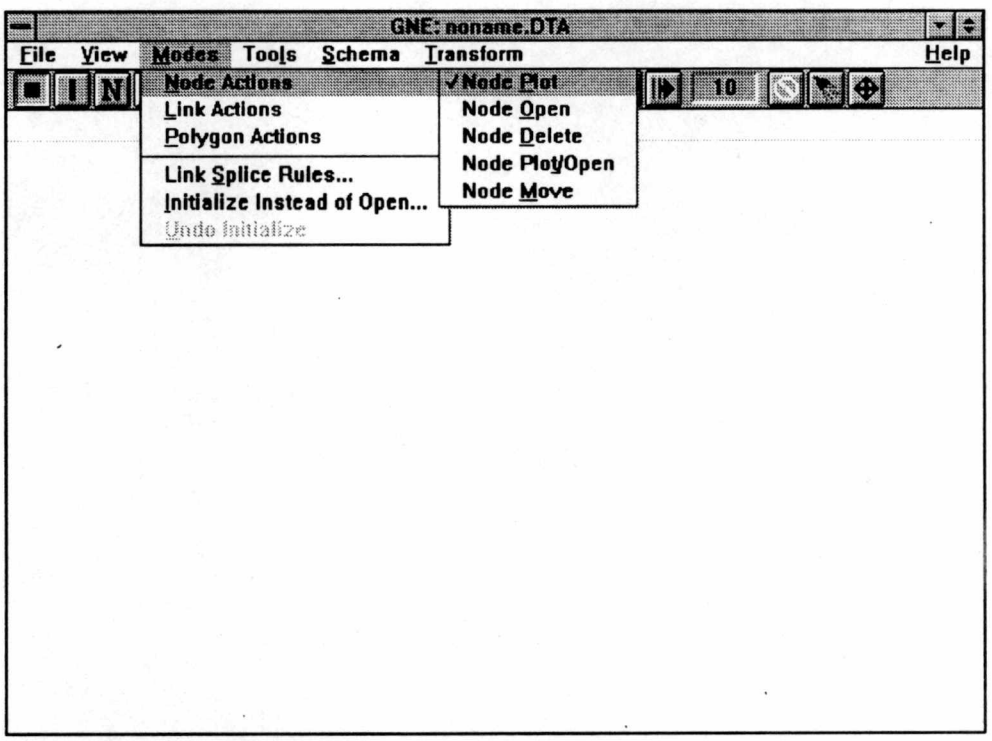


Figure 13 - Node Plot Mode

Move the mouse until the correct coordinate numbers are shown in the box in the top, middle of the screen. When the correct coordinate numbers are reached, push the right mouse button.

4. Name the nodes by clicking on the Mode menu, clicking on Node Actions, then Node Edit. Click on the node that will be named. This node name should be the same as the "number/label" that was established. See Figure 14 which shows how to get to the Node Open menu.

(NOTE: It may be more practical to plot 10 to 20 nodes as in Step 4 and then name the nodes as in Step 5. Then plot more nodes. If all nodes are plotted and then named, it could be difficult to try to name them. Also, if the plot appears to be "up side down", because a Cartesian coordinate system was used, then a change must be made in the Transform menu by clicking Scale, then clicking Y and changing the value from 1 to -1. This will turn the plot right-side-up. See Figure 15 which shows where to transform the X-axis.)

5. Plot the links for the highway network by going to the Mode menu, clicking on the Link Actions, then Link Plot. Links are the highways, centroid connectors, and pieces of string (see definitions listed in the next step). Connect the nodes to build the roads and centroid connectors. It would be helpful to be viewing

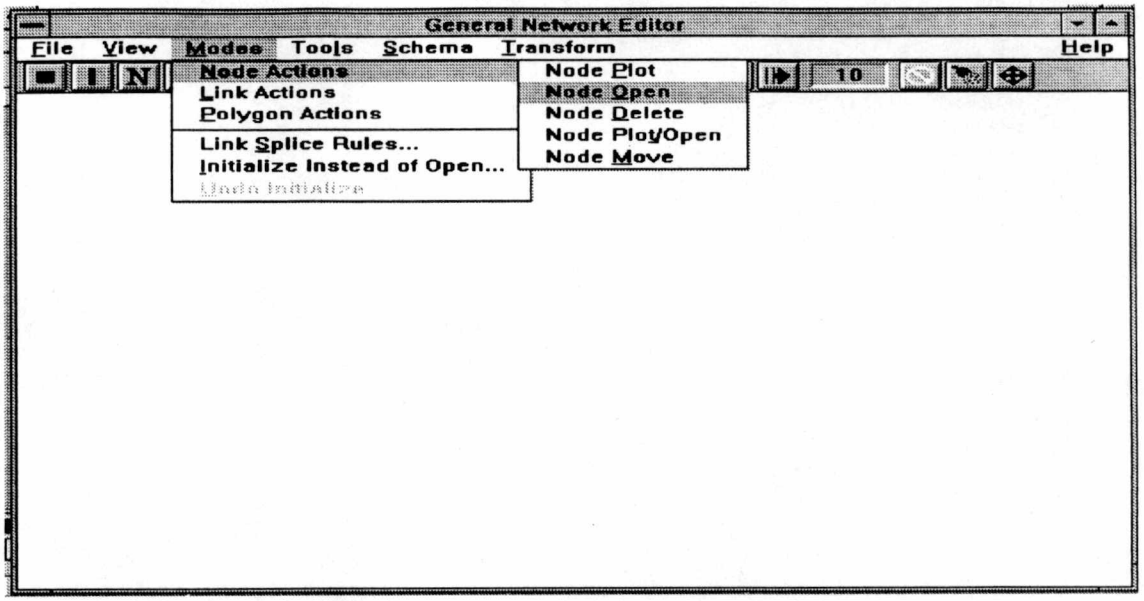


Figure 14 - Node Open Mode

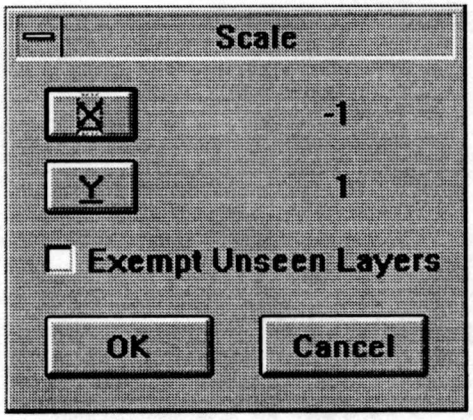


Figure 15 - Transform Scale Menu

a map that has all the nodes plotted on it. See Figure 16 which shows how to get to the Link Plot menu.

(NOTE: To make connecting the nodes with links easier, it would be helpful to view the node names/numbers. To do this, click on the View menu (see Figure 17 which shows the View Menu), then Labels. Then click on the Node Labels (see Figure 18 which shows the Node Labels menu). For each node type, click the First button and go to name (see Figure 19 which shows this menu). Then close this window. Go to Format and select the placement of the node name and the font (see Figure 20 which shows the Format menu). This viewing can be done for the links as well by following the same steps except click on Link Labels instead of Node Labels.)

6. Name the links and determine the link types by going to the Mode menu, clicking on Link Actions, then Link Open (see Figure 21 which shows the Link Open Menu). Then click on the two nodes that connect the link. The name of the link could be the road name or the node numbers that are connected. The link types and their definitions are the following:

    a. One-way street - a street that permits only one direction of travel

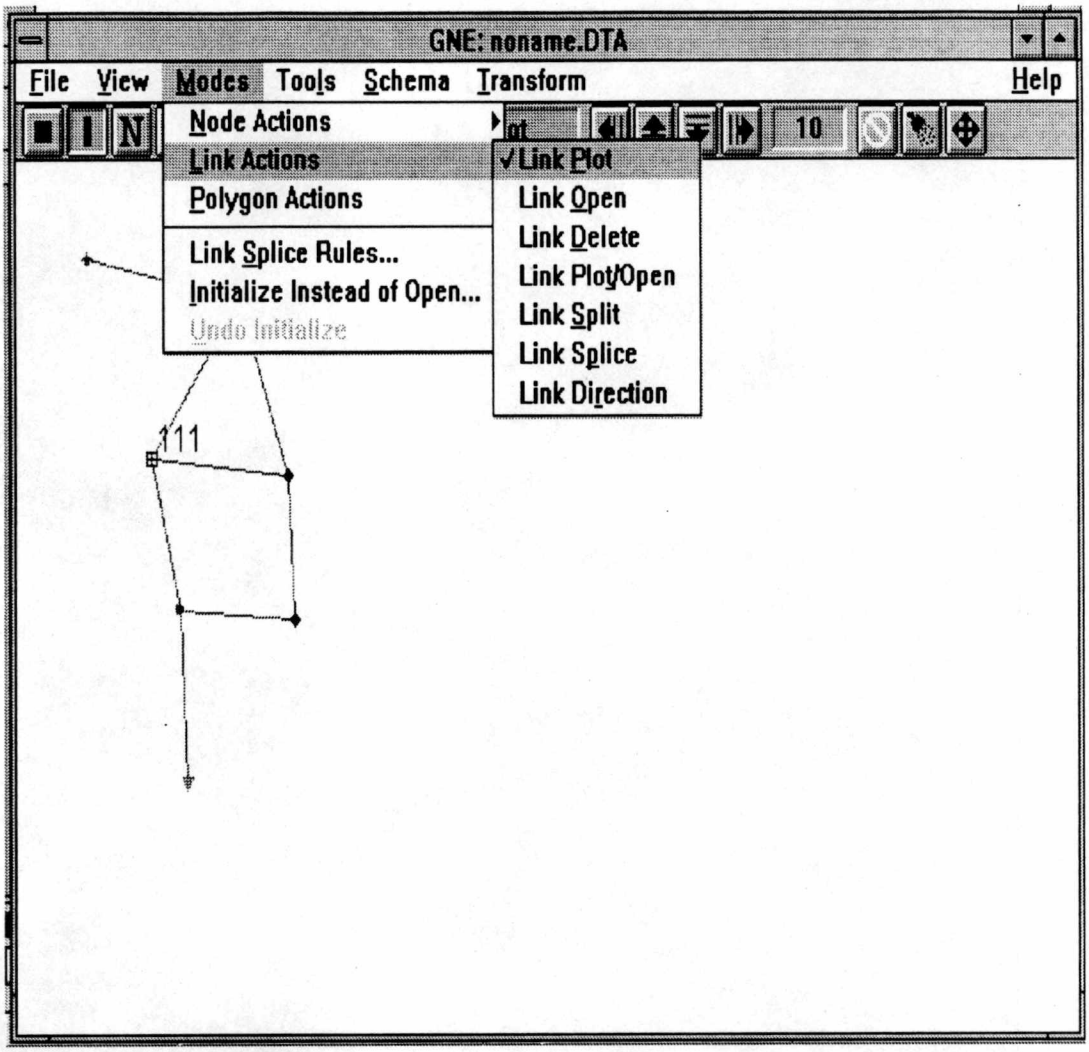


Figure 16 - Link Plot Mode

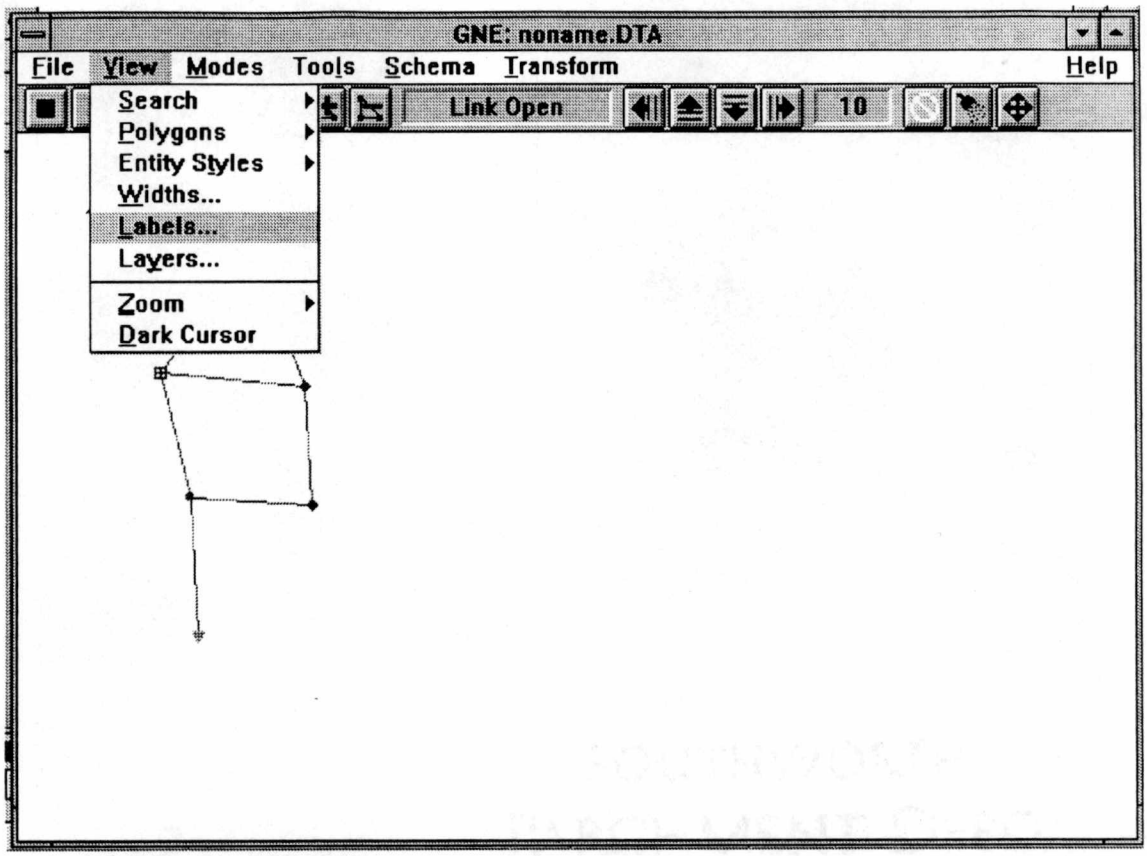


Figure 17 - View Labels Mode

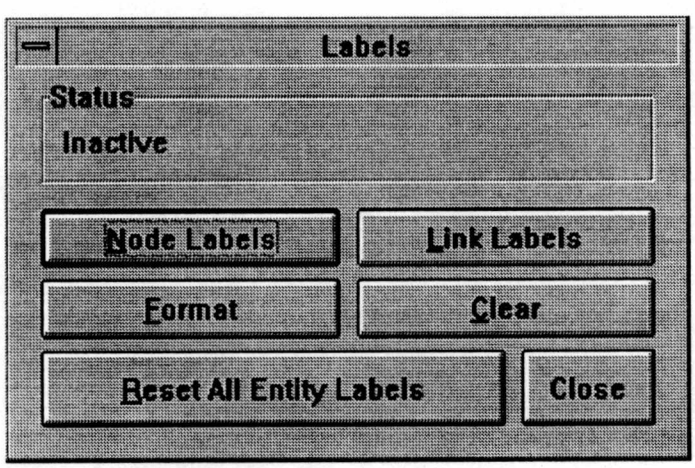


Figure 18 - Labels Menu

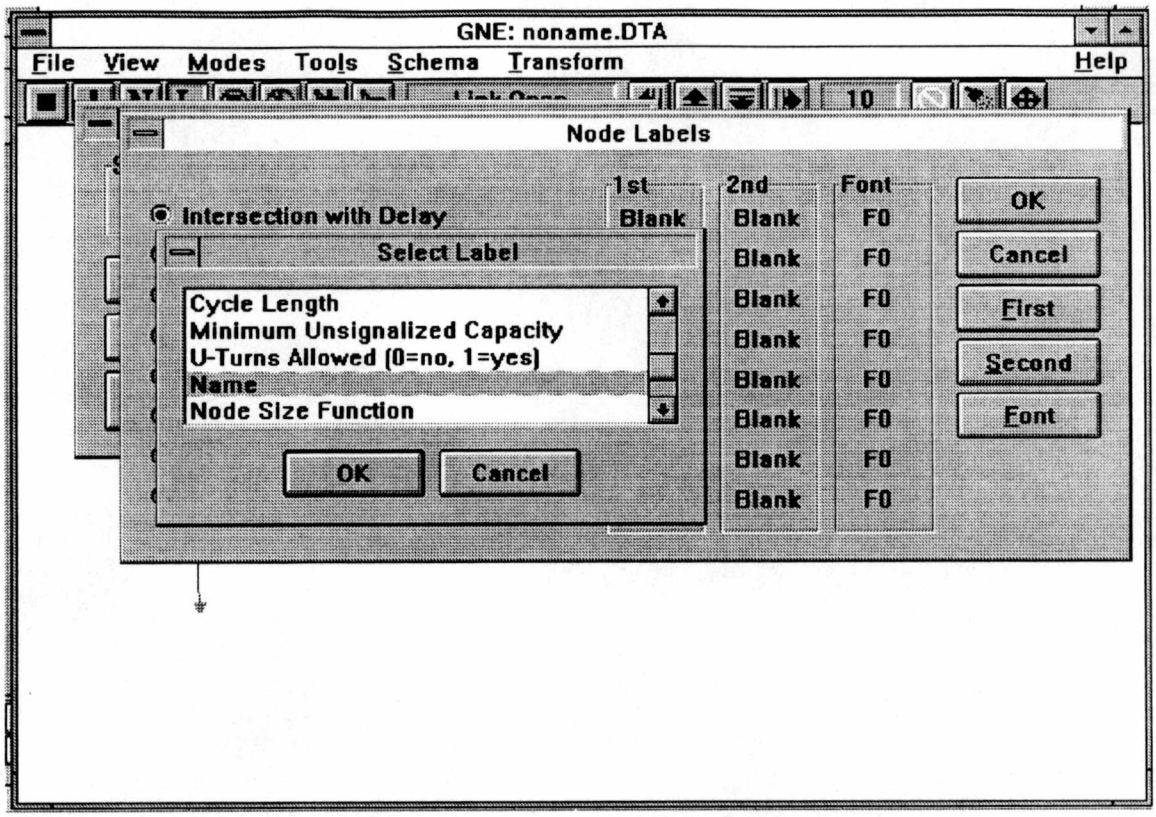


Figure 19 - Node Labels for Intersections with Delay

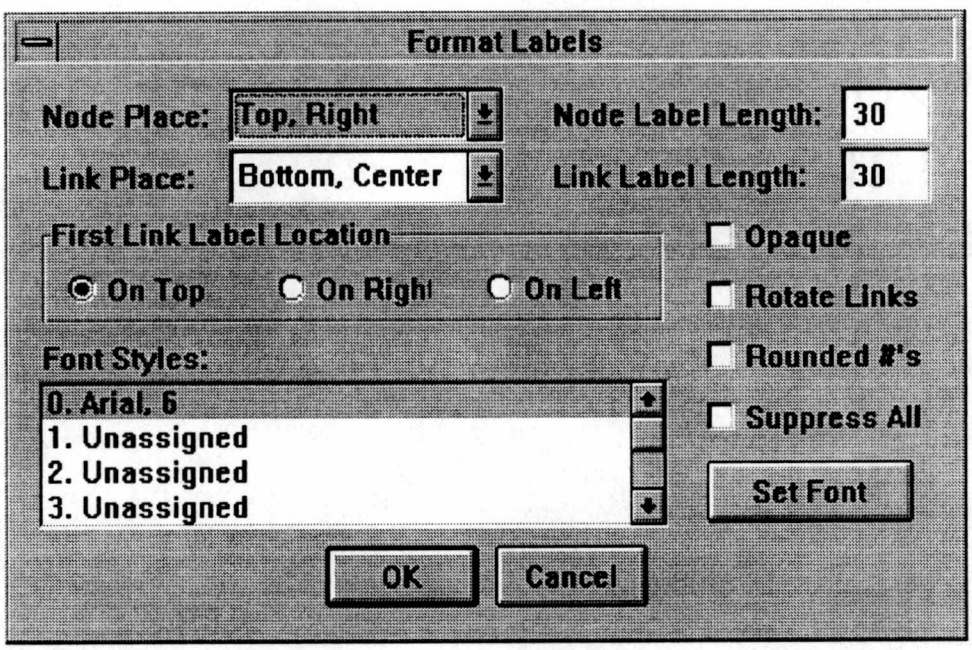


Figure 20 - Format Labels Menu

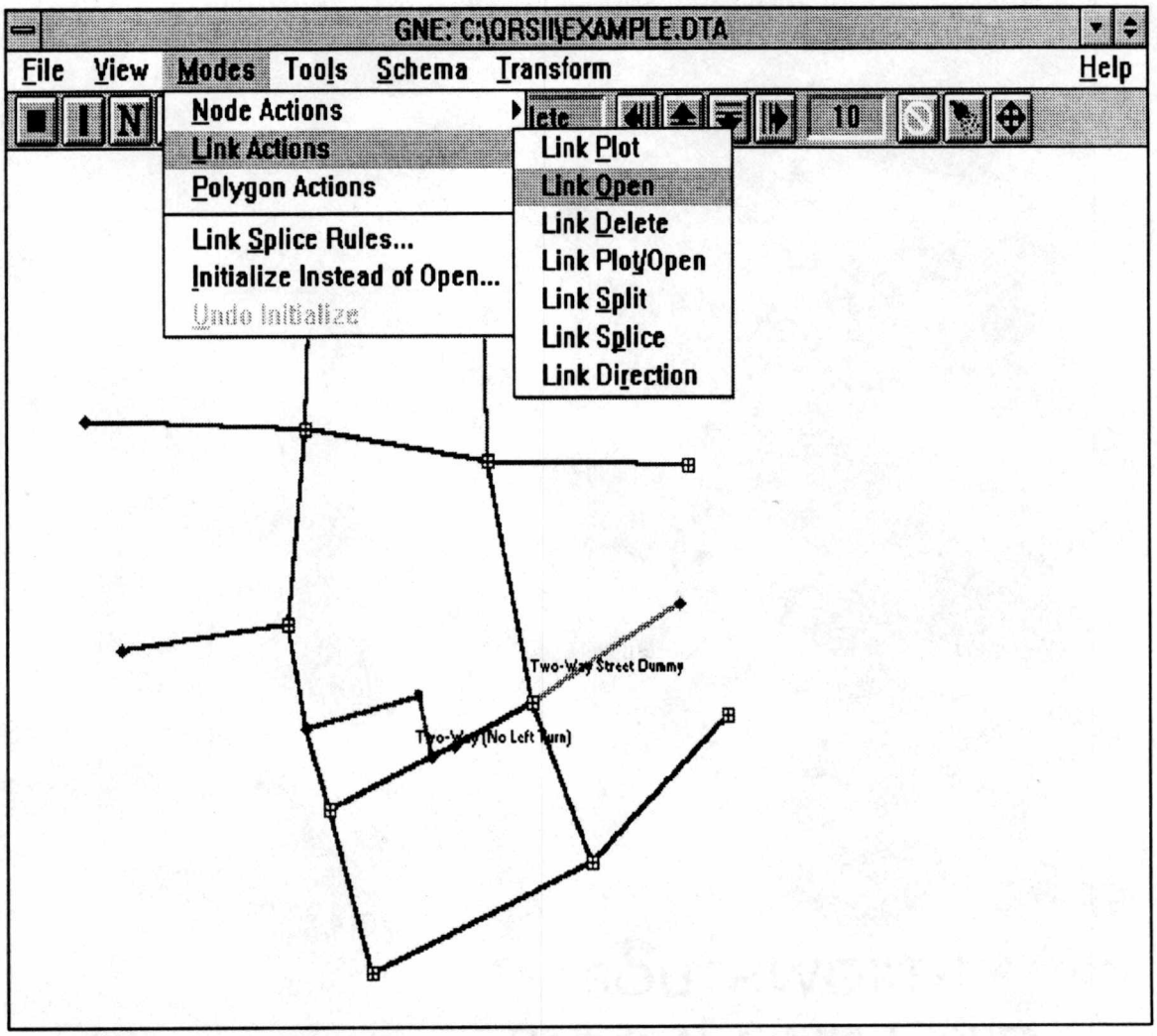


Figure 21 - Link Open Menu

b. Two-way street - a street that permits traffic in two directions

c. Centroid connector - a link that connects the centroid with a road

d. Two-way (no left turn) street - a street that permits traffic in two directions but does not allow any left turns at the intersection. A two-way street dummy link has to be used with this type of link when restricting left turns at a single, isolated intersection. See Figure 22 which shows how to restrict left turns at an intersection.

e. One-way street dummy - a "dummy street" that allows traffic to flow in one direction but the travel time is zero. These are useful for building complex interchanges and intersections and for building one-way (no left-turn links).

f. Two-way street dummy - a "dummy street" that allows traffic to flow in both directions of travel but the travel time is zero. These are useful for building complex interchanges and intersections and for canceling the effect of a two-way (no left turn) link.

g. Centroid connector dummy - may be used in place of centroid connectors when excess times are zero.

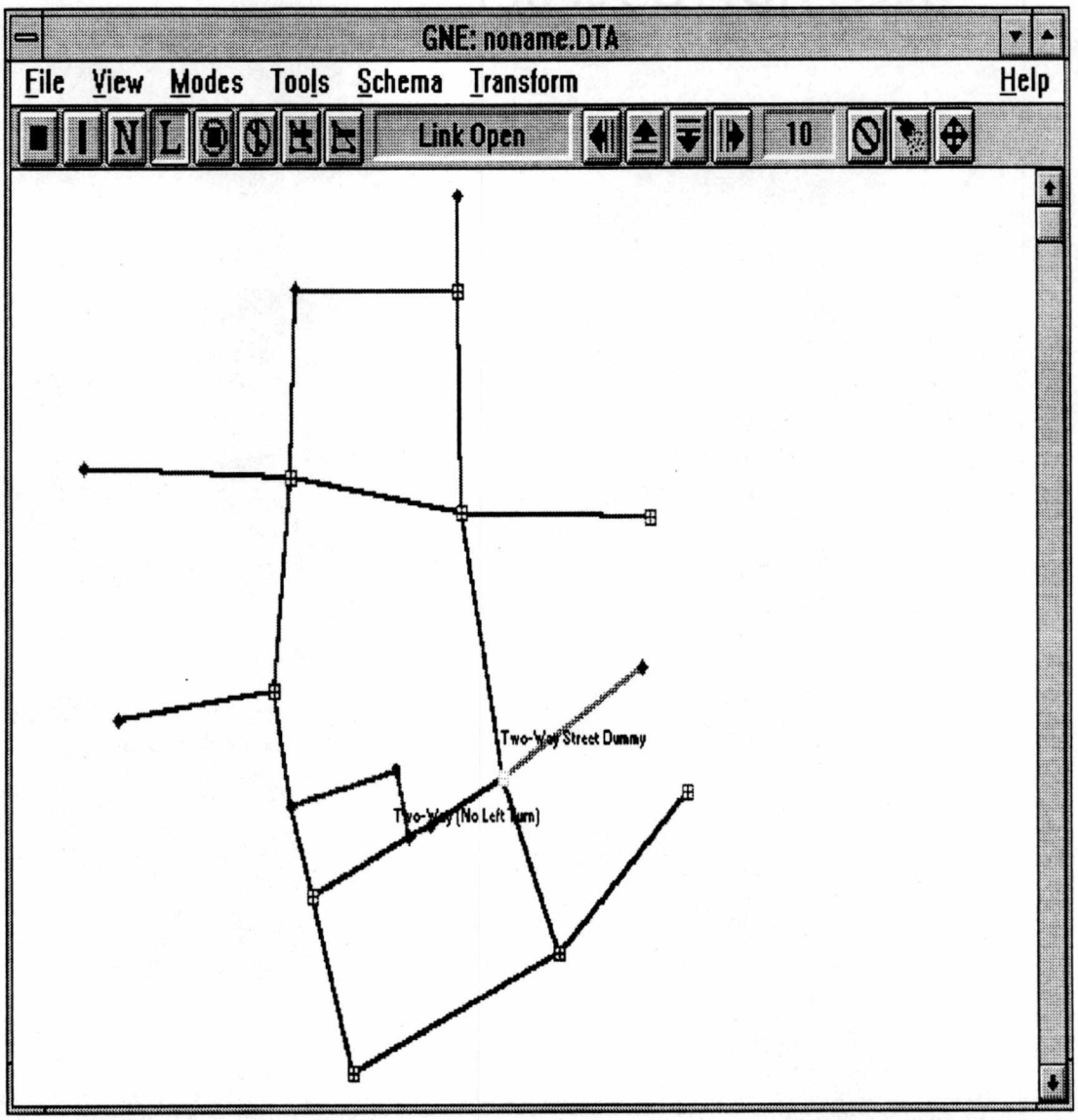


Figure 22 - How to Restrict Left Turns at an Intersection by Using Two-way No Left Turn Street and Two-way Street Dummy

h. Piece of string - used to connect productions and attraction tag or district tag to other nodes (traffic cannot flow across a piece of string).

7. Designate node types to each node by clicking on the Mode menu, clicking on Node Actions, then Node Open. Click onto each node and add the data. The types of nodes and their definitions are the following:

a. Intersection with delay - these include signalized and STOP controlled intersections. They permit flow in any direction but penalties may be added to any turns.

b. Centroid - represent traffic analysis zones.

c. Seed tag - typically not used in the network building process. Should be used to determine the shortest path from a centroid or special generator to other nodes. Only one of these can be used at a time per network. It should be connected to a centroid or special generator by a piece of string. Precise travel times between the tagged origin and all centroids and external stations are found on their respective attribute pages.

d. Intersection without delay - connects links where traffic flow is not impeded.

e. External station - represent external stations.

f. Special generator centroid - represents locations where a special generator exists. The input data is the same as for a centroid, however, during the trip distribution process, the productions and attractions are not balanced or modified.

g. Production/Attraction tag - modifies trip productions and attractions that are calculated for centroids or special generators. The productions and attractions on the tag are added to the productions and attractions that are calculated for the centroid or special generator (a negative number would subtract from the calculated productions and attractions).

h. District tag - used to aggregate zones into larger areas. To aggregate, attach centroids and special generators with pieces of string to a district tag. See Figure 23 which shows how to connect centroids to make a district tag.

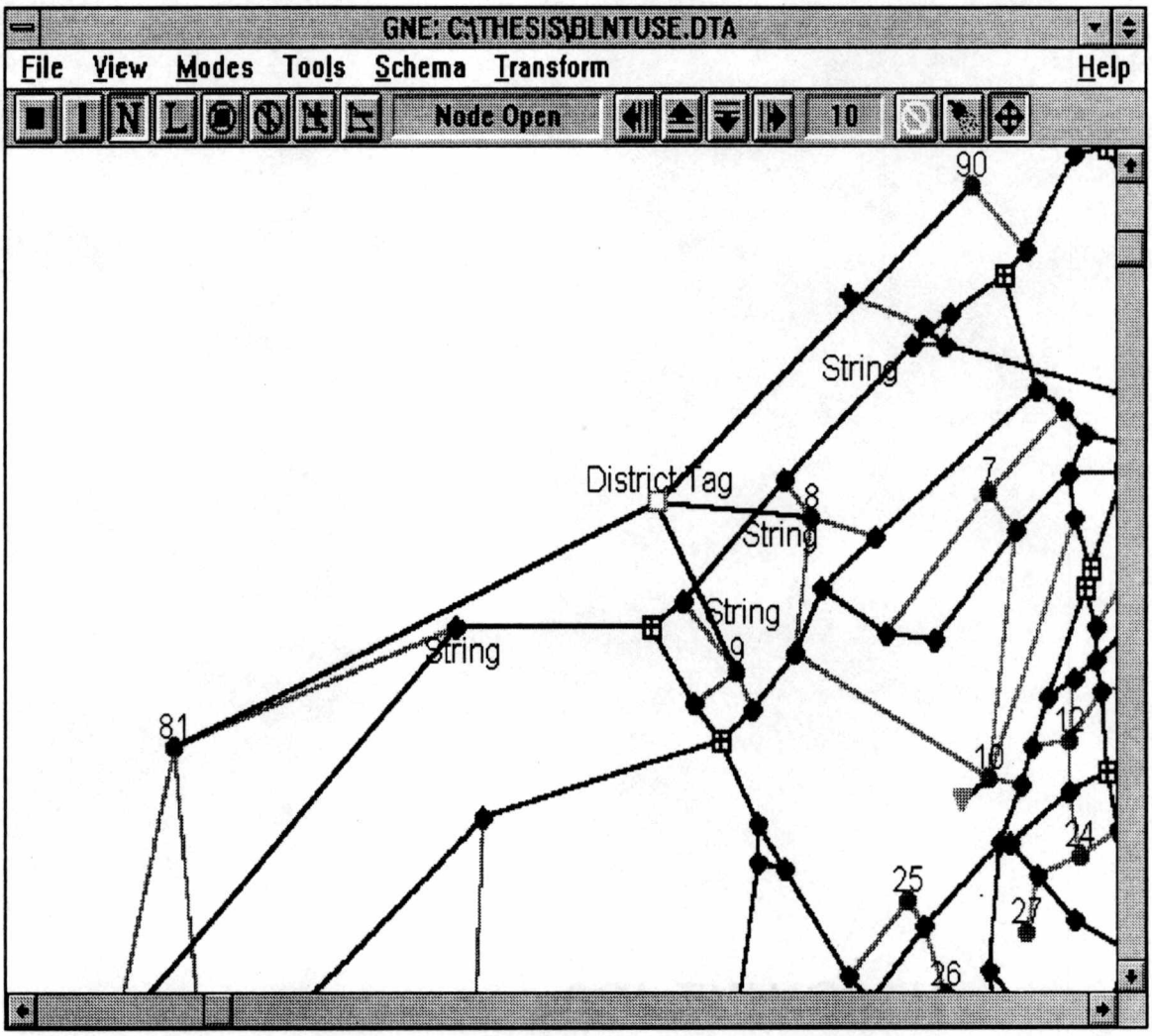


Figure 23 - Centroids Attached to District Tag

(NOTE: Steps 7 and 8 can be done interchangeably, if desired or appropriate)

8. Assign attributes to all the nodes by clicking on the Mode menu, clicking on Node Actions, then Node Open. Click onto each node and then open the attributes button (see Figure 24 which shows where to open the attribute menu). The attributes that are needed for each type of node and their definitions (if needed) are the following:

    a. Intersection with delay - see Figure 25- which shows the attributes for an intersection with delay.

        i. Through adjustment - This is the amount of time it takes vehicles to pass through an intersection with penalties (in minutes).

        ii. Left adjustment - This is the amount of time it takes vehicles to make a left turn at an intersection with penalties (in minutes).

        iii. Immediate right adjustment - This is the amount of time it takes vehicles to make a right turn at an intersection with penalties (in minutes).

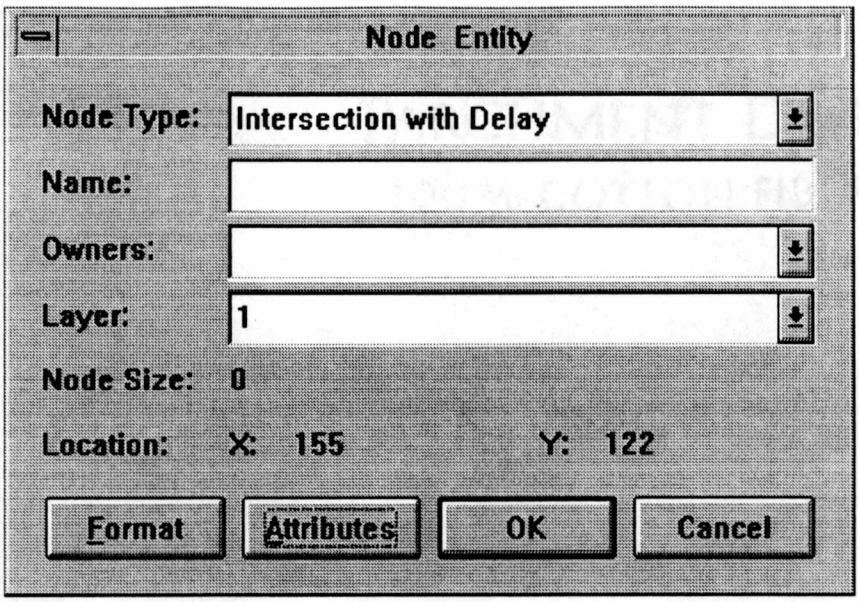


Figure 24 - Node Open Attributes Button

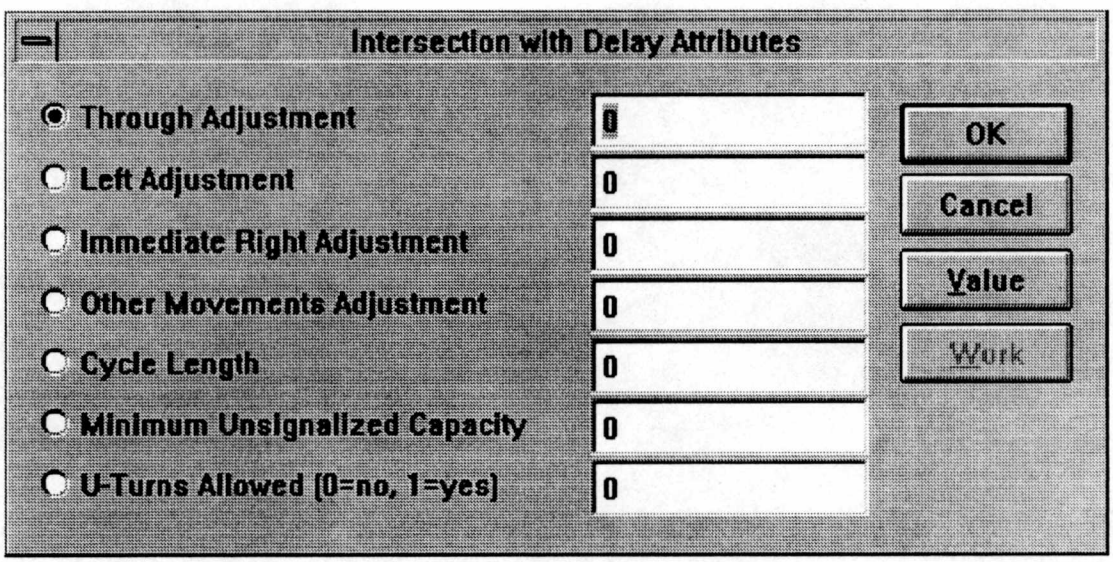


Figure 25 - Intersection with Delay Attributes

iv. Other movements adjustment - This is the amount of time it takes vehicles to make any other movement at an intersection with penalties (in minutes).

v. Cycle length - The total cycle time of the traffic signal in seconds.

vi. Minimum unsignalized capacity - This is important only to one-way and two-way STOP controlled intersections. This is the minimum hourly capacity of a signed approach, regardless of the amount of conflicting traffic. Enter a value only if you want to override the default value used by QRS which is 33 vehicles per hour. If the traffic in your area is aggressive, then a higher number may be more appropriate.

vii. U-turns allowed (0=no, 1=yes)

b. Centroid - See Figure 26 which shows the attributes for a Centroid

i. Income ($1,000's)

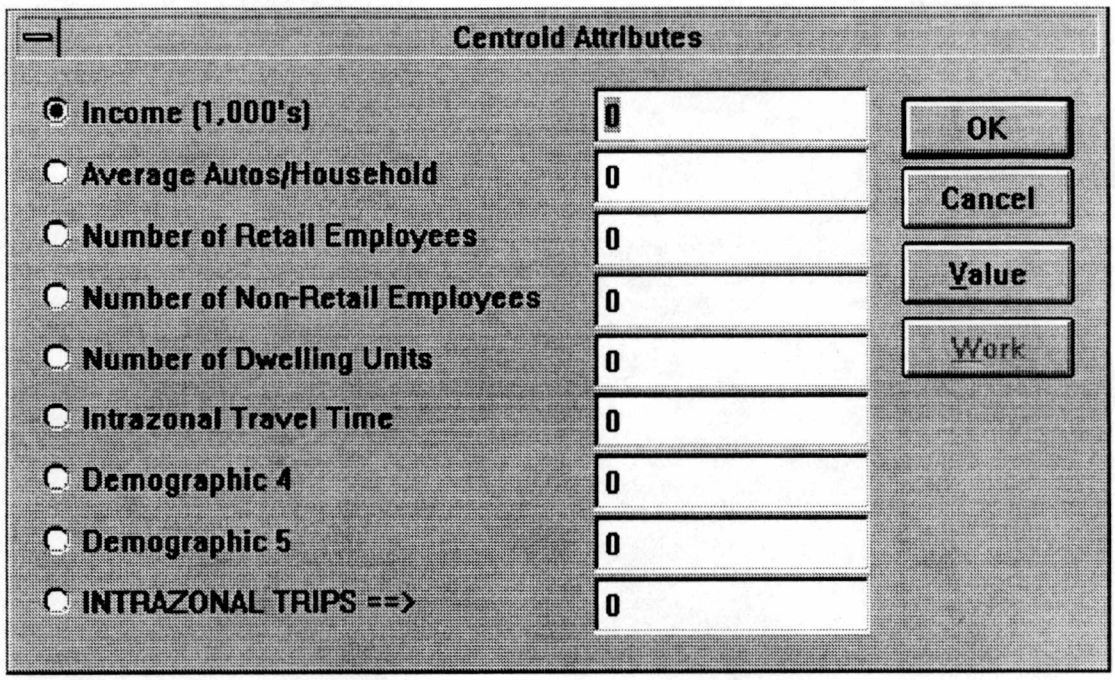


Figure 26 - Centroid Attributes

ii. Average autos/household

iii. Number of retail employees

iv. Number of non-retail employees

v. Number of dwelling units

vi. Intrazonal travel time - The average length of time it takes to get from the origin to the destination for the trips within a zone. To calculate the time, "mark" intrazonal time, then hit "work". Enter the intrazonal speed and the gross area of the traffic analysis zone. Another method is to directly enter the time which can be calculated by using the following equation:

Intrazonal Time = 0.5 * (Zonal Area) + Intrazonal Speed (area type), where:

Zonal Area = area of traffic analysis zone in square miles

Intrazonal Speed (area type) = intrazonal speed in miles per hour (varies by area type - for example use 15 mph for the

central business district and 30 mph for rural areas)

vii. Demographic 4 - A demographic that is user established and could be used to calculate productions or attractions.

viii. Demographic 5 - A demographic that is user established and could be used to calculate productions or attractions.

ix. INTRAZONAL TRIPS - This is the total calculated trips that stay within the zone (QRS calculates this item - do not enter anything).

c. Seed tag - See Figure 27 which shows the attributes for a seed tag.

i. Just do skim tree (1=yes) - If a skim tree is desired, enter 1 for this value. Only one of these seed tags can be used in the entire network at any given time. When QRS finds this tag, it produces a file called RESULT.DTA. The file consists of a network whose links are all on a shortest path between any node and the tagged origin.

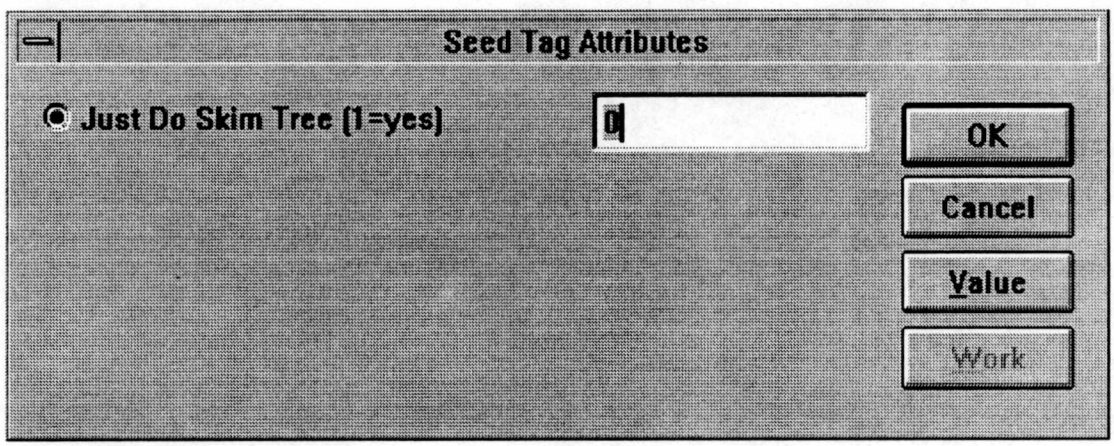


Figure 27 - Seed Tag Attributes

d. Intersection without delay

i. No attributes needed

e. External station - See Figure 28 which shows the attributes for an external station.

i. Home-based work (HBW) productions*

ii. Home-based nonwork (HBNW) productions*

iii. Non-home-based (NHB) productions*

iv. Home-based work (HBW) attractions*

v. Home-based nonwork (HBNW) attractions*

vi. Non-home-based (NHB) attractions*

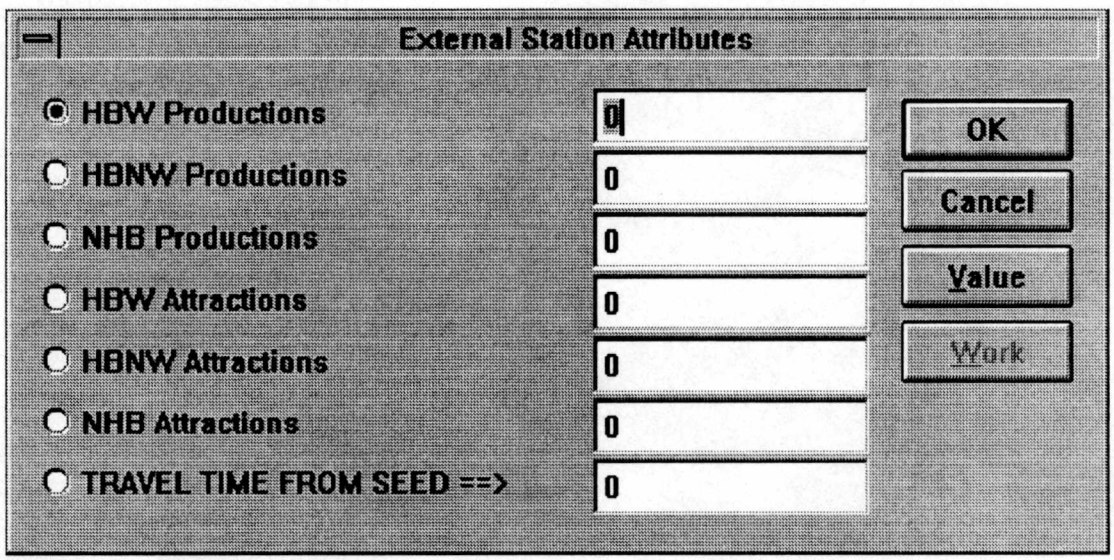


Figure 28 - External Station Attributes

vii. TRAVEL TIME FROM SEED - This is the travel time from the zone which was tagged with a seed tag (QRS calculates this item - do not enter anything).

(* - these should be person trips)

f. Special generator centroid - See Figure 29 which shows the attributes for a special generator centroid

i. Income ($1,000's)

ii. Average autos/household

iii. Number of retail employees

iv. Number of non-retail employees

v. Number of dwelling units

vi. Intrazonal travel time - See Centroid

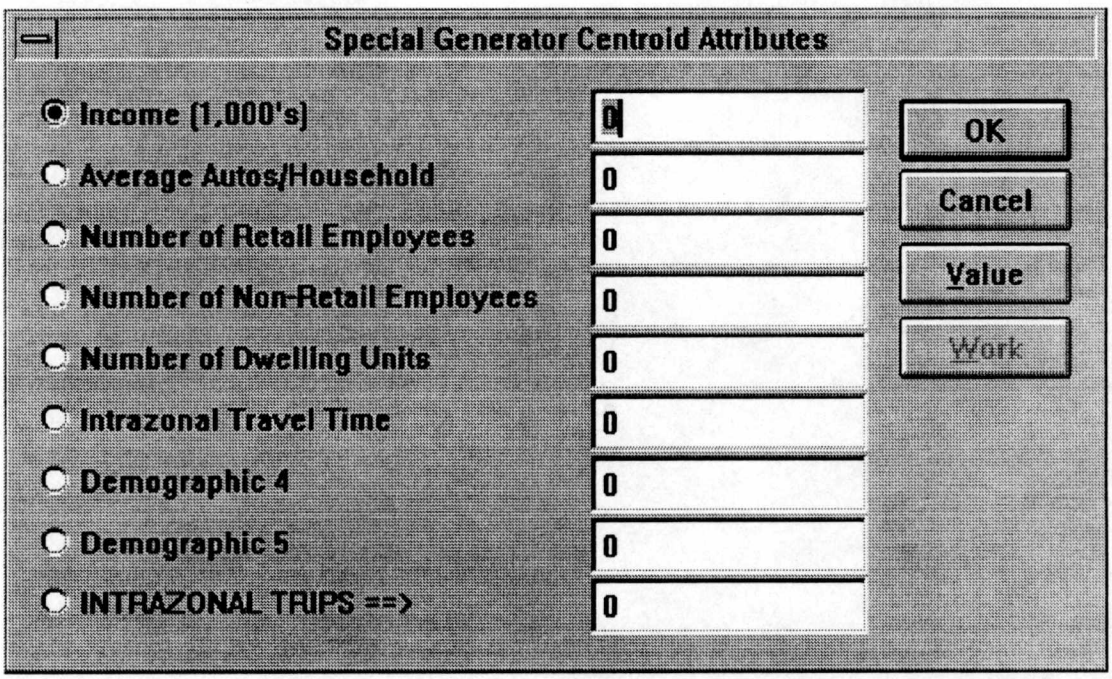


Figure 29 - Special Generator Centroid Attributes

vii. Demographic 4 - See Centroid

viii. Demographic 5 - See Centroid

ix. INTRAZONAL TRIPS - See Centroid

g. Production/Attraction tag - See Figure 30 which shows the attributes for a production/attraction tag.

i. Home-based work (HBW) productions

ii. Home-based nonwork (HBNW) productions

iii. Non-home-based (NHB) productions

iv. Home-based work (HBW) attractions

v. Home-based nonwork (HBNW) attractions

vi. Non-home-based (NHB) attractions

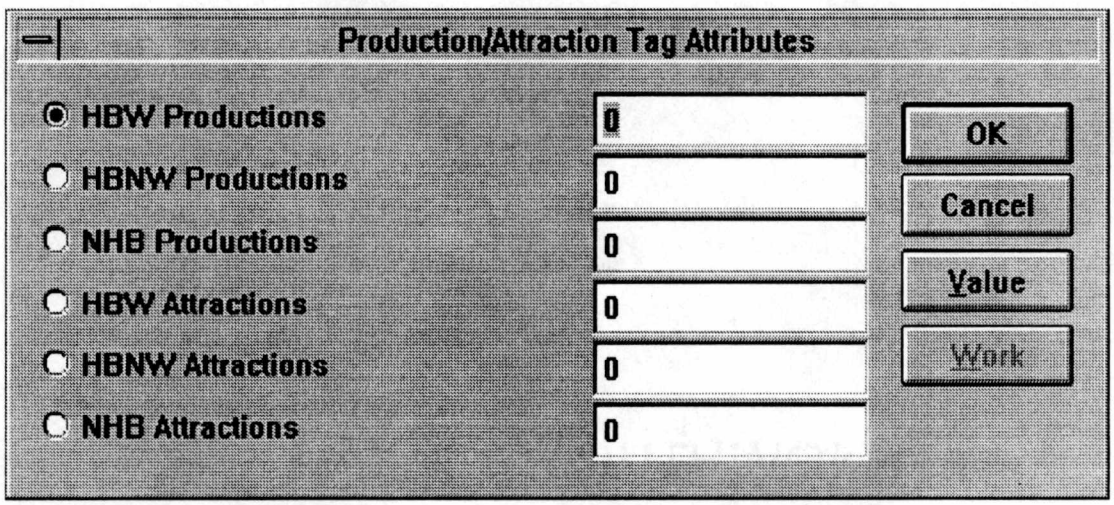


Figure 30 - Production/Attraction Tag Attributes

h. District tag

i. No attributes needed

9. Assign attributes to all the links by clicking on the Mode menu, clicking on Link Actions, then Link Open. Click onto each node and then open the attributes button. The attributes that are needed for each type of link and their definitions (if they are needed) are the following:

a. One-way street - See Figure 31 which shows the attributes for a one-way street.

i. Approach Codes - Define the through traffic code, lane geometry, progression, and the functional classification. The approach codes must be added perfectly or error messages will be seen. See Figure 32 which shows several different intersections and their respective approach codes. The following variables should be used:

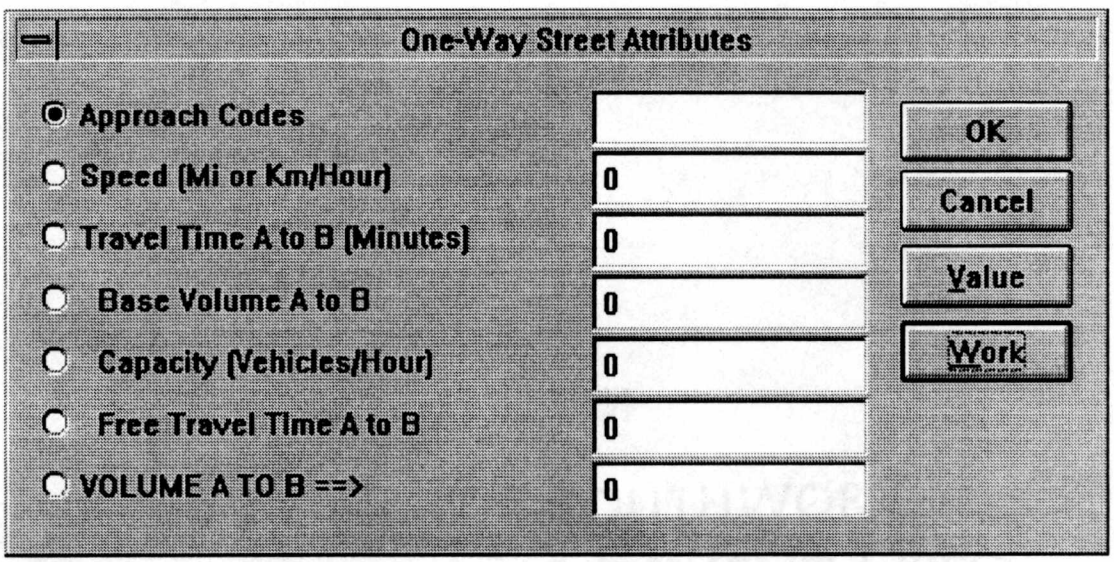


Figure 31 - One-Way Street Attributes

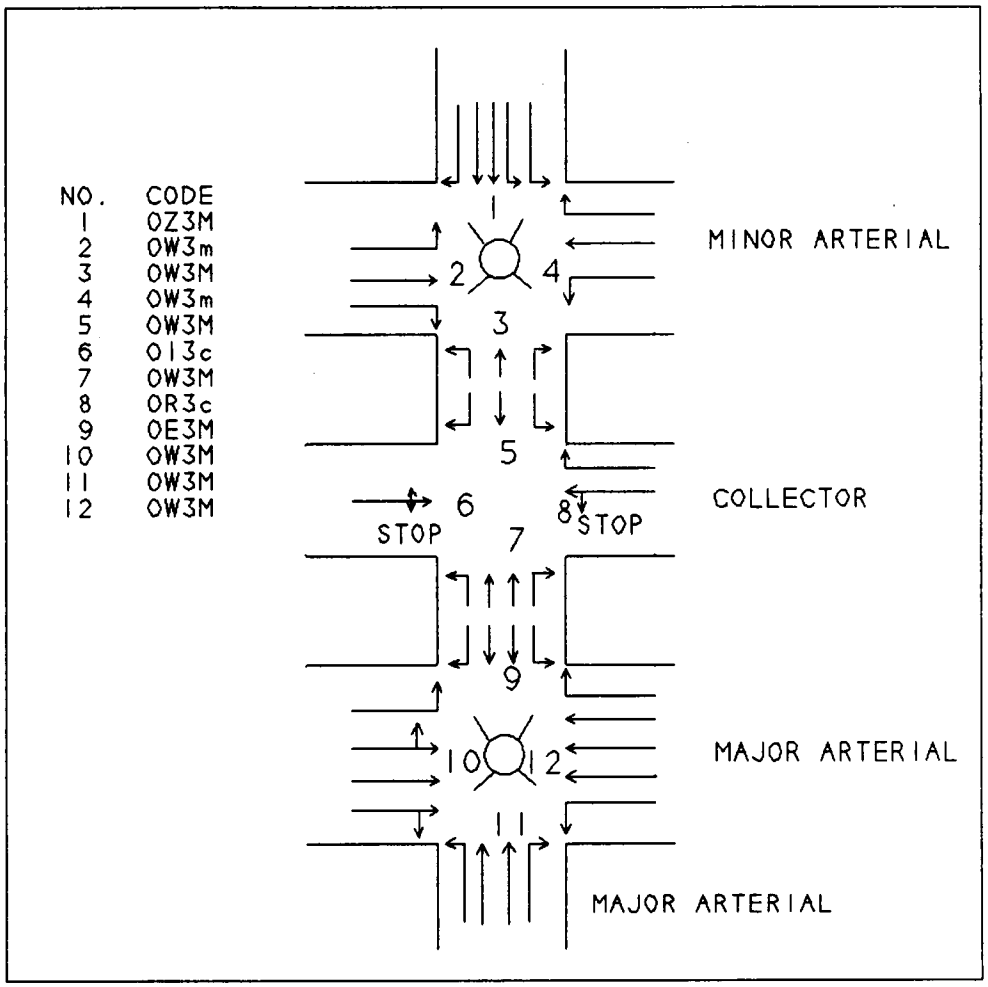


Figure 32 - Approach Codes for Various Intersection Types

Through Traffic Code:

- This is used to ascertain opposing and conflicting flows and to apply proper turn penalties to the various movements at the intersection. At signalized intersections, the code also determines the number of through/right or left/through/right phases.

- Zero and 1 - 9 - QRS will determine the code when zero is entered. See Figure 33 which shows how QRS will determine the code.

Lane Geometry and Sign Code

- This is used to code presence of signs, exclusive lanes, and ramp meters. There are 10 codes.

- S - Approach does not have exclusive lanes or STOP signs

- 1 - For an unsignalized intersection, the approach has a stop sign and two lanes, a left/through lane and a through/right lane

- 2 - For an unsignalized intersection, the approach has a STOP sign and two lanes, a left/through lane and a through/right lane

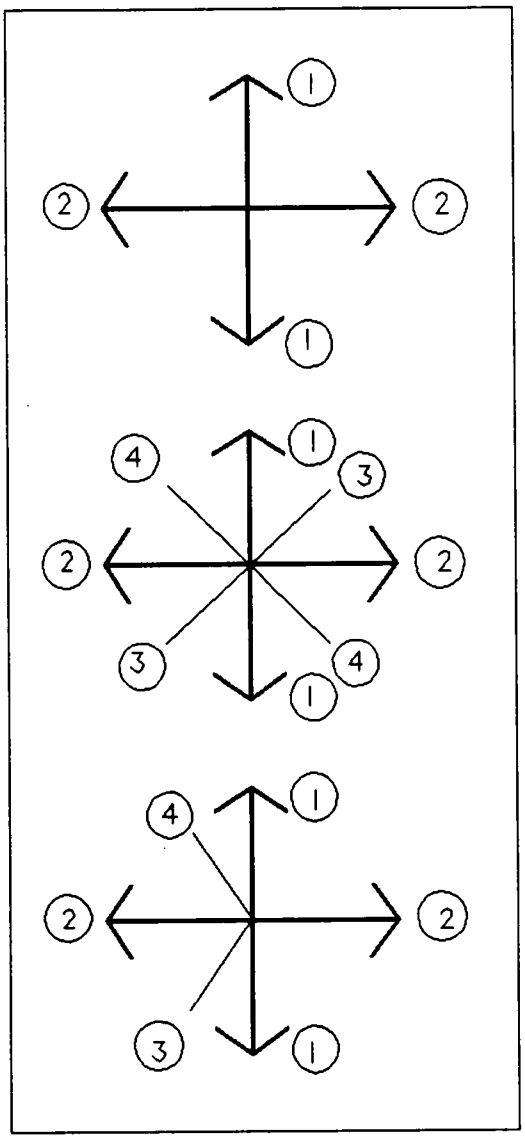


Figure 33 - Through Traffic Codes - How QRS Determines Code

- R - For an unsignalized intersection, the approach has a STOP sign and two lanes, a left/through lane and a right lane. For a signalized intersection, the approach has an exclusive right lane, but no exclusive left lane

- E - The approach has an exclusive left lane, but no stop sign.

- W - The approach has both an exclusive left lane and an exclusive right lane, but no STOP sign.

- D - The approach has two exclusive left lanes but no STOP sign.

- Z - The approach has two exclusive left lanes plus an exclusive right lane, but no STOP sign.

- M - The link has a ramp meter with two approach lanes (one-way links only).

- m - The link has a ramp meter with one approach lane (one-way link only).

Progression Code

- This variable is the same as is used with the Highway Capacity Manual for platooning at signalized intersections.
- Set it from 1 - 5. The progression code for unsignalized intersections should be 3.

Functional Class Code

- This variable is the functional classification of the roadway
- F - Freeway
- M - Major Arterial
- m - Minor Arterial
- c - Collector
- l - local
- O - Other

(NOTE: If there is any uncertainty with the approach codes, a code of 0S3O would be appropriate.)

ii. Speed* (mi or km/hour) - If a speed is entered, it will override the default value that is set in the Schema System Attributes menu.

iii. Travel time A to B* (minutes)

iv. Base volume A to B - The volume of traffic on the link that will not be predicted by the model (an example would be the number of external to external trips from the origin station to the destination station). This volume is added to the values calculated by the model.

v. Capacity (vehicles/hour) - The maximum number of vehicles that should travel down one side of a street in a single hour based on level of service C from the *Highway Capacity Manual*. An ideal value is 1800 vehicles per hour per lane, however, use 1600 vehicles per hour per lane to account for loss at signalized and STOP controlled intersections (Horowitz, 1998).

vi. Free travel time A to B - The time that it takes for a vehicle to traverse the link when traffic is very light.

vii. VOLUME A to B - This is the total calculated trips for the link (QRS calculates this item - do not enter anything).

(* There are three ways to code travel time and speed in GNE:

- Set the speed and travel time to zero - the travel time will be calculated from the default speed that is set in the Schema System Attributes menu.

- Give the link a speed but set the travel time to zero - the travel time will be calculated from the speed and distance between the nodes.

- Give the travel time.)

b. Two-way street - See Figure 34 which shows the attributes for a two-way street.

   i. Approach Codes - See One-way street

   ii. Speed* (mi or km/hour)

   iii. Travel time A to B* (minutes)

   iv. Travel time B to A* (minutes)

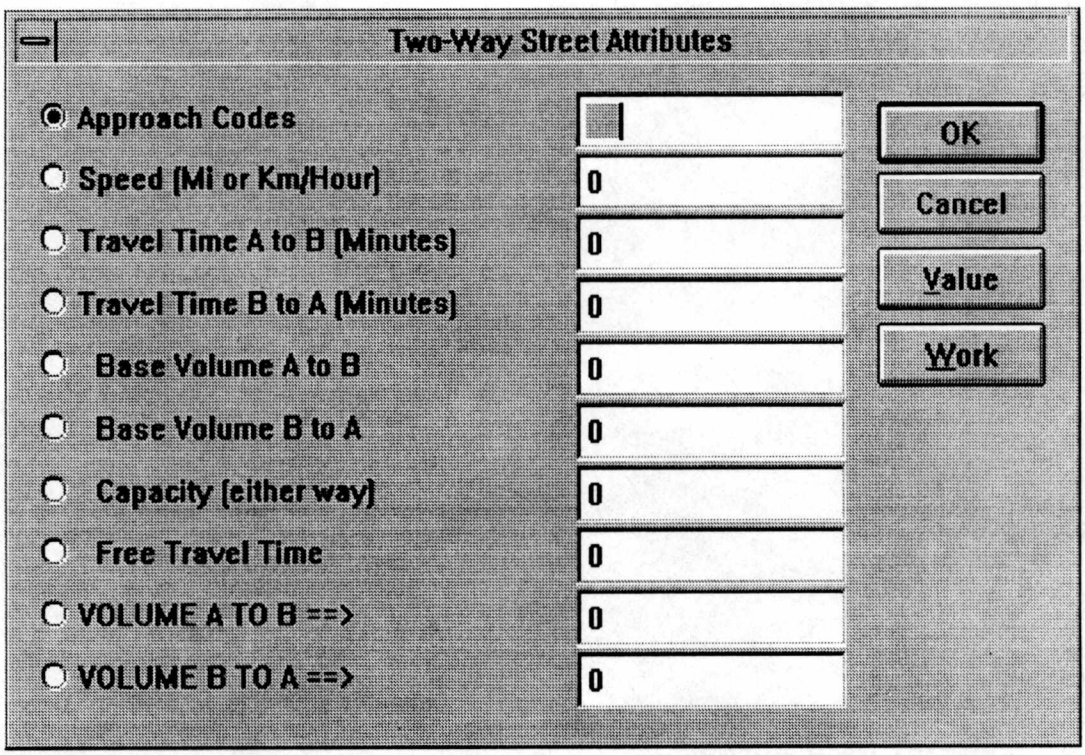


Figure 34 - Two-Way Street Attributes

v. Base volume A to B - See One-way street

vi. Base volume B to A - See One-way street

vii. Capacity (either way) - See One-way street

viii. Free travel time A to B - See One-way street

ix. Free travel time B to A - See One-way street

x. VOLUME A to B - See One-way street

xi. VOLUME B to A - See One-way street

(* There are four ways to code travel time and speed in GNE:

- Set the speed and both travel times to zero - the travel time will be calculated from the default speed that is set in the Schema/Attributes menu.

- Give the link a speed but set both travel times to zero - the travel

time will be calculated from the speed and distance between the nodes.

- Give a travel time for "A to B" and set "B to A" to zero. It will be assumed that "B to A" travel time will be the same as "A to B".

- Give both the "A to B" and B to A" travel times.)

c. Centroid connector - See Figure 35 which shows the attributes for a centroid connector.

   i. Speed (mi or km/hour)

   ii. Travel time A to B (minutes) - after entering the speed on the attribute page, go to the travel time worksheet, enter the distance, enter the out-of pocket cost, and then hit "B" - this calculation is unnecessary if there are no dollar costs (parking, etc.) and if walking is insignificant

   iii. Travel time B to A (minutes) - See Travel time A to B (minutes)

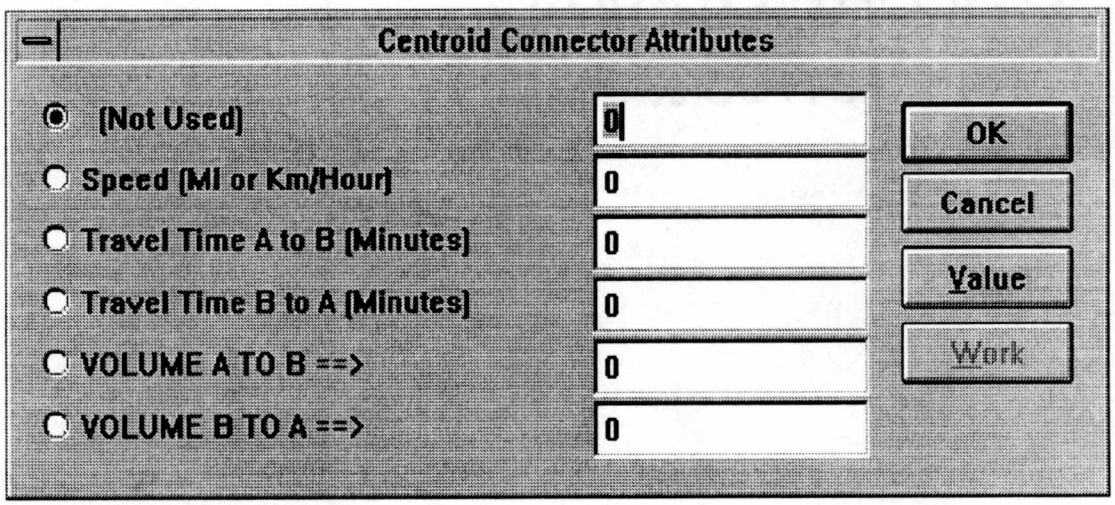


Figure 35 - Centroid Connector Attributes

iv. VOLUME A to B - See Two-way street

v. VOLUME B to A - See Two-way street

d. Two-way (no left turn) street - See Figure 36 which shows the attributes for a two-way (no left turn) street.

i. Approach Codes - See One-way street

ii. Speed (mi or km/hour) - See Two-way street

iii. Travel time A to B (minutes) - See Two-way street

iv. Travel time B to A (minutes) - See Two-way street

v. Base volume A to B - See Two-way street

vi. Base volume B to A - See Two-way street

vii. Capacity (either way) - See Two-way street

viii. Free travel time A to B - See Two-way street

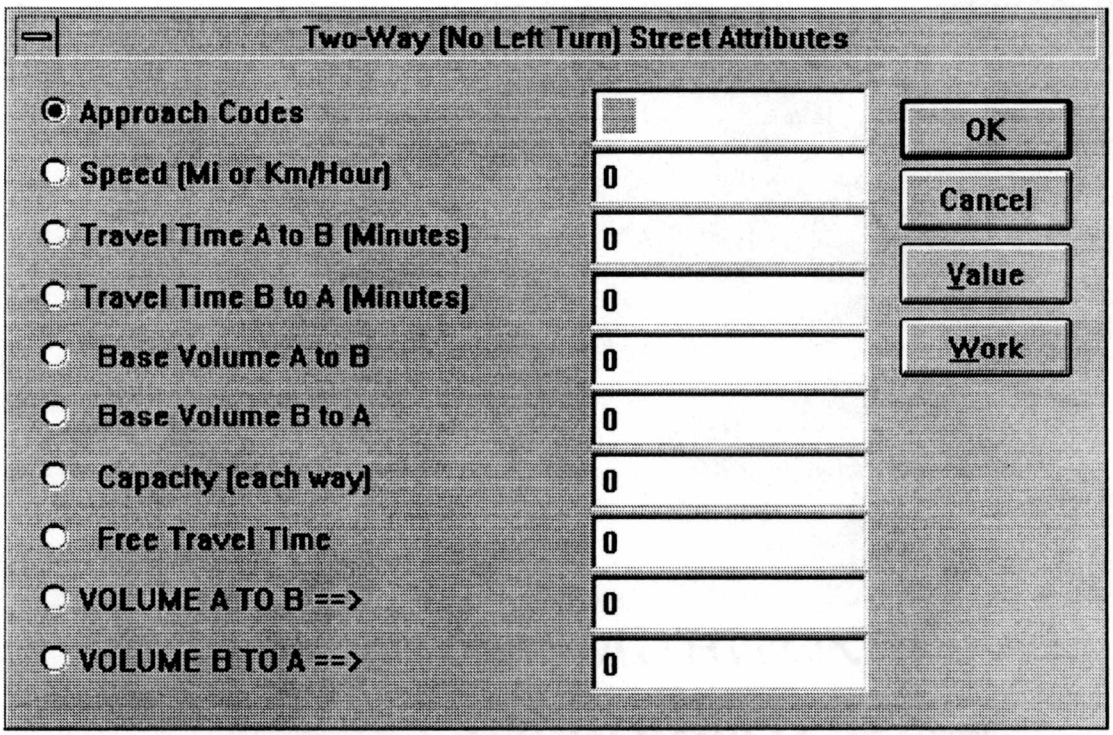


Figure 36 - Two-Way (No Left Turn) Street Attributes

ix. Free travel time B to A - See Two-way street

x. VOLUME A to B - See Two-way street

xi. VOLUME B to A - See Two-way street

e. One-way street dummy - See Figure 37 which shows the attributes for a one-way street dummy.

i. Approach Codes - See One-way street

ii. VOLUME A to B - See One-way street

f. Two-way street dummy - See Figure 38 which shows the attributes for a two way street dummy.

i. Approach Codes - See Two-way street

ii. VOLUME A to B - See Two-way street

iii. VOLUME B to A - See Two-way street

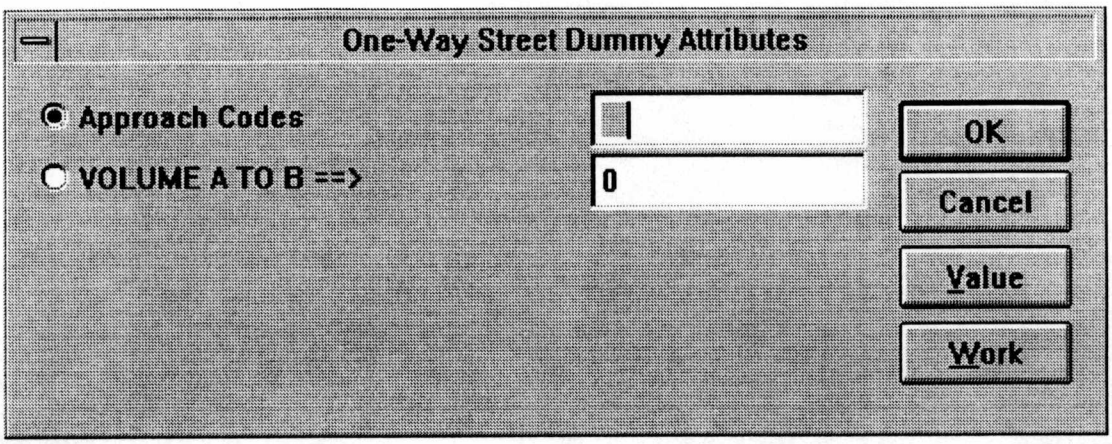


Figure 37 - One-Way Street Dummy Attributes

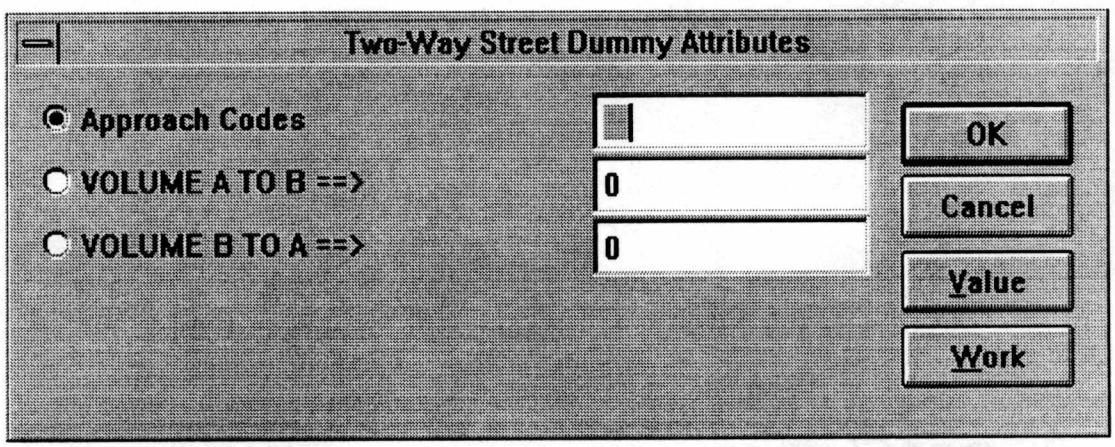


Figure 38 - Two-Way Street Dummy Attributes

g. Centroid connector dummy - See Figure 39 which shows the attributes for a centroid connector dummy.

i. VOLUME A to B - See Two-way street

ii. VOLUME B to A - See Two-way street

h. Piece of string

i. No attributes needed

10. Set system attributes to desired settings by clicking on Schema and then clicking System Attributes. Fill in any or all attributes that may apply to the network. Figure 40 shows the system attributes menu. See the following attributes and their definitions (if needed) and variables:

a. Through penalty - This is the amount of time it takes vehicles to pass through an intersection with penalties (in minutes). This is added to any Through Adjustments that are entered at individual intersections. The typical value for this item is zero minutes (Horowitz, 1994, p. 1-10).

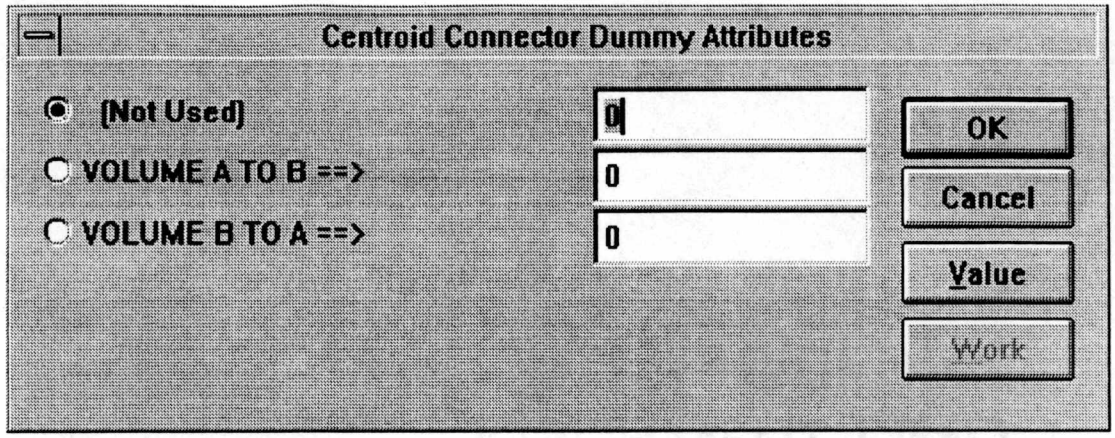


Figure 39 - Centroid Connector Dummy Attributes

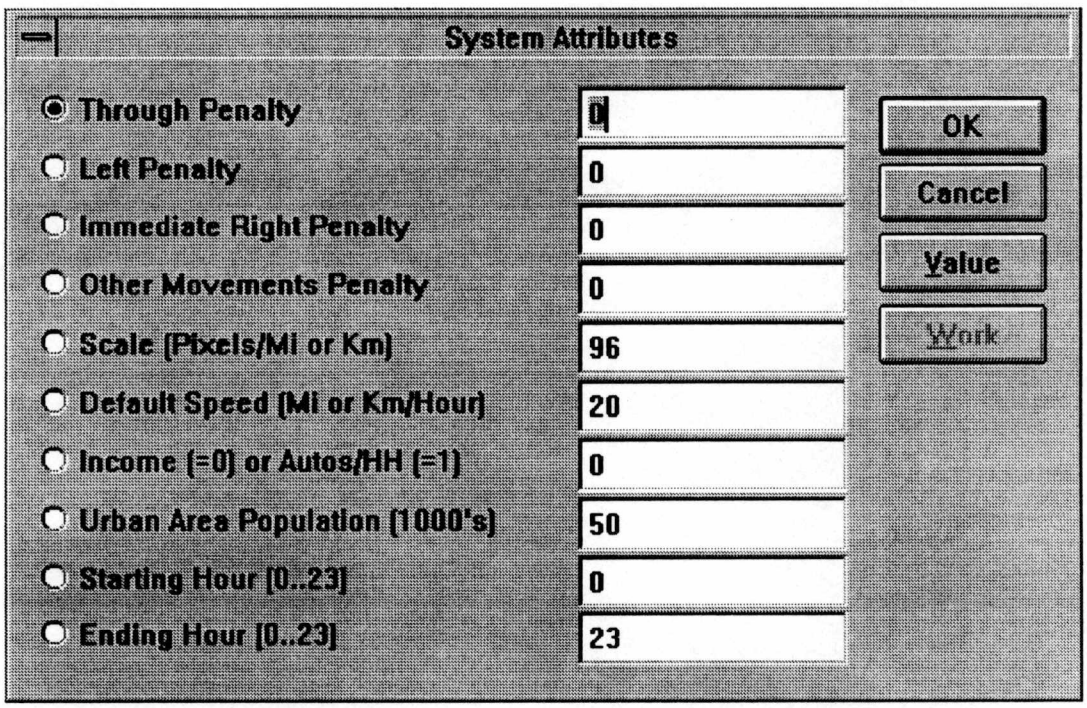


Figure 40 - System Schema Attributes

b. Left penalty - This is the amount of time it takes vehicles to make a left turn at an intersection with penalties (in minutes). This is added to any Through Adjustments that are entered at individual intersections. The typical value for this item is 0.25 minutes (Horowitz, 1994, p. 1-10).

c. Immediate right penalty -This is the amount of time it takes vehicles to make a right turn at an intersection with penalties (in minutes). This is added to any Through Adjustments that are entered at individual intersections. The typical value for this item is zero minutes (Horowitz, 1994, p. 1-10).

d. Other movements penalty - This is the amount of time it takes vehicles to pass through or make a turn at an intersection with penalties (in minutes). This is added to any Through Adjustments that are entered at individual intersections.

e. Scale (pixels/mi or km) - Set the scale in GNE equal to the scale of the coordinate file. The scale is in pixels per mile (if 1 unit = 0.01 miles in your scale, then the scale would be 100 pixels per mile). To get the scale of a map, measure one mile on the screen and find the number of pixels by subtracting the coordinates of two points a

mile apart. You can get the coordinates by using the left mouse button while in the node plotting mode.

f. Default speed (mi or km/hour) - This is the speed that is used to calculate travel time on the links if a speed is not given on a particular link. This speed also applies to centroid connectors.

g. Income (=0) or autos/hh (=1) - QRS uses either income or autos per household to estimate productions and attractions. If income should be used, then enter a zero. If autos per household should be used, then enter a one.

h. Urban area population (1,000's)

i. Starting hour (0..23) - This is the starting hour for the time period that should be analyzed (0 = midnight, 23 = 11:00 p.m.).

j. Ending hour (0..23) - This is the ending hour for the time period that should be analyzed (0 = midnight, 23 = 11:00 p.m.).

11. Add the external to external trips to the network. There are two ways to accomplish this task. The first way can be done in the GNE. The second way

needs to be done in the *Note Pad* software that is included in the Microsoft Package in the Accessories program.

a. These external trips can be represented by adding the volumes to the link attributes "BASE VOLUME A to B" and "BASE VOLUME B to A" along all the links from the origin external station to the destination external station. The links should represent the path that a driver would take in going from the origin external station to the destinations external station. Node A is the first node that is clicked, make sure that the trips are added to the appropriate direction.

b. Save the file and go to Windows. Open the Accessories Icon and then open the *NotePad* application. Then open the file "ADDTRIPS.txt". This is a trip table that can add trips to the network without adding them to the GNE file. They should be added to the portion of the Home Based Work trips because they are vehicle trips as opposed to person trips. An example of how to code these trips is given in the following example:

Given: 3 External Stations with data shown in Table 18.

Table 18 - External to External Trips for Stations 91, 92, and 93 for Example Problem

Origin	Destination		
	91	**92**	**93**
91	-	92	255
92	92	-	233
93	295	271	-

Find: Edit the ADDTRIPS.txt file to add the given external trips.

Solution: Open the NotePad Software from the Accessories Menu. Then open ADDTRIPS.txt file. (Note: It is usually located in the QRSII subdirectory). Enter the given data. It should look like Figure 41 (Notes are given in {}, do not add any data in {}).

After adding these trips, save the file as ADDTRIPS.txt or QRS will not read it. For more information on the ADDTRIPS.txt file and other type of data that can be entered, see the *Reference Manual - Quick Response System II* in the QRS section.

```
91 {add first station}
92 {add second station - the first two numbers are the origin stations}
END OF ROWS {Add "END OF ROWS" comment}
91 {add first station}
92 {add second station - these are the destination stations}
END OF COLUMNS {Add "END OF COLUMNS" comment}
0.0 92.0  {the first number is the number of trips that go from 91 to 91, the second
          number is the number of trips that go from 91 to 92 - add only one space
          between numbers and make sure the numbers are in tenths}
92.0 0.0 {the first number is the number of trips that go from 92 to 91, the second
          number is the number of trips that go from 92 to 92 - add only one space
          between numbers and make sure the numbers are in tenths}
91
93
END OF ROWS
91
93
END OF COLUMNS
0.0 255.0
295.0 0.0
92
93
END OF ROWS
92
93
END OF COLUMNS
0.0 233.0
271.0 0.0
END OF TABLES          {This comment should be in file - the number preceding
                       this comment are home-based work trips}
END OF TABLES          This comment should be in file - the number preceding
                       this comment are home-based non-work trips}
END OF TABLES          {This comment should be in file - the number preceding
                       this comment are non-home-based trips}
END OF TABLES          {This comment should be in file - the number preceding
                       this comment are other trips}
{Blank Row - should be in file}
→ {Dash - should be in file}
```

Figure 41 - ADDTRIPS.txt File that Shows External to External Trips

The Quick Response System

The network that was drawn in the GNE needs to be run so that any errors can be fixed prior to calibrating the network. There are several steps to follow.

1. Open the QRS program from the QRSII group.

2. Go to the File menu, click on Highway, then open the file that was created in GNE. See Figure 42 which shows how to open a highway file.

3. Hit Run and wait until an error message occurs or the Information block says "QRS II is inactive". See Figure 43 which shows which button to activate.

4. If there are error messages, the GNE file needs to be modified until no more error messages appear or the disk or directory needs to be changed. If the error message lists a serial number for a node, centroid, or link, then the user must find that node, centroid, or link and make corrections. The serial number has to do with the way the nodes were originally plotted. To find the serial number, in GNE go to the View menu, chose labels, then hit node labels. For each of the node types, hit "first" then chose serial. When finished, look at the network to find the node with the serial number. Make any changes that are necessary. Remember to save the changes.

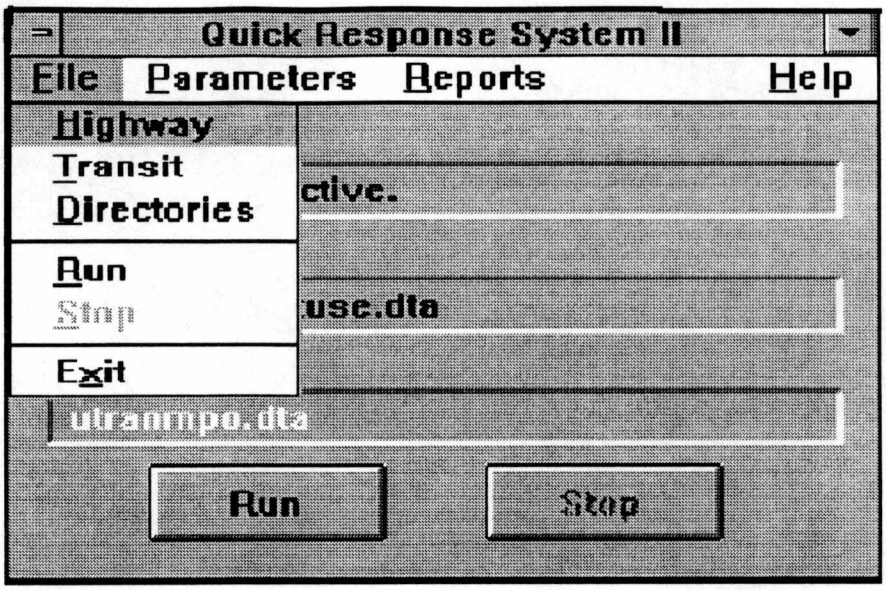


Figure 42 - QRS Highway File Menu

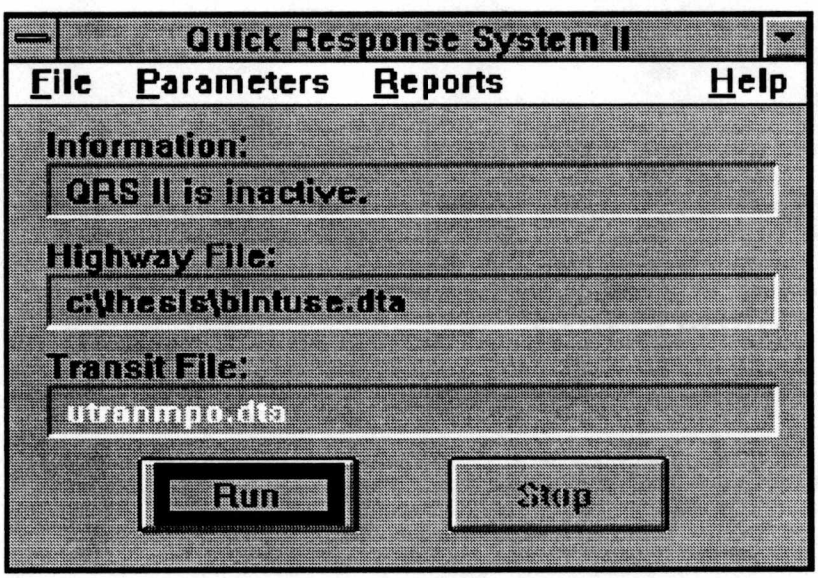


Figure 43 - QRS Run Button

Also, the *Reference Manual for Quick Response System II™ For Windows Version 4*, lists the most common error messages that relate to files, directories, and disks. They are the following:

Error	Description
2	File does not exist
4	Too many open files
5	Directory is full; file cannot be accessed
15	Invalid drive number
100	Disk read error, unexpected end of file
101	Disk write error disk is full
106	Invalid numeric format; data files have been corrupted; application schema modified inappropriately

(NOTE: If an error comes up that can not be solved, write the message down and call AJH Associates for assistance.)

5. After all error messages are corrected, then it is time to actually "run" the network to be able to find the volumes of traffic on the links or roadways. To do this, all variables should be set to locally accepted values or the default values may be used. It is best to keep all default variables unless locally accepted ones exist or there is justification for using other variables. These variables should be set in the

Parameters menu. See Figure 44 for the parameter menu. The following are Parameters:

a. Attraction - This is the number of attractions that are calculated from the dwelling units, retail employment, non-retail employment, and other demographic data that is given by trip purpose. See Figure 45 for the attraction parameters. The following default values are from NCHRP Report 187:

HBW Attraction (zone) = 1.7*retail employment + 1.7* non-retail employment

HBNW Attraction (zone) = 10.0*retail employment + 0.5* non-retail employment + 1.0*dwelling units

HBNW Attraction (zone) = 2.0*retail employment + 2.5* non-retail employment + 0.5*dwelling units

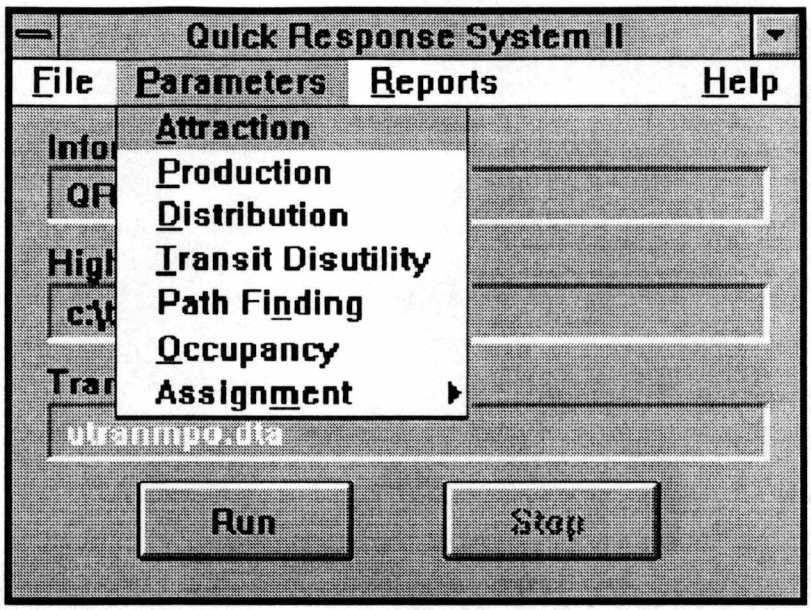


Figure 44 - QRS Parameters Menu

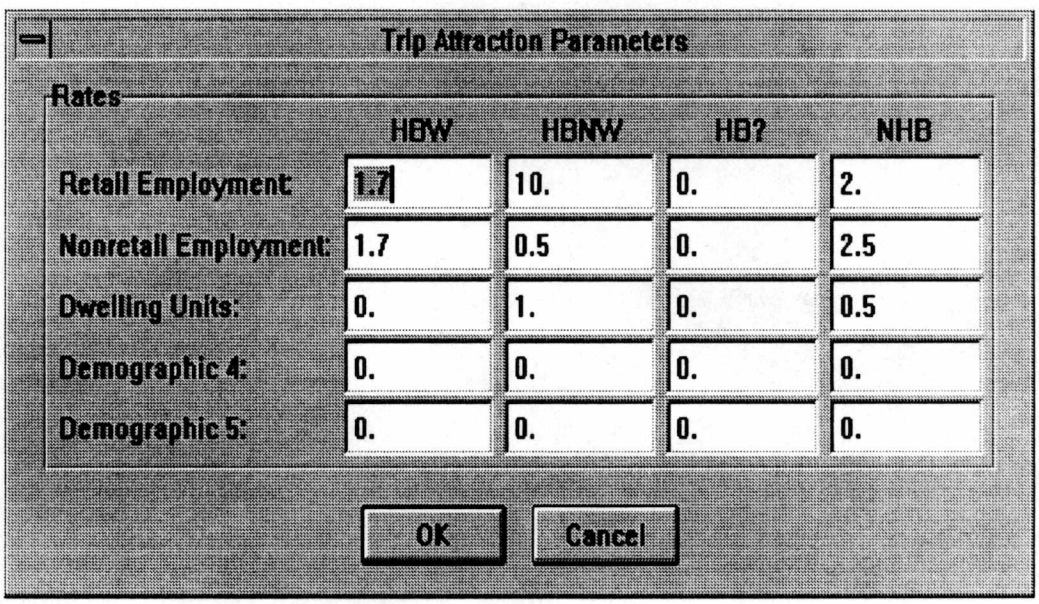


Figure 45 - QRS Trip Attraction Parameters

b. Production - This is the number of productions that are calculated by trip purpose. The default values are from NCHRP Report 187. See Figure 46 for the trip production parameters. The following options are available:

i. Make NHB Productions Equal Attractions - This is used to force the non-retail home based trip productions to equal trip attractions. Normally set to "yes".

ii. Flip Directions of Direct and Reverse - This is used when an impact of a site is being analyzed. This will turn the trips from the site from attractions to productions. Normally set to "no".

iii. Inflation Index - Ignore if using auto ownership. If the income level that is use, is not in 1980 dollars, then a value must be inserted. This value should be the consumer price index of the year of the data divided by the consumer price index of 1980.

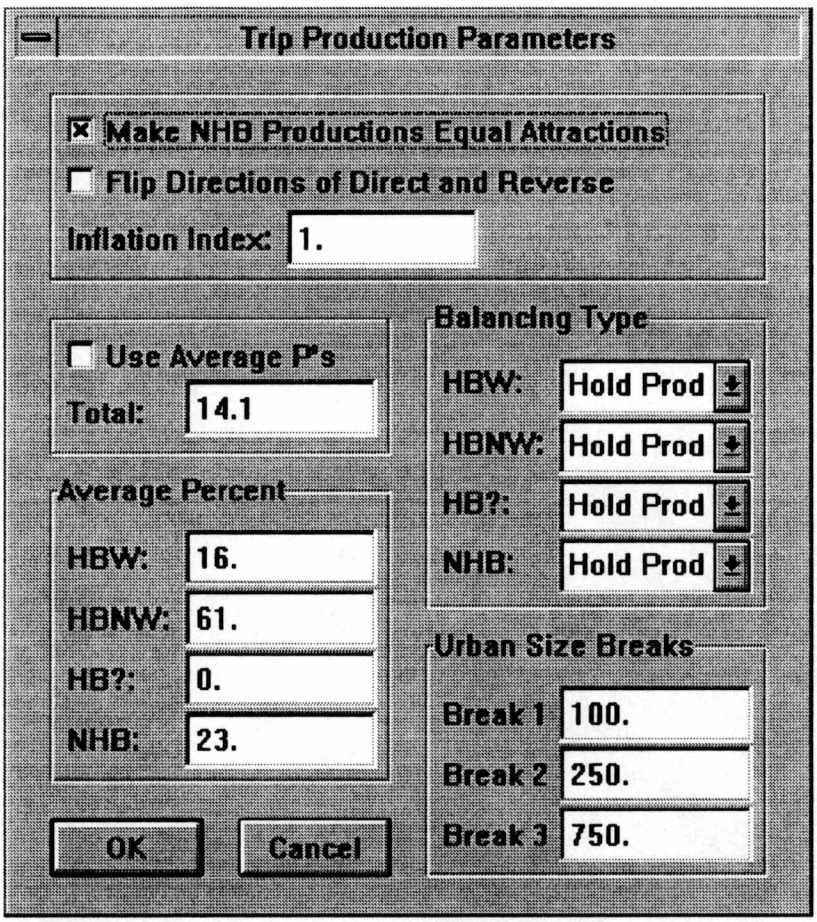


Figure 46 - QRS Trip Productions Parameters

iv. Use Average P's - Check this if it is desired to only use the number of dwelling units to calculate productions. If this is checked, the number in the "Total" should be the number to multiply the dwelling units by to get the number of productions. If the box is not checked, the number of productions will be based on the number of dwelling units, area population, and income or auto ownership. The rates are based on the current *NCHRP 187 Report.* These rates are in the text files called "PRATES#.TXT". There are four of these and they relate to the area population that was input into the GNE file.

v. Average Percent - This is the percentage of productions by trip purpose. The default values are based on NCHRP Report 187.

vi. Balancing Type - This tells QRS how to balance the trips by purpose. The choices are the following:

Hold Productions - this holds the productions constant and adjusts the attractions (typical)

Hold Attractions - this holds the attractions constant

and adjusts the productions

None - there will be no balancing of productions and attractions

c. Distribution - This is the type of distribution that is performed. The variables determine how the friction factors are applied. See Figure 47 which shows the distribution parameters. The following options are available:

i. Trip Purpose - Check the box at the left if it is desired to analyze a particular trip purpose.

ii. Iterations - Specify the number of iterations desired to make sure the number of trips that arrive at the zone is the same as the number expected. This is typically set at 3.

iii. Friction Function - Specify the method to determine the friction factor, exponential, power, or table. See the following information for the three methods of friction factors:

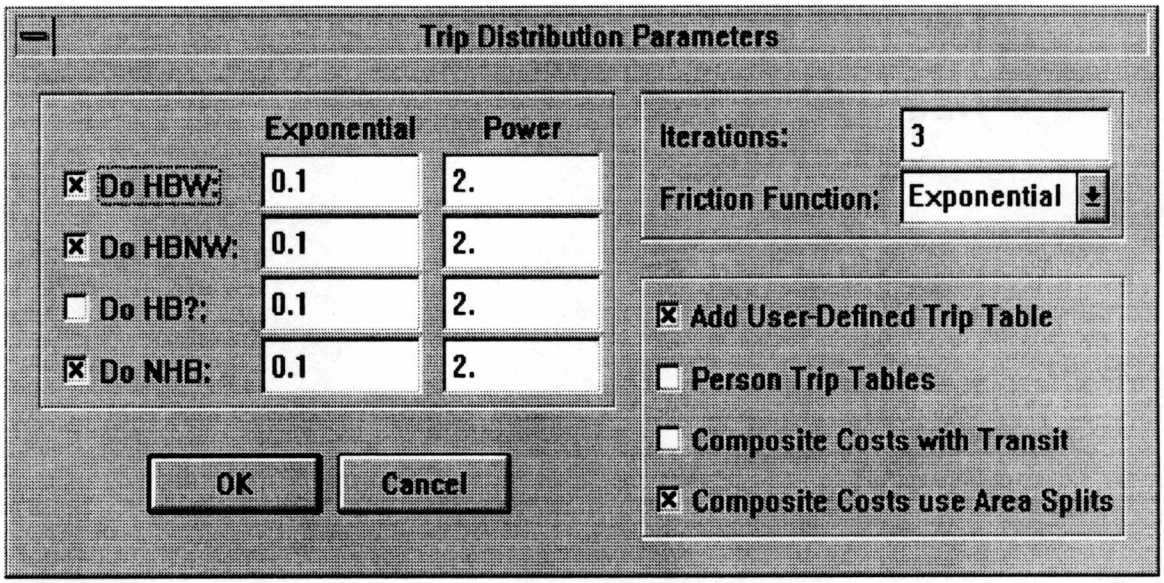


Figure 47 - QRS Trip Distribution Parameters

Exponential - The equation used is $F_{ij} = 1/(e^{P*Tij})$, where P is the number that is set to the right of the trip purpose, and Tij = the travel time between zones i and j.

Power - The equation used is $Fij = 1/(T_{ij}^{Q})$, where Q is the number that is set to the right of the trip purpose, and Tij = the travel time between zones i and j. Note that the numbers for P and Q would be significantly different.

Table - There is a table that has friction factors based on travel times for each trip purpose called FRICTION.TXT. These friction factors are the ones listed in the NCHRP Report 187.

iv. Add User-Defined Trip Table - Check this box if there is a separate table, ADDTRIPS.TXT, that includes additional trips. This would be used if the external to external trips were added to the ADDTRIPS.TXT file.

v. Person Trip Tables - Check this box if the ADDTRIPS.TXT file contains person trips. If it is not checked, it will be considered a vehicle trip table.

vi. Composite Costs with Transit - Use this to use friction factors that will increase accessibility and decrease travel times in the gravity model. This is for use with transit files.

d. Transit Disutility - This is used if there is a transit network and it is desired to do a mode split. See *Reference Manual for Quick Response System II™ For Windows Version 4* or *A QRSII/GNE Primer* for more information.

e. Path Finding - This is used if there is a transit network. See *Reference Manual for Quick Response System II™ For Windows Version 4* or *A QRSII/GNE Primer* for more information.

f. Occupancy - This determines the trip type, person or vehicle, to be used for traffic assignment. See Figure 48 for occupancy parameters.

i. Trip Purpose Occupancy - Use the vehicle occupancy rate of the planning area for each trip purpose. This is used to convert person trips to vehicle trips if "person trip" is checked under Trip Type.

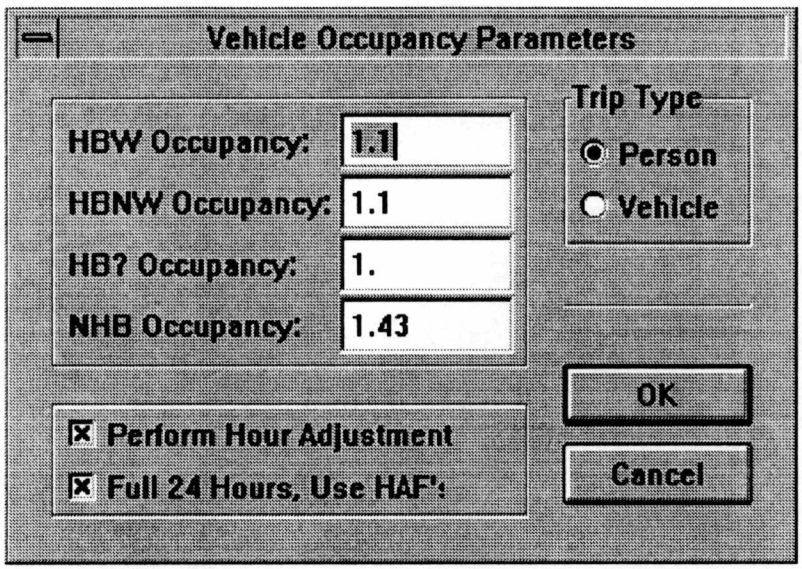


Figure 48 - QRS Vehicle Occupancy Parameters

ii. Trip Type - This is normally set to person trips. If "vehicle trip" is checked, then the occupancy rates are ignored.

iii. Perform Hour Adjustment - Check this box if it is desired to have vehicle occupancies modified by time of day. The HADJUST.TXT file will be used to make the modifications.

iv. Full 24 Hours, Use HAF - Check this only if it is desired to have exactly one half of the trips go from their production to attraction zones and one half go from their attraction to production zones. It is possible to do a 24 hour analysis if the starting and ending hours are set to 0 and 23, respectively, in the highway systems attribute menu in GNE. See GNE section for more information.

(NOTE: The "Default HAF", hourly average factor, must be set when a vehicle trip table, VEHTRIPS.txt, is provided. This trip table contains vehicle trips with origins and destinations at each zone and are for a specified time period. See QRS section for more information involving the vehicle trip table.

This is used to recalculate travel times in traffic assignment. It would be the HAF term as described in the highway traffic assignment section. Normally this is automatically calculated by the model when doing an iterative trip assignment. You need to supply a value in two cases. First, if the "Full 24 Hours, Use HAF" box has been checked, then you need a value for the Default HAF to represent the probability that trips occur in any one hour. A second case where you need a value for the Default HAF is if you supply a separate vehicle trip table with an ADDTRIPS.TXT file. In these cases the hourly adjustment factor would be found through a calculation involving the time distribution of trips. First determine what portion of trips occur in each of the hours you are concerned with. Raise these numbers to the fifth power and add them up. That would be used as the hourly averaging factor. For example, suppose you supplied a separate trip table which represented 3 hours of travel with the first hour having 10% of the trips, the second hour 50%, and the third hour 40%. The hourly averaging factor would then be:

$$HAF = 0.1^5 + 0.5^5 + 0.4^5$$

$$HAF = 0.00001 + 0.015625 + 0.01024$$

$$HAF = 0.025875$$

Note that if your data was for only one hour the HAF would be $(1.0)^5$ or 1.0 (Horowitz, 1994, p. 3-11).)

g. Assignment - This determines how calculations are made for traffic flow based on congestion on links and delays at intersections. See Figure 49 which shows the traffic assignment parameters menu. The following are the submenus:

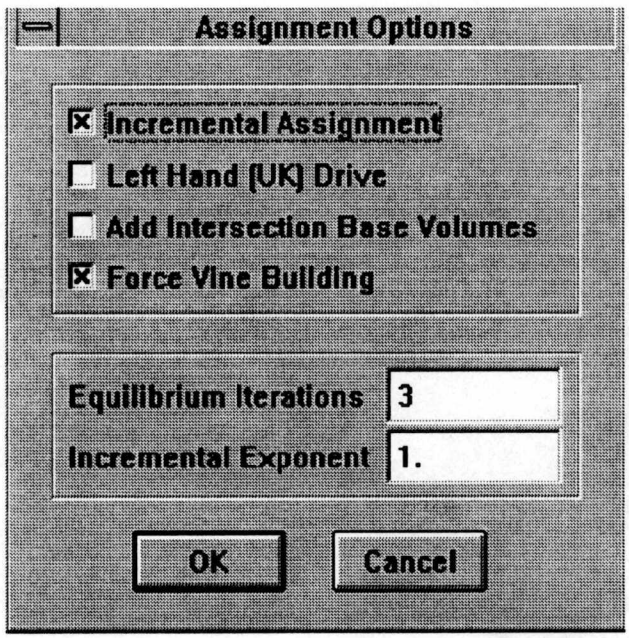


Figure 49 - QRS Traffic Assignment Options

i. Options - The following options exist:

Incremental Assignment - Check this for traffic assignment to be reached with equilibrium between traffic volumes and capacity. Assignment is calculated using the number of iterations specified in Equilibrium Iterations. Use a value of zero if the "all-or-nothing" assignment is desired.

Left Hand (UK) Drive - Check this if traffic travels in the left lane (i.e. Great Britain, Japan, Australia, not used in the United States).

Add Intersection Base Volumes - Check this if base volumes were added at intersections and if it is desired to use these volumes.

Force Vine Building - Check this to make sure the shortest, most perfect path is chosen during traffic assignment.

Incremental Exponent - Set this to one when choosing incremental assignment so that the traffic volumes will be equally split during each iteration.

ii. BPR Global and BPR Classes - These menus allow the user to set defaults to determine travel times on the links. QRS uses the BPR Speed/Volume function. See Figures 50 and 51 which show the BPR Global and BPR Classes menus, respectively. The equation for new travel time is:

NewTime = (1-step)*BaseTime + step*FreeTime*(1 + mult*$(v/c)^{Exp}$*HAF), where

NewTime = Calculated new travel time on link

Step = Travel time step size (this is used to average travel times from successive iterations and helps to reach equilibrium faster). A typical value for this is 0.25 for convergence when using capacity restraint and 1.0 for equilibrium/incremental assignment methods (Horowitz, 1995, p. 107).

FreeTime = Free travel time which is set in GNE

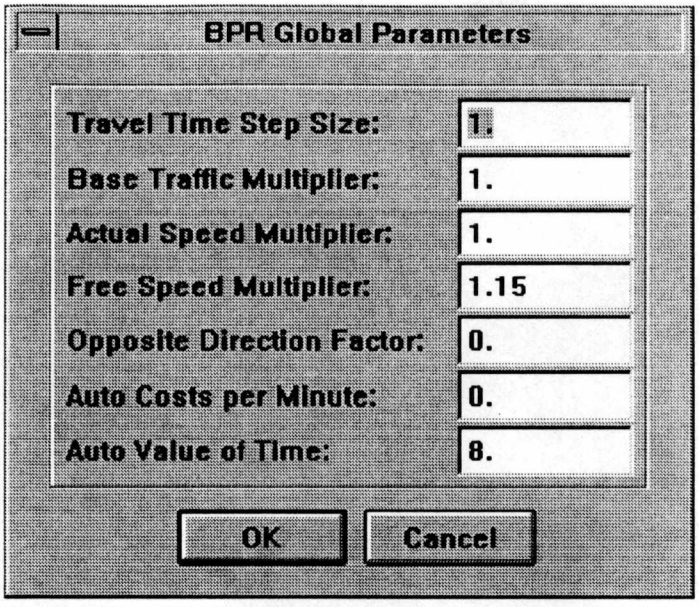


Figure 50 - QRS Traffic Assignment BPR Global Parameters

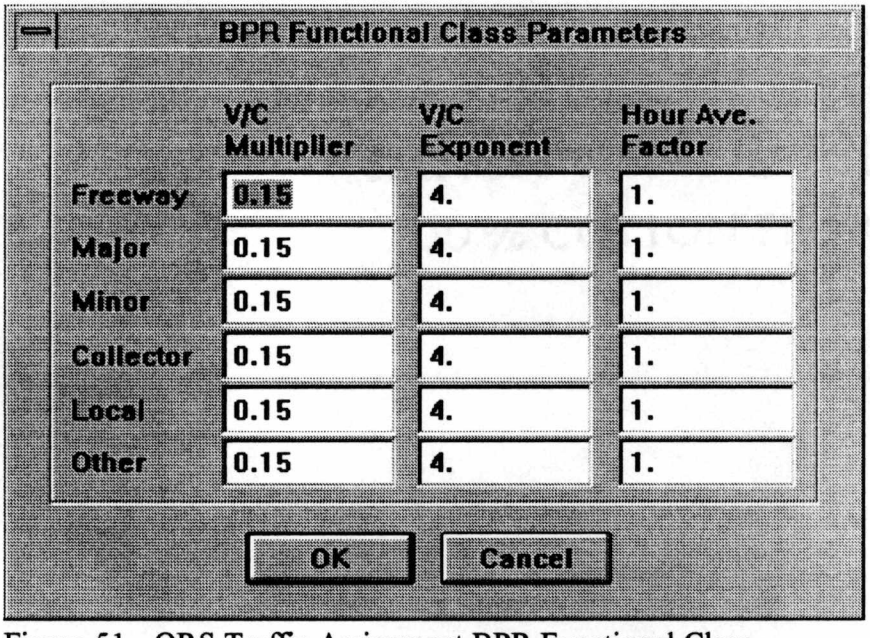


Figure 51 - QRS Traffic Assignment BPR Functional Class Parameters

Mult = Volume/capacity multiplier. The typical value is 0.15 for level of service C (Horowitz, 1994, p. 3-14). A value of 0.80 is typical for level of service E (Horowitz, 1995, p. 108). This is set in BPR Classes by functional classification.

v/c = Volume/capacity ratio for link determined by QRS.

Exp = Volume/capacity exponent. Typical value is 4 (Horowitz, 1994, p. 3-14). This is set in BPR Classes by functional classification.

HAF = "Hourly averaging factor, the probability that the trips occur in the time period of interest" (Horowitz, 1994, p. 3-14). This was set in the Occupancy menu.

The other items that need to be determined in the BPR Global menu are the following:

Base Traffic Multiplier - This can be used to modify any base volumes that were entered on the links (i.e. external to external trips). If the trips were added as 24 hour counts

and it is desired to analyze only the peak period, then a peak hour factor should be entered, such as 0.10. Another use would be to convert the counts to a future year by a growth factor. If the growth factor is 25%, then the multiplier would be 1.25.

Free Speed Multiplier - The is used to calculate the free speed on a link if it is not given. It is multiplied by the actual speed (input into GNE) to get free speed. This represents the speed on the link when no other vehicles exist. The actual speed occurs when the link is operating as design capacity (Horowitz, 1994, p. 3-15).

Actual Speed Multiplier - This is used to increase or decrease all traffic speeds if they were set low or high. This value should be one if the speed were set correctly.

Opposite Direction Factor -

> It is possible to add a portion of the opposite-direction volume to the subject-direction volume when computing the volume-to-capacity ratio of small roads. This parameter permits QRSII to closely approximate the 1985 Highway Capacity Manual procedures for two-lane roads. To properly use this parameter, set all capacities according to level-of-service E (with a 100/0 directional split)

and set the Opposite Direction Factor to 0.4. QRSII applies the Opposite Direction Factor only to links with capacities of less than 2200 vehicles per hour. When the Opposite Direction Factor is set (i.e. greater than zero), the equilibrium/incremental assignment method should be adopted (Horowitz, 1995, p. 108).

Auto Costs Per Minute - Adding a value (cents) will add impedance along one-way and two-way streets.

Auto Value of Time - Adding a value (cents/minute) will add impedance along one-way and two-way streets.

iii. Signalized - default values are from 1985 Highway Capacity Manual. Values from the 1994 manual can be used. See Figure 52 which shows the default values.

iv. Unsignalized - default values are from 1985 Highway Capacity Manual. Values from the 1994 manual can be used. See Figure 53 which shows the default values.

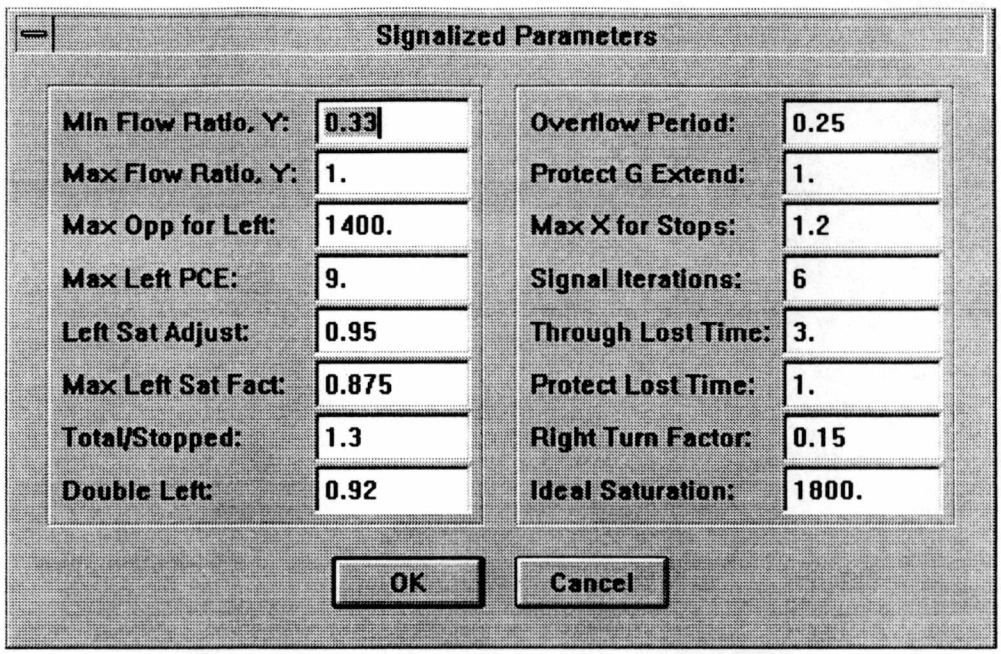


Figure 52 - QRS Traffic Assignment Signalized Parameters

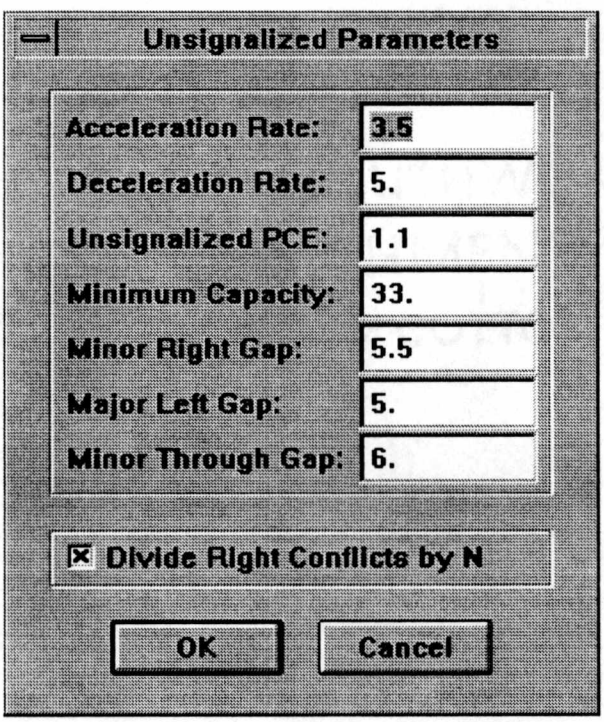


Figure 53 - QRS Traffic Assignment Unsignalized Parameters

v. All-way Stop - default values are from 1985 Highway Capacity Manual. Values from the 1994 manual can be used. See Figure 54 which shows the default values.

vi. Metered Ramp - default values are from 1985 Highway Capacity Manual. Values from the 1994 manual can be used. See Figure 55 which shows the default values.

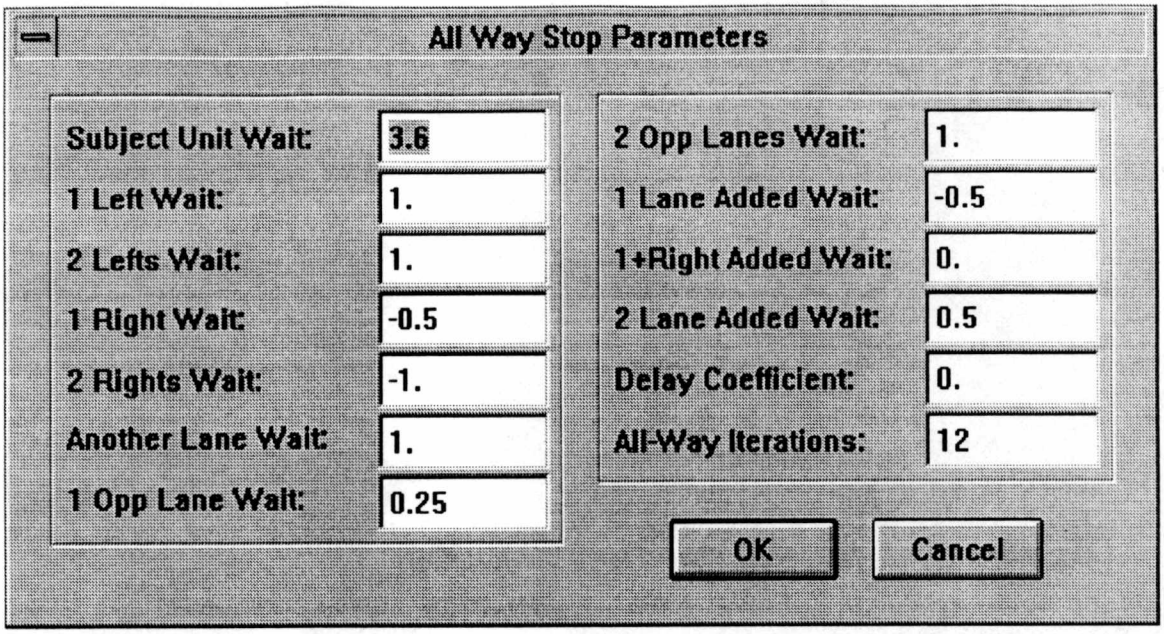


Figure 54 - QRS Traffic Assignment All Way Stop Parameters

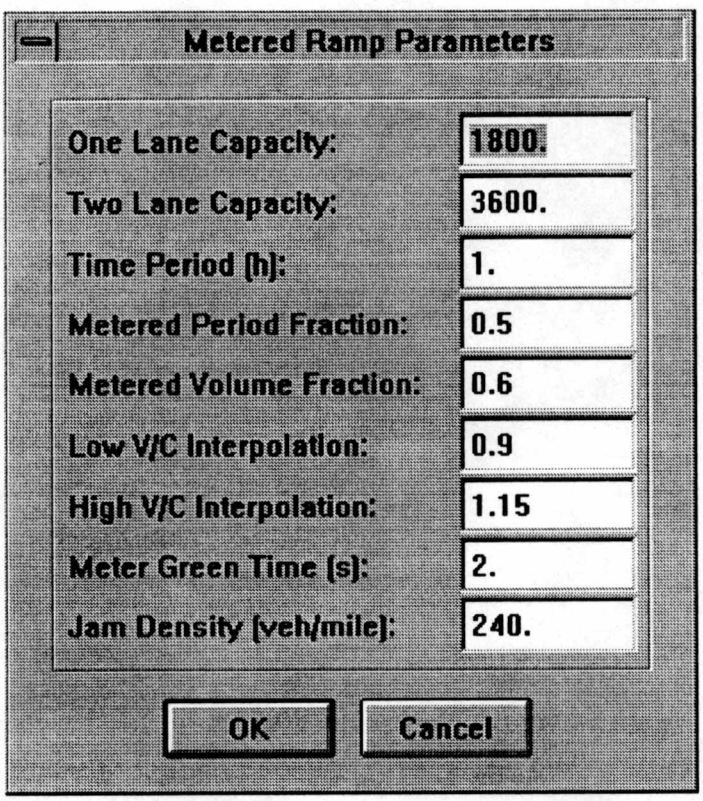


Figure 55 - QRS Traffic Assignment Metered Ramp Parameters

Chapter 5 - Case Study - Blount County, Tennessee

This case study describes how a QRS II traffic forecasting model was developed for Blount County, Tennessee. This study was based on the data and network that was developed for the Knoxville Urban Area Metropolitan Planning Organization for transportation planning purposes. The original study was coded in MINUTP, a travel demand forecasting software that is developed by Comsis Corporation. In 1990, the population of Blount County was 85,969. The base year for the model was 1996 and the future years were 2005, 2010, and 2020. This chapter will highlight the application of QRSII discussed in Chapter 4 to the planning principals discussed in Chapter 3.

Geographic Data

The Planning Area

The planning area for this case study includes all of Blount County, Tennessee. This whole county area was chosen because forecasts were being made for the next twenty years and that most of the county will be developed by that time. Other reasons for including the entire county is that there is a major tourist destination in the county, the Great Smoky Mountains National Park, and it serves as a bedroom community for Knoxville, Tennessee. See Figure 56 which shows the Blount County Area.

Traffic Analysis Zone Boundaries

The traffic analysis zones used in the case study are the same as those used by the Knoxville Urban Area Metropolitan Planning Organization. There are 90 traffic analysis

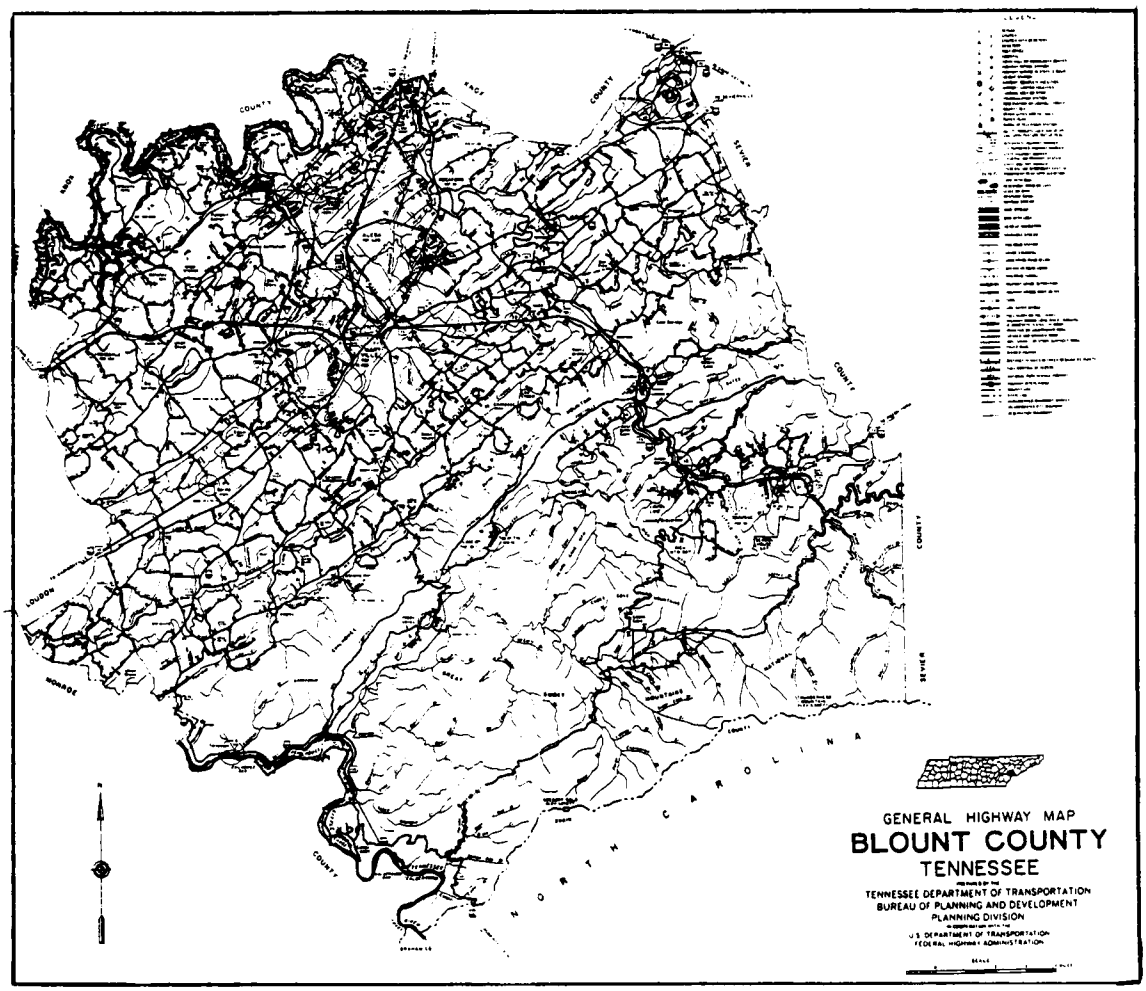


Figure 56 - Blount County, Tennessee

zones in the county. The census tracts that are set by the United States Census Bureau, were used as boundaries for the zones. Several zones were set within each census tract and no zone is split into more than one census tract. The boundaries of census tracts are roadways, power lines, railroads, and natural boundaries such as waterways and mountain ridges. Some of the roadways that are classified on the Blount County 2005 Thoroughfare Plan, 1990, were used as boundaries within the census tracts. See Figures 57 and 58 for traffic analysis zones in Blount County and Maryville and Alcoa. A reason for using the census tracts as boundaries for the zones is that data is available by census tract and it is easily accessible from the United States Census Bureau.

Centroids

The centroids used in the case study are the same as those used by the Knoxville Urban Area Metropolitan Planning Organization. These are based on development prior to the 1990 census. The coordinates for each of the centroids were taken from the coordinate file from the MINUTP network.

The centroid coordinates were plotted in GNE with the node plot action. They were then labeled as centroids and named with their respective numbers (i.e. 1 to 89).

Centroid Connectors

Some of the centroid connectors used in the case study are the same as those used by the Knoxville Urban Area Metropolitan Planning Organization and others were modified. If

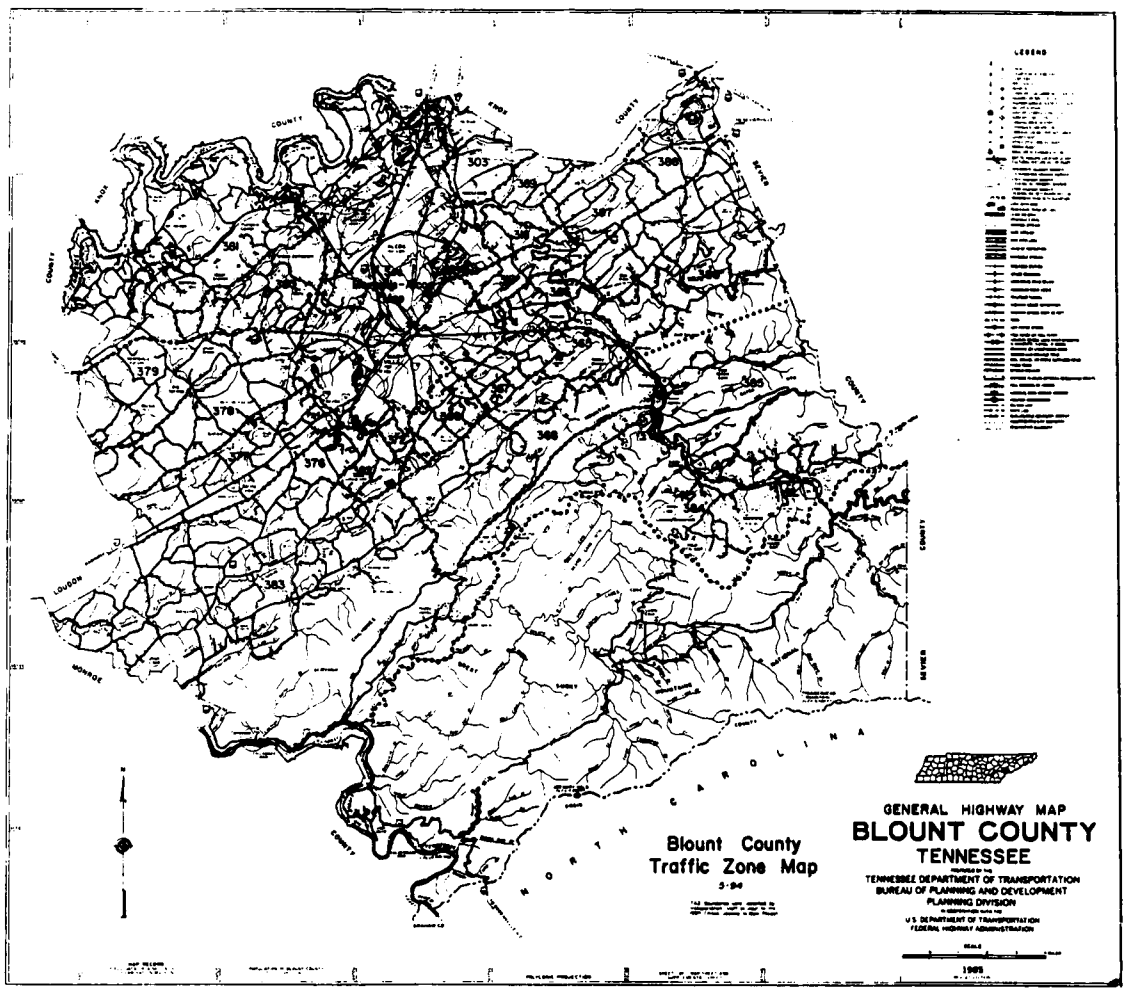


Figure 57 - Traffic Analysis Zones in Blount County

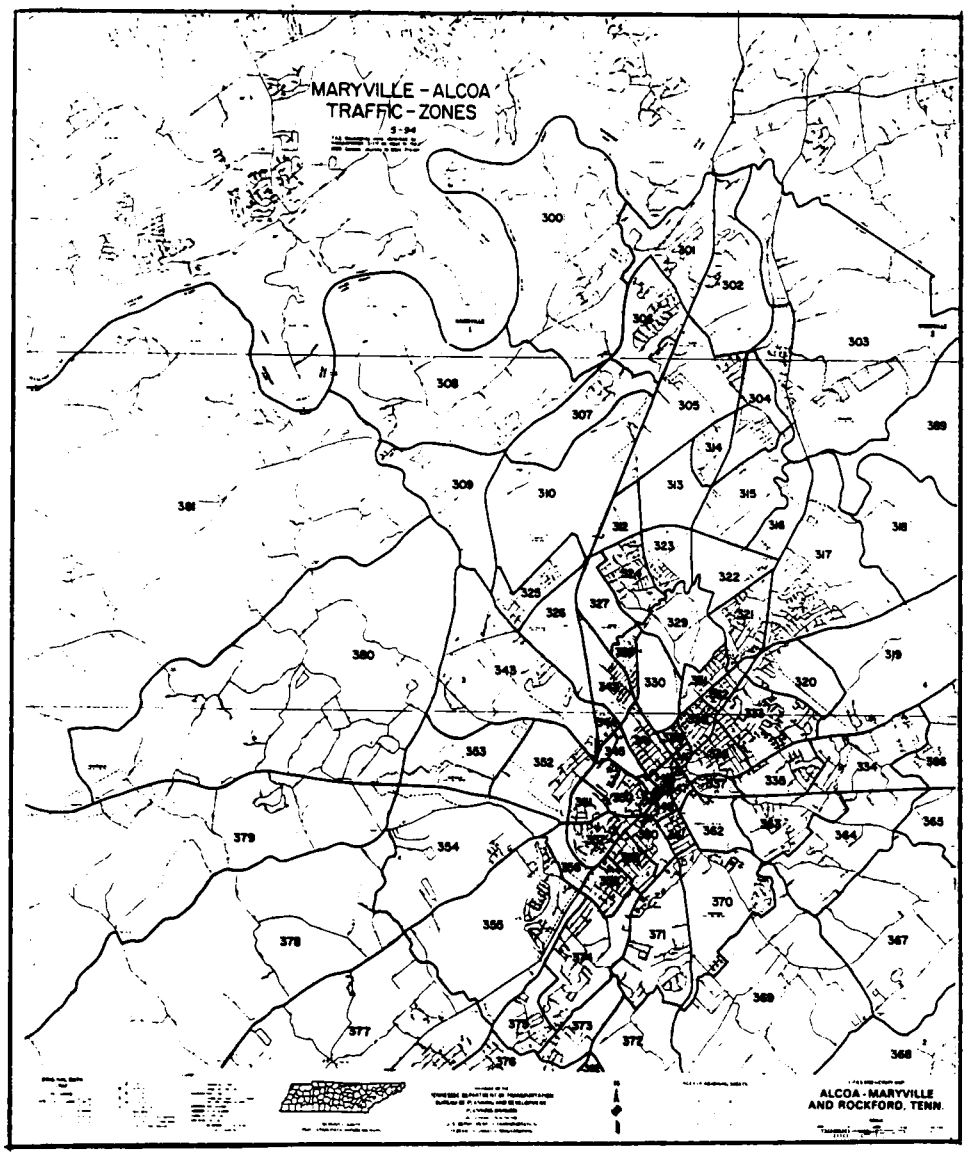


Figure 58 - Traffic Analysis Zones in Maryville and Alcoa

the original centroid connector intersected at an intersection of roads, it was moved so that the turning movements at that intersection were not skewed. The coordinates of where the centroid connector intersected with the roadway system were taken from the coordinate file from the MINUTP network.

Roadways to Include and Data Requirements

All existing roadways in the 2005 Thoroughfare Plan for Blount County are included in the case study, see Figures 59 and 60 which show these roadways for the county and the Cities of Alcoa and Maryville, respectively. These roadways were defined by the Knoxville Urban Area Metropolitan Planning Organization as Interstate, Major and Minor Arterials, and Major and Minor Collectors. Also included in this case study is the one-way pair system in downtown Maryville. This one-way pair was represented by a six lane facility in the study by the Knoxville Urban Area Metropolitan Planning Organization. However, in the case study, the roads are represented as one two-way street and two one-way two-lane streets.

The data that was used by the Knoxville Urban Area Metropolitan Planning Organization for the roadways was used in the case study. This data included speeds, functional classification, capacity, and where data is available, travel times on the links. Travel time studies were conducted on the roadways in Blount County that had daily traffic

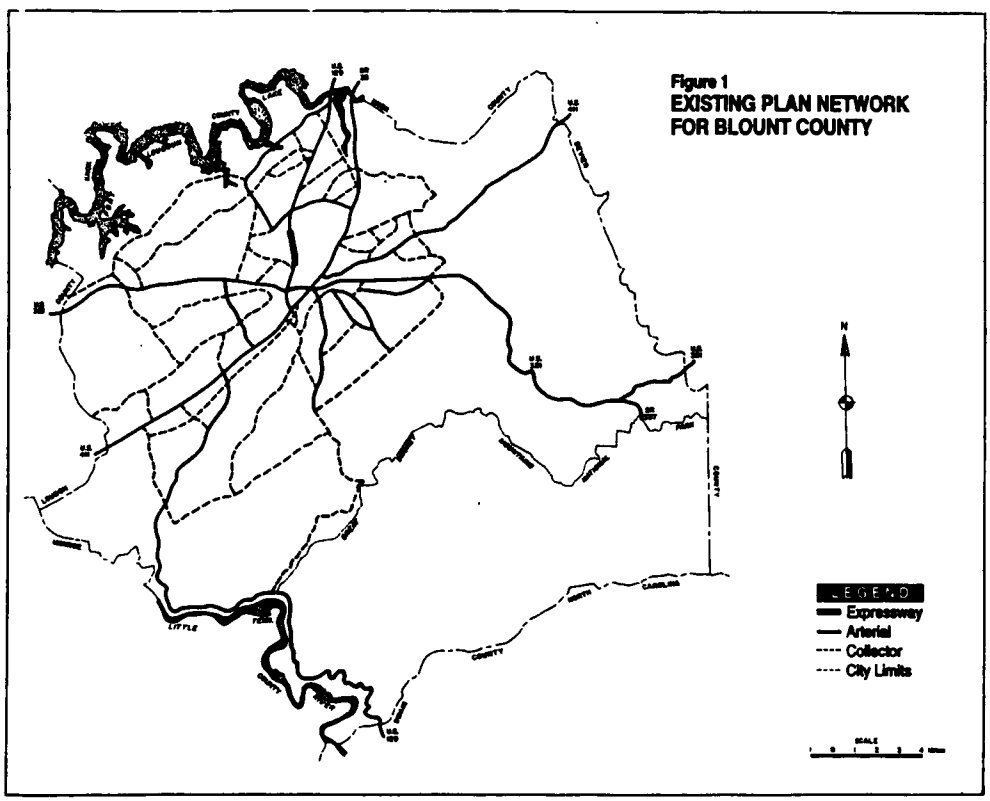


Figure 59 - 2005 Thoroughfare Plan for Blount County (Knoxville Urban Area Metropolitan Planning Organization)

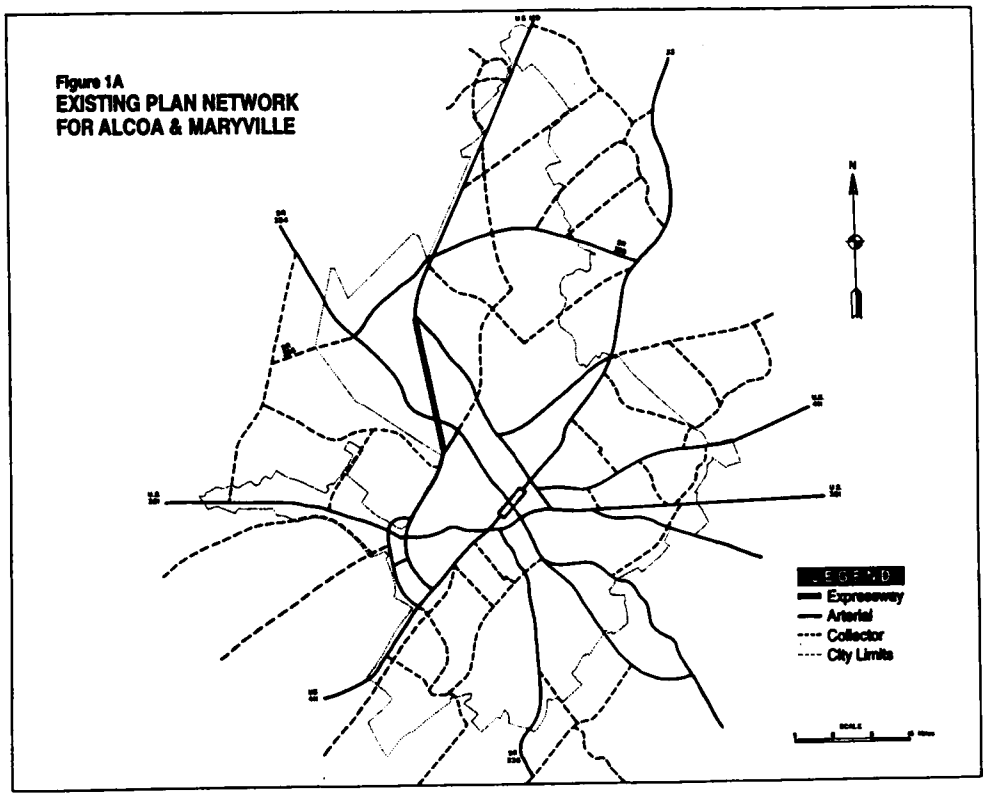


Figure 60 - 2005 Thoroughfare Plan for Maryville and Alcoa (Knoxville Urban Area Metropolitan Planning Organization)

volumes higher than 10,000. The geometric data at the intersections, such as the traffic control device and the number of left turn, through, and right turn lanes, was noted via field studies.

The link data from the MINUTP model was used as a basis for the attributes of the links in the General Network Editor. The links were plotted after all of the coordinates of the nodes were plotted. Link data was entered in conjunction with node data.

Types of Intersections to Include and Data Required

All signalized intersections and STOP controlled intersections along the roadways that were used were included in the case study. The entrance and exit ramps for Pellissippi Parkway at Alcoa Highway and Topside Road were also included. All of the coordinates of the points of intersections of roadways were taken from the MINUTP network file.

At signalized intersections, the cycle length and permitted U-turns were included. No other data was included for through and turning movement adjustments or minimum unsignalized capacity.

Current Socio-Economic Data

Dwelling Units

For the modeling process for Blount County, the 1990 data from the United States Census Bureau's Census Transportation Planning Package by traffic analysis zone was

used as base data. The population was 85,969. In the cities of Alcoa and Maryille, building permit data was collected for years 1990 through 1996. Then these building permits were sorted by traffic analysis zone and counted. They were then added to the 1990 base data. In the "county" portions (non-city), the recorded plats for subdivisions were reviewed for the number of lots created. The lots created were then sorted by traffic analysis zone and counted. These plats only accounted for ninety percent of the subdivisions in the county so the total lots created for each traffic analysis zone were increased by ten percent (Lamb). Then these lots created by traffic analysis zone were added to the 1990 base data. Commercial properties were not added in the total lots created. The only problem with using the lots created data is that some lots may have never been developed and others may have been developed with more than one dwelling unit. See Table 19 for an example that shows how the building permits and lots created were added to the 1990 data. This figure shows data for ten of the 90 traffic analysis zones.

The dwelling unit data was entered in General Network Editor in the attributes for centroid connectors.

Auto Ownership and Income

In Blount County the average auto ownership for each census tract was found from the decennial 1990 census in the publication 1990 Census of Population and Housing. The average auto ownership for each traffic analysis zone used was the average for the census

Table 19 - Dwelling Unit Data for Selected Ten Traffic Analysis Zones in Blount County

TAZ	1990 *	1991 *	1992 *	1993 *	1994 *	1995 *	Dwelling Units to be Added to 1990 Dwelling Units	1990 Base Dwelling Units	1996 Total Dwelling Units
1	0	0	0	0	2	0	2	746	748
2	0	0	0	0	0	0	0	1,261	1,261
3	0	0	0	0	0	4	4	1,296	1,300
4	0	1	0	0	0	0	1	495	496
5	0	0	0	0	0	0	0	342	342
6	1	0	0	0	0	0	1	858	859
7	0	93	1	0	0	0	94	477	571
8	1	0	0	3	18	0	22	1,336	1,358
9	0	0	0	2	0	0	2	499	501
10	0	1	0	0	0	0	1	196	197

* - Lots Created with 10% Increase and Building Permits Issued during the Year

tract within which it lies. It was assumed that the auto ownership ratio for 1996 was the same as for 1990 since no trend data is easily accessible.

Like the auto ownership data, income is only available by census tract for Blount County. The data for each traffic analysis zone is the same as the census tract in which it lies. This data is available in the decennial census by census tract. Since 1996 was used as the base year and no data for 1996 was available, the 1990 data was used and converted to 1980 dollars using the consumer price index because QRSII requires 1980 income data. An example of how the calculations were performed are as follows:

1980 Income = 1990 Income*(1980CPI)/(1990CPI), where

1980 Income = Average income in 1980 dollars

1990 Income = Average income in 1990 according to Census data

1980 CPI = Consumer Price Index in 1980

1990 CPI = Consumer Price Index in 1990

Example:

Given: The 1990 average income for census tract 103 was $29,805. The 1980 and 1990 Consumer Price Indices were 246.8 and 391.4, respectively.

Solution:

1980 Income = $29,805*246.8/391.4

1980 Income = $18,794

The Quick Response System software requires either auto ownership or income data. Therefore, a choice needed to be made for which data to use. It was determined that auto ownership be used instead of income based on the fact that income may be more difficult to forecast.

The auto ownership data was entered in the General Network Editor for each centroid in its attribute menu.

Employment

Unfortunately, no data was found for the Blount County on a census tract level. The best data that is available was for the major employers such as ALCOA, Denso, the McGhee Tyson Airport, and etc. from the Blount County Industrial Board. Each of the major employers and the number of employees were placed into traffic analysis zones. Other sources of employment were school district offices, local government offices, and newspaper articles. Employment figures for the schools and administrative offices were obtained from each school district. The schools and administrative offices and the total numbers of employees were placed into traffic zones. The number of employees by location for each of the local government offices were obtained from the cities of Alcoa and Maryville. Each of the offices and the total numbers of employees were placed into

their respective traffic zones. Each of these three types of data were both mapped by traffic analysis zone and were input into a spread sheet.

The Tennessee Department of Employment Security has information that shows the number of jobs available by county. The total number of employees was available for 1990 to 1995 but not for 1996. A regression analysis was done to get of slope and intercept for a straight line so that 1996 employment could be projected. This regression analysis was done with a spreadsheet, Excel. See Table 20 for the example.

In order to get a count for employment by zone, each of the major employers were identified and jobs counted. Then, a zone by zone drive by was used to estimate the total number of other jobs. That is, while driving along a road, a tape recorder was used to name each place of business as well as cross roads. Then each business was placed into its respective traffic analysis zone. From there, estimates were made for each business for the total number of employees. The estimates were based on calling certain businesses, such as a car dealership, grocery store, hotel and small business. These businesses were divided into retail employers and non-retail employers. Then the totals for the estimates were added together for each zone. Table 21 shows what a typical list from a drive-by would show.

After all businesses were documented, they were aggregated by traffic analysis zone and total numbers of retail and non-retail employees were calculated. The numbers of

Table 20 - Regression Data Used for Predicting 1996 Employment

Year Number	Year	Total Employees
1	1990	23,821
2	1991	24,973
3	1992	26,471
4	1993	26,927
5	1994	23,779
6	1995	29,172
7	1996	?
From Regression Analysis:	Y intercept = 23,494	Slope = 675
	1996 Employment =	675(7)+23,494
	1996 Employment =	28,219

Table 21 - Employment Estimate Example for a "Drive-By" of an Area

Business/Cross Road	Traffic Analysis Zone	Non-Retail Employee Est.	Retail Employee Estimate
William Blount Drive			
Smoky View Quick Stop	79		20
Oasis Garden Center	54		40
Old Glory Road			
Day Care Center	54	14	
Lowes	54		80
Party Center/Wall Paper Plus	54		30
Tractor Supply Company	54		25
First Tennessee Bank	54		10
Ben Atchley Road			
Foothills Mall Drive			

employees were estimated by calling the number of businesses. These were then added to the other major employers, schools, and government offices. See Tables 22 and 23 which show how spreadsheets were set up to determine retail and non-retail employment, respectively. The total number of employees was calculated by adding the employment figures for each traffic analysis zone. After a comparison was made between the "estimated" number and the "predicted" number changes were made so that the estimated number would be equal to the predicted number. The numbers of employees were increased or decreased from the estimates in some zones where it was legitimate to add or decrease employees because of over or under estimating.

The retail and non-retail employment was coded into the General Network Editor for each centroid in its attribute menu.

Special Generators

The only special generator in Blount County that was used is the McGhee Tyson Airport. The total number of employees for the airport is a known variable. The ITE *Trip Generation 5th Edition* was used to determine the number of trips generated by the airport. From there productions and attractions were determined. The number of employees is estimated to be 1,500 and the average weekday trip ends by the number of employees is 13.40. The 1,500 employees includes the actual airport and others such as United Parcel Service and FedEx. The total weekday trip ends would be 20,100 (1,500 employees * 13.40 weekday trip ends per employee). These trips would be attractions

Table 22 - Employment Estimation - Calculations of Retail Employment by Traffic Analysis Zone

TAZ	Grocery Stores	Restaurants	Shopping Center	Convenience Market	Auto Dealer	Other	1996 Base Retail Employment
1		20		30		14	64
2				25		25	50
3				20			20
4							0
5		100		50	300		450
6		50			200		250
7							0
8							0
9				10		5	15
10	20	50		5			75

Table 23 - Employment Estimation - Calculations of Non-Retail Employment by Traffic Analysis Zone

TAZ	Schools	Major Employers	Industrial Parks	Field Work/ Other	1996 Base Non-Retail Employment
1				10	10
2	8	465		35	508
3		300	103	5	408
4			102	35	137
5			490	697	1,187
6		300		171	471
7				15	15
8				85	85
9				15	15
10		3,000		1,160	4,160

because the airport is a "work" place. Also, the trips need to be converted to person trips. The vehicle occupancy listed in the trip generation manual ranged from 1.79 to 2.42. It was assumed that the vehicle occupancy was the average of this range, 2.1. This occupancy was used because there is no known occupancy rates for the airport. Therefore, the total number of attractions used for the airport was estimated to be 42,310 (20,100 * 2.42). This total was split evenly for the three trip purposes.

A node was plotted and defined as a production/attraction tag where the airport exists. This tag was attached to centroid 10 (which is coded as a Special Generator Centroid) with a piece of string and the attractions were added in the attributes menu. The number of employees that was used to determine the number of attractions for the airport was subtracted from the non-retail employees in the zone. See Figure 61 which shows the special generator that was plotted in the General Network Editor.

Socio-Economic Data Projections

Dwelling Units

The method used to project dwelling units was to average the number of building permits issued per year and the number of lots created per year by traffic analysis zone. This average was multiplied by the number of years from the base year to the projected year and then added to the base year's number of dwelling units. For example, looking at

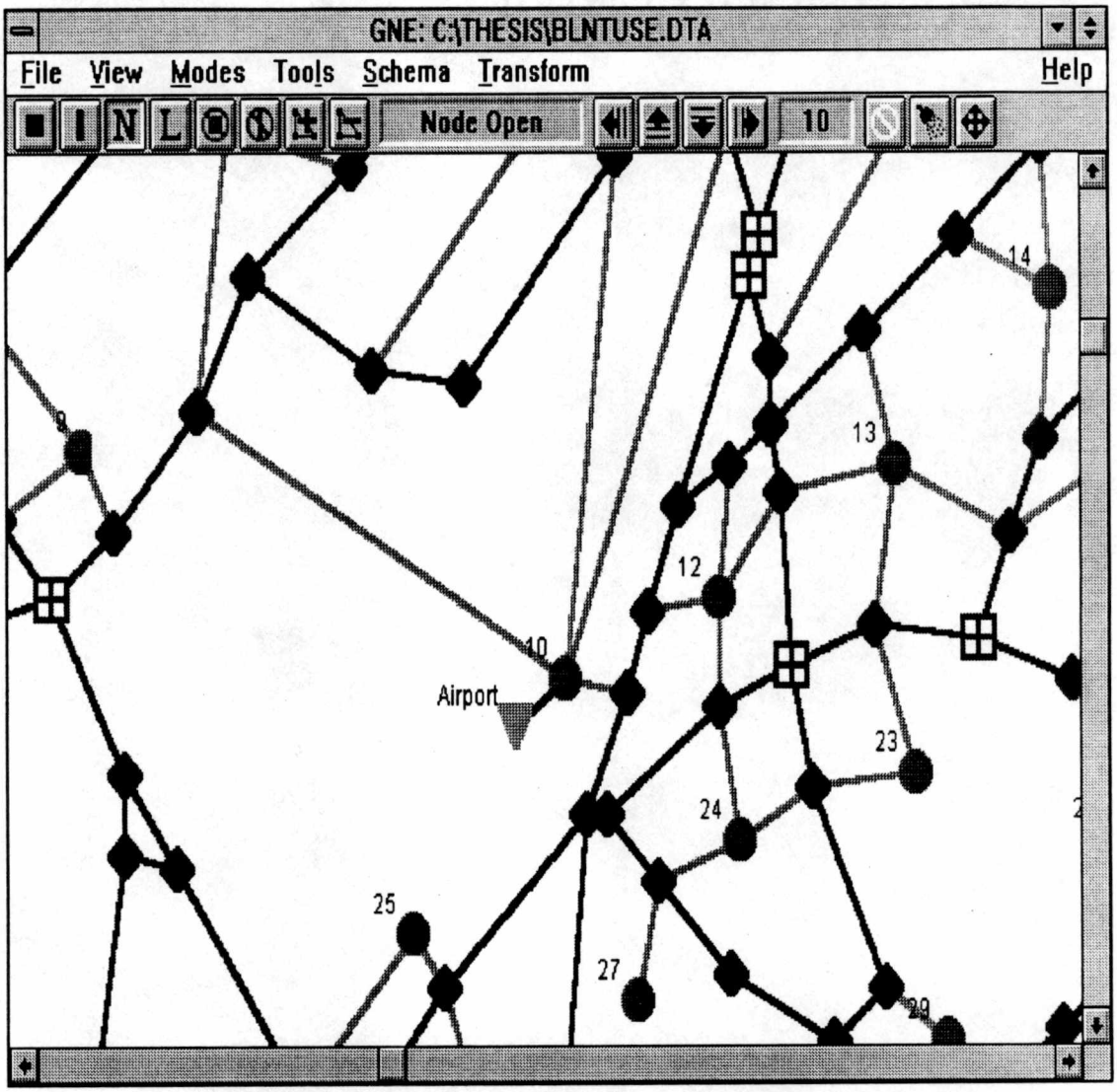


Figure 61 - Airport Production/Attraction Tag Connected to Special Generator Centroid

Table 19, the rate of development for traffic analysis zone 8 is 22 dwelling units in 6 years. That is 22/6=3.67 dwelling units per year. In 2005, the development is estimated to be 33 (9*3.67) additional dwelling units. The projection for 2005 is 1,391 (1358+33).

After projections were made for all zones, the total number of dwelling units was calculated. For checks and balances, the number of dwelling units was multiplied by 2.35 which is the average number of persons per household as taken from the 1990 census. The number calculated was an estimate of the population. This population estimate was then compared to population estimates from the Blount County Planning Department for the future years of 2005, 2010 and 2020. The population estimates were within five percent so the total number of dwelling units was considered realistic. After the total number of dwelling units was considered valid then the amount of development activity in each zone was analyzed. The number of added dwelling units in each traffic analysis zone was compared to the vacant land available and future land use. If a zone had a high development activity level in the past six years, then that trend would be the same for the next twenty years. In some zones it is not possible for this type of trend to continue because the zone is currently built-out or a different type of land use is planned. A different type of land use could be an industrial park or commercial center. An example of where there was very high yearly growth and the area is built-out is the area surrounding Eagleton Elementary School (traffic analysis zone 317). Therefore, the trend of high growth would not continue into the future and the growth rate was reduced.

At the opposite extreme, where there was very small growth but a lot of vacant land (traffic analysis zone 380) the growth trend should be increased. If changes are made to any of the zones, the changes should be documented. The total number of dwelling units should not change.

Auto Ownership/Income

The rate of auto ownership was determined to remain constant throughout the future time frame. Therefore, no changes were made in this category. The income level was not used in the modeling process, so no projections were made.

Employment

The total employment trend was found by using the data that was provided by the Tennessee Department of Employment Security. The trend that was established by straight line method for the 1996 base data was used for employment projections for 2005, 2010, and 2020 projections. See Table 24 which shows the projections.

The total projections were then split into retail and non-retail employment. That is, the same ratio of retail employment to total employment and non-retail employment to total employment were used. From there zonal employment was estimated based on the zone's 1996 employment to total 1996 employment (i.e. future employment/zone = 1996 total employment * future total employment / 1996 employment/zone). These projections were then compared to future land uses in the traffic analysis zones and any

Table 24 - Total Employment Projections for 2005, 2010, and 2020

Year Number	**Year**	**Total Employees**
1	1990	23,821
2	1991	24,973
3	1992	26,471
4	1993	26,927
5	1994	23,779
6	1995	29,172
7	1996	?
16	2005	?
21	2010	?
31	2020	?
From Regression Analysis:	Y intercept = 23,494	Slope = 675
	1996 Employment =	675(7) + 23,494
	1996 Employment =	28,219
	2005 Employment =	675(16) + 23,494
	2005 Employment =	34,294
	2010 Employment =	675(21) + 23,494
	2010 Employment =	37,669
	2020 Employment =	675(31) + 23,494
	2020 Employment =	44,419

plans by major employers or industrial parks. Where employment figures were low and there were plans to development and industrial park (TAZ 380), additional employees were added. Then in areas where there was high employment, such as in the ALCOA South Plant (TAZ 330), the employment projections were lowered. See the following examples for further clarification:

Example:

Given: The base 1996 non-retail employment in TAZ 380 is 68, there is no retail employment, the total non-retail employment in 1996 is 22,328. The projected non-retail employment is 35,170 for 2020. The county has an industrial park planned in this TAZ that should be fully developed by 2010 and approximately 700 employees would be working there. Find the 2020 employment.

Solution:

Projection strictly based on the equation:

FEMPtaz = 68*35,170/22,328

68*1.58

107 employees in TAZ 380, however

A good estimate would include 700 + 107 = 807 employees. Because the 700 employees were added in this TAZ, then 700 non-retail employees needed to be taken from a zone where there would not be much employment growth. See next

example.

Example:

Given: The base 1996 non-retail employment in TAZ 330 is 905, there is no retail employment, the total non-retail employment in 1996 is 22,328. The projected non-retail employment is 35,170 for 2020. The industrial use (ALCOA) in this zone is has no plans for expansion and the remainder of the zone has many development barriers such as lack of transportation facilities and creeks and wetlands. Find the 2020 employment.

Solution:

Projection strictly based on the equation:

FEMPtaz = 905*35,170/22,328

905*1.58

1,425 employees in TAZ 330, however

This estimate was too high because there are no plans to increase the number of employees, therefore, there should be no increase in the number of employees. The 2020 employment should remain at 905 and the additional 521 employees should be placed in other zones such as TAZ 380 in the previous example.

While making these changes in the forecasted number of employees on a traffic analysis

zone basis, the total number of employees did not change. All changes that were made were noted and discussed with agencies such as the Blount County Industrial Board.

Special Generators

The McGhee Tyson Airport remained the only special generator in the future. The plans for the airport were consulted for growth projections and expansion in the future.

External Trips

All of the data used for the external trips are based on the average daily traffic at the external stations. This data was available from the Tennessee Department of Transportation and the Knoxville-Knox County Metropolitan Planning Commission. Both of these agencies are responsible for conducting yearly counts.

External to External Trips

For the Blount County model, the external to external trips at the external station were calculated by using the percentages from the current NCHRP Report 187. The 1996 population of Blount county is estimated to be very close to 100,000 therefore, the through trips were estimated to be 15% of the total average daily traffic at the external station. See Table 25 which shows the average daily traffic at each external station and the number of trips that are estimated to be through trips.

Table 25 - Blount County External to External Trips

External Station	Average Daily Traffic	Estimated Through Trips*
91	8,800	1,148
92	8,100	1,057
93	22,400	2,922
94	49,500	6,456
95	5,900	770
96	3,000	391
97	5,800	757
98	5,500	717
99	600	78

* ADT = External Trips * (1+proportion of through trips)
External Trips = ADT/(1 + 0.15)
External Trips = ADT/1.15
External to External Trips = External Trips * 0.15

The external to external trips were distributed from the origin station to the destination station by using the following equation:

$$Yij = ADTi * (ADTj/\Sigma ADT\text{-}ADTi), \text{ where}$$

Yij = through trips from origin external station to destination external station,

ADTi = the average daily traffic at origin external station,

ADTj = the average daily traffic at destination external station,

ΣADT = the sum of average daily traffic of all external stations,

A trip table was made and was entered into the ADDTRIPS.TXT file under home based work trips. See Table 26 for the trip table and Appendix B for the ADDTRIPS.txt file.

External to Internal Trips

The number of trips at the external station that are external to internal trips were calculated by using the following equations from the NCHRP 187 manual:

ADT = External Trips * (1 + proportion of through trips)

External Trips = ADT/(1 +proportion of through trips)

External Trips = ADT/1.15

External to External Trips = External Trips * 0.15

Internal to External Trips = ADT - 2(External to External Trips)

Table 26 - External to External Trip Distribution for Blount County Case Study

Origin Zone	Destination Zones								
	391	**392**	**393**	**394**	**395**	**396**	**397**	**398**	**399**
391	-	92	295	945	65	32	64	61	6
392	92	-	271	870	60	30	59	56	6
393	255	233	-	2406	166	82	163	154	16
394	564	515	1659	-	367	182	361	341	36
395	67	61	198	634	-	22	43	41	4
396	34	31	101	322	22	-	22	21	2
397	66	60	194	623	43	21	-	40	4
398	63	57	184	591	41	20	40	-	4
399	7	6	20	64	4	2	4	4	-

Table 27 shows the ADT and the number of trips that are external to internal/internal to external by external station.

The external to internal trips needed to be converted to productions and attractions by trip purpose. The MINUTP model did not convert these by the three trip purposes, home-based work, home-based non-work, and non-home-based and no origin to destination data exists for the past 30 years. These trips were converted to productions and attractions based on Table 28. This table is based on a non-centralized population which Blount County would be considered.

Table 29 shows the productions and attractions by trip purpose for external station 91.

The external to internal trips were coded in the General Network Editor at the external stations in the attributes menu, the productions and attractions by trip purpose.

External Trip Projections

The average daily traffic counts for several years were used to develop a trend for forecasting future average daily traffic counts. After the projections were made, the same method for estimating external to external and external to internal trips was used. See Table 30 which shows how the projections for 2005, 2010, and 2020 were made for external station 91.

Table 27 - External to Internal Trips for Blount County

External Station	Average Daily Traffic	Estimated Through Trips*	External to Internal Internal to External
91	8,800	1,148	6,504
92	8,100	1,057	5,986
93	22,400	2,922	16,556
94	49,500	6,456	36,588
95	5,900	770	4,360
96	3,000	391	2,218
97	5,800	757	4,286
98	5,500	717	4,066
99	600	78	444

Table 28 - External to Internal Trip Percentages by Trip Purpose

Trip Purpose	Resident (Productions)	Non-Resident (Attractions)	Total
Home-Based Work	15%	10%	25%
Home-Based Other	27	23	50
Non-Home-Based	8	17	25
Total	50	50	100

Table 29 - External to Internal Trips by Trip Purpose for External Station 91

Trip Purpose	Productions	Attractions
Home-Based Work	976	650
Home-Based Other	1,756	1,496
Non-Home-Based	520	1,106
Total	3,252	3,252

Table 30 - Average Daily Traffic Projections at External Station 91

Year	Count	Projection
1985	6860	
1986	7160	
1987	8390	
1988	7410	
1989	8070	
1990	8700	
1991	7890	
1992	7270	
1993	9300	
1994	10830	
1995	8780	
1996	8800	
	slope = 207.1	Intercept = -404,009.6
2005		11,292
2010		12,327
2020		14,399

Calibration

After all error messages were cleared during the "run" process with Quick Response System, the calibration process was started. Corridors were selected to compare estimated traffic volumes to actual average daily traffic. The goal was to have at least one half of the links where ground counts exist, have estimated traffic volumes within ten percent of the average daily traffic. Where estimated volumes were more than ten percent higher than average daily traffic, speeds were decreased. If the estimated volumes were greater than ten percent lower than average daily traffic, speeds were increased. The speeds that were edited were done so on a reasonable basis. That is, where the actual speed was 45 miles per hour, the range of change was between 30 miles per hour and 60 miles per hour. The volumes on the centroid connectors were also checked to see if they made sense. If the volumes loading onto the roadway network were too high or low, then the connections were moved.

All of the volume comparisons were made by looking at a map that had the average daily traffic plotted and by looking at the OUTPUT.DTA file in the General Network Editor that was created by the Quick Response System software. Changes were made to the original file and saved as version 1, 2, 3, etc. until a calibrated file was created. Each change to the network was recorded so that it was easy to trace in the event that a change could be undone.

The Quick Response System II Software

The General Network Editor

The Blount County network file that was created in the GNE is shown in Figure 62. The total time to create the file was about 40 hours. All of the nodes and links were hand entered based on the coordinate files from the MINUTP version of the Blount County network. After all nodes and links were plotted, they were named, defined and attributes were added.

The Quick Response System

The network created in the GNE was then run by using the QRS part of the software. The first 10 - 20 runs produced errors which were corrected as they appeared. The majority of the error messages were approach code errors for the through movements. The original code was 0 so that QRS could determine the code, however, because of the alignment of the roadways, the correct codes needed to be entered. After all error messages were cleared the parameters were set. See Figures 63 through 67 which show the parameters for attractions, productions, distribution, occupancy and assignment options. The default values for BPR Global, BPR Classes, signalized, unsignalized, and all-way stop parameters were used. All of the default values are listed in the users manual.

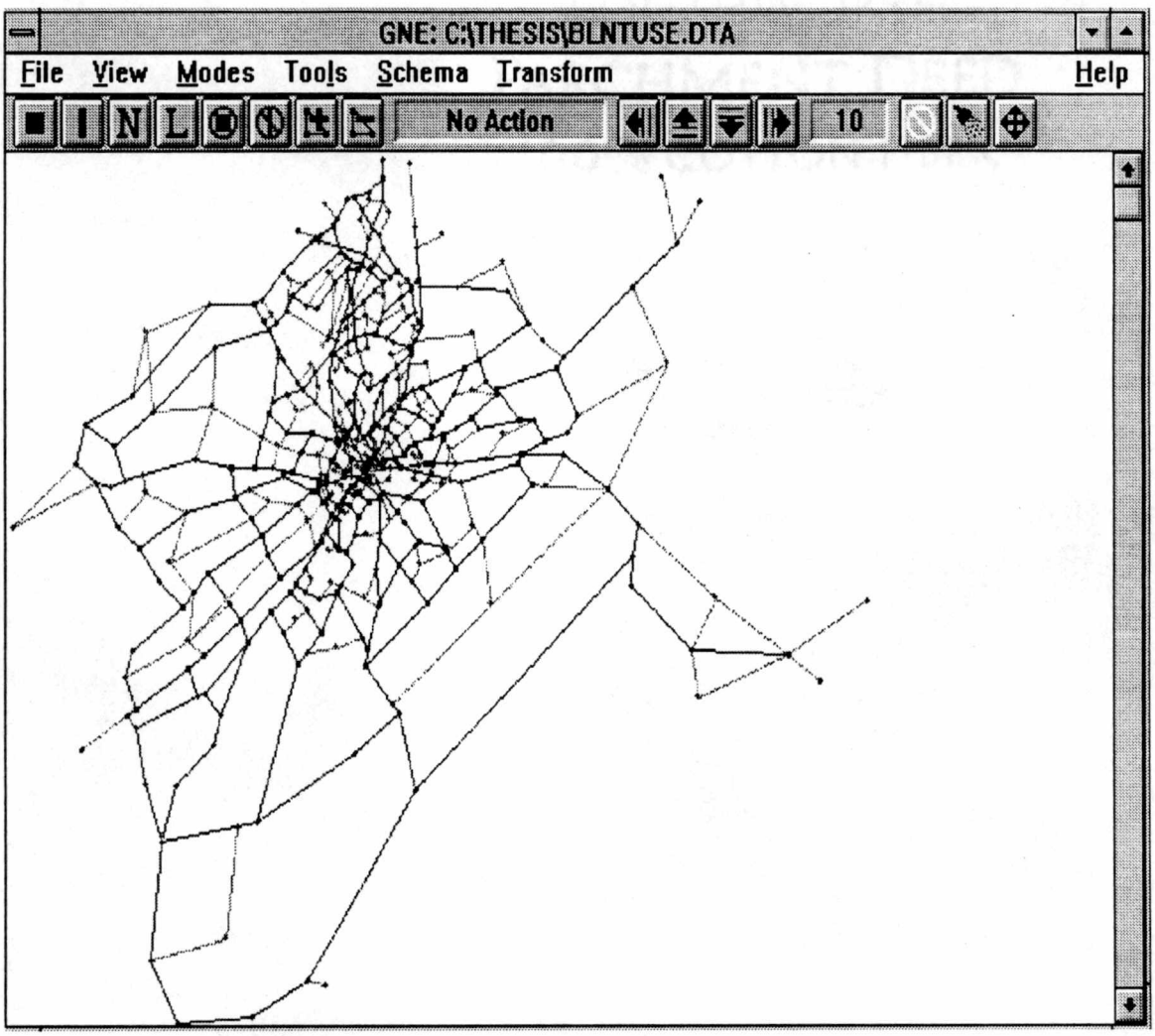


Figure 62 - Blount County GNE Network

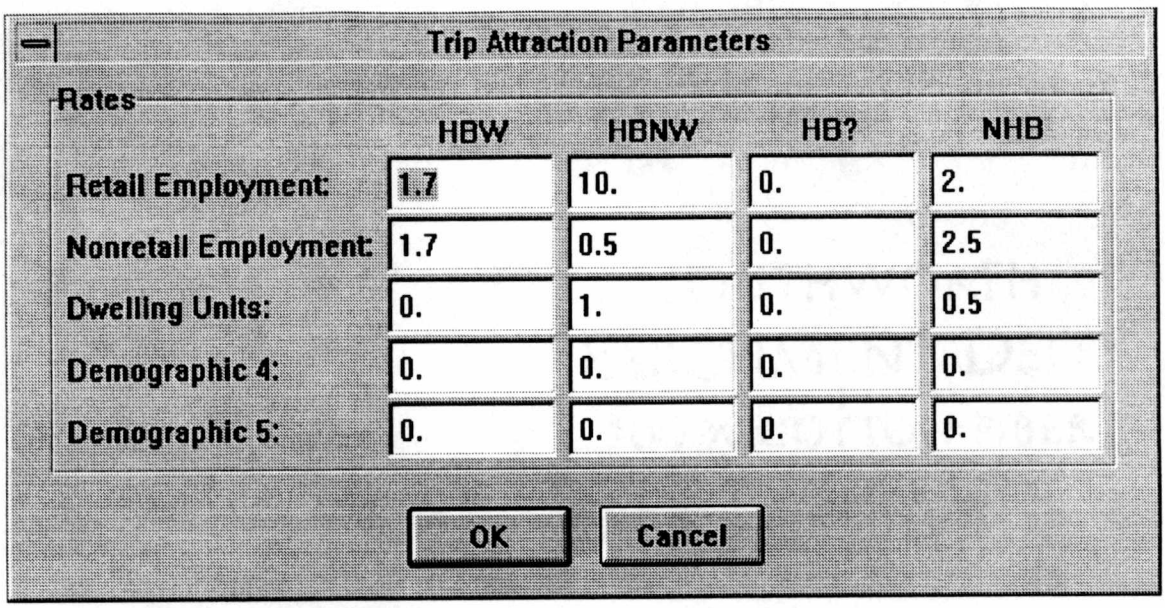


Figure 63 - Blount County Trip Attraction Parameters

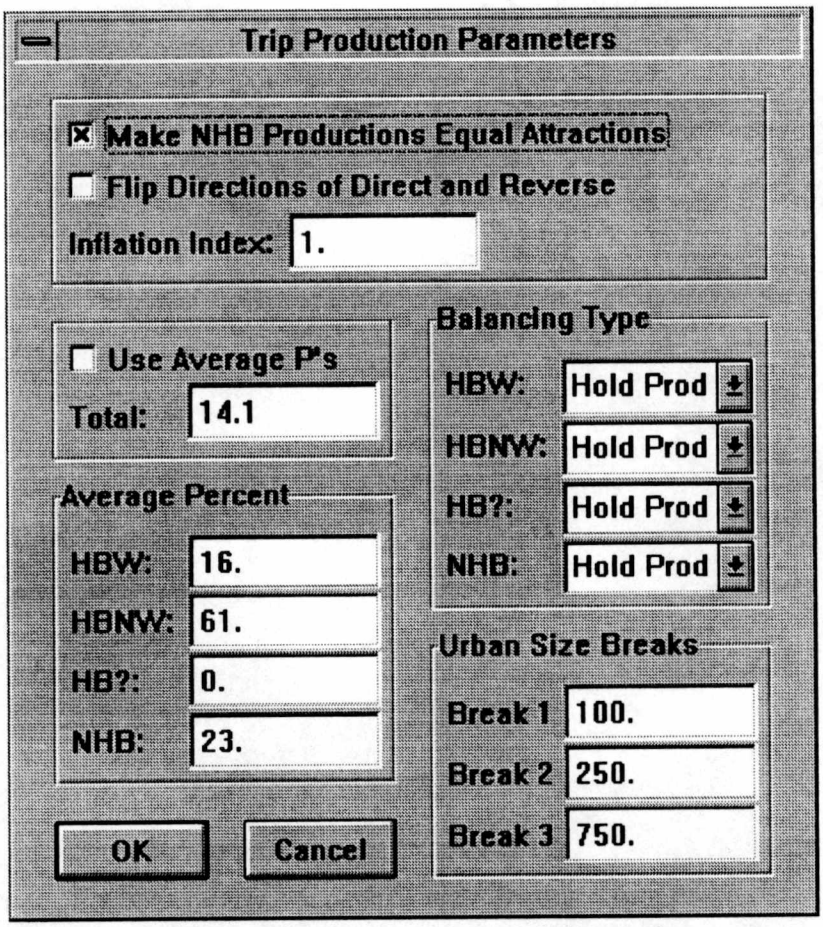


Figure 64 - Blount County Trip Production Parameters

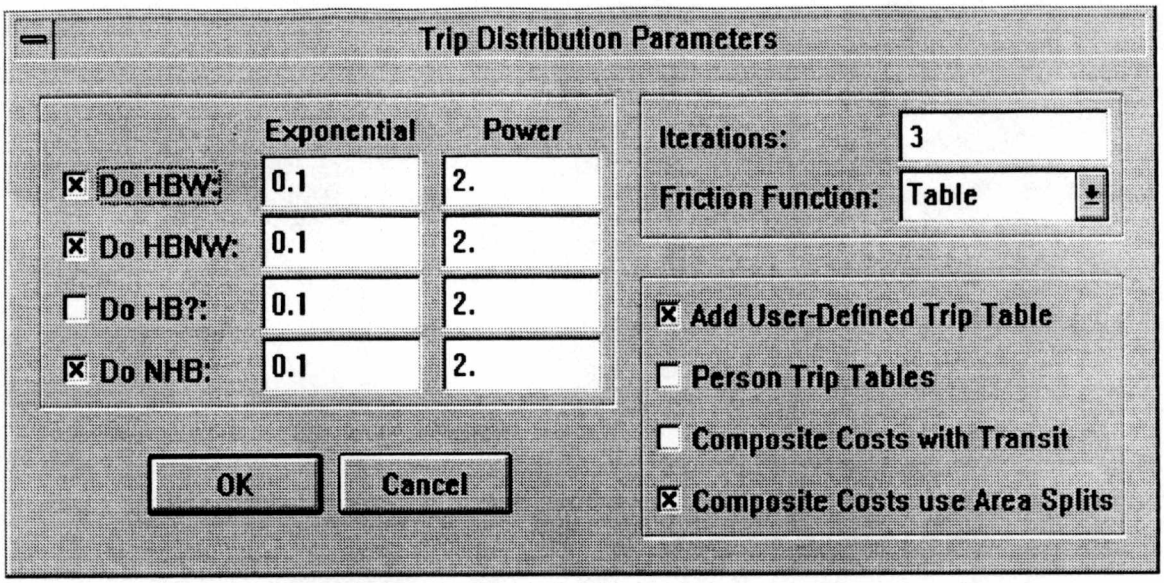


Figure 65 - Blount County Trip Distribution Parameters

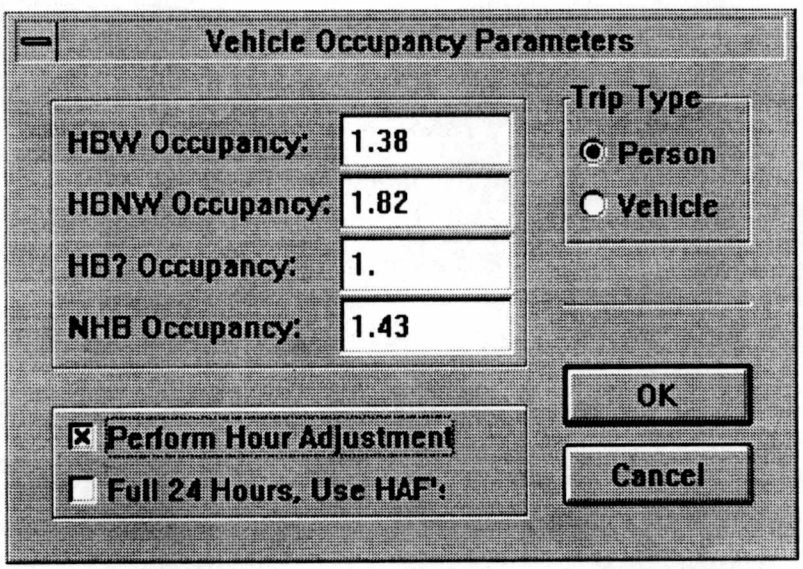


Figure 66 - Blount County Vehicle Occupancy Parameters

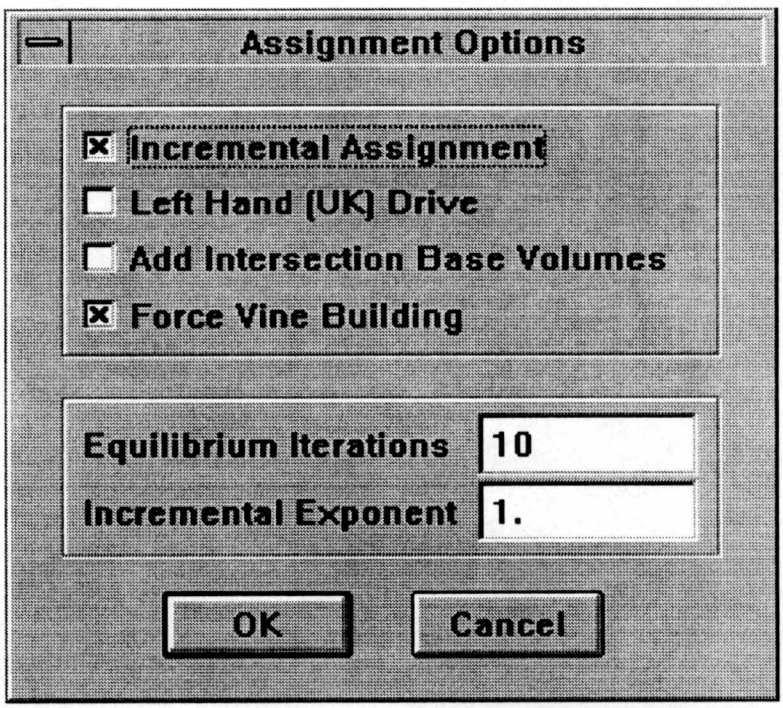


Figure 67 - Blount County Traffic Assignment Options

For traffic assignment, ten equilibrium iterations using incremental assignment was chosen as the option because it is suggested by Alan Horowitz in a workshop for travel demand forecasting using Quick Response System II software. This type of incremental assignment is known to have traffic volumes converge on links. After the first run using this assignment options, many of the links were found to have estimated traffic volumes within ten percent of the average daily traffic.

Chapter 6 - Conclusions and Discussion

The objectives of this thesis were to:

1. Outline the four step travel demand forecasting process;
2. Discuss the use of QRS II to develop a model to perform the four step traffic forecasting process; and
3. Demonstrate by specific examples how QRS II was applied to the Blount County case study.

The four step travel demand forecasting process is discussed as well as all of the input variables that are required. The input variables are based on local data from several sources. There are at least two sources of information that discuss the four step travel demand forecasting process in detail, NCHRP Report 187 and its replacement NCHRP Report 365. Both of these sources have recommended values and equations to use socio-economic data to estimate current and future travel. It is best to use locally developed values and equations if they are available so that the best estimates can be made.

Specific instructions are given for using the Quick Response System II software package that is developed by AJH Associates. These instructions include drawing a network and selecting parameters to use for running the network. Version 4 of the software is discussed, however, at the time of writing this document Version 5 became available. The input variables and parameters are nearly identical, except that default values are based on the 1994 Highway Capacity Manual. A new version of the software is in

development which utilizes the variables from the NCHRP Report 365 when published.

The methodology of developing the Blount County Case Study was discussed in detail in the document. This case study includes data collection, network building, and network running. The case study parallels the work that was done by the Knoxville Urban Area Metropolitan Planning Organization for Blount County.

By carefully incorporating good local data into a highway network and the Quick Response System II software, reasonable current and future traffic volumes can be estimated. The better the data going into the model the better the data coming out of the model. Where possible use locally established equations for the best results. When using nationally accepted values, be certain that the results reflect what is happening in the local area.

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National Highway Institute, Introduction to Urban Travel Demand Forecasting - Participant's Notebook. October 1994.

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APPENDICES

APPENDIX A

CONSUMER PRICE INDICES
1971 - 1997

5/14/98

Consumer Price Index

U.S. Department of Labor
Bureau of Labor Statistics
"Washington, D.C. 20212"

WWW.STATS.BLS.GOV/CPIHOME.HTM

All Urban Consumers - (CPI-U)

U.S. City Average

YEAR	AVG.
1971	40.5
1972	41.8
1973	44.4
1974	49.3
1975	53.8
1976	56.9
1977	60.6
1978	65.2
1979	72.6
1980	82.4
1981	90.9
1982	96.5
1983	99.6
1984	103.9
1985	107.6
1986	109.6
1987	113.6
1988	118.3
1989	124
1990	130.7
1991	136.2
1992	140.3
1993	144.5
1994	148.2
1995	152.4
1996	156.9
1997	160.5

APPENDIX B

ADDTRIPS.txt FILE FOR BLOUNT COUNTY

The data in this ADDTRIPS.txt file is from Table 26 in the text. It is the distribution of external to external trips for stations 91 thtough 99.

```
91
92
END OF ROWS
91
92
END OF COLUMNS
0.0 92.0
92.0 0.0
91
93
END OF ROWS
91
93
END OF COLUMNS
0.0 255.0
295.0 0.0
91
94
END OF ROWS
91
94
END OF COLUMNS
0.0 564.0
945.0 0.0
91
95
END OF ROWS
91
95
END OF COLUMNS
0.0 67.0
65.0 0.0
91
96
END OF ROWS
91
96
END OF COLUMNS
0.0 34.0
32.0 0.0
91
97
END OF ROWS
91
```

97
END OF COLUMNS
0.0 66.0
64.0 0.0
91
98
END OF ROWS
91
98
END OF COLUMNS
0.0 63.0
61.0 0.0
91
99
END OF ROWS
91
99
END OF COLUMNS
0.0 7.0
6.0 0.0
92
93
END OF ROWS
92
93
END OF COLUMNS
0.0 233.0
271.0 0.0
92
94
END OF ROWS
92
94
END OF COLUMNS
0.0 515.0
870.0 0.0
92
95
END OF ROWS
92
95
END OF COLUMNS
0.0 61.0
60.0 0.0
92
96
END OF ROWS
92

96
END OF COLUMNS
0.0 31.0
30.0 0.0
92
97
END OF ROWS
92
97
END OF COLUMNS
0.0 60.0
59.0 0.0
92
98
END OF ROWS
92
98
END OF COLUMNS
0.0 57.0
56.0 0.0
92
99
END OF ROWS
92
99
END OF COLUMNS
0.0 6.0
6.0 0.0
93
94
END OF ROWS
93
94
END OF COLUMNS
0.0 1659.0
2406.0 0.0
93
95
END OF ROWS
93
95
END OF COLUMNS
0.0 198.0
166.0 0.0
93
96
END OF ROWS
93

96
END OF COLUMNS
0.0 101.0
82.0 0.0
93
97
END OF ROWS
93
97
END OF COLUMNS
0.0 194.0
163.0 0.0
93
98
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93
98
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154.0 0.0
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END OF ROWS
93
99
END OF COLUMNS
0.0 20.0
16.0 0.0
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95
END OF ROWS
94
95
END OF COLUMNS
0.0 634.0
367.0 0.0
94
96
END OF ROWS
94
96
END OF COLUMNS
0.0 322.0
182.0 0.0
94
97
END OF ROWS
94

97
END OF COLUMNS
0.0 623.0
361.0 0.0
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98
END OF ROWS
94
98
END OF COLUMNS
0.0 591.0
341.0 0.0
94
99
END OF ROWS
94
99
END OF COLUMNS
0.0 64.0
36.0 0.0
95
96
END OF ROWS
95
96
END OF COLUMNS
0.0 22.0
22.0 0.0
95
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95
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43.0 0.0
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95
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0.0 41.0
41.0 0.0
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99
END OF ROWS
95

99
END OF COLUMNS
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4.0 0.0
96
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END OF ROWS
96
97
END OF COLUMNS
0.0 21.0
22.0 0.0
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98
END OF ROWS
96
98
END OF COLUMNS
0.0 20.0
21.0 0.0
96
99
END OF ROWS
96
99
END OF COLUMNS
0.0 2.0
2.0 0.0
97
98
END OF ROWS
97
98
END OF COLUMNS
0.0 40.0
40.0 0.0
97
99
END OF ROWS
97
99
END OF COLUMNS
0.0 4.0
4.0 0.0
98
99
END OF ROWS
98

```
99
END OF COLUMNS
0.0 4.0
4.0 0.0
END OF TABLES
END OF TABLES
END OF TABLES
END OF TABLES

→
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VITA

Barbara Grim Hatcher, an native of Pennsyslvania has been a transportation engineer for six years. She attended the Pennsylvania State University at University Park and graduated in January 1992 with a Bachelor of Science Degree in Civil Engineering. While at Penn State, she joined the cooperative education program and worked with a consulting firm, Pacuilli, Simmons and Associates, and with the Federal Highway Administration. Upon graduation she engaged in employment with the Missouri Highway and Transportation Department in the Planning Division. In 1993, she gained employment with the Knoxville Knox County Metropolitan Planning Commission in the Transportation Division. While working, she started pursing a Master of Science Degree in Civil and Environmental Engineering in the field of transportation at the University of Tennessee at Knoxville. In 1997 she received a license to practice engineering in the State of Tennessee. The Master of Science Degree was received in August 1998.