QUICK RESPONSE URBAN TRAVEL ESTIMATION SCENARIO FOR THE STILLWATER AREA

By

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This report presents a long-range transportation planning scenario for the City of Stillwater. The overall objective of this report is to predict the future condition of the street network and give reasonable suggestions to help accomodate any difficulty.

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CHAPTER I

INTRODUCTION

Maintaining a transportation network that will remain responsive to the needs of its users and that is capable of accomodating changes in land-use is essential for the welfare of the community. Designing and operating this network requires a reliable estimate of the future traffic volumes that will use the network.

The traditional urban travel demand forecasting procedures have been designed to provide future traffic volumes which are needed for the long-range planning of transportation systems [16]. These procedures require a two to three year time period, much of which is taken up by very costly data collection, data processing, and model calibrations. Quite often, these planning procedures fail to permit an analytical response to the various policy issues within the desired time and cost constraints. The need for methods designed to aid in making decisions and trade-offs on projects created a need for simplified methodologies that are easy to understand, relatively inexpensive to apply, responsive to the policy issues, and meet the so-called quick-response analysis time criteria.

In the summary of a workshop entitled "Quick-Response and Sketch-Planning", quick-response techniques were defined as "those techniques that support the required decision-making time frame within the given cost and staff resource constraints" [15]. The quick-response techniques may be applied across all the various planning scales, i.e., regional, subarea, corridor, and project. Table 1 provides an overview of these techniques and the application areas for which they are most suitable [15].

Objective and Purpose of Research

The objectives of this study are: 1) to provide an overview of the procedures documented in the NCHRP Report 187, "Quick Response Urban Travel Estimation Techniques and Transferable Parameters", 2) to apply the microcomputer programs QRS and QRS II to forecast the year 2010 traffic volumes which are required to update the Master Plan for the City of Stillwater, 3) to test the validity of the default paramters embodied in the QRS and QRS II, and 4) to compare, in brief, QRS and QRS II.

The results of this study can be used for prioritizing improvements in the street plan, as an aid in selecting bike routes, and to review requests for new land-use developments.

TABLE 1

OVERVIEW OF QUICK-RESPONSE TECHNIQUES

Technique	Application Area		
	Regional	Corridor or Subarea	Project
Computerized			
Conventional models			
UTPS	X	X	X
PLANPAC/BACKPAC	X	X	X
NAG (network aggregation)	X	X	
CAPM (sketch planning)	X		
SCAGM (small city gravity model)	X		
DRAM/EMPAL (land use)	X		
Windowing or focusing	X	X	
Air-quality analysis	X		
FREQ (freeway operations)	X	X	
Carpool-matching programs	X		
Noncomputerized			
NCHRP Rept. 187			
Four-step (quick response)	X	X	X
Site impact		X	X
Corridor diversion		X	
Energy-conservation estimation	X	X	X
Air-quality analysis	X	X	X
Manual of planning for your community	X	X	X
AASHTO Red Book (user-benefit analysis)			X
Pivot point (corridor mode choice and route diversion)		X	
Land use and arterial spacing		X	
Planner-aids case studies	X	X	
Macrolevel manual		X	
Parking-management handbook	X	X	
Sampling			
Ground-count factoring	X	X	X
Design of small-sample home-interview travel surveys	X		
Statewide manual (sampling techniques)	X		
Automobile on-board surveys	X	X	
Transit on-board surveys	X	X	
External cordon (O-D manual)	X	X	
1980 Census	X	X	
VMT or PMT sampling	X	X	
Reasonableness checking			
Characteristics of Urban Transportation Systems (CUTS)	X	X	X
Characteristics of Urban Travel Demand (CUTD)	X	X	X
Traveler response to transportation system changes	X	X	X
NCHRP Report 187 (defaults)	X	X	X
ITE trip generation	X	X	X
FHWA trip-generation analysis manual, 1975 (Appendix E)	X	X	
Friction factors	X		

Source: Reference [14]

Overview of This Thesis

This thesis is divided into six chapters. Chapter two presents an overview of the NCHRP Report 187 and the microcomputer programs QRS and QRS II. Chapter three discusses the quick response models used in the NCHRP Report 187, and the theory behind these models. Chapter four presents a case study for the City of Stillwater using the NCHRP Report 187 techniques. This chapter defines the study area, the data needed to carry out the analysis, and the procedures used in the study. Chapter five presents a summary of the results obtained by applying the NCHRP Report 187 techniques which are embodied in QRS and QRS II to the Stillwater scenario. It also presents a comparison of the output obtained using default parameters built in QRS and QRS II versus user-supplied or calculated parameters. Chapter six provides a summary and recommendations.

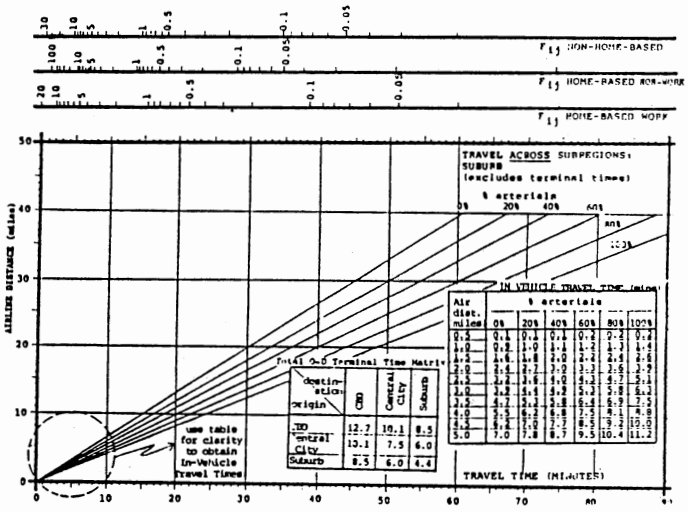
CHAPTER II

LITERATURE REVIEW

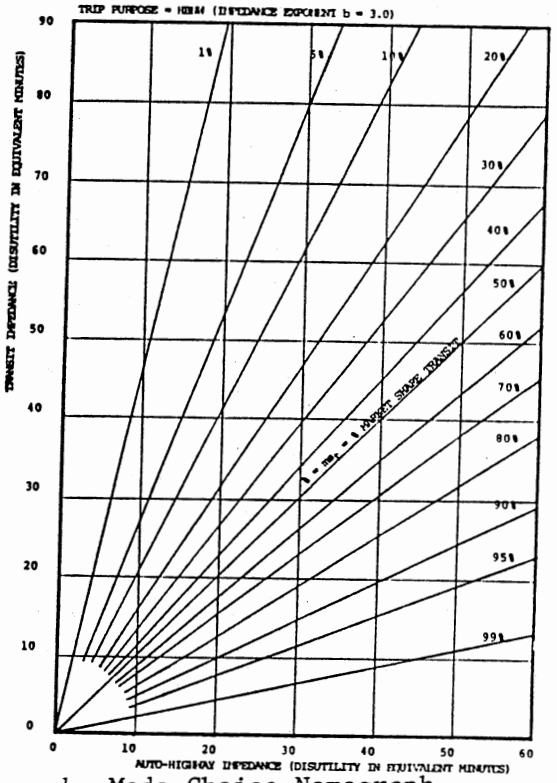
Description of NCHRP Report 187

In 1978 the Transportation Research Board published the NCHRP Report 187 entitled "Quick Response Urban Travel Estimation Techniques and Transferable Parameters". The procedures described in this report were designed to minimize data input, thus saving time and money as well as producing output summaries relevant to the decision makers. In order to minimize data input, the user must make full use of the transferable parameters and factors presented in the report. This allows the user "to carry out a simplified travel demand analysis without the necessity of reference to other sources" [19].

In developing the NCHRP Report 187, several shortcuts were taken [19]. For example, networks are not coded, model calibrations are eliminated through use of selected parameters from past studies, and data input is minimized by using estimates from nomographs such as those shown in Figure 1. The Report provides step-by-step instructions and work sheets for the user.



a. Travel Time vs Friction Factors vs Airline Distance by trip purpose.



b. Mode Choice Nomograph

Figure 1. Examples of Nomographs [19].

The approach described in the NCHRP Report 187 parallels the standard four-step transportation planning modules of trip generation, trip distribution, mode choice, and traffic assignment. These modules were developed in such a manner that each could be applied independently of the others, yet they can be combined to operate interdependently [19]. The results of one module are required as input to the next module.

The data needed for each module are presented in the form of tables, graphs, nomographs and charts in the NCHRP Report 187. This data is designed to provide generally transferable parameters which have been consistently reported for four urbanized area population groups [19]. These population groups are:

1. 50,000 to 100,000 population
2. 100,000 to 250,000 population
3. 250,000 to 750,000 population
4. 750,000 to 2,000,000 population

The chapter on trip generation in the NCHRP Report 187 contains tables which enable the user to make estimates of trip productions and trip attractions from land-use and socioeconomic characteristics. The trip distribution chapter presents charts for converting airline distance into travel time and for determining distribution factors

by trip purpose which are used for calculating the number of trips made between zones using the gravity model. The mode choice chapter contains nomographs for determining impedance values measured in equivalent minutes which are used for calculating market shares for transit and auto. The chapter on traffic assignment presents the "all-or-nothing assignment technique" which is used to assign vehicle-trips to the road segments connecting all origin and destination zones.

Development of QRS and QRS II

The NCHRP Report 187 has become a popular reference tool in the years following its publication. Thus, some years later, the FHWA established funds for the creation of a microcomputer software that would incorporate the Report's quick-response techniques for travel demand forecasting [4]. The resulting software, called the quick-response microcomputer software (QRS), was released into the public domain in February 1984 [3].

Quick Response Microcomputer System (QRS), is a computer package developed by the University of California at San Diego, UCSD, to perform the computations described in the NCHRP Report 187. The program is written in UCSD PASCAL Version IV.0 [3].

All the modules within QRS are menu-driven, that is, a list of possible responses is presented to the user on the screen. Application of QRS is subject to the following

limitations:

- maximum number of zones = 50
- maximum number of assignment links = 800
- number of trip purposes = 3
- number of friction factors = 40

With the introduction of QRS, larger planning problems could be addressed. However, QRS becomes difficult to use as the size of the problem increases. A new upgraded version, QRS II, was introduced to the market in July of 1987.

Quick Response System II (QRS II), was developed by Alan J. Horowitz, at the Center for Urban Transportation Studies, University of Wisconsin in Milwaukee. It is an entirely new implementation of the theory and philosophy found in the original NCHRP Report [6]. QRS II departs from the earlier version in that it requires that a network be drawn. The program is written to run under the MS-DOS operating system.

All the data needed for QRS II are entered through the General Network Editor (GNE). The limitations in QRS II are:

- maximum number of zones = 285 for the professional version, and 40 for the educational version.
- number of trip purposes = 3
- number of friction factors = 60

A general description of QRS and QRS II is presented in Appendix A.

Applications of the NCHRP Report 187

In April 1980, and November 1981, the Urban Planning and Transportation Management Division of the FHWA conducted a survey to determine the studies which have been conducted using the quick-response procedures described in the NCHRP Report 187. The reported applications were divided into four categories: long-range system analysis, corridor or subarea analysis, site impact analysis, and intersection capacity analysis.

1. Long-range system analysis

Long-range system planning is used to analyze trends and anticipate problems in the transportation network. It usually covers a large geographic area and is comprehensive in scope. The following are examples of long-range system planning.

a. Santa Fe, New Mexico: To evaluate the performance of the highway system in a long-range planning context it was necessary to develop an estimate of travel patterns for the forecast year. This was done using the quick-response trip generation and distribution procedures. Conventional traffic assignment techniques were used to determine the link volumes [16].

b. Santa Barbara County, California: Traffic forecasts

were developed using the quick-response trip generation, distribution, and traffic assignment procedures to analyze the impact of expected urban growth on the transportation system, identify problems and needs, and make recommendations for improvements. A computerized version of the trip distribution procedure was used to reduce the time needed for computations [16].

2. Corridor or subarea analysis

Corridor analysis is usually performed to evaluate traffic conditions along a major arterial or highway segment. The scope of the analysis is limited to the arterial or highway section and local streets within a two-mile radius. The following examples illustrate the corridor analysis applications.

a. Brockton, Massachussetts: Previous analysis of the exisitng traffic conditions indicated that the traffic flow along the east-west corridor appeared to be severely impeded at several locations. A further study was desired to determine future traffic impact at these sites and to evaluate the possibility of roadway modifications to improve the east-west traffic flow. The approach involved the sequential application of trip generation, trip distribution, modal split, and traffic assignment. This method produced traffic-volume estimates for a 1975 base year and 1995 forecast year [16].

b. Portland, Oregon: Quick-response techniques were

used in the preparation of a transportation corridor refinement study of the areawide transportation master plan. The refinement study investigated several alternative routes and their impact on adjacent land development. The study also evaluated the ability of several routes to serve projected land developments such as regional shopping centers and industrial sites [16].

3. Site impact analysis

Site impact analysis is necessary to evaluate the effects of the traffic generated by a major land-use development on the surrounding street network. Two examples are cited to help illustrate this type of analysis.

a. Phoenix, Arizona: A regional shopping center and associated commercial/residential development was proposed and an analysis of the resulting traffic impact in the vicinity of this development was requested [16].

b. Des Moines, Iowa: The number of trips that would be generated by the construction of a new office building was estimated. This information was needed for a city council meeting during which the addition of a traffic signal near the proposed building was to be discussed [16].

4. Intersection capacity analysis

Intersection capacity analysis is performed to determine the level of service at an intersection. The

results of the traffic assignment obtained from QRS or QRS II can be used as input volumes for use in the critical movement technique. This type of analysis was carried out in Omaha, Nebraska to determine the level of service for several intersections within a major travel corridor, and in Tacoma, Washington to evaluate the capacity of an intersection influenced by a major new development [16].

The survey results indicated that quick-response procedures were most often used for evaluating the traffic impact of proposed land-use changes, that is site impact. Corridor and subarea analyses were the second most prominent uses, followed by intersection capacity analysis and long-range system planning [16].

Applications of QRS and QRS II

In the City of Spokane, Washington, QRS was used to forecast the demand for light rail transit [15]. The task involved determination of trip generation estimates, trip distribution and mode choice for the base year 1980. Forecasted transit use for the target year 2000 was then determined.

A second application was reported in Berkeley, California [7]. QRS was used in a class project to estimate and assess the localized highway and transit travel impacts of a large increase in commercial floorspace anticipated over the next few years in downtown Berkeley.

In Wausau, Wisconsin QRS II was selected to assess the effects of new urban development north of Wausau's central business district [6]. It appeared that this development could greatly strain the capacity of a two-lane bridge just north of the CBD. Demographic data taken from land-use forecasts were used to generate trips. The trip distribution and traffic assignment modules were then implemented.

CHAPTER III

QUICK RESPONSE METHODOLOGY

Introduction

In 1978 a two-phase research effort sponsored by the NCHRP resulted in the publication of two volumes in the NCHRP series. Phase I identified travel-related urban policy issues and assessed the existing methods and procedures. The findings are presented in NCHRP Report 186 [18]. Phase II developed a user's guide which describes transferable parameters and factors for quick-respose planning. The later findings are presented in the NCHRP Report 187 [19].

The quick response technique described in the NCHRP Report 187 involves the same elements as the sequential travel demand forecasting technique, namely, trip generation, trip distribution, mode choice, and traffic assignment.

Trip Generation

The purpose of trip generation is to estimate the number of trips produced by and attracted to a parcel of land, called a zone. The trip generation module is the

most critical phase because it sets the scope of the entire planning process. Subsequent modules are affected by the accuracy of the production and attraction estimates which in turn are influenced by the variables used in the trip generation module.

Trips are stratified by purpose since the travel making behavior of individuals differs for different trip purposes [22]. The three trip purposes used in the NCHRP Report 187 are:

1. Home based work (HBW),
2. Home based non-work (HBNW),
3. Non-home based (NHB).

The trip generation process involoves estimating trip productions, and trip attractions.

Trip productions are usually estimated based upon the number of households in a zone. The technique used is the cross-classification method which categorizes household trip making rates according to such household attributes as automobile ownership and income [4]. However, the use of auto ownership as a criterion has been highly questioned [8]. The results of a recent study indicated that auto ownership is not as effective an indicator of household travel demand as was generally believed [8].

The steps involved in determining trip productions are:

1. Setting up income or auto ownership ranges.
2. Classifying zones by income or auto ownership.
3. Multiplying the number of households by the production rates for the appropriate income or auto ownership range.
4. Dividing the total trips into HBW, HBNW, and NHB trip purposes.

Chapter Two of the NCHRP Report 187 provides production rates based on household income and auto ownership. The production rates were established for the four area population groups discussed earlier. An example of the trip production rates is presented in Table 2.

Trip attractions are determined using an aggregate trip analysis approach [13]. Equations with appropriate independent variables are developed, usually using multiple regression analysis. The equations used in the NCHRP Report 187 are of the form:

$$\text{HBW attractions} = a\,(X + Y) \quad (1)$$

$$\text{HBNW attractions} = b_1\,(X) + b_2\,(Y) + b_3\,(Z) \quad (2)$$

$$\text{NHB attractions} = c_1\,(X) + c_2\,(Y) + c_3\,(Z) \quad (3)$$

where

X = number of retail employees.

Y = number of non-retail employees.

Z = number of dwelling units.

a, b's, c's = regression coefficients.

Part C of Table 3 in Chapter Two of the NCHRP Report

TABLE 2

DEFAULT PRODUCTION RATES BY POPULATION GROUP

Income Range 1970 $ (000's)	Avg Autos Per HH[d]	Average Daily Person Trips Per HH[e]	% HH by Autos Owned[b]				Average Daily Person Trips Per HH by No. of Autos/HH[c]				% Average Daily Person Trips by Purpose[f]		
			0	1	2	3+	0	1	2	3+	HBW	HBNW	NHB
0-3	0.56	4.5	53	39	7	1	2.0	6.5	11.5	12.5	21	57	22
3-4	0.81	6.8	32	58	10	1	2.2	8.0	13.0	15.0	21	57	22
4-5	0.88	8.4	26	61	12	1	2.6	9.5	14.5	16.5	21	57	22
5-6	0.99	10.2	20	62	17	1	3.0	11.0	15.5	18.0	18	59	23
6-7	1.07	11.9	15	64	20	1	3.0	12.5	16.5	19.5	18	59	23
7-8	1.17	13.2	11	64	23	2	3.5	13.3	17.0	21.5	16	61	23
8-9	1.25	14.4	8	62	28	2	4.8	14.0	17.5	22.5	16	61	23
9-10	1.31	15.1	6	60	32	2	5.5	14.3	17.5	24.0	16	61	23
10-12.5	1.47	16.4	3	49	44	3	6.2	15.0	18.5	25.5	15	62	23
12.5-15	1.69	17.7	2	38	52	8	6.1	15.0	19.0	25.5	14	62	24
15-20	1.85	18.0	2	28	57	13	6.0	13.5	19.5	23.0	13	62	25
20-25	2.03	19.0	1	21	58	20	6.0	13.0	20.0	23.0	13	62	25
25+	2.07	19.2	1	19	59	21	6.0	12.5	20.0	23.0	13	62	25
Weighted Average	1.55	14.1	12	47	35	6	4.6	12.6	17.2	21.4	16	61	23

Source: Reference [19]

187 gives suggested values for the regression coefficients. These coefficients were obtained from the Office of Planning Methodology and Technical Support at the Urban Mass Transportation Administration (UMTA).

Comparison of the trip generation data from various sources indicates that similar land-use activities in the United States and Canada have similar trip generation characteristics [7]. Thus, for small urban areas where data collection is infeasible due to lack of funds and/or time, the default generation rates presented in the NCHRP Report can be used. Another source of trip generation rates is the ITE Trip Generation Report [1].

In general, total trip productions will not equal total attractions. However, the gravity model used in trip distribution requires that the total productions and total attractions be equal. This is accomplished using the areawide control factors which are calculated for each trip purpose as follows:

$$F_1 = \frac{\text{HBW total P's - S.G. P's - E.S. P's}}{\text{HBW total A's - S.G. A's - E.S. A's}} \quad (4)$$

$$F_2 = \frac{\text{HBNW total P's - S.G. P's - E.S. P's}}{\text{HBNW total A's - S.G. A's - E.S. A's}} \quad (5)$$

$$F_3 = \frac{\text{NHB total P's - S.G. P's - E.S. P's}}{\text{NHB total A's - S.G. A's - E.S. A's}} \quad (6)$$

where

S.G. = special generator such as an airport, university, large shopping center, etc.

E.S. = external stations. These are zones that are outside the boundary of the analysis area. They should be included if their productions and attractions are large.

Multiplying the F's by the individual zone attractions results in balanced production and attraction totals. It should be noted that special generators, and external stations do not enter the balancing process. In cases where special generators and external stations are not included in the study area, then the second and third terms of Equations 4 through 6 are eliminated and the equations reduce to the first part.

Trip Distribution

Trip distribution is the process of estimating how person-trips from one zone are distributed among available destination zones, i.e., how individuals choose their destinations.

Many mathematical models have been developed to explain and predict the distribution of traffic among zones [11]. However, the majority of urban transport studies have used the gravity model since it is the easiest to understand [10].

The gravity model assumes that the number of trips produced in a zone and attracted to other zone is directly

proportional to the size of the attractor and inversely proportional to the spatial seperation (usually measured in zone-to-zone travel time) between the two zones [19]. The model can be expressed mathematically as:

$$T_{ij} = P_i * \frac{A_j * F_{ij}}{\sum_{j=1}^{n} A_j * F_{ij}} \qquad (7)$$

where

T_{ij} = trips produced in analysis area i and attracted to analysis area j;

P_i = total trip productions at i;

A_j = total trip attractions at j;

F_{ij} = travel time factor for trips between zones i and j, which is a function of travel time (t_{ij}) between the zone centroids;

i = origin zone number i = 1,2,...,n;

j = destination zone number j = 1,2,...,n;

n = number of zones under study.

The travel time factors, F_{ij}'s, commonly referred to as friction factors, may be regarded as a measure of the deterrence that travel time has on tripmaking patterns [10]. Friction factors have usually been determined using either the "power" form, or the "exponential" form. The "power" friction factors are calculated as:

$$F_{ij} = 1/(t_{ij})^{a_k} \quad (8)$$

The "exponential" friction factors are expressed as:

$$F_{ij} = e^{-a_k * t_{ij}} \quad (9)$$

where

t_{ij} = travel time between zones i and j.

a_k = trip distribution parameter for trip purpose k.

Table 8 in the NCHRP Report 187 gives recommended values using the "power" function for the four population groups. These values have been obtained through calibration of the gravity model [19].

Figures 7 through 30 in Chapter three of the NCHRP Report 187 provide graphs for determining the appropriate friction factors. These graphs can be divided into two sets. The first set was developed for trip interchanges within a subregion, that is, within the central business district (CBD), central city (CC), and suburbs (S). The second set of graphs is used when trip interchanges occur across subregions, i.e., CBD to CC, CC to S, S to CBD, and the like. To use these graphs, the airline distance between the centroids of the zones, and the percent of over-the-road distance traveled on arterial routes must be known for every trip interchange.

Application of the gravity model results in the number of trips produced in zone i and attracted to zone j, T_{ij}, This is shown by the trip matrix form shown in Figure 2.

ORIGIN ZONES	DESTINATION ZONES 1	2	3			n	Σ
1	t_{11}	t_{12}	t_{13}			t_{1n}	o_1
2	t_{21}	t_{22}				t_{2n}	o_2
3	t_{31}	t_{32}					o_3
n	t_{n1}					t_{nn}	o_n
Σ	d_1	d_2	d_3			d_n	

Σ columns = Trip productions Σ rows = Trip attractions

Figure 2. Trip Distribution Matrix

From the trip matrix, two requirements immediately become apparent:

$$\sum_{j=1}^{n} T_{ij} = P_i \qquad (10)$$

$$\sum_{i=1}^{n} T_{ij} = A_j \qquad (11)$$

The gravity model is formulated so that the production constraint given by Equation 10 is satisfied. However, the attraction constraint given by Equation 11 is not usually satisfied. Two reasons may be cited for this discrepency [3]: 1) the A_j's are not absolute measures of the attraction of trips to a zone but are relative measures which could have different absolute magnitudes, and 2) travel time alone is not sufficient to give an indication of the "friction" on travel caused by distance, so the F_{ij}'s are only approximated in the relationships presented earlier.

Given the reasons stated above, it is clear that an iterative process must be employed to attain an acceptable attraction balance. The necessary equation is discussed in most standard textbooks and can be expressed as:

$$A_j^k = \frac{A_j * A_j^{k-1}}{\sum_{j=1}^{n} T_{ij}^{k-1}} \qquad (12)$$

where

A_j = total number of trips attracted to zone j, obtained from the trip generation module

A_j^{k-1} = attraction total at iteration k-1.

A_j^k = adjusted attractions for zone j at iteration k; note that $A_j^1 = A_j$

T_{ij}^{k-1} = attraction total for zone j obtained by applying the gravity model at iteration k-1.

k = number of iterations

To help illustrate the process, consider column 1 in Figure 2. Applying the gravity model formulation once results in the number of trips between zones. Thus, the trips from all zones i to zone 1 are T_{11}, T_{21},..., T_{n1}. When the attraction constraint given by Equation 11 is not satisfied that is, $T_{11} + T_{21} + \ldots + T_{n1}$ does not equal A_1, the iterative equation must be used. It can be expressed as:

$$A_1^2 = \frac{A_1 * A_1^1}{T_{11} + T_{21} + \ldots + T_{n1}} \qquad (13)$$

It is easily seen that when k = 2, $A_1^{k-1} = A_1$.

The adjusted attraction (A_1^2) is then used in the gravity model resulting in a new set of T_{11}. If their sum does not match the original attractions obtained from the trip generation module the iterative process should be used again. The equation becomes:

$$A_1^3 = \frac{A_1 * A_1^2}{T_{11} + T_{21} + \ldots + T_{n1}} \qquad (14)$$

Two iterations are generally considered satisfactory to meet the attraction constraint.

Mode Choice

Mode choice is the process of estimating the percentage of person-trips made by the mass transit and auto modes. The mode choice models are based on consumer behavior theory and are generally disaggregate in nature. They employ probabilistic interpretation of the individual travel decisions [22]. The theory of disaggregate models is based upon the utility function which is a function of the attributes and characteristics of the trip maker and the mode under consideration.

The utility of mode m, referred to as impedance in the NCHRP Report 187, is measured in equivalent minutes and is expressed as follows:

$$I_{ijm} = (w_1*IVTT)+(w_2*OVTT)+(OPTC/w_3*Income) \qquad (15)$$

where

I_{ijm} = impedance from origin zone i to destination zone j by mode m in equivalent minutes.

w_1 = weight for in-vehicle travel time.

w_2 = weight for out-of-vehicle travel time. The

traveling individual perceives a walking or waiting minute as w_2 * (traveling minute). A value of 2.5 was suggested by UMTA and has been used in the NCHRP Report 187 to convert out-of-vehicle time into equivalent minutes of impedance.

w_3 = weight which an individual associates with his "nonworking" time. The UMTA describes default value of an individual's own time equal to one-third of the value associated with an equivalent amount of working time.

IVTT = in-vehicle travel time in minutes.

OVTT = out-of-vehicle travel time in minutes.

OPTC = out-of-pocket trip cost in dollars.

The general equation used in the mode choice module can be written as [19]:

$$T_{ijm} = \frac{e^{-I_{ijm}}}{\sum_{k=1}^{m} e^{-I_{ijm}}} \qquad (16)$$

where

T_{ijm} = Percent of trips made from origin zone i to destination zone j by mode m.

k = number of available modes.

Further research by UMTA has shown that it is possible

to replace e^{-I} by I^{-b}, where I is a measure of the trip impedance dependent on the trip purpose. It was believed that the exponent b would behave in a manner similar to the gravity model, and this assumption was fortified by UMTA [19]. This allows for the transformation of the logit equation into a very simplified modal formula given by [19]:

$$MS_t = \frac{I^b_{ijm}}{I^b_{ijm} + I^b_{ijt}} * 100 \qquad (17)$$

where

MS_t = transit market shares expressed in percentage.

I_{ijm} = auto impedance for O-D movement i-j,

I_{ijt} = transit impedance for O-D movement i-j,

b = model exponent of the trip time, dependent on trip purpose. The NCHRP Report 187 recommends values of 2.0 for HBW, 3.0 for HBNW, and 2.7 for NHB trip purposes.

The procedures of the mode choice analysis can be summarized in three general steps:

1. Determine transit and auto impedances using the nomographs presented in the NCHRP Report 187 (Figures 60 and 61 for transit, and Figures 62 to 73 for auto). An example of the transit impedance nomographs is presented in Figure 3. The user must know the airline distance and transit fare. Then, with the airline distance on hand, the user can draw a vertical line to the appropriate transit

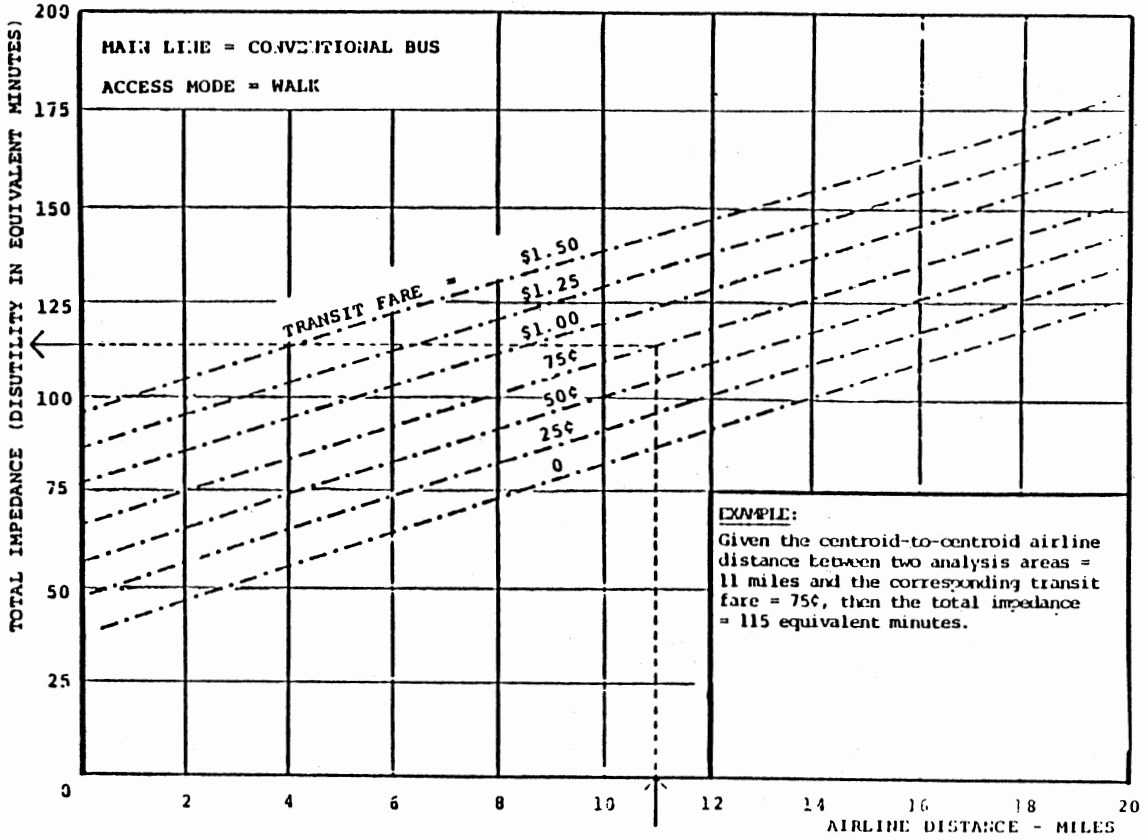


Figure 3. Transit Impedance Nomograph [19]

fare. A horizontal line is then drawn to determine the total transit impedance.

Similarly, Figure 4 provides an example of the auto impedance nomographs. To use the nomographs the user should know the airline distance, parking cost at destination, operating cost, and average operating speed. Impedance is determined by drawing a vertical line from the airline distance to the appropriate average operating speed and then drawing a horizontal line to obtain the auto impedance in minutes.

2. Determine the transit and auto market shares, using either the charts in Figures 74 through 76 of the NCHRP Report 187 which are based upon trip purpose, or Equation 16. Figure 5 presents the chart for HBW trip purpose to illustrate its use. The user must have performed the first step, that is, the determination of auto and transit impedance. The transit market share is determined by drawing a vertical line from the transit impedance axis to intersect the vertical line drawn from the auto impedance axis.

3. Determine transit and auto trips using the following equations:

$$T_{ijt} = MS_t \times T_{ij}, \tag{18}$$

and

$$T_{ijm} = MS_m \times T_{ij} \tag{19}$$

where

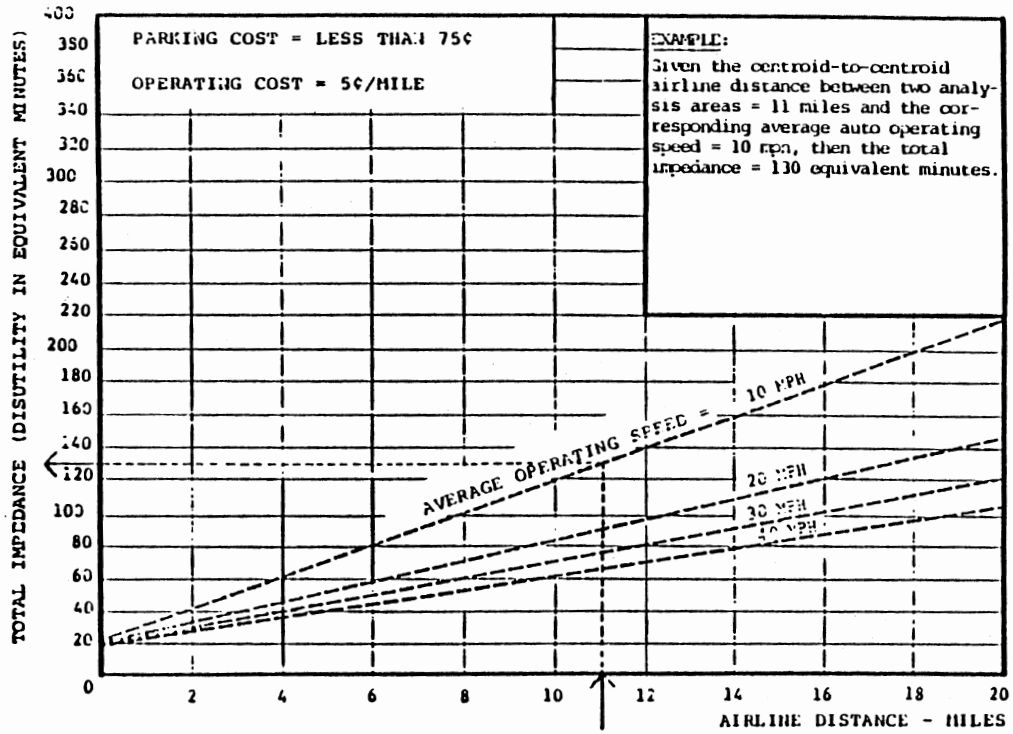


Figure 4. Auto Impedance Nomograph [19]

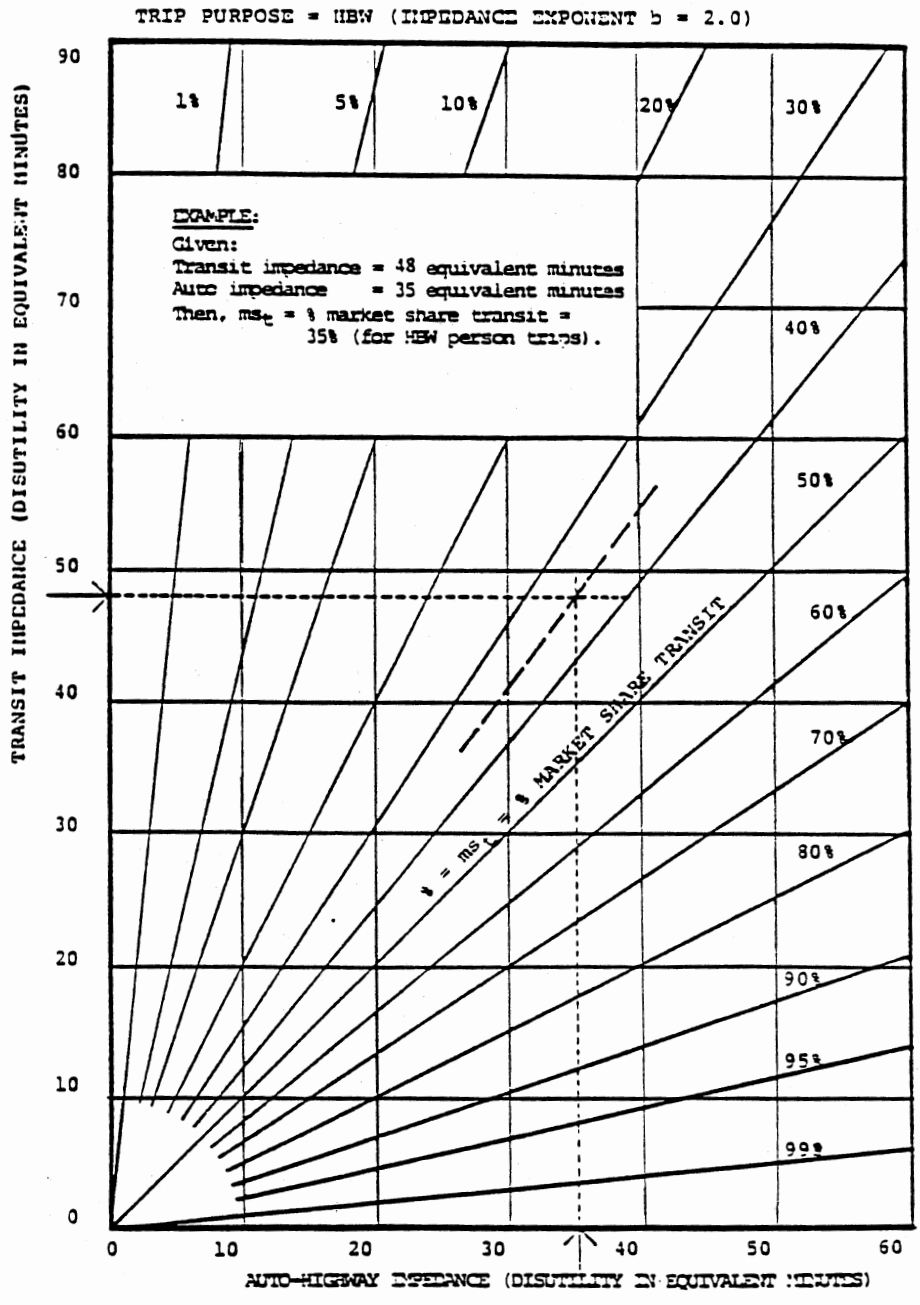


Figure 5. Transit Market Share [19]

T_{ijt} = number of transit person-trips,

T_{ija} = number of auto person-trips,

T_{ij} = total number of trip interchanges between zones i and j, obtained from the trip distribution.

Traffic Assignment

The purpose of traffic assignment is to allocate the zone to zone vehicle trips between each origin and destination pair to the system of streets within the analysis area [19].

Assigning traffic requires a map showing the functional classification of the streets. The street network is represented in terms of links and nodes. Links are roadway sections, defined by the nodes at their ends. Nodes are numbered points representing zonal centroids or intersections of links.

The assignment technique used in the NCHRP Report 187 is the "all-or-nothing" technique. This technique requires the determination of a minimum travel time path for every trip interchange, and then, accumulates the number of trips on each street segment along the shortest path [19]. As the name indicates, the all-or-nothing technique assigns all trips to the shortest path and none to alternative routes.

Several assumptions are embodied in the all-or-nothing technique: 1) travel time over the path used is less than or equal to the travel times over all paths not used, 2) each driver is fully aware of all alternative routes by which he can travel, and 3) travel time is insensitive to traffic volumes [19,21].

CHAPTER IV

SCENARIO FOR LONG RANGE TRANSPORTATION PLANNING FOR THE CITY OF STILLWATER

Background

In 1968 the Stillwater Planning Commission, entered into an agreement with state and federal agencies to conduct a comprehensive transportation study for the City of Stillwater. The findings of this study are reported in the 1968-1990 technical Report [12]. In 1975, a continuing phase study was conducted to update the transportation system. The results are summarized in a report entitled "Stillwater Metropolitan Area Transportation Study, 1975-2000", hereafter referred to as the 1975-2000 technical report [13].

Short-range and long-range programs for street and highway improvements were suggested and are presented in the 1975-2000 technical and comprehensive transportation plan report [13]. These programs are based on projected socio-economic, land-use, and travel patterns.

Study Area and Traffic Zones

The 1975-2000 technical report designated an area of 95 square miles as the study area and this area is used throughout this thesis. The area selected is large enough to accomodate future growth in the City of Stillwater.

To facilitate the compilation, analysis, and projection of the socio-economic data and traffic volumes, the study area was divided into smaller areas known as internal traffic zones. In addition to the internal traffic zones, external stations were used to measure the vehicular movement between the study area and outlying areas.

The 1975-2000 technical report consisted of 106 internal traffic zones and 6 external stations as shown in Figure 6. However, QRS can handle a maximum of only 50 zones and, the educational version of QRS II can handle up to 40 zones. Thus, the number of zones had to be reduced to the maximum allowable of QRS II, that is, 40 zones. In doing so, internal traffic zones were aggregated based upon similarities in socio-economic and land-use characteristics. Table 3 lists the internal traffic zones used in this thesis and shows the corresponding zones used in the 1975-2000 technical report which have been combined to meet the QRS II criterion. The internal traffic zones as well as the external stations are presented graphically

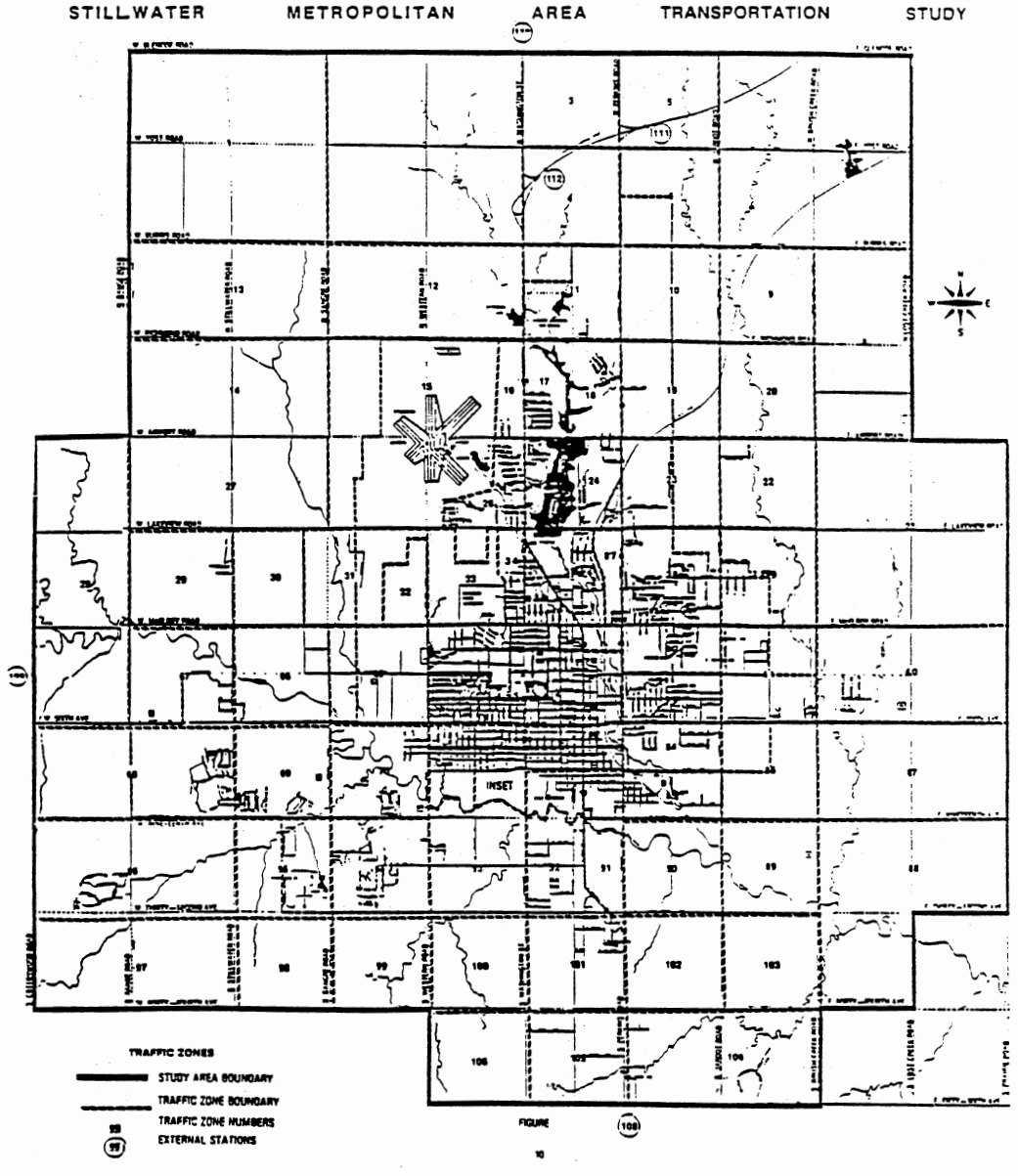


Figure 6. Traffic Zones Used In The 1975-2000 Technical Report

TABLE 3

AGGREGATION OF ZONES

Zone Number in QRS & QRS II	Zone Number in the 1975-2000 Technical Report
1	1, 2, 12, 13
2	3, 4, 5, 6, 7, 8, 9, 10, 11, 20
3	17, 18, 19
4	23, 24, 25
5	16, 26
6	15
7	14, 27, 29, 30
8	28
9	66, 67
10	31, 32, 33, 34, 65
11	35
12	36
13	37, 38
14	21, 22, 39
15	40, 87
16	41, 86
17	42, 43
18	44, 55, 56, 57
19	45, 53, 54, 58, 59, 60, 61
20	46
21	48, 50, 51, 52
22	47
23	49, 62, 63, 64
24	68, 69
25	70, 71, 72, 73, 74
26	75, 76, 77, 78, 79
27	80, 81, 82, 83
28	84, 85
29	88, 89, 103
30	90, 91, 92, 101, 102
31	104, 105
32	93, 100, 106
33	94, 95, 98, 99
34	96, 97

in Figure 7. Zone 1 through zone 34 are internal traffic zones. Zone 21 which represents Oklahoma State University is treated as a special generator. Zones 35 through 40 are external stations.

Study Time Period

Since this thesis relies on the 1975-2000 technical report land-use data and productions and attractions, it is necessary to use the year 1975 as the base year. Discussion with the Planning Commission for the City of Stillwater revealed that land-use and the total productions and attractions forecasts made for the year 2000 in the 1975-2000 technical report are considered high. Thus, it was agreed that these forecasts can be used for the year 2010. In doing so, the target year has been designated as the year 2010.

Data Needed

The data needed for trip generation, trip distribution, and traffic assignment is summarized in Table 4. Data needed for the mode choice analysis is not presented because it was no part of this transportation planning process. This is due to the lack of transit mode of travel in the City of Stillwater.

The data available in the 1975-2000 technical report is used in this study. This data includes:

1. Map of the study area delineating all traffic

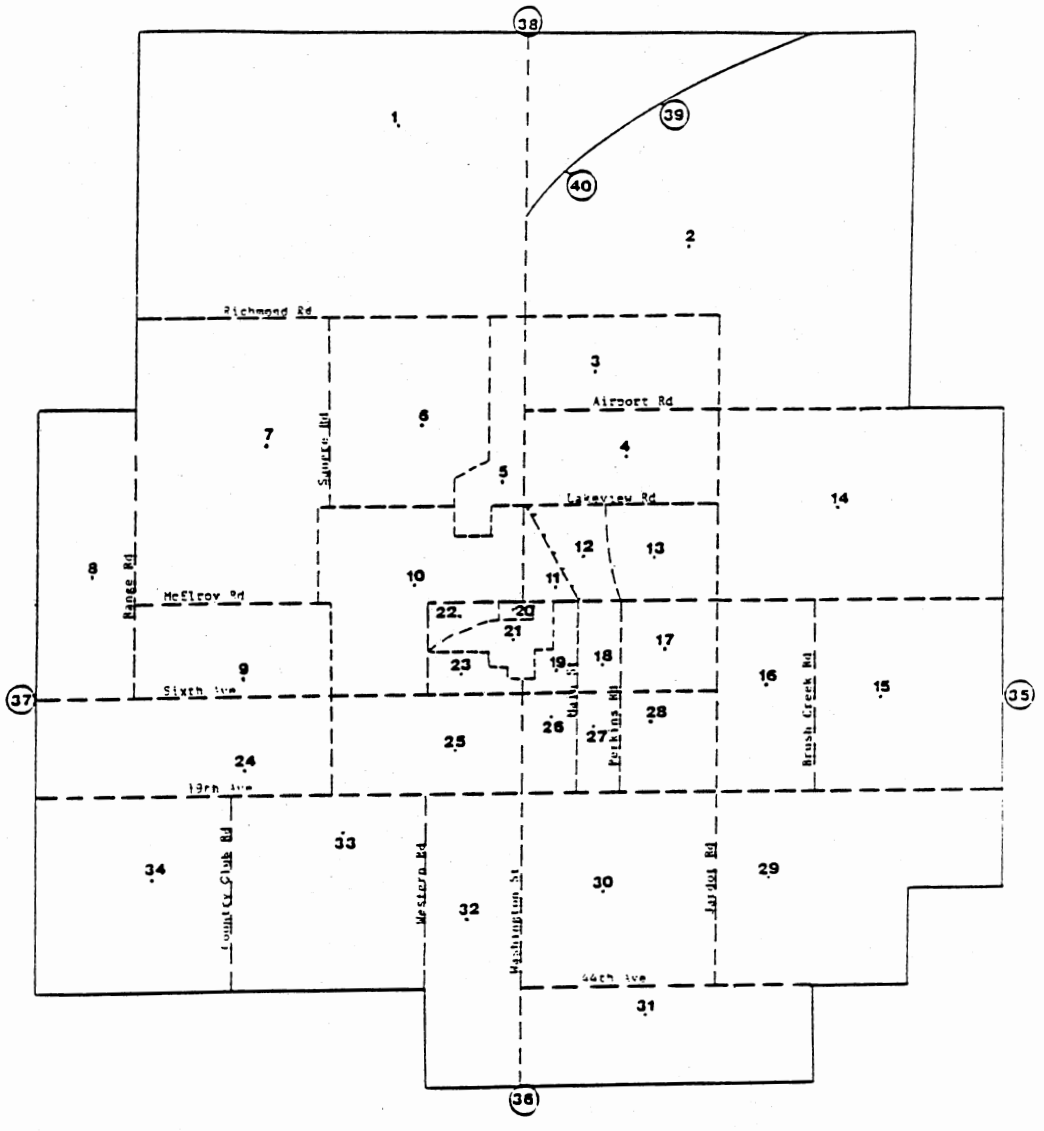


Figure 7. Traffic Zones Used In QRS and QRS II

TABLE 4

DATA NEEDED FOR EACH MODULE

TRIP GENERATION
1. Production rates and the percent of trips made for each trip purpose.
2. Coefficients of attraction equations by trip purpose
3. Land use and socio-economic data for every zone. This consists of income, retail employment, non-retail employment, and dwelling units.
4. List of special generators as in the case of large shopping centers, univeristies, and so on.
TRIP DISTRIBUTION
1. Productions and attractions by trip purpose for every zone in the study area. This is usually obtained from the trip generation module.
2. Travel time matrix, i.e. interzonal and intrazonal travel time.
3. Friction factors by trip purpose.
TRAFFIC ASSIGNMENT
1. Vehicle-trip matrix for each trip purpose.
2. Functional classification street map.
3. Speed or travel time for every link.

zones. This map has been presented earlier in Figure 6 of this chapter.

2. Land-use data for 1975 and 2010. These data consist of retail employment, non-retail employment, and dwelling units for every zone. Tables 5 and 6 present the base year 1975 land-use data and the target year 2010 forecasted data. The forecasted land-use data reported in the 1975-2000 technical report are for the year 2000. However, it is assumed that these forecasts can be used as the year 2010 land-use data.

3. Productions and attractions by trip purpose for the internal traffic zones and external stations as shown in Table 7.

4. Friction factors by trip purpose for use in the gravity model. These factors are presented in Table 8.

It should be noted that since the internal traffic zones were combined in this thesis to meet the QRS II criterion, the data presented in this chapter are extracted from the 1975-2000 technical report. As the results of this thesis rely heavily upon the input data, it is assumed that the data available in the 1975-2000 technical report is adequate.

In addition to the data obtained from the 1975-2000 technical report, the following data is needed.

1. Street map for the City of Stillwater as shown in Figure 8. This is obtained from the Planning Office for The City of Stillwater.

TABLE 5

LAND-USE DATA AND EMPLOYMENT FOR THE YEAR 1975

Zone Number	Retail Employment	Non-Retail Employment	Dwelling Units
1	7	4	47
2	2	12	104
3	11	355	187
4	8	335	354
5	3	3	486
6	0	20	3
7	0	0	74
8	0	0	8
9	31	4	23
10	20	110	483
11	21	608	426
12	148	1509	491
13	47	379	756
14	0	0	62
15	0	45	71
16	51	41	235
17	137	560	673
18	191	246	451
19	672	264	1363
20	0	1466	380
21	98	4755	3641
22	37	97	513
23	197	584	1381
24	4	2117	135
25	108	885	1301
26	379	1817	441
27	460	266	228
28	54	105	342
29	0	10	59
30	46	108	364
31	0	23	46
32	0	0	141
33	0	4	236
34	0	0	33

Source: Reference [13]

TABLE 6

LAND-USE DATA AND EMPLOYMENT FOR THE YEAR 2010

Zone Number	Retail Employment	Non-Retail Employment	Dwelling Units
1	195	270	72
2	92	158	348
3	82	3293	718
4	57	2878	685
5	38	41	1146
6	13	649	35
7	31	67	282
8	0	19	30
9	69	70	51
10	48	154	938
11	63	623	440
12	378	1821	624
13	189	750	2317
14	44	80	411
15	38	61	114
16	95	104	870
17	510	1797	2035
18	398	441	388
19	304	304	1232
20	0	0	243
21	98	4755	3641
22	37	97	616
23	32	592	1495
24	89	2728	865
25	320	1047	1510
26	348	348	537
27	428	499	276
28	132	136	674
29	12	41	79
30	131	152	668
31	25	43	87
32	82	98	829
33	126	706	952
34	19	44	69

Source: Reference [13].

TABLE 7

TRIP PRODUCTIONS AND ATTRACTIONS
FOR THE YEAR 1975

ZONE	HBWP	HBWA	HBNWP	HBNWA	NHBP	NHBA
1	43	11	258	148	390	390
2	107	14	741	195	690	690
3	173	359	1244	422	2140	2140
4	327	337	2352	674	2540	2540
5	455	6	3234	847	1276	1276
6	3	20	21	5	140	140
7	69	0	495	125	351	351
8	8	0	54	14	66	66
9	22	34	154	343	646	646
10	447	128	2385	1009	1748	1748
11	394	617	2834	1328	1493	1493
12	454	1636	3271	3303	3390	3390
13	701	418	5036	1733	2626	2626
14	59	0	412	104	278	278
15	66	44	475	119	472	472
16	217	90	1565	896	1422	1422
17	623	684	4479	2804	3652	3652
18	418	429	3001	2632	4652	4652
19	1263	918	9740	8885	12491	12491
20	352	1438	2531	640	6734	6734
21	1680	1369	7335	13875	15114	15114
22	475	131	1707	1226	1684	1684
23	1279	766	9195	4648	5862	5862
24	124	2081	899	1615	974	974
25	1205	974	8662	3249	7869	7869
26	408	1783	2939	5228	9166	9166
27	211	712	1519	4895	7608	7608
28	316	156	2277	1105	2252	2252
29	55	10	379	99	310	310
30	338	151	2427	1064	2106	2106
31	43	22	308	77	294	294
32	131	0	937	237	498	498
33	219	4	1569	397	810	810
34	31	0	216	56	178	178

Source: Reference [13].

TABLE 8

FRICTION FACTORS BY TRIP PURPOSE

Travel Time in Minutes	HBW	HBNW	NHB
1	800	60000	1200
2	440	27000	580
3	330	14000	355
4	260	9100	240
5	228	6800	190
6	207	5500	158
7	191	4800	125
8	176	4200	120
9	165	3700	110
10	156	3400	102
11	148	3150	96
12	141	2950	90
13	132	2700	87
14	125	2500	83
15	120	2350	80
16	116	2200	76
17	110	2050	74
18	105	1950	72
19	102	1850	70
20	100	1750	68
21	97	1680	66
22	93	1600	64
23	91	1520	62
24	89	1470	61
25	86	1410	60
26	84	1380	59
27	82	1320	57
28	80	1280	56
29	78	1250	55
30	76	1220	54
31	74	1200	53
32	72	1180	52
33	71	1150	51
34	70	1100	50
35	68	1070	49

Source: Reference [13].

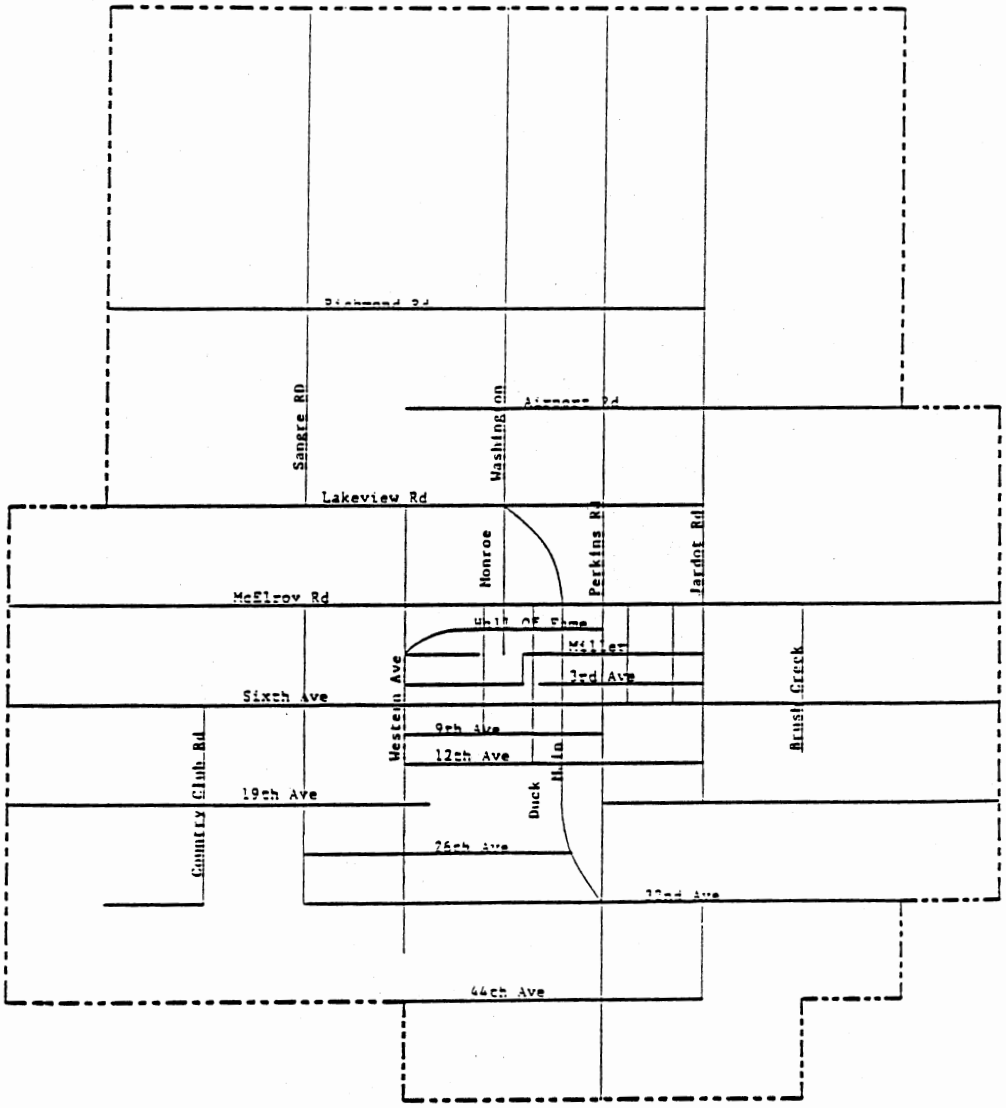


Figure 8. Street Map For The City Of Stillwater

2. Median income per zone for the year 1980 presented in Table 9. These values were obatined from the United States Bureau of Census.

3. Percent change in annual income for the State of Oklahoma as presented in Table 10. This data was obtained from the Economics Department at Oklahoma State University.

4. The Consumer Price Index (CPI) shown in Table 11.

Procedures Used

The planning process involves applying the trip generation, trip distribution, traffic assignment, and capacity analysis modules. The procedures for each module will be presented seperately.

Trip Generation

Before applying the trip generation technique some preliminary tasks had to be performed. Land-use data such as retail employment, non-retail employment, and dwelling units obtained from the 1975-2000 technical report was organized by zone and are presented in Tables 5 and 6.

The year 1980 median income for every zone was abstracted from the United States Bureau of Census Data. These income values were then projected for the year 2010 using the forecasted percent change in annual income obtained for the State of Oklahoma. These percent changes in annual income were obtained from the Economics Department at Oklahoma State University. It is assumed

TABLE 9

MEDIAN INCOME PER ZONE
FOR THE YEAR 1980

Zone Number	Median Annual Income ($)
1	8286
2	15168
3	25164
4	19043
5	25164
6	25164
7	16014
8	15240
9	25502
10	12142
11	12195
12	15675
13	17340
14	17340
15	12533
16	13303
17	15924
18	9570
19	7444
20	9382
21	9384
22	9384
23	13900
24	24360
25	18539
26	10543
27	9376
28	12144
29	10841
30	19785
31	11398
32	19207
33	24876
34	8006

Source: U.S. Bureau of Census

TABLE 10

PERCENT CHANGE IN ANNUAL INCOME FOR THE STATE OF OKLAHOMA

Year	Annual Percent Change
1981	13.244
1982	6.262
1983	-1.510
1984	5.451
1985	3.289
1986	1.258
1987	1.839
1988	4.452
1989	4.088
1990	4.362
1991	5.751
1992	5.865
1993	5.326
1994	5.364
1995	5.016
1996	5.001
1997	5.308
1998	5.185
1999	6.418
2000	6.597
2001	6.072
2002	5.956
2003	5.748
2004	7.038
2005	7.071
2006	6.678
2007	6.728

Source: Economics Department at OSU

TABLE 11

CONSUMER PRICE INDEX (CPI)

Year	CPI	Year	CPI
1967	100.0	1989	371.4
1968	104.2	1990	386.4
1969	109.8	1991	402.8
1970	116.3	1992	419.6
1971	121.3	1993	437.0
1972	125.3	1994	458.2
1973	133.1	1995	481.8
1974	147.1	1996	506.0
1975	161.2	1997	530.3
1976	170.5	1998	555.7
1977	181.5	1999	577.2
1978	195.4	2000	601.2
1979	217.4	2001	627.0
1980	246.8	2002	655.5
1981	272.4	2003	687.2
1982	289.1	2004	713.8
1983	298.4	2005	744.6
1984	311.1	2006	776.8
1985	322.2	2007	811.9
1986	328.4	2008	846.4
1987	340.2	2009	881.4
1988	355.2	2010	916.5

Source: Economics Department at OSU

that the percent change in annual income for the City of Stillwater is the same as that of the state. Table 12 presents the forecasted income for every zone expressed in the year 2010 dollar value.

Trip productions and attractions were determined based upon user-supplied rates for the year 1975 to test if they match the productions and attractions reported in the 1975-2000 technical report. Next, trip productions and attractions were determined for the target year 2010 based on user-supplied rates, and the default rates presented in the NCHRP Report 187 which are built in QRS and QRS II.

Trip productions. Trip productions can be determined using default rates or user-supplied rates. To determine trip productions based on the default rates presented in the NCHRP Report 187, the year 2010 income for every zone was converted to the 1970 and 1980 dollar bases using the Consumer Price Index (CPI). The default production rates used in QRS and QRS II are based on 1970 and 1980 dollar values, respectively. Table 13 presents the forecasted income for the year 2010 indexed back to 1980 and 1970.

User-supplied production rates were developed based on the 1975-2000 technical report trip productions. The steps necessary to develop production rates are as follows:

1. Set up income ranges using the year 1975 dollar value. A maximum of 13 income ranges is permitted by QRS

TABLE 12

FORECASTED INCOME PER ZONE
FOR THE YEAR 2010

Zone Number	Forecasted Income ($)
1	39212
2	71780
3	119085
4	90118
5	119085
6	119085
7	75784
8	72121
9	120684
10	57460
11	57711
12	74180
13	82059
14	82059
15	59311
16	62955
17	75358
18	45289
19	35228
20	44399
21	44408
22	44408
23	65780
24	115280
25	87733
26	49893
27	44370
28	57469
29	51304
30	93630
31	53939
32	90895
33	117722
34	37887

TABLE 13

THE YEAR 2010 MEDIAN INCOME EXPRESSED IN 1970 AND 1980 DOLLARS

Zone Number	Forecasted Income ($)	1970 Income Using CPI	1980 Income Using CPI
1	39212	4976	10559
2	71780	9108	19329
3	119085	15111	32067
4	90118	11436	24268
5	119085	15111	32067
6	119085	15111	32067
7	75784	9616	20407
8	72121	9152	19421
9	120684	15315	32499
10	57460	7291	15472
11	57711	7823	15541
12	74180	9413	19975
13	82059	10413	22097
14	82059	10413	22097
15	59311	7526	15972
16	62955	7989	16953
17	75358	9562	20292
18	45289	5747	12196
19	35228	4470	9486
20	44399	5634	11956
21	44408	5635	11959
22	44408	5635	11959
23	65780	8347	17712
24	115280	14628	31043
25	87733	11133	23625
26	49893	6332	13436
27	44370	5630	11948
28	57469	7293	15476
29	51304	6510	13816
30	93630	11881	25213
31	53939	6845	14525
32	90895	11546	24501
33	117722	14939	31701
34	37887	4808	10203

and QRS II.

2. Stratify zones based on income ranges, that is, determine which zones fall within an income range.

3. Add the number of trips produced by all zones within a given income range and divide that total by the corresponding total number of dwelling units for the same zones. This results in the average number of trips produced per household, that is, production rates.

4. Calculate the percentage of average daily trips produced for every trip purpose using the following equations:

$$\% \text{ HBW trips} = \frac{\text{HBW trips}}{(\text{HBW} + \text{HBNW} + \text{NHB}) \text{ trips}} \quad (20)$$

$$\% \text{ HBNW trips} = \frac{\text{HBNW trips}}{(\text{HBW} + \text{HBNW} + \text{NHB}) \text{ trips}} \quad (21)$$

$$\% \text{ NHB trips} = \frac{\text{NHB trips}}{(\text{HBW} + \text{HBNW} + \text{NHB}) \text{ trips}} \quad (22)$$

Since the production rates were determined using the year 1975 productions, the income for that year was needed. But, no income data was available for the year 1975, therefore, the zonal income for the year 1980 obtained from the Census Data had to be converted to 1975 dollar value using the CPI. It is assumed that the real income in the

year 1975 and the year 1980 remained constant. In other words, the annual increase in income was offset by inflation, thus, making the percent annual increase in income equivalent to the CPI. Table 14 presents the 1980 income for every zone, and the corresponding value in terms of the year 1975 dollar. Applying the above listed steps resulted in the user-supplied production rates shown in Table 15.

With the trip production rates table on hand, the next step is to determine the trip productions for the target year 2010. This requires that the year 2010 income be converted to the year 1975 dollar base since the production rates are based on the year 1975 dollar value. Table 16 presents the zonal income for the year 2010, and its 1975 equivalent values as determined using the CPI.

Trip Attractions. Trip attractions are estimated based on retail employment, non-retail employment, and dwelling units in a zone. The attraction equations for each trip purpose are presented in Chapter III.

Attractions can be determined using either the default coefficients, or user-supplied coefficients. Table 17 presents the default coefficients which are reproduced from Table 3, Part C, of Chapter Two of the NCHRP Report 187.

User-supplied coefficients were determined using linear regression analysis. These coefficients are based

TABLE 14

THE YEAR 1980 MEDIAN INCOME EXPRESSED IN 1975 DOLLARS

Zone Number	Median Annual Income for 1980 ($)	1975 Income Using CPI
1	8286	5412
2	15168	9907
3	25164	16436
4	19043	12438
5	25164	16436
6	25164	16436
7	16014	10460
8	15240	9954
9	25502	16657
10	12142	7931
11	12195	7965
12	15675	10238
13	17340	11326
14	17340	11326
15	12533	8186
16	13303	8689
17	15924	10401
18	9570	6251
19	7444	4862
20	9382	6128
21	9384	6128
22	9384	6128
23	13900	9079
24	24360	15911
25	18539	12109
26	10543	6886
27	9376	6124
28	12144	7932
29	10841	7081
30	19785	12923
31	11398	7445
32	19207	12545
33	24876	16248
34	8006	5229

TABLE 15

USER SUPPLIED TRIP PRODUCTION RATES
DEVELODED FOR THE YEAR 1975

Income Range ($1000)	Zones Within a Range	Average Daily Vehicle-Trips per Household	Percent Trips by Purpose		
			HBW	HBNW	NHB
0-5	19	17.2	5.4	41.5	53.1
5-6	1, 34	13.9	6.6	42.5	50.9
6-7	18, 20, 22 26, 27	21.6	4.3	26.9	68.8
7-8	10, 11, 28 29, 31	11.5	8.1	52.7	39.2
8-9	15, 16	13.8	6.7	48.4	44.9
9-10	2, 8, 23	12.1	7.7	55.5	36.8
10-11	7, 12, 17	13.6	6.8	49.1	44.1
11-12	13, 14	11.1	8.3	59.8	31.9
12-13	4, 25, 30, 32	13.6	6.8	48.9	44.3
13-16	24	14.8	6.2	45.0	48.8
16+	3, 5, 6, 9, 33	12.9	7.2	51.4	41.4

TABLE 16

THE YEAR 2010 MEDIAN INCOME EXPRESSED IN 1975 DOLLARS

Zone Number	Forecasted Annual Income for 2010 ($)	1975 Income Using CPI
1	39212	6897
2	71780	12625
3	119085	20945
4	90118	15851
5	119085	20945
6	119085	20945
7	75784	13329
8	72121	12685
9	120684	21227
10	57460	10106
11	57711	10151
12	74180	13047
13	82059	14433
14	82059	14433
15	59311	10432
16	62955	11073
17	75358	13254
18	45289	7966
19	35228	6196
20	44399	7809
21	44408	7811
22	44408	7811
23	65780	11569
24	115280	20276
25	87733	15431
26	49893	8776
27	44370	7804
28	57469	10108
29	51304	9024
30	93630	16468
31	53939	9487
32	90895	16003
33	117722	20706
34	37887	6664

TABLE 17

DEFAULT COEFFICIENTS FOR ATTRACTION EQUATIONS

HBW Trip Attractions = [1.7(Total Employment)]
HBNW Trip Attractions = [10.0(Retail Employment) + 0.5(Non-Retail Employment) + 1.0(Dwelling Units)]
NHB Trip Attractions = [2.0(Retail Employment) + 2.5(Non-Retail Employment) + 0.5(Dwelling Units)]

Source: Reference [19]

on the year 1975 trip attractions and land-use data available in the 1975-2000 technical report and are presented in Table 18. The results of the regression analysis are shown in Table 19.

Trip productions and attractions for OSU. The 1975-2000 technical report indicated that different travel characteristics exist for Oklahoma State University and the remainder of the study area. In the NCHRP Report 187 terminology, OSU is regarded as a special generator. As a result, the trip productions and attractions for Oklahoma State University, zone 21, were determined seperately.

Productions and attractions for OSU were estimated based on OSU Police Department parking records. It is assumed that each parking permit results in a trip production and attraction to OSU. Over a period of six years from 1980 to 1986 the average number of parking permits issued to the school employees and off-campus students is 3750 and 5200 permits, respectively.

Home based work trips were determined based on the number of parking permits given to school employees. Home based non-work trips were estimated using the number of parking permits issued to off-campus students. Non-home based trips are determined based on the percentage allocated for the NHB trip purpose in the 1975-2000 technical report. This percentage is obtained by dividing the NHB trip attractions by the total trip attractions for

TABLE 18

DATA NEEDED FOR REGRESSION ANALYSIS

Zone Number	Retail Employment	Non-Retail Employment	Dwelling Units	No. of Trip Attractions		
				HBW	HBNW	NHB
1	7	4	47	11	148	390
2	2	12	104	14	195	690
3	11	355	187	359	422	2140
4	8	335	354	337	674	2540
5	3	3	486	6	847	1276
6	0	20	3	20	5	140
7	0	0	74	0	125	351
8	0	0	8	0	14	66
9	31	4	23	34	343	646
10	20	110	483	128	1009	1748
11	21	608	426	617	1328	1493
12	148	1509	491	1636	3303	3390
13	47	379	756	418	1733	2626
14	0	0	62	0	104	278
15	0	45	71	44	119	472
16	51	41	235	90	896	1422
17	137	560	673	684	2804	3652
18	191	246	451	429	2632	4652
19	672	264	1363	918	8885	12491
20	0	1466	380	1438	640	6734
21	98	4755	3641	1369	13875	20100
22	37	97	513	131	1226	1684
23	197	584	1381	766	4648	5862
24	4	2117	135	2081	1615	974
25	108	885	1301	974	3249	7869
26	379	1817	441	1783	5228	9166
27	460	266	228	712	4895	7608
28	54	105	342	156	1105	2252
29	0	10	59	10	99	310
30	46	108	364	151	1064	2106
31	0	23	46	22	77	294
32	0	0	141	0	237	498
33	0	4	236	4	397	810
34	0	0	33	0	56	178

Source: Reference [13].

TABLE 19

ATTRACTION EQUATIONS ANALYSIS

Trip Purpose	Equations	Mean	Std Error of Est.	Coefficient of Determination
HBW	0.93(total employment) + 11.96	423.4	57.1	0.9906
HBNW	9.86(retail employment) + 0.5(nonretail employ) + 1.56 (dwelling units) -10.6	1519	179.7	0.9926
NHB	12.9(retail employment) +1.14(nonretail employ) +2.64(dwelling units) +232	2631	1058	0.8920

zone 21 for the three trip purposes, that is [(15114 / 1369 + 13875 + 15114) * 100 = 49.5 %].

External Stations Productions and Attractions. The NCHRP Report 187 requires that the user supply the productions and attractions for every external station included in the study. The 1975-2000 technical report gives the total productions and attractions for external stations 35 through 40. These values are given for the years 1975 and 2000. It is assumed that the year 2000 P's and A's for the external stations are the same P's and A's used for the year 2010 in this study. However, these values should be split into HBW, HBNW, and NHB trip purposes.

To determine the percentage of trips made for each trip purpose, the 1975-2000 is used. It is assumed that the percentage for each trip purpose for the external stations is the same as the percentage used for internal traffic zones. Thus, to determine the percentage share for HBW trip purpose, the total trip productions or attractions for that trip purpose taken from the 1975-2000 technical report is divided by the total trip productions or attractions for all trip purposes. The percentage shares for HBNW and NHB are determined in a similar fashion. The resulting percentages are 6.8 percent for HBW trip purpose, 47.4 percent for HBNW trip purpose, and 45.8 percent for NHB trip purpose.

Multiplying these percentages by the total trip

productions or attractions for every external station taken from the 1975-2000 technical report results in the number of trips by trip purpose. The results are shown in Table 20. Similarly, the year 2010 projected P's and A's which are equal to the year 2000 values available in the 1975-2000 technical report are divided into HBW, HBNW, and NHB trip purposes. The outcome of this is shown in Table 21.

Balancing Trip Productions and Attractions. Inspection of the total productions and total attractions shows that they do not match. The areawide control factors, F's, are calculated and applied to the individual zone attractions to balance the total productions and attractions. Zone 21, that is, OSU, is marked as a special generator. Zones 35, 36, 37, 38, 39, and 40 are marked as external stations and thus do not enter the balancing process.

Trip Distribution

With the balanced productions and attractions at hand, the next step is to develop trip tables for HBW, HBNW, and NHB trip purposes. The initial step is to develop a travel time matrix consisting of interzonal and intrazonal travel times. Interzonal travel time is defined as the travel time between zones consisting of terminal times at each end plus the in-vehicle travel time. Intrazonal travel time, on the other hand, is the average travel time for trips beginning and ending in the same zone, including terminal

TABLE 20
P'S AND A'S FOR EXTERNAL STATIONS
FOR THE YEAR 1975

ZONE	HBW		HBNW		NHB	
	P'S	A'S	P'S	A'S	P'S	A'S
35	241	241	1706	1706	1652	1652
36	268	268	1896	1896	1836	1836
37	295	295	2086	2086	2020	2020
38	117	117	829	829	803	803
39	8	8	59	59	57	57
40	20	20	142	142	138	138

TABLE 21

P'S AND A'S FOR SPECIAL GENERATOR AND
EXTERNAL STATIONS FOR THE YEAR 2010

ZONE	HBW		HBNW		NHB	
	P'S	A'S	P'S	A'S	P'S	A'S
21	3750	3750	5200	5200	8750	8750
35	328	328	2323	2323	2249	2249
36	335	335	2370	2370	2295	2295
37	399	399	2820	2820	2725	2725
38	144	144	1019	1019	987	987
39	23	23	166	166	161	161
40	37	37	261	261	252	252

time. The procedures used in determining the travel time matrix differ in QRS and QRS II, therefore will be presented seperately.

Determination of Interzonal Travel Time using QRS. Inter-zonal travel time is determined based on the x-y coordinates of zone centroid, the zone location, and percent of distance traveled on arterials for every origin-destination (O-D) movement. Referrring to Figure 9, the x and y coordinates are measured from the centroid of a zone to the x and y axis drawn from an arbitrary origin. In this study, the coordinates of the zone centroids presented in Table 22 are measured from the study area map which is drawn to a scale of one inch equals one mile.

Zonal location defines each zone as central business district (CBD), or central city (CC), or suburb (S). In this study, all zones were designated as CC since no defined boundaries exist between for the CBD, CC, and S.

The percent distance traveled in each zonal location for every O-D movement and the percent of distance traveled on arterials is estimated using the functional classification street map for the City of Stillwater. Since all zones are classified as central city (CC), one-hundred percent of the distance for every trip interchange is traveled in the central city. The percent of distance traveled on arterials is approximated from the street map for every O-D movement and is presented in Appendix B.

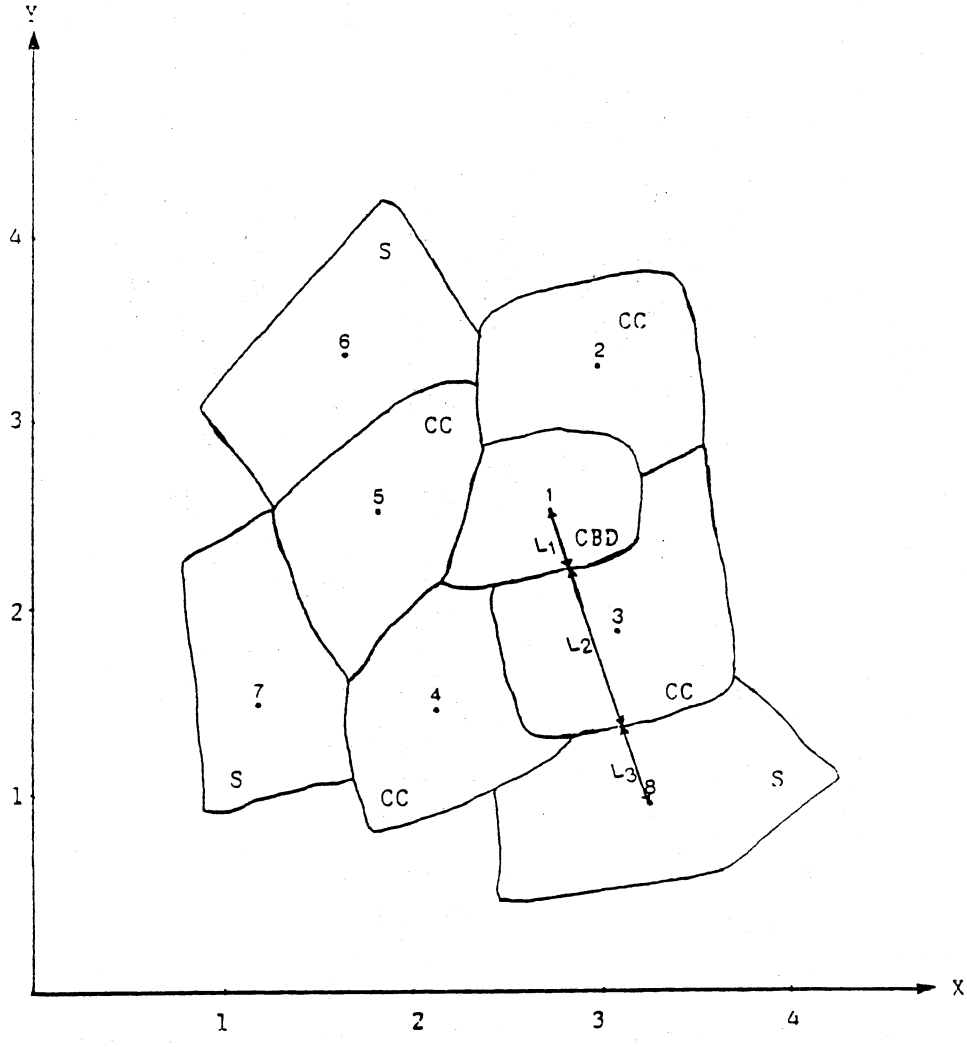


Figure 9. Illustration of X-Y Coordinates and Zonal Location

TABLE 22

X AND Y COORDINATES

ZONE	X-COORDINATE	Y-COORDINATE
1	3.44	9.75
2	6.69	8.75
3	5.75	7.38
4	6.17	6.44
5	4.78	6.22
6	4.00	6.75
7	2.44	6.75
8	0.70	5.25
9	2.00	4.20
10	3.81	5.10
11	5.44	5.15
12	5.70	5.37
13	6.38	5.35
14	8.20	5.88
15	8.75	3.80
16	7.50	3.94
17	6.50	4.31
18	5.87	4.20
19	5.44	4.12
20	5.00	4.78
21	5.00	4.50
22	4.38	4.78
23	4.50	4.15
24	2.12	3.22
25	4.40	3.50
26	5.38	3.63
27	5.88	3.50
28	6.38	3.56
29	7.69	2.12
30	5.78	2.00
31	6.00	0.75
32	4.50	1.75
33	3.06	2.56
34	1.20	2.16

Scale: 1 inch = 1 mile

Determination of Intrazonal Travel Time using QRS. Intrazonal travel time is calculated based on travel time of surrounding zones. The method involves the measurement of airline distance from the centroid of the zone of intra-travel to the centroids of all adjacent zones. These airline distances are then averaged, and the intrazonal airline distance is taken as one-half of this average [19].

Determination of Interzonal Travel Time using QRS II. In QRS II, interzonal travel time is determined by adding the travel time on the centroid connector to the travel time on all links that fall on the minimum path. The centroid connector travel time is defined as the time required to travel from the centroid of a zone to the nearest intersection. The equation used is:

$$t_{cc} = p_1 * v_1 + p_2 * v_2 + p_3 * v_3 \qquad (23)$$

where

t_{cc}= travel time on centroid connector.

p_1 = weight for walking time that has no units. QRS II suggests a value of 1.3 for p_1.

p_2 = dimensionless weight for in-vehicle travel time. A value of 1.0 is suggested in QRS II.

p_3 = reciprocal of the value of time in units of minutes per cents. QRS II recommends a value of 0.125.

v_1 = walking access time in minutes

v_2 = network access time in minutes

v_3 = parking charges attributable to this one-way trip in cents.

Travel time on all links constituting the shortest path is determined as a function of volume and "design capacity". The equation used is:

$$t_{link} = v_1 * (p_1 + p_o * v_2^{p_2} * v_3^{p_3}) \qquad (24)$$

where

t_{link} = travel time on link.

p_o = constant used in the Traffic Assignment Manual published by the Bureau of Public Roads. A value of 0.15 is suggested in QRS II

p_1 = constant used in the Traffic Assignment Manual published by the Bureau of Public Roads. A vlaue of 1 is suggested in QRS II.

p_2 = constant used in the Traffic Assignment Manual published by the Bureau of Public Roads. A value of 4 is suggested in QRS II.

p_3 = constant used in the Traffic Assignment Manual published by the Bureau of Public Roads. A value of -4 is suggested in QRS II.

v_1 = free flow travel time on links which is defined as the travel time necessary for vehicle to travel over a link when traffic is very light.

v_2 = estimated volume on link in vehicles per hour.

v_3 = design capacity in vehicle per hour.

Determination of Intrazonal Travel Time Using QRS II. QRS II calculates intrazonal travel time based on the area of the zone and the average speed of vehicles on intrazonal trips. The equation used is the multiplicative functional form, and can be expressed as follows:

$$t_{intra} = p_o * (1/v_1) * (v_2)^{0.5} \quad (25)$$

where

t_{intra}= travel time on intrazonal trips.

p_o = number of minutes in an hour multiplied by three over four.

v_1 = average speed for trips in miles per hour.

v_2 = area of a zone in square miles.

Travel Time Factors. Three sets of travel time factors were used in this study. The first set of travel time factors which is used in QRS and QRS II was taken from the 1975-2000 technical report. These factors are presented in Table 8. The second set is determined based on Equation 8 using the suggested values for the trip distribution parameter, a_k, given in the user manual for QRS II. The third set of travel time factors is also determined using Equation 8 along with the a_k values determined from the 1968-1990 technical report. It should be noted that the second and third sets of travel time factors were only used

in QRS II.

The suggested values in QRS II for a_k are 1.99 for HBW trip purpose, 2.73 for HBNW trip purpose, and 2.68 for NHB trip purpose. To determine the a_k's from the 1968-1990 technical report, Figures 10 through 12 were utilized [12]. The values of a_k were determined from the slope of the straight line drawn on the figures. In doing so, the trip distribution parameters, a_k's, for HBW, HBNW, and NHB trip purposes are determined. These values are 1.99 for HBW trip purpose, 1.26 for HBNW trip purpose, and 2.81 for NHB trip purpose.

Applying the Gravity Model. The gravity model was applied to compute the trip interchanges between zones, T_{ij}. This was repeated using 1) travel time factors taken from the 1975-2000 technical report for QRS and QRS II, 2) travel time factors determined using the power function based on suggested values given in QRS II, and 3) travel time factors determined from the 1968-1990 technical report. Two iterations are selected to ensure that the attraction constraint given by Equation 11 is satisfied.

Traffic Assignment

The method used in the traffic assignment module is the all-or-nothing technique [19]. This technique assigns all trips to the shortest path and none to alternative routes.

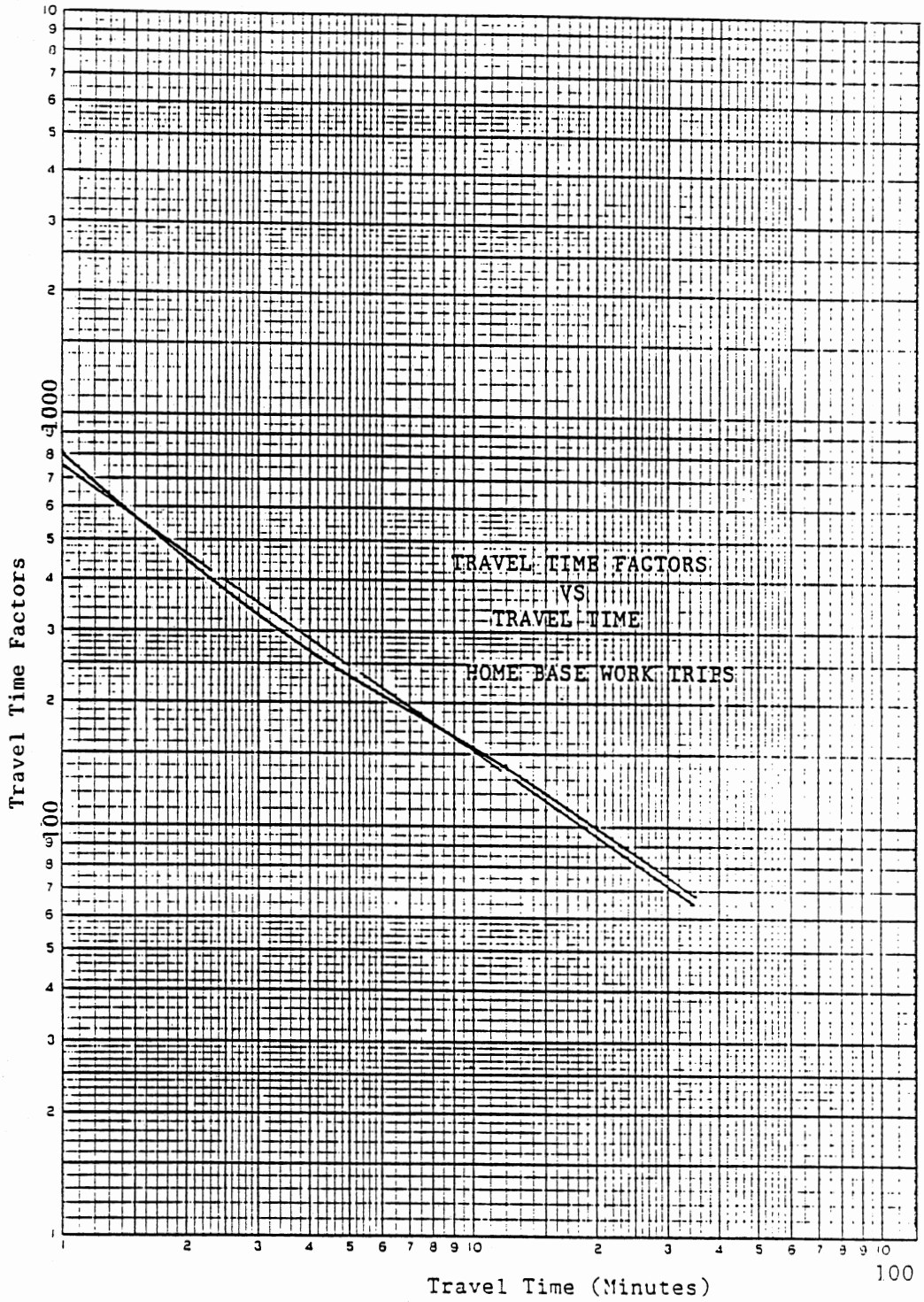


Figure 10. HBW Travel Time Factors [12]

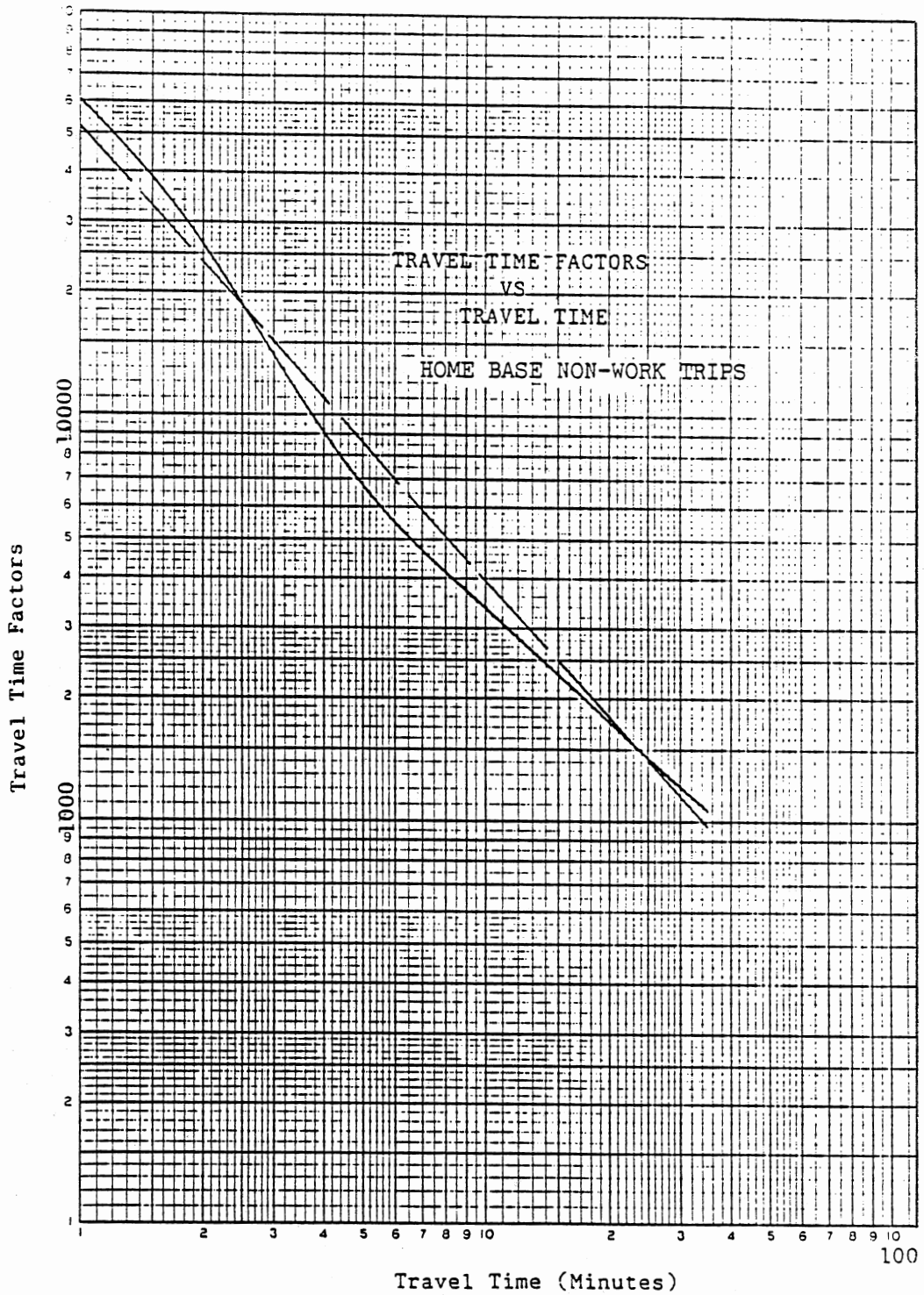


Figure 11. HBNW Travel Time Factors [12]

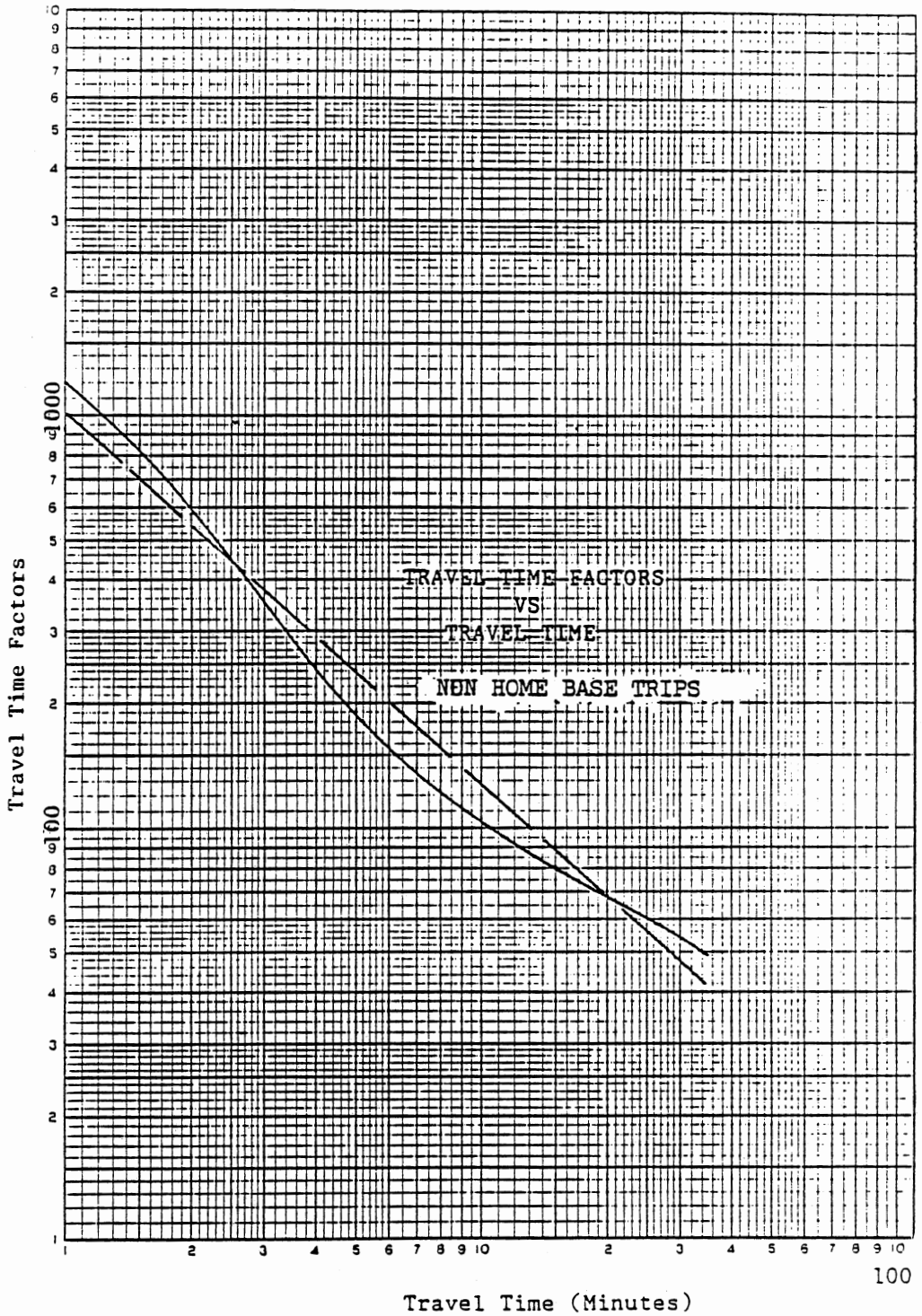


Figure 12. NHB Travel Time Factors [12]

In QRS, a list of links that comprise the minimum path connecting each origin-destination pair was developed based on a logical (shortest) path as determined by inspection of the functional classification street map. These lists are presented in Appendix C. Three assumptions were used in the assignment process. They are:

1. Travel time on traveled route is less than or equal to travel time on other alternative routes. Thus, drivers prefer traveling on arterials over collectors and on collectors over local streets.

2. For trip interchange i-j and trip interchange j-i, the same path is used.

3. Route selection is independent of traffic volumes.

QRS II, on the other hand, compiles a list of links on the shortest path between all pairs of zones during path finding. The shortest path is determined from the travel times on the links derived from the speed of vehicles on each link. This indicates that the speed on every link must be known. Trips are then loaded on the links connecting origin and destination zones.

Intersection Capacity Analysis

Intersection capacity analysis is necessary to predict the operating conditions of the street network. The data required for this analysis consists of the number of lanes on each approach, hourly volumes, percent of left and right

turn movements, and percent of heavy vehicles and buses.

The initial step is to convert daily traffic volumes obtained from the traffic assignment module into peak hour volumes. Using the 1968 technical report prepared by ODOT, the peak hour is selected between 5:00 and 6:00 pm, and the conversion factor is 8.73 percent [12]. Multiplying the assigned daily volumes by the conversion factor will result in the peak hour volumes.

Intersection capacity analysis is performed using the procedures outlined in the NCHRP Report 187 and the Highway Capacity Manual (HCM) [11]. These methods will be presented seperately.

Intersection Capacity Analysis Using NCHRP Report 187. This method which is based on the 1965 Highway Capacity Manual requires the determination of hourly capacity for signalized intersection approaches using Table 51 found in Chapter Eight of the NCHRP Report. The equation is:

$$A.C. = (P.C.) * f_p * f_l * f_{rt} * f_{lt} * f_{hv} * G/C \quad (16)$$

where

A.C. = adjusted capacity in vph of green

P.C. = possible capacity (Table 51)

f_p = urbanized area population adjustment factor (Table 51)

f_l = location adjustment factor (Table 51)

f_{rt} = right turn adjustment factor

f_{lt} = left turn adjustment factor

f_{hv} = heavy vehicles adjustment factor

G/C = green to cycle ratio

Table 51 of the NCHRP Report 187 assumes a 0.85 peak-hour factor (PHF), 5 percent commercial trucks, 10 percent left turn, 10 percent right turn, and a 0.5 G/C. These assumptions are made in this study.

Dividing the peak hour volume for each intersection approach by its corresponding capacity results in a volume to capacity ratio. The NCHRP Report 187 suggested upper limits for V/C ratios in determining the appropriate level of service (LOS) are given in Table 23.

Intersection Capacity Analysis Using the 1985 HCM. The 1985 HCM approach is based upon the critical movement technique. Worksheets similar to the one shown in Figure 13 have been provided to facilitate the planning analysis. The steps are presented in details in Chapter Nine of the Highway Capacity Manual [16]. These steps are:

Step 1. Record demand hourly volumes. The terminology "demand volumes" is used because these volumes are projections of expected traffic at some future time. These volumes are recorded in the appropriate spaces provided in the corners of the worksheet.

Step 2. Record geometrics. Sketch the approach lanes and lane configurations on the worksheet within the

TABLE 23

SUGGESTED UPPER LIMITS OF V/C
FOR LOS DETERMINATION

LEVEL OF SERVICE	MAXIMUM V/C RATIO
A	0.6
B	0.7
C	0.8
D	0.9
E	1.0
F	(varies)

Source: Reference [19]

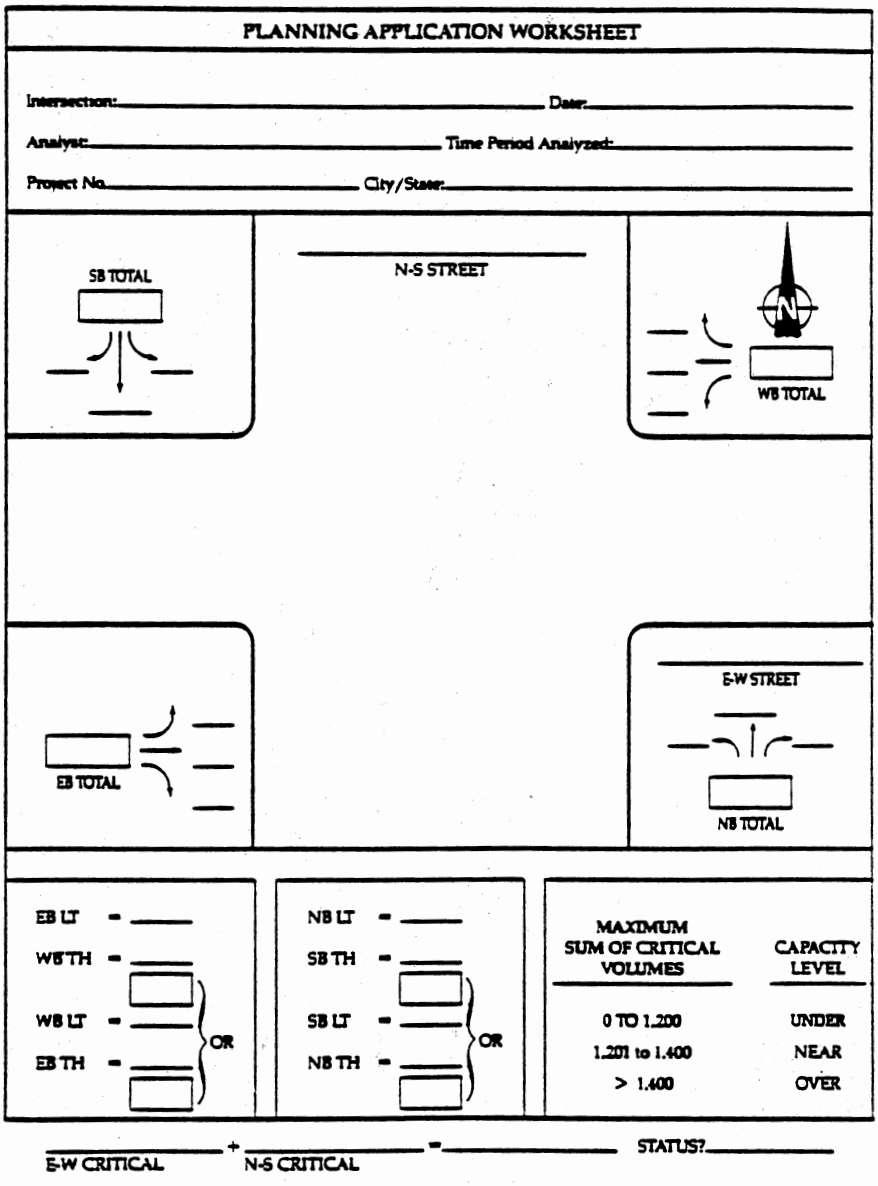


Figure 13. Planning Capacity Worksheet [11]

intersection schematic diagram. Then, identify the traffic movement or combination of movements for each traffic lane.

Step 3. Identify lane impedance. Identify left-turn movements in shared lanes that interfere with opposing through traffic. These movements will impede through vehicles using the same lane.

Step 4. Assign lane volume. Through and turning movement volumes in each lane must be distributed as uniformly as possible.

Step 5. Find the sum of critical lane volumes. These represent the total demand volume per lane at the intersection which in turn equals the sum of critical lane volumes on each street. These volumes should be recorded in the appropriate boxes provided in the worksheet.

Step 6. Check intersection capacity. The sum of critical lane volumes is checked against the capacity criteria. The results of the planning analysis give a general indication of the acceptability of the capacity of the intersection for the forecast future demand condition.

Five intersections were selected for applying the HCM procedures. They are: Perkins and Sixth, Perkins and McElroy, Duck and Hall of Fame, Main and Sixth, and Western and Sixth. Applying the HCM procedures to these intersections should enable the planner to determine whether they operated under, near, or over capacity.

CHAPTER V

RESULTS AND DISCUSSION

Trip Generation

The output of the trip generation module includes trip productions (P's), and trip attractions (A's). The P's and A's were determined for the base year 1975 based on the user-supplied rates shown in Table 15 to compare them with the P's and A's available in the 1975-2000 technical report. The output is presented in Table 24. The year 1975 is selected because of the availability of trip productions and attractions for that year. Tables 25, 26 and 27 give the zonal productions obtained using QRS and from the 1975-2000 technical report and the percent difference between them for every trip purpose. It can be seen from Table 25 that the percent difference in HBW trip productions varied from 174 percent to -10 percent. The percent difference shown in Table 26 for HBNW trip purpose ranged from 200 percent to a -63 percent, while the percent difference for NHB trip purpose shown in Table 27 varied from 189 percent to a -78 percent.

Similarly, Tables 28 through 30 present the zonal attractions calculated using QRS and the corresponding

TABLE 24

TRIP PRODUCTIONS AND ATTRACTIONS FOR THE YEAR 1975
BASED ON USER-SUPPLIED RATES USING QRS

	HBW		HBNW		NHB	
ZONE	P	A	P	A	P	A
1	44	10	312	144	251	219
2	97	13	690	188	555	314
3	174	340	1240	578	999	1040
4	329	319	2347	799	1891	1420
5	451	6	3222	789	2596	1325
6	3	19	20	15	16	31
7	69	0	491	115	395	195
8	7	0	53	12	43	21
9	21	33	153	344	123	465
10	449	121	3203	1006	2580	1659
11	396	585	2825	1176	2275	2089
12	456	1541	3256	2980	2622	4926
13	702	396	5013	1832	4037	3034
14	58	0	411	97	331	164
15	66	42	471	133	379	239
16	218	86	1558	890	1255	1325
17	625	648	4462	2681	3594	4182
18	419	406	2990	2710	2409	3935
19	1266	870	9038	8884	7279	12568
20	353	1363	2520	1326	2029	2674
21	3382	4513	24142	9024	19445	16297
22	476	125	3401	1214	2740	1941
23	1283	726	9157	4389	7375	6853
24	125	1973	895	1309	721	2821
25	1208	923	8626	3537	6948	5837
26	410	2042	2924	5333	2355	8125
27	212	675	1512	5024	1218	6839
28	318	148	2268	1118	1826	1719
29	55	9	398	97	315	167
30	338	143	2414	1075	1944	1677
31	43	21	305	83	246	148
32	131	0	935	220	753	372
33	218	4	1565	370	1260	628
34	31	0	219	51	176	87
35	241	241	1706	1706	1652	1652
36	268	268	1896	1893	1836	1836
37	295	295	2086	2086	2020	2020
38	117	117	829	829	803	803
39	8	8	59	59	57	57
40	20	20	142	142	138	138

TABLE 25

PERCENT DIFFERENCE IN HBW TRIP PRODUCTIONS
FOR THE YEAR 1975

ZONE	HBW P'S FROM QRS	HBW P'S FROM THE 1975-2000 TECHNICAL REPORT	% DIFFERENCE
1	10	11	-9.1
2	13	14	-7.1
3	340	359	-5.3
4	319	337	-5.3
5	6	6	0
6	19	20	-5.0
7	0	0	0
8	0	0	0
9	33	34	-2.9
10	121	128	-5.5
11	585	617	-5.2
12	541	1636	-5.8
13	396	418	-5.3
14	0	0	0
15	42	44	-4.5
16	86	90	-4.4
17	648	684	-5.3
18	406	429	-5.4
19	870	918	-5.2
20	363	1438	-5.2
21	750	1369	173.9
22	125	131	-4.6
23	726	766	-5.2
24	973	2081	-5.2
25	923	974	-5.2
26	2042	1783	14.5
27	675	712	-5.2
28	148	156	-5.1
29	9	10	-10.0
30	143	151	-5.3
31	21	22	-4.5
32	0	0	0
33	4	4	0
34	0	0	0

TABLE 26

PERCENT DIFFERENCE IN HBNW PRODUCTIONS FOR THE YEAR 1975

ZONE	HBNW P'S FROM QRS	HBNW P'S FROM THE 1975-2000 TECHNICAL REPORT	% DIFFERENCE
1	144	148	-2.7
2	188	195	-3.6
3	578	422	36.9
4	799	674	18.5
5	789	847	-6.8
6	15	5	200.0
7	115	125	-8.0
8	12	14	-14.3
9	344	343	0.3
10	1006	1009	-0.3
11	1176	1328	-11.4
12	2980	3303	-9.8
13	1832	1733	5.7
14	97	104	-6.7
15	133	119	-11.8
16	890	896	-0.7
17	2681	2804	-4.4
18	2710	2632	2.9
19	8884	8885	-0.1
20	1326	640	107.2
21	5200	13875	-62.5
22	1214	1226	-0.9
23	4389	4648	-5.6
24	1309	1615	-18.9
25	3537	3249	-8.9
26	5333	5228	2.0
27	5024	4895	2.6
28	1118	1105	1.2
29	97	99	-2.0
30	1075	1064	1.0
31	83	77	7.8
32	220	237	-7.2
33	370	397	-6.8
34	51	56	-8.9

TABLE 27

PERCENT DIFFERENCE IN NHB PRODUCTIONS
FOR THE YEAR 1975

ZONE	NHB P'S FROM QRS	NHB P'S FROM THE 1975-2000 TECHNICAL REPORT	% DIFFERENCE
1	219	390	-43.8
2	314	690	-54.5
3	1040	2140	-51.0
4	1419	2540	-44.1
5	1325	1276	3.8
6	31	140	-77.9
7	195	351	-44.4
8	21	66	-68.2
9	464	646	-28.2
10	1658	1748	-5.1
11	2088	1493	39.9
12	4920	3390	45.1
13	3032	2626	15.5
14	164	278	-41.0
15	239	472	-49.4
16	1323	1422	-6.9
17	4177	3652	14.4
18	3927	4652	-15.6
19	12541	12491	0.4
20	2674	6734	-60.3
21	8750	15114	-42.1
22	1941	1684	15.3
23	6845	5862	16.8
24	2821	974	189.6
25	5832	7869	-25.9
26	8110	9166	-11.5
27	6821	7608	-10.3
28	1717	2252	-23.8
29	167	310	-46.1
30	1676	2106	-20.4
31	148	294	-49.7
32	372	498	-25.3
33	628	810	-22.5
34	87	178	-51.1

values from the 1975-2000 technical report for every trip purpose. The percent difference as shown in Table 28 varied from 174 percent to -10 percent. The percent difference for HBNW trip purpose shown in Table 29 varied from 200 percent to -63 percent. Also, the percent difference for NHB trip purpose shown in Table 30 varied from 190 percent to -78 percent.

The percent difference for all trip purposes is significantly large. The differnece can be related to the aggregeation of zones, and the use of different explanatory variables in the production rates and attraction equations.

Using QRS, the P's and A's were determined for the target year 2010 based on the user-supplied rates given in Table 15, land-use data shown in Table 6, and the income shown in Table 16. This process was then repeated using the default rates. Table 31 presents the year 2010 P's and A's calculated based upon user-supplied rates. The P's and A's determined using default rates are presented in Table 32.

The same procedures are repeated for QRS II, that is, the P's and A's are estimated based on default rates and user-supplied rates for the year 2010. Table 33 presents the resulting P's and A's based on default rates. Similarly, Table 34 presents the resulting P's and A's based on user-supplied rates.

TABLE 28

PERCENT DIFFERENCE IN HBW TRIP ATTRACTIONS
FOR THE YEAR 1975

ZONE	HBW A'S FROM QRS	HBW A'S FROM THE 1975-2000 TECHNICAL REPORT	% DIFFERENCE
1	10	11	-9.1
2	13	14	-7.1
3	340	359	-5.3
4	319	337	-5.3
5	6	6	0
6	19	20	-5.0
7	0	0	0
8	0	0	0
9	33	34	-2.9
10	121	128	-5.5
11	585	617	-5.2
12	1541	1636	-5.8
13	396	418	-5.3
14	0	0	0
15	42	44	-4.5
16	86	90	-4.4
17	648	684	-5.3
18	406	429	-5.4
19	870	918	-5.2
20	1363	1438	-5.2
21	3750	1369	173.9
22	125	131	-4.9
23	726	766	-5.2
24	1973	2081	-5.2
25	923	974	-5.2
26	2042	1783	14.5
27	675	712	-5.2
28	148	156	-5.1
29	9	10	-10.1
30	143	151	-5.3
31	21	22	-4.5
32	0	0	0
33	4	4	0
34	0	0	0

TABLE 29

PERCENT DIFFERENCE IN HBNW TRIP ATTRACTIONS
FOR THE YEAR 1975

ZONE	HBNW A'S FROM QRS	HBNW A'S FROM THE 1975-2000 TECHNICAL REPORT	% DIFFERENCE
1	144	148	-2.7
2	188	195	-3.6
3	578	422	37.0
4	799	674	18.5
5	789	847	-6.8
6	15	5	200.0
7	115	125	-8.0
8	12	14	-14.3
9	344	343	0.3
10	1006	1009	-0.3
11	1176	1328	-11.4
12	2980	3303	-9.8
13	1832	1733	5.7
14	97	104	-6.7
15	133	119	11.8
16	890	896	-0.7
17	2681	2804	-4.4
18	2710	2632	3.0
19	8884	8885	0.0
20	1326	640	107.2
21	5200	13875	-62.5
22	1214	1226	-1.0
23	4389	4648	-5.6
24	1309	1615	-18.9
25	3537	3249	8.9
26	5333	5228	2.0
27	5024	4895	2.6
28	1118	1105	1.2
29	97	99	-2.0
30	1075	1064	1.0
31	83	77	7.8
32	220	237	-7.2
33	370	397	-6.8
34	51	56	-8.9

TABLE 30

PERCENT DIFFERENCE IN NHB TRIP ATTRACTIONS
FOR THE YEAR 1975

ZONE	NHB A'S FROM QRS	NHB A'S FROM THE 1975-2000 TECHNICAL REPORT	% DIFFERENCE
1	219	390	-43.3
2	314	690	-54.5
3	1040	2140	-51.4
4	1419	2540	-44.1
5	1325	1276	3.8
6	31	140	-77.9
7	195	351	-44.4
8	21	66	-68.2
9	464	646	-28.2
10	1658	1748	-5.1
11	2088	1493	39.9
12	4920	3390	45.1
13	3032	2626	15.5
14	164	278	-41.0
15	239	472	-49.4
16	1323	1422	-7.0
17	4177	3652	14.4
18	3927	4652	-15.6
19	12541	12491	0.4
20	2674	6734	-60.3
21	8750	15114	-42.1
22	1941	1684	15.3
23	6845	5862	16.8
24	2821	974	189.6
25	5832	7869	-25.9
26	8110	9166	-11.5
27	6821	7608	-10.3
28	1717	2252	-23.8
29	167	310	-46.1
30	1676	2106	-20.4
31	148	294	-49.7
32	372	498	-25.3
33	628	810	-22.5
34	87	178	-51.1

TABLE 31

2010 TRIP PRODUCTIONS AND ATTRACTIONS BASED ON USER-SUPPLIED RATES USING QRS

	HBW		HBNW		NHB	
ZONE	P	A	P	A	P	A
1	67	432	477	2170	385	3013
2	323	232	2307	1529	1859	2286
3	667	3139	4761	3575	3835	6707
4	636	2730	4542	3070	3658	5825
5	1064	73	7599	2183	6120	3562
6	33	616	232	507	187	1000
7	262	91	1870	779	1506	1221
8	28	18	199	56	160	101
9	47	129	338	795	272	1105
10	871	188	6220	2014	5009	3271
11	409	638	2917	1619	2350	2685
12	580	2045	4137	5611	3333	8599
13	2152	873	15368	5853	12374	9410
14	382	115	2725	1115	2195	1744
15	106	92	756	583	608	861
16	808	185	5769	2346	4646	3641
17	1890	2146	13493	9102	10868	14000
18	360	780	2573	4750	2072	6661
19	1144	565	8169	5071	6580	7521
20	226	0	1611	379	1298	642
21	3750	3750	5200	5200	8750	8750
22	572	125	4084	1374	3290	2214
23	1389	580	9913	2944	7984	5034
24	803	2620	5735	3591	4620	6542
25	1402	1271	10012	6034	8064	9308
26	499	647	3561	4443	2868	6304
27	256	862	1830	4900	1474	6819
28	626	249	4469	2421	3600	3637
29	73	49	524	262	422	410
30	620	263	4429	2410	3568	3627
31	81	63	577	404	465	601
32	770	167	5497	2151	4427	3358
33	884	774	6312	3080	5084	4944
34	64	59	458	317	369	477
35	328	328	2323	2323	2249	2249
36	335	335	2370	2370	2295	2295
37	399	399	2820	2820	2725	2725
38	144	144	1019	1019	987	987
39	23	23	166	166	161	161
40	37	37	261	261	252	252

TABLE 32

2010 TRIP PRODUCTIONS AND ATTRACTIONS BASED ON DEFAULT RATES USING QRS

	HBW		HBNW		NHB	
ZONE	P	A	P	A	P	A
1	180	790	857	2157	346	1101
2	869	425	4143	1347	1671	753
3	1792	5738	8547	3181	3446	8755
4	1710	4989	8154	2681	3288	7651
5	2860	134	13642	1547	5501	751
6	87	1125	417	489	168	1666
7	704	167	3357	626	1354	370
8	75	32	357	40	144	62
9	127	236	607	776	245	339
10	2341	343	11166	1495	4502	950
11	1098	1166	5238	1381	2112	1904
12	1558	3733	7428	5315	2995	5621
13	5783	1596	27582	4582	11122	3412
14	1026	211	4893	891	1973	493
15	285	168	1357	525	547	285
16	2172	338	10356	1872	4176	885
17	5079	3922	24225	8034	9768	6530
18	968	1426	4619	4588	1862	2092
19	3075	1034	14666	4424	5904	1984
20	607	0	2893	243	1166	122
21	9088	8250	43342	6998	17477	13904
22	1533	228	7333	1035	2957	625
23	3732	1061	17796	2111	7176	2291
24	2159	4789	10297	3119	4152	7431
25	3769	2324	17975	5234	7248	4013
26	1340	1183	6392	4191	2578	1835
27	689	1576	3286	4806	1325	2245
28	1682	456	8023	2062	3235	941
29	197	90	940	220	379	166
30	1667	481	7952	2054	3206	976
31	217	116	1036	358	418	201
32	2069	306	9868	1698	3979	824
33	2376	1414	11333	2565	4570	2493
34	172	107	821	281	331	182
35	784	858	2989	1911	1127	2131
36	800	875	3050	1950	1150	2175
37	952	1041	3630	2321	1369	2585
38	344	376	1312	839	494	935
39	56	61	213	137	81	152
40	88	96	336	214	126	239

TABLE 33

2010 TRIP PRODUCTIONS AND ATTRACTIONS BASED ON DEFAULT RATES USING QRS II

	HBW		HBNW		NHB	
ZONE	P	A	P	A	P	A
1	132	791	433	2157	168	1101
2	840	425	3205	1347	1208	753
3	1680	5737	8012	3184	3231	8755
4	1685	4989	6965	2694	2583	7651
5	2681	134	12789	1546	5157	751
6	81	1125	390	489	157	1666
7	693	166	2867	625	1063	370
8	72	32	276	39	104	62
9	119	236	569	776	229	338
10	1981	343	7552	1495	2847	950
11	929	1166	3542	1381	1334	1903
12	1507	3738	5747	5314	2167	5620
13	5699	1596	23559	4582	8739	3411
14	1011	210	4179	891	1550	493
15	240	168	917	524	346	285
16	2004	338	7642	1872	2881	885
17	5006	3921	20691	8033	7676	6530
18	831	1426	2724	4588	1062	2092
19	2173	1033	5989	4424	2276	1984
20	446	0	1462	243	570	121
21	3746	8250	5709	6998	8385	13904
22	1131	227	3707	1034	1445	624
23	3444	1060	13132	2111	4951	2291
24	2024	4788	9653	3119	3892	7430
25	3724	2323	15353	5233	5695	4012
26	1150	1183	3770	4191	1469	1834
27	506	1575	1661	4805	647	2241
28	1423	455	5427	2062	2046	941
29	169	90	554	219	216	166
30	1655	481	7330	2054	2837	976
31	183	115	700	358	264	201
32	2039	306	8429	1698	3127	823
33	2227	1414	10624	2565	4284	2493
34	126	107	415	281	161	182
35	328	397	2323	1744	2249	2759
36	335	405	2370	1780	2295	2815
37	399	482	2820	2118	2731	3350
38	144	174	1019	765	987	1210
39	23	28	166	125	161	197
40	37	45	261	196	252	310

TABLE 34

2010 TRIP PRODUCTIONS AND ATTRACTIONS BASED
ON USER-SUPPLIED RATES USING QRS II

	HBW		HBNW		NHB	
ZONE	P	A	P	A	P	A
1	62	432	420	2170	1073	3007
2	331	232	2319	1529	2082	2283
3	648	3139	4816	3575	3798	6705
4	608	2730	4562	3670	4968	5823
5	1035	74	7687	2183	6061	3561
6	32	616	235	507	185	1000
7	250	91	1878	979	2045	1220
8	29	18	200	56	180	101
9	46	129	342	795	270	1103
10	893	188	6251	2014	5613	3270
11	419	638	2932	2619	2633	2683
12	554	2045	4156	5611	4525	8588
13	2058	873	15431	5853	16803	9404
14	365	115	2737	1115	2981	1743
15	109	92	760	583	682	860
16	773	185	5794	2346	3090	3638
17	1807	2146	13553	9102	14758	13985
18	357	780	2365	4750	6649	3533
19	1064	565	7185	5071	18362	7511
20	224	0	1481	379	1090	642
21	3746	4513	5173	9023	8920	16294
22	566	124	3754	1374	2762	2213
23	1327	580	9756	2943	5310	5033
24	781	2619	5802	3590	4575	6558
25	1340	1271	10056	6034	10950	9298
26	518	647	3557	4443	3334	6293
27	253	862	1682	4900	1237	6805
28	641	249	4491	2421	4033	3633
29	76	49	525	262	353	409
30	603	263	4480	2409	3553	3622
31	84	63	579	403	389	600
32	748	167	5560	2150	4384	3355
33	859	773	6386	3080	5034	4939
34	59	58	402	317	1028	476
35	328	328	2323	2323	2249	2279
36	335	335	2370	2370	2295	2295
37	339	339	2820	2820	2731	2731
38	144	144	1019	1019	987	987
39	23	23	166	166	161	161
40	37	37	261	261	252	252

The total trip productions and trip attractions in QRS and QRS II obtained using default rates are compared to the total P's and A's based upon user-supplied rates. The results are shown in Table 35. In addition, the total P's and A's based on user-supplied rates were compared to the total P's and A's available in the 1975-2000 technical report. The results are presented in Table 36.

Trip productions and attractions for Oklahoma State University and external stations for the year 2010 are presented in Table 37. It is necessary to differentiate between the P's and A's for the special generator (OSU), and external stations (zones 35 through 40) from the the rest of the internal traffic zone to emphasize the fact that these values were determined manually and fed into QRS and QRS II.

As mentioned earlier in Chapter III, the gravity model requires that the total productions and attractions be equal. Inspection of the total P's and A's for every trip purpose obtained based on user-supplied rates shows that they do not match, i.e., total trip productions and total trip attractions are not equal. Thus, the areawide control factors, F's, are determined for every trip purpose adjusting the individual zonal attractions so that their total would match the total productions. Zone 21, that is, Oklahoma State University, is designated as a special generator, and zones 35, 36, 37, 38, 39, and 40

TABLE 35

COMPARISON OF TRIP GENERATION RESULTS
FOR THE YEAR 2010

	BASED UPON USER SUPPLIED RATES	BASED UPON DEFAULT RATES	PERCENT DIFFERNECE
	USING QRS		
HBW P	25110	44041	-43.
HBNW P	157618	150706	+5.
NHB P	132976	81783	+63.
HBW A	28097	35338	-20.
HBNW A	99366	48635	+104.
NHB A	156342	60780	+157.
	USING QRS II		
HBW P	24538	39584	-38.
HBNW P	155796	118053	+32.
NHB P	158661	65355	+142.
HBW A	28663	38598	-26.
HBNW A	103190	56697	+82.
NHB A	163930	64385	+155.

TABLE 36

EVALUATION OF TRIP GENERATION RESULTS
FOR THE YEAR 2010

	BASED UPON USER SUPPLIED RATES	FROM THE 1975-2000 TECHNICAL REPORT	PERCENT DIFFERENCE
	USING QRS		
HBW P	25110	22379	+12.2
HBNW P	157618	155146	+1.6
NHB P	132976	126576	+5.1
HBW A	28097	22379	+20.2
HBNW A	99366	155146	-36.0
NHB A	156342	126576	+23.5
	USING QRS II		
HBW P	24538	22379	+9.7
HBNW P	155796	155146	+0.4
NHB P	158661	126576	+25.4
HBW A	28663	22379	+22.6
HBNW A	103190	155146	-33.5
NHB A	163930	126576	+29.5

TABLE 37

P'S AND A'S FOR SPECIAL GENERATOR AND
EXTERNAL STATIONS FOR THE YEAR 2010

ZONE	HBW		HBNW		NHB	
	P'S	A'S	P'S	A'S	P'S	A'S
21	3750	3750	5200	5200	8750	8750
35	328	328	2323	2323	2249	2249
36	335	335	2370	2370	2295	2295
37	399	399	2820	2820	2725	2725
38	144	144	1019	1019	987	987
39	23	23	166	166	161	161
40	37	37	261	261	252	252

are designated as external stations. Thus, in determining the F's, the productions and attractions of the special generator and external stations are subtracted from the total productions and attractions as indicated in Equations 4 to 6 presented in Chapter III. The resulting areawide control factors, F's, for HBW, HBNW, and NHB trip purposes are presented in Table 38.

Multiplying the areawide control factors by the individual attractions for every zone results in balanced trip productions and attractions. Tables 39 and 40 present the balanced trip productions and attractions for the year 2010 for QRS and QRS II.

The balanced productions and attractions based on user-supplied rates were used in the trip distribution and traffic assignment modules.

TABLE 38

AREAWIDE CONTROL FACTORS
BY TRIP PURPOSE

		F_1	F_2	F_3
Default Rates	QRS	1.29	3.39	1.48
User-Supplied Rates	QRS	0.88	1.64	0.84
Default Rates	QRS II	1.05	2.69	1.16
User-Supplied Rates	QRS II	0.87	1.62	1.03

TABLE 39

2010 BALANCED TRIP PRODUCTIONS AND ATTRACTIONS
BASED ON USER-SUPPLIED RATES USING QRS

	HBW		HBNW		NHB	
ZONE	P	A	P	A	P	A
1	67	383	477	3431	2567	2567
2	323	206	2307	2418	1948	1948
3	667	2784	4761	5653	5714	5714
4	636	2421	4542	4854	4963	4963
5	1064	65	7299	3452	3035	3035
6	33	546	232	802	852	853
7	262	81	1870	1232	1040	1040
8	28	16	199	89	86	86
9	47	114	338	1257	941	941
10	871	167	6220	3184	2787	2787
11	409	566	2917	2560	2288	2288
12	580	1814	4137	8872	7326	7326
13	2152	774	15363	9254	8017	8017
14	382	102	2725	1763	1486	1486
15	106	82	756	922	734	734
16	808	164	5769	3709	3102	3102
17	1890	1903	13493	14392	11928	11928
18	360	692	2573	7510	5675	5675
19	1144	501	8169	8018	6408	6408
20	226	0	1611	599	547	547
21	3750	3750	5200	5200	8750	8750
22	572	111	4081	2172	1886	1886
23	1389	514	9913	4655	4289	4289
24	803	2324	5735	5678	5574	5574
25	1402	1127	10012	9541	7930	7930
26	499	574	3561	7025	5371	5371
27	256	765	1830	7748	5810	5810
28	626	221	4469	3828	3099	3099
29	73	43	524	414	349	349
30	620	233	4429	3811	3090	3090
31	81	56	577	639	512	512
32	770	148	5497	3401	2861	2861
33	881	687	6312	4870	4212	4212
34	64	52	458	501	406	406
35	328	291	2323	3673	1916	1916
36	335	297	2370	3747	1955	1955
37	399	354	2820	4459	2322	2322
38	144	128	1019	1611	841	841
39	23	20	166	262	137	137
40	37	33	261	413	215	215

TABLE 40

2010 BALANCED TRIP PRODUCTIONS AND ATTRACTIONS
BASED ON USER-SUPPLIED RATES USING QRS II

	HBW		HBNW		NHB	
ZONE	P	A	P	A	P	A
1	62	356	420	3437	2909	2909
2	331	191	2319	2422	2208	2208
3	684	2580	4816	5662	6484	6484
4	608	2244	4562	4862	5631	5631
5	1035	60	7687	3457	3444	3444
6	32	506	235	804	967	967
7	250	75	1878	1234	1180	1180
8	29	14	200	89	98	98
9	46	106	342	1259	1066	1066
10	893	154	6251	3189	3162	3162
11	419	524	2932	2564	2595	2595
12	554	1681	4156	8887	8306	8306
13	2058	718	15431	9271	9095	9095
14	365	95	2737	1766	1685	1685
15	109	76	760	923	831	831
16	773	152	5794	3716	3518	3518
17	1807	1763	13553	14416	13525	13525
18	357	642	2365	7523	6431	6431
19	1664	465	7185	8032	7265	7265
20	224	0	1481	600	620	620
21	3750	4513	5200	9024	16294	16294
22	567	102	3754	2177	2140	2140
23	1328	477	9956	4662	4868	4868
24	781	2153	5802	5688	6324	6324
25	1341	1045	10057	9558	8993	8993
26	519	532	3557	7037	6086	6086
27	254	709	1682	7761	6582	6582
28	642	205	4492	3834	3514	3514
29	77	41	526	415	396	396
30	603	216	4481	3817	3504	3504
31	84	52	579	639	581	581
32	749	138	5561	3407	3245	3245
33	860	636	6386	4879	4777	4777
34	60	48	402	502	461	461
35	328	328	2323	2323	2249	2249
36	335	335	2370	2370	2295	2295
37	399	399	2820	2820	2731	2731
38	144	144	1019	1019	987	987
39	23	23	166	166	161	161
40	37	37	261	261	252	252

Trip Distribution

The output from the trip distribution module includes a trip interchange matrix, T_{ij}, and a trip length distribution for all trip purposes.

Using QRS, the zone to zone trip tables for HBW, HBNW, and NHB trip purposes are presented in Appendix D. QRS II does not provide the zone to zone trip tables in the form of an output. Examination of the trip matrices obtained from QRS should enable the user to pinpoint the activities taking place in every zone, that is, the number trips produced by and attracted to every zone. Trips are divided into intrazonal and interzonal trips. Intrazonal trips occur when $i = j$. Interzonal trips designate trips made when $i \neq j$.

Two iterations were performed to satisfy the attraction constraint given by Equation 11. Thus, summing vertically in the trip matrices for every destination zone shows that the attraction constraint is met. Similarly, summing trips originating from a zone shows that the production constraint given by Equation 10 is satisfied.

The trip interchange matrices obtained using the friction factors taken from the 1975-2000 technical report are used later in the traffic assignment module.

The trip length distributions obtained from QRS for the different trip purposes are shown in Figures 14 through 16. The results of QRS II are presented in Figures 17

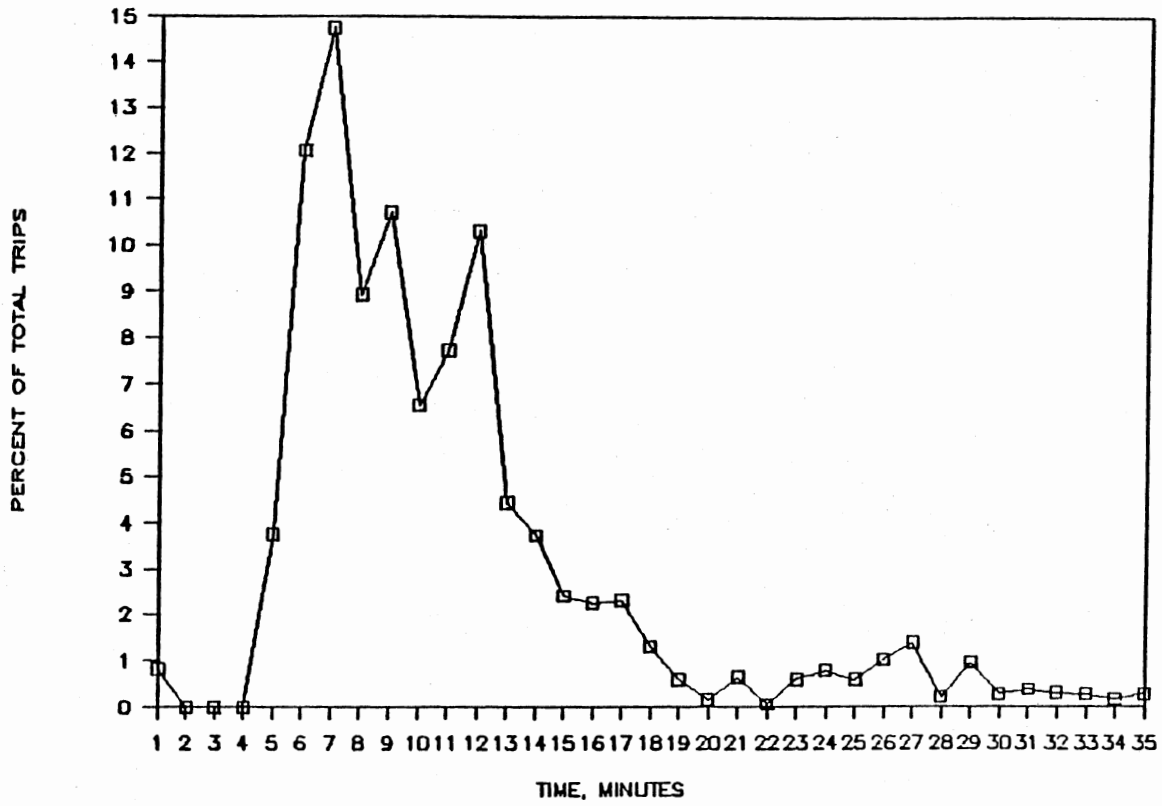


Figure 14. HBW Trip Length Distribution Using QRS

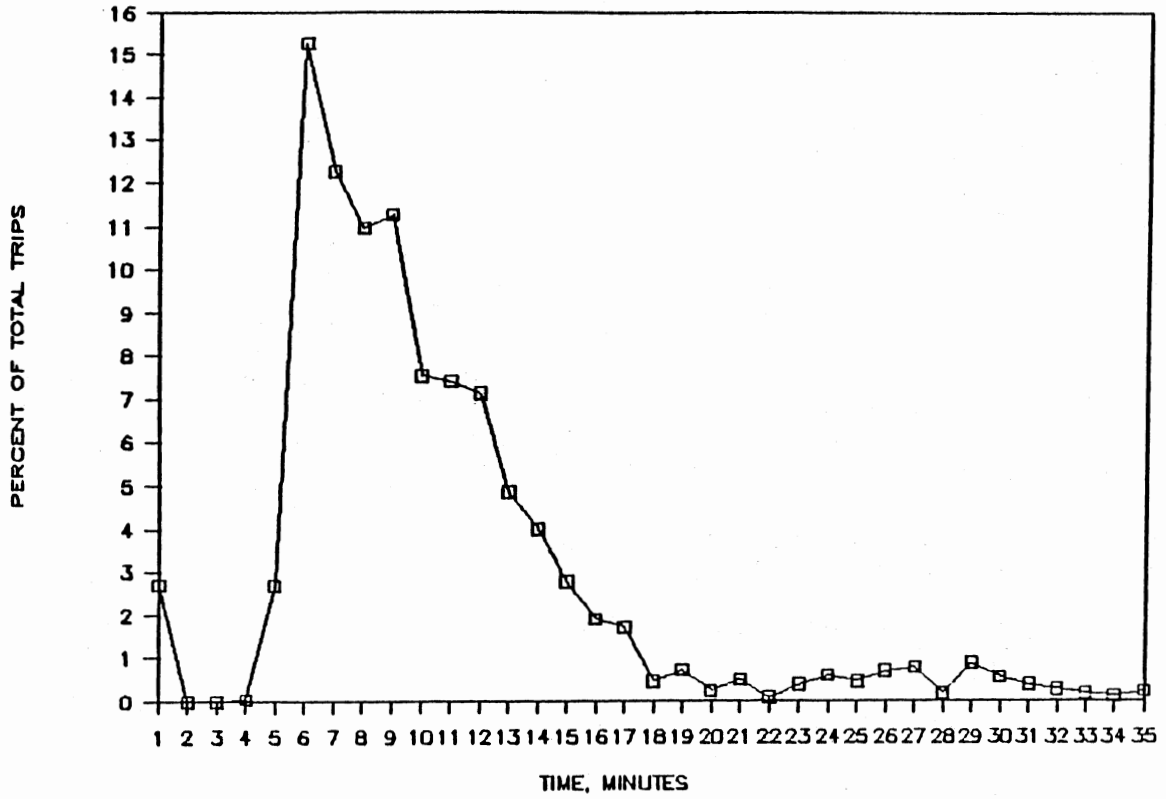


Figure 15. HBNW Trip Length Distribution Using QRS

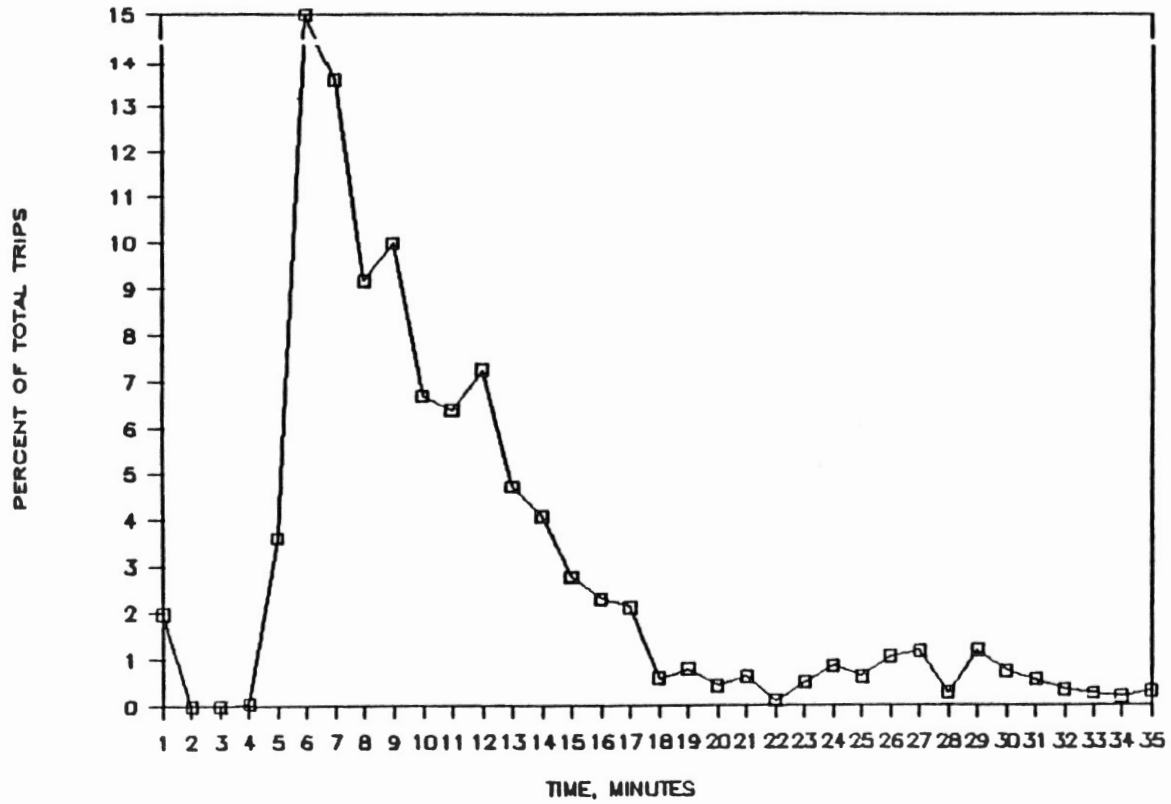


Figure 16. NHB Trip Length Distribution Using QRS

through 19. These results are based on the friction factors taken from the 1975-2000 technical report.

The average trip length for the City of Stillwater can be determined from the trip length distribution. Using QRS II, the gravity model was applied using the power function to determine the friction factors. The trip distribution parameter, a_k, used in the gravity model was determined based on 1) figures presented in the 1968-1990 technical report, and 2) the suggested values given by QRS II. The average trip lengths determined from QRS and QRS II, along with the actual trip lengths determined in the 1968-1990 technical report are presented in Table 41.

The difference in the average trip length obtained using QRS and QRS II is attributable to the difference in the form of friction factors and the fact that intrazonal travel time using QRS II is smaller than intrazonal travel using QRS. Note that the suggested values of a_k resulted in values of average trip length that are very close to those obtained using the a_k values derived from the 1968-1990 technical report. This indicates that the suggested values for the a_k given in QRS II can be used as transferable parameters. Note also that the average trip length obtained using the friction factors from the 1975-2000 technical report in QRS II is the closest to the actual average trip length reported in the 1968-1990 technical report.

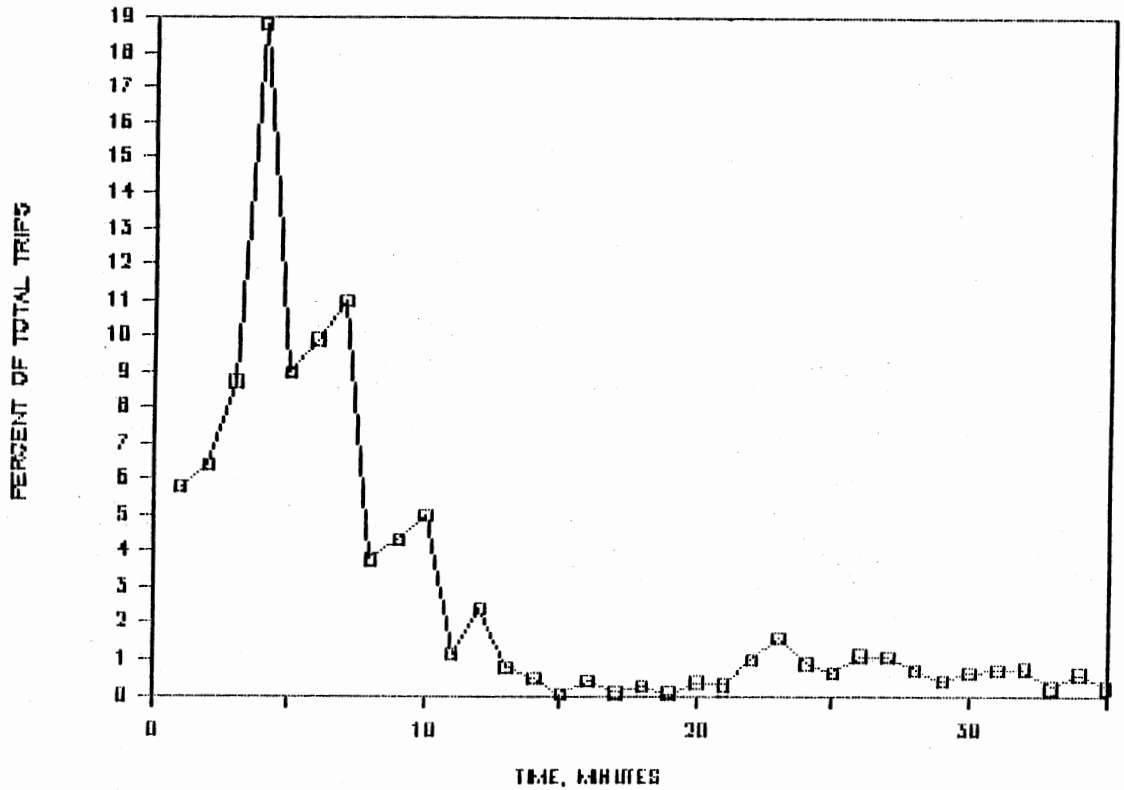


Figure 17. HBW Trip Length Distribution Using QRS II

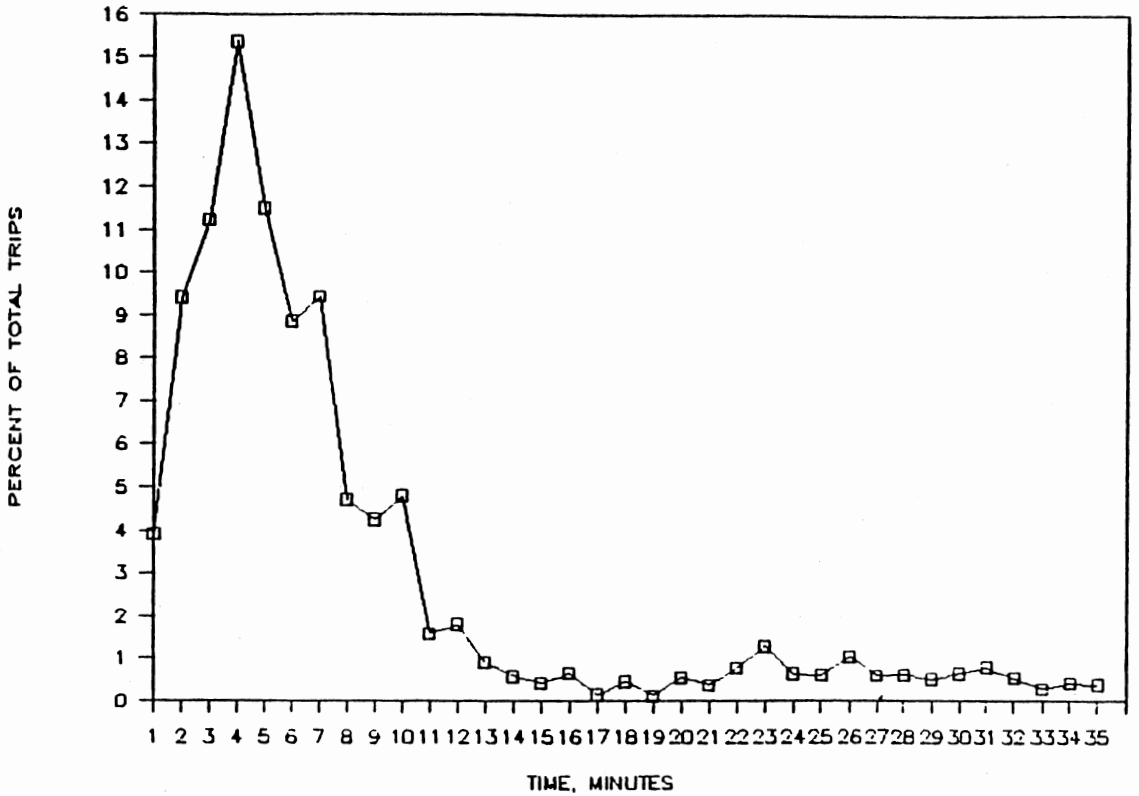


Figure 18. HBNW Trip Length Distribution Using QRS II

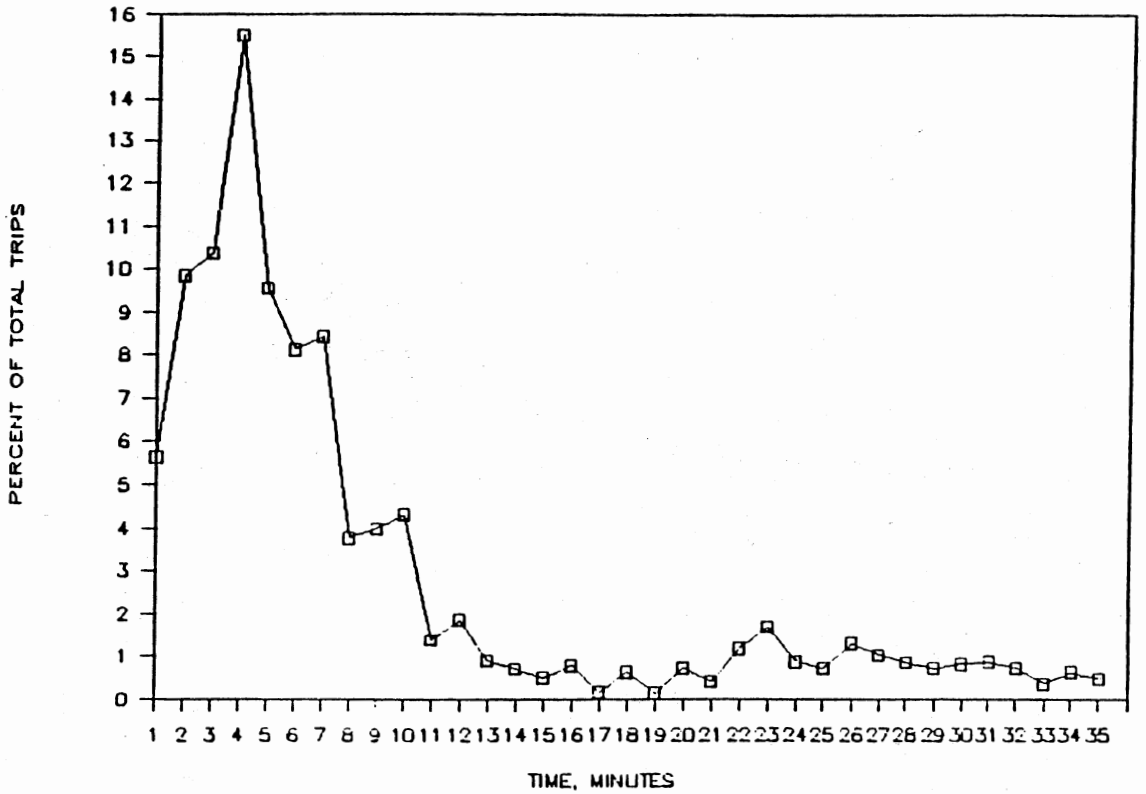


Figure 19. NHB Trip Length Distribution Using QRS II

TABLE 41

AVERAGE TRIP LENGTH USING QRS AND QRS II

TRIP PURPOSE	AVERAGE TRIP LENGTH IN MINUTES				
	USING QRS	USING QRS II BASED UPON			ACTUAL TRIP LENGTH RECORDED IN THE 1968-1990 TECHNICAL REPORT
		F_{ij} FROM 1975-2000 TECHNICAL REPORT	"a_k" FROM 1968-1990 TECHNICAL REPORT	DEFAULT VALUE FOR "a_k"	
HBW	12.2	7.8	6.4	6.7	8.9
HBNW	10.6	8.0	7.7	6.1	8.7
NHB	11.2	7.9	5.9	6.5	8.9

Traffic Assignment

The results of the traffic assignment module are the expected future traffic volumes on the street network. The method used is the all-or-nothing technique. The process is repeated using QRS and QRS II.

Using QRS, the assignment process is accomplished using the functional classification street map shown in Figure 20. Links are numbered for identification, thus, the reader should refer to the figure to determine the roadway segement represented by the link number.

Results of the QRS assignment process are presented in Table 42. The output consists of link numbers and their corresponding average daily volumes. The output presented in Table 42 can be represented in terms of "desire lines". Desire lines indicate which roads are traversed by the users of the street network. A thicker desire line means heavy traffic flow for the roadway, and a thin line indicates that only light traffic flows on the street. Figure 21 shows a graphic representation of the assigned daily traffic.

The traffic assignment module is carried out in QRS II using the trip distribution output determined based on the friction factors found in the 1975-2000 technical report. The assignment process is carried out using the functional classification street map shown in Figure 22 which shows

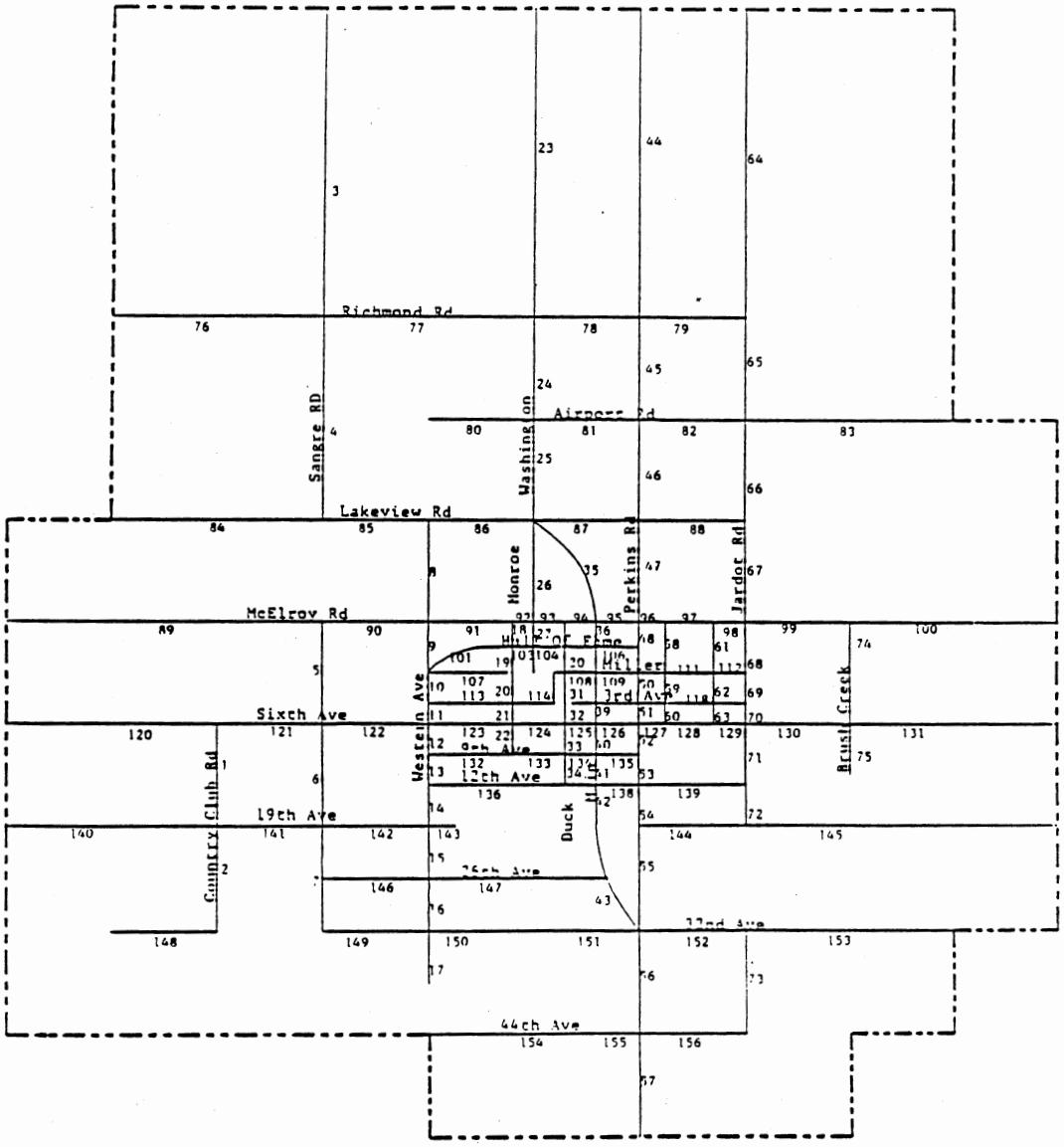


Figure 20. Street Map Showing Link Numbers Used in QRS

TABLE 42

FORECASTED ASSIGNED DAILY VOLUMES USING QRS

LINK #	0	1	2	3	4	5	6	7	8	9
00		21190	1540	2910	4090	6080	10780	1666	18690	14890
10	17420	15870	12250	13920	13510	12340	8750	8170	4900	15500
20	19040	16880	14510	10470	18850	25370	12650	19650	22980	4330
30	6860	15990	11720	15050	1860	26530	21260	24590	25350	21880
40	19560	14460	10530	11180	7580	21690	37980	63010	49730	51380
50	43090	36880	25520	16360	13840	14360	11490	11490	7120	4120
60	4120	860	4555	2590	1730	1070	1110	4620	5330	4820
70	4740	1180	170	00	970	00	00	240	900	750
80	1530	1480	510	00	3310	8030	8850	9760	5960	840
90	10520	16610	20580	29990	27333	26000	17040	9080	4410	3350
100	00	3420	5100	5300	7310	5630	1270	2630	8330	14110
110	28860	41520	1570	14530	8020	7620	7620	12400	4480	00
120	8790	31450	31660	27610	32350	31130	26720	21450	17980	18630
130	24840	11060	24160	16210	11210	17450	6780	4460	4130	2910
140	00	4010	3090	00	170	00	4750	290	1370	3020
150	9200	7960	2200	1670						

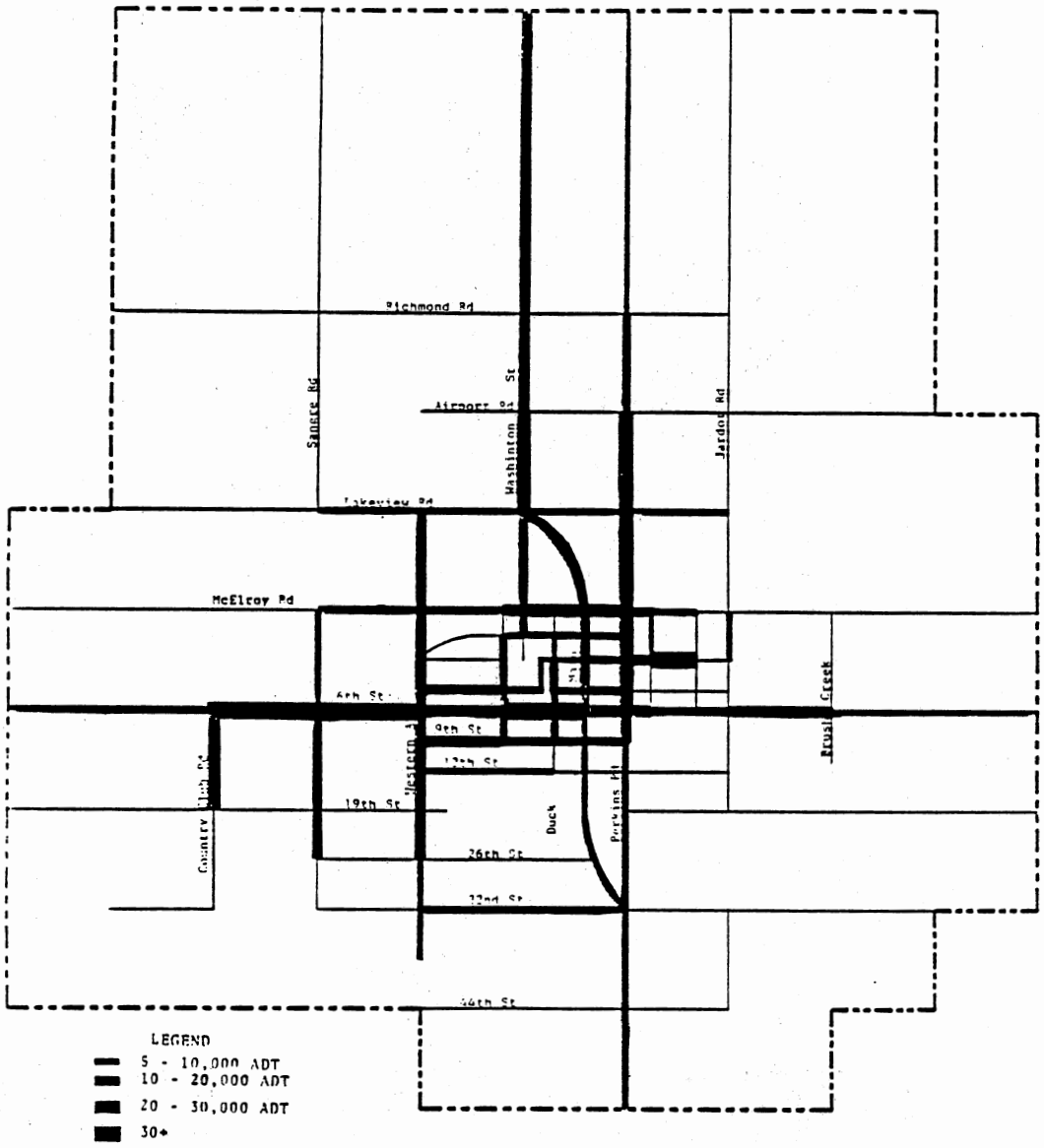


Figure 21. Desire Lines of Travel Using QRS

the numbering of links used in QRS II. The forecasted average daily assigned volumes obtained from QRS II assignment module are presented in Table 43. These volumes can be shown graphically in terms of desire line as seen in Figure 23.

The result of the assignment process for QRS differs from that of QRS II. The difference can be attributed to the fact that QRS II determines the shortest path internally while QRS requires the user to determine the shortest path (usually by inspection) and then enter the links which fall on the shortest path for every origin-destination movement.

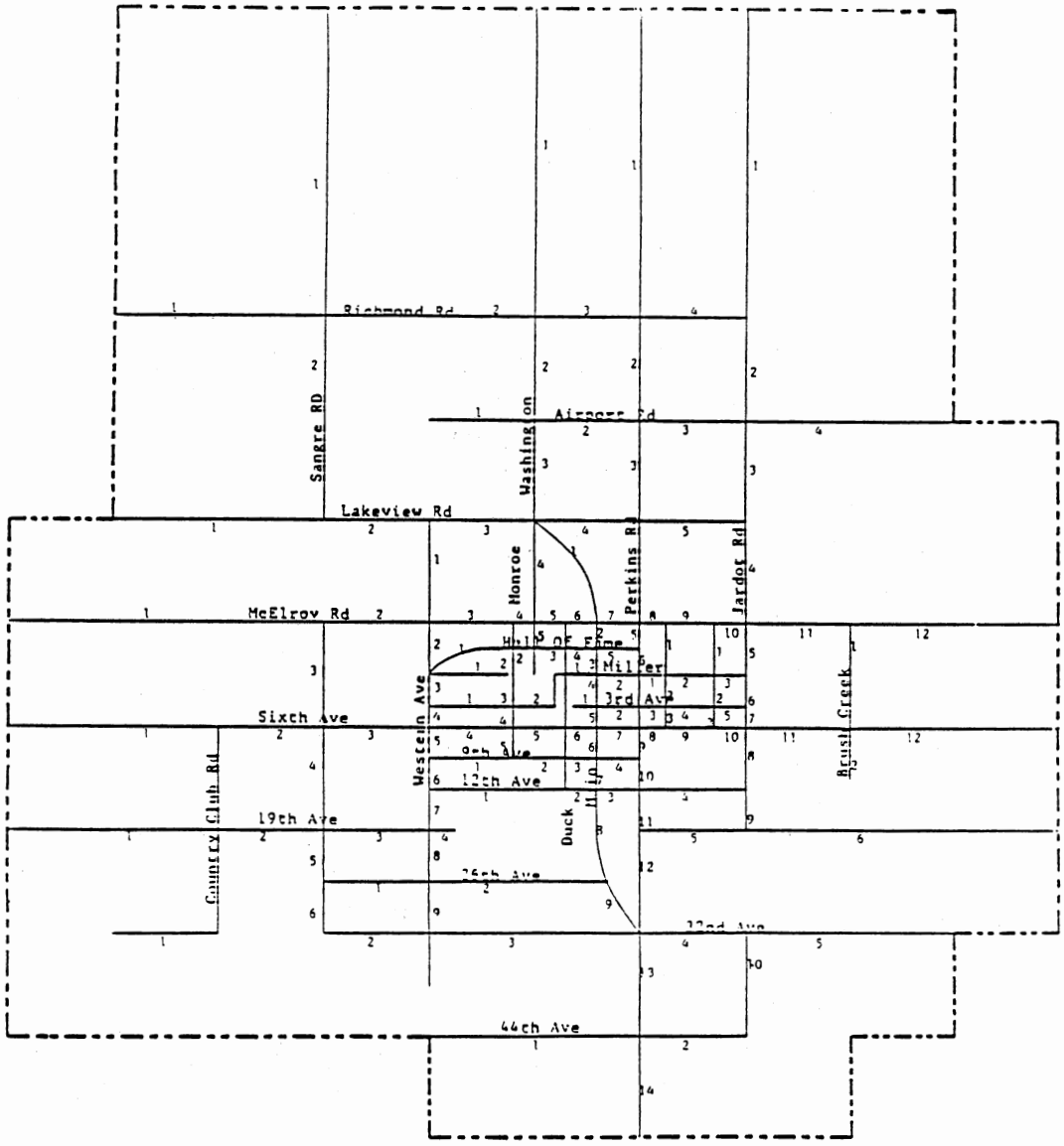


Figure 22. Street Map Showing Link Numbers Used in QRS II

TABLE 43

FORECASTED ASSIGNED DAILY VOLUMES FOR THE YEAR 2010 USING QRS II

LINK DESCRIPTION	ASSIGNED DAILY VOLUMES	LINK DESCRIPTION	ASSIGNED DAILY VOLUMES
Country Club 1	2349	Main 5	5819
Country Club 2	0	Main 6	5521
Sangre 1	0	Main 7	6518
Sangre 2	2680	Main 8	8099
Sangre 3	218	Main 9	584
Sangre 4	13425	Perkins 1	1924
Sangre 5	15258	Perkins 2	8843
Sangre 6	378	Perkins 3	15487
Western 1	8935	Perkins 4	25190
Western 2	10459	Perkins 5	51798
Western 3	36094	Perkins 6	43104
Western 4	41535	Perkins 7	43104
Western 5	13299	Perkins 8	43104
Western 6	9347	Perkins 9	32726
Western 7	10137	Perkins 10	27560
Western 8	11787	Perkins 11	21810
Western 9	10367	Perkins 12	20687
Monroe 1	0	HWY 177 13	10126
Monroe 2	2772	HWY 177 14	9954
Monroe 3	8431	Burdick 1	0
Monroe 4	15259	Burdick 2	13723
Monroe 5	11810	Burdick 3	13723
HWY 177 1	4170	Stallard 1	0
HWY 177 2	10275	Stallard 2	0
Washington 3	20069	Stallard 3	0
Washington 4	19530	Jardot 1	0
Washington 5	25881	Jardot 2	779
Duck 1	15120	Jardot 3	584
Duck 2	5407	Jardot 4	6117
Duck 3	11398	Jardot 5	2795
Duck 4	13219	Jardot 6	2795
Duck 5	3242	Jardot 7	2795
Duck 6	9141	Jardot 8	355
Boomer 1	8179	Jardot 9	355
Main 2	0	Jardot 10	0
Main 3	7434		
Main 4	7640		

TABLE 43 (Continued)

LINK DESCRIPTION	ASSIGNED DAILY VOLUMES	LINK DESCRIPTION	ASSIGNED DAILY VOLUMES
Richmond 1	0	3rd 1	0
Richmond 2	6987	3rd 2	0
Richmond 3	1581	3rd 3	0
Richmond 4	0	3rd 4	0
Airport 1	2417	3rd 5	0
Airport 2	1649	HWY 51 1	11856
Airport 3	722	HWY 51 2	15315
Airport 4	0	6th 3	44307
Lakeview 1	103	6th 4	15452
Lakeview 2	7927	6th 5	18099
Lakeview 3	6895	6th 6	15464
Lakeview 4	4009	6th 7	15166
Lakeview 5	1672	6th 8	39588
McElroy 1	0	6th 9	29061
McElroy 2	424	6th 10	29061
McElroy 3	206	6th 11	13068
McElroy 4	7938	HWY 51 12	9759
McElroy 5	7938	9th 1	1134
McElroy 6	3734	9th 2	17743
McElroy 7	18969	9th 3	11959
McElroy 8	24651	9th 4	10962
McElroy 9	19278	12th 1	825
McElroy 10	3310	12th 2	9966
McElroy 11	3310	12th 3	8144
Hall of Fame 1	21970	12th 4	0
Hall of Fame 2	24742	19th 1	0
Hall of Fame 3	29255	19th 2	515
Hall of Fame 4	22119	19th 3	3562
Hall of Fame 5	21707	19th 4	0
Farm 1	5842	19th 5	1123
University 1	0	19th 6	0
University 2	10240	26th 1	0
Knoblock 1	10240	26th 2	2600
Miller 1	29714	32nd 1	0
Miller 2	25899	32nd 2	389
Miller 3	14032	32nd 3	7457
Virginia 1	15430	32nd 4	10916
Virginia 2	0	32nd 5	355
Virginia 3	0	32nd 6	0

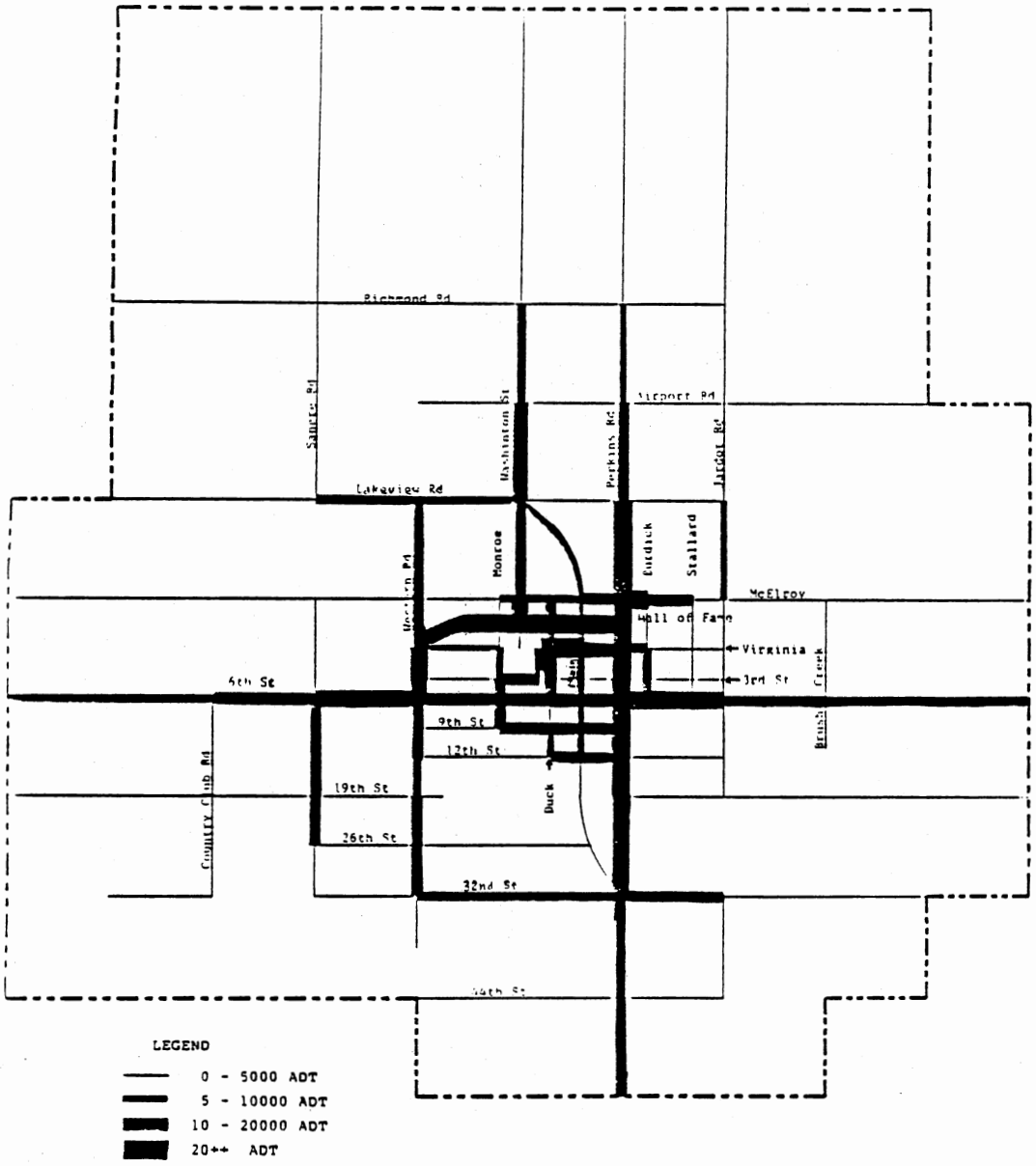


Figure 23. Desire Lines of Travel Using QRS II

Intersection Capacity Analysis

An analysis of intersection capacity is necessary for anticipating future traffic conditions on the roadway facilities. It can be used to measure the overall performance of the street network system. Two approaches were used in the capacity analysis: 1) NCHRP Report 187, and 2) Highway Capacity Manual.

Using the NCHRP approach, the peak hour volumes derived by multiplying the daily assigned volumes by the the percent share for peak hour are divided by the capacity to obtain a volume to capacity ratio. The level of service (LOS) for every intersection approach is used as the criteria for traffic condition evaluations. Any intersection whose LOS exceeded LOS C is considered a potential problem.

Table 44 presents the results of the intersection capacity analysis for the traffic assignment volumes obtained from QRS. Inspection of the column labeled LOS in Tables 44 reveals several locations where traffic congestion is expected. Table 45 presents the locations where LOS exceeds level C. It also gives the required approach width needed to improve the level of service to LOS C. Since all links are two-way streets, the required approach widths in Table 45 give the distance from the curb to the division line.

The results of the intersection capacity analysis for the traffic volumes obatined from QRS II are presented in Table 46. The locations where LOS exceeds level C are summarized in Table 47. In addition, the required approach width necessary to improve the LOS to level C is presented.

The Highway 1985 Capacity Manual (HCM) approach is based on the sum of the critical lane volumes. Several major intersections have been analyzed using the worksheets provided in the HCM. It is assumed that 10 percent of the traffic will make left turn, 10 percent will make right turn, and 5 percent trucks and through buses. For intersections with more than one approach lane the volumes are divided equally among the lanes. The results of this capacity analysis are presented in Figures 24 through 28 for QRS output, and in Figures 29 through 33, for QRS II. The outcome of the capacity analysis using HCM should enable the planner to determine whether the intersection is operating under, near, or above capacity.

The NCHRP Report 263 entitled "Simplified Procedures for Evaluating Low-Cost TSM projects - User's Manual" was reviewed to determine what kind of improvements are suggested that could remedy the congestion problem experienced at many intersections. The term "deficiency" is used in the NCHRP Report 263 to describe situations

where inadequate capacity to handle the peak-hour volume exists. The "strategy" according to the NCHRP Report 263 is to reduce delays by increasing capacity.

Capacity can be increased by improving the signal timing, adding new lanes, signal coordination along collectors, increasing auto occupancy, introducing transit mode, and designation of one-way streets. Improving the signal timing option should be considered first because it is less expensive and easier to implement. This option is the best solution for intersections that have two lanes per approach in addition to a left-turn bay since no lanes can be added. However, improving signal timing does not necessarily dictate a better level of service since the signal phasing may already be optimal.

The second option, adding new lanes, should be considered only if improving the signal timing does not provide the desired LOS. Adding new lanes, however can be costly and time consuming, and thus involves factors which makes it less desirable. Adding new lanes should only be done as a last resort.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The results of this study show that the quick-response procedures described in the NCHRP Report 187 are adequate for long-range planning of small urban areas. The location of street segments and intersections where volume exceeds capacity have been determined. This data can be used in evaluating the overall performance of the transportation network for the City of Stillwater. Based on the capacity analysis output, plans to upgrade the street network should be implemented. Nevertheless, there are some 4-lane streets in Stillwater where traffic is impeded and thus cannot be improved by adding new lanes. It can be concluded that regardless of any recommended transportation plan, traffic problems will continue to exist.

Limitations of NCHRP Report 187

The quick-response procedures presented in NCHRP Report 187 have been applied to address a variety of problems. In doing so, some limitations became apparent. These limitations are:

1. Although the quick-response technique was designed to work with a limited amount of data input, in many cases,

these data are not available.

2. The use of transferable parameters is viewed as an extremely desirable aspect; however, a number of these have been developed from rather outdated information.

3. Quick-response procedures focus almost entirely on internal traffic considerations, therefore, analysis of external stations requires O-D movement surveys.

4. The all-or-nothing technique causes problems where there are several alternative routes to a certain destination since subjective determination of routes may be argued.

Evaluation of QRS

In general, QRS is a useful tool for quick calculations of zonal productions and attractions. However, default parameters should be used with caution. The default values are suggested for use where local data are not available. The variables used in the attractions equations may not be the best representatives of the attractivness of a zone. Hence, the user should have the flexibility to choose different land-use characteristics as measures of attractivness. This shortcoming can be attributed to the methods used in the NCHRP Report 187.

The trip distribution model is probably the most desirable of all models. Given travel times, the gravity model can be applied with extensive savings in time. Even in cases where travel times are not available, the

data needed to determine travel times is easily obtained. The NCHRP Report 187 gives the time requirements for the manual trip distribution procedures. Table 7 in the NCHRP Report 187 indicates a total of 25.5 hours for an analysis area of 34 zones. The total time spent using QRS is less than 2 hours. In fact, most of that time was spent entering the data necessary for the travel time matrix. Once all necessary data was available, the gravity model was iterated twice in about 5 minutes.

The traffic assignment model is not highly recommended. Determining a logical path for every trip interchange and then entering the numbers of links connecting the origin and destination zones into the computer is tedious and repeatitious. When all links are entered they cannot be saved or reviewed, making corrections impossible. A time log of the traffic assignment model was kept as an evaluation aid. The time necessary to enter the link numbers for every O-D movement was close to six hours. In addition, the time spent to prepare the link list took about 13 hours.

QRS is fairly easy to use and understand. The user is generally well informed about the data which he needs to enter. The users of QRS should be familiar with the NCHRP Report 187 techniques since it was designed to be a computerized application of the Report. QRS has, therefore, inherited all the methodological short-cuts and shortcomings that were included in the NCHRP Report 187.

Evaluation of QRS II

QRS II is an upgraded version of QRS. It is designed to work with the minimum amount of input data. This is highly favorable since quick-response procedures are most effective when used with the minimum necessary input data.

QRS II requires the user to draw a network using the General Network Editor (GNE). The network is drawn to scale and consists of nodes and links. Once all nodes and links have been drawn and defined the data is entered for every one. Drawing the network and entering the data needed for every node and link is the most time consuming. But, the network can be saved making it easy to edit it any time.

The trip generation model is essentially the same as that of QRS. The default or suggested rates available in QRS II should be used only when local data is not available.

The trip distribution model uses the gravity model. Friction factors can be determined using either the "power" form, the "exponential" form, or can be supplied by the user. Travel times between zones are easily determined by adding the link travel times to the centroid connector travel times.

The traffic assignment model is definitely an improvement over QRS. QRS II determines the shortest path and loads the trips on the path, resulting in time saving.

In general, QRS II is sophisticated yet simple to use and understand. All input and output data files can be edited, reviewed, and re-used as needed. The developer of QRS II did not adopt the short-cuts used in the NCHRP Report 187, resulting in a highly valuable package.

Comparison of QRS and QRS II

The similarities and differences between QRS and QRS II are outlined as follows:

1. QRS is written in UCSD Pascal, QRS II in MS-DOS. QRS II has a positive advantage in this respect.

2. QRS handles a maximum of 50 zones. QRS II has two versions. The educational version handles a maximum of 40 zones. The professional version, on the other hand, can handle up to 285 zones.

3. QRS II requires the user to provide a network. QRS does not.

4. QRS and QRS II use the same attraction equations suggested in the NCHRP Report 187.

5. Production rates used in QRS II are the same as those used in QRS with the exception that income has been converted to a 1980 dollar base.

6. Travel time determination is easier using QRS II than QRS.

7. QRS allows the user to enter a set of friction factors or use the default facotrs. QRS II is more flexible. It allows the user to use one of four

alternatives, namely, default, user-supplied, "power" form, or "exponential" form.

8. QRS requires the user to enter a list of links connecting every O-D movement. QRS II loads trips internally.

9. Input and output files are easily manipulated in QRS II. QRS is not as flexible.

In conclusion, QRS II impresses the user as being a better package than QRS.

Recommendations

Many successful applications have been made using the quick-response technique as presented in the literature review. Yet, many more can be made provided that the limitations are fully understood. Although some accuracy may be sacrificed, it is widely accepted that these techniques provide reasonable results within the desireable time frame and cost constraints.

Two recommendations can be made with respect to transportation planning in Stillwater.

1. Socio-economic and land-use data should be updated to more closely reflect the actual activities of road users.

2. A comprehensive transportation planning study should be conducted every ten years. This is necessary to keep all forecasts and actual representations of the traffic conditions up to date.

Other recommendations can be given regarding the quick-response technique.

1. Default rates for trip generation should be updated continuously.

2. Case studies should be developed to serve as guidelines for future applications, in addition to enhancing the credibility of the procedures.

3. A better traffic assignment approach should be used, yet it should be a simplified one. The all-or-nothing technique is not sensitive to changes in the street network.

4. Data for external stations should be reviewed to determine whether transferable parameters can be developed.

5. Introduce the quick-response procedures into educational programs to accelerate local acceptance of these techniques.

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APPENDICES

APPENDIX A

QUICK RESPONSE MICROCOMPUTER SYSTEM

Trip Generation

QRS and QRS II calculate trip productions based on the number of dwelling units in each zone using either default production rates or user specific rates. Attractions are calculated using default or user specific coefficients for the attractions equations.

The following data is needed for each zone:

1. Average income or average autos owned per household,
2. Number of retail employment,
3. Number of nonretail employment,
4. Number of dwelling units.

Trip Distribution

Both systems use the traditional gravity model formula. The required input data for each of the three trip purposes include the following:

1. Balanced productions and attractions for each zone,

2. Travel time/friction factor relationship,

3. Intrazonal travel time,

4. Interzonal travel time

Productions and attractions are obtained from the trip generation module.

Default friction factors are available for the four population groups. They may be used when user-specific factors are not available. In addition, QRS II gives the user flexibility in choosing to work with "exponential" or "power" forms in determining friction factors

Intrazonal travel time, which is the travel time within a zone, can be: 1) direct input in QRS and QRS II, or 2) may be calculated based upon travel time of surrounding zones using QRS, or 3) calculated based on area of the zone and average speed of vehicles on intrazonal trips using QRS II.

Iterzonal travel time, i.e. travel time between zones, can be entered directly for each trip interchange in QRS. If the travel time data are not available, QRS will calculate them given the following data:

1. Zone type for each zone (CBD, CC, or S).
2. X and Y coordinates for each zone centroid measured as airline distance (straight line distance) in miles per inch.
3. Map scale (miles per inch).
4. Circuity factor to convert airline distance to over-the-road distance.

5. For each trip interchange the following percentages: a) distance in CBD, b) distance traveled on arterials, c) distance in CC, d) distance traveled on arterials, e) distance in S, f) distance travled on arterials.

QRS II calculates interzonal travel time by adding the travel time on links connecting the trip orgin to its destination. Travel time on links is determined as a function of volume and capacity. If volume and capacity are not known, QRS II can determine interzonal trave time based on free flow speed alone.

Traffic Assignment

The QRS traffic assignment module is basically a book-keeping function. Trip tables saved in the mode choice module are used as input. Any number of trip tables can be used as long as the tables are of equal size. Normally, trip tables for the three trip purposes are combined to make a single assignment of total daily traffic. The user needs to provide a list of links connecting every origin-destination movement.

QRS II determines the shortest path between any two zones making it a simple matter to load vehicle trips onto the appropriate links. During path finding, QRS II compiles a list of links on the shortest path between all pairs of zones. The trips are then loaded after the trip distribution model has been performed.

APPENDIX B

PERCENT ARTERIALS TRAVELED FOR EVERY ORIGIN-DESTINATION MOVEMENT

ORIGIN ZONE 1

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
1	10
2	40
3	50
4	50
5	40
6	20
7	30
8	20
9	20
10	40
11	70
12	60
13	40
14	40
15	30
16	40
17	50
18	80
19	50
20	60
21	60
22	50
23	50
24	20
25	40
26	60
27	60
28	60
29	40
30	50
31	50
32	40
33	40
34	30

ORIGIN ZONE 2

2	10
3	20
4	30
5	50
6	50
7	60
8	30

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
9	30
10	50
11	60
12	50
13	70
14	70
15	30
16	60
17	60
18	50
19	40
20	60
21	40
22	30
23	40
24	20
25	30
26	40
27	50
28	60
29	70
30	70
31	70
32	50
33	40
34	30

ORIGIN ZONE 3

3	50
4	60
5	60
6	40
7	30
8	20
9	30
10	40
11	60
12	60
13	50
14	60
15	50
16	70
17	60
18	50
19	60
20	70
21	70

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
22	70
23	60
24	40
25	40
26	50
27	60
28	70
29	60
30	60
31	60
32	50
33	40
34	30

ORIGIN ZONE 4

4	70
5	70
6	60
7	60
8	50
9	60
10	70
11	60
12	50
13	60
14	40
15	30
16	60
17	60
18	70
19	50
20	50
21	40
22	30
23	40
24	30
25	60
26	60
27	70
28	70
29	70
30	60
31	50
32	50
33	40
34	40

ORIGIN ZONE 5

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
5	40
6	30
7	20
8	40
9	70
10	70
11	80
12	80
13	60
14	50
15	40
16	40
17	50
18	70
19	70
20	80
21	70
22	80
23	70
24	50
25	60
26	50
27	70
28	70
29	40
30	80
31	40
32	40
33	30
34	30

ORIGIN ZONE 6

6	10
7	20
8	10
9	20
10	20
11	60
12	50
13	60
14	40
15	40
16	50
17	50

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
18	60
19	60
20	70
21	60
22	70
23	70
24	60
25	70
26	60
27	70
28	70
29	50
30	70
31	50
32	70
33	70
34	60

ORIGIN ZONE 7

7	10
8	10
9	10
10	20
11	20
12	50
13	50
14	50
15	40
16	30
17	60
18	60
19	60
20	50
21	50
22	60
23	60
24	50
25	20
26	50
27	30
28	60
29	30
30	70
31	30
32	50
33	40
34	20

ORIGIN ZONE 8

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
8	10
9	10
10	10
11	30
12	40
13	30
14	30
15	40
16	60
17	60
18	50
19	50
20	40
21	40
22	35
23	35
24	10
25	20
26	20
27	50
28	50
29	50
30	20
31	50
32	30
33	50
34	50

ORIGIN ZONE 9

9	10
10	60
11	70
12	80
13	80
14	70
15	70
16	70
17	60
18	60
19	50
20	70
21	60
22	50

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
23	70
24	60
25	70
26	70
27	70
28	80
29	50
30	80
31	40
32	70
33	70
34	80

ORIGIN ZONE 10

10	60
11	80
12	80
13	80
14	70
15	60
16	90
17	80
18	90
19	70
20	80
21	60
22	70
23	70
24	70
25	90
26	50
27	80
28	80
29	40
30	70
31	40
32	80
33	70
34	70

ORIGIN ZONE 11

11	80
12	80
13	80
14	70

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
15	70
16	80
17	70
18	80
19	20
20	60
21	50
22	70
23	40
24	50
25	70
26	50
27	70
28	60
29	50
30	90
31	60
32	40
33	60
34	70

ORIGIN ZONE 12

12	40
13	60
14	60
15	60
16	80
17	70
18	60
19	60
20	40
21	30
22	50
23	40
24	70
25	70
26	30
27	70
28	70
29	40
30	70
31	30
32	70
33	70
34	60

ORIGIN ZONE 13

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
13	20
14	30
15	40
16	60
17	20
18	70
19	70
20	70
21	50
22	80
23	30
24	80
25	80
26	70
27	80
28	60
29	50
30	80
31	50
32	70
33	60
34	60

ORIGIN ZONE 14

14	10
15	20
16	30
17	60
18	60
19	30
20	40
21	40
22	60
23	30
24	70
25	70
26	40
27	70
28	70
29	40
30	60
31	40
32	60
33	70
34	70

ORIGIN ZONE 15

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
15	10
16	40
17	50
18	60
19	60
20	60
21	50
22	50
23	70
24	70
25	60
26	60
27	70
28	60
29	20
30	50
31	20
32	40
33	70
34	60

ORIGIN ZONE 16

16	70
17	60
18	80
19	90
20	80
21	70
22	80
23	90
24	90
25	90
26	70
27	80
28	60
29	30
30	70
31	30
32	60
33	60
34	80

ORIGIN ZONE 17

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
17	10
18	10
19	20
20	50
21	20
22	50
23	10
24	80
25	80
26	50
27	60
28	20
29	20
30	70
31	40
32	70
33	80
34	80

ORIGIN ZONE 18

18	20
19	30
20	50
21	30
22	70
23	30
24	70
25	60
26	70
27	80
28	60
29	30
30	80
31	80
32	70
33	70
34	70

ORIGIN ZONE 19

19	10
20	10
21	20
22	30

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
23	30
24	70
25	60
26	10
27	70
28	50
29	30
30	80
31	50
32	60
33	70
34	70

ORIGIN ZONE 20

20	50
21	50
22	50
23	30
24	70
25	80
26	20
27	70
28	70
29	50
30	80
31	40
32	40
33	70
34	70

ORIGIN ZONE 21

21	10
22	20
23	20
24	70
25	50
26	10
27	50
28	40
29	30
30	60
31	30
32	20
33	60
34	60

ORIGIN ZONE 22

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
22	50
23	30
24	80
25	80
26	30
27	70
28	70
29	50
30	80
31	50
32	30
33	70
34	70

ORIGIN ZONE 23

23	10
24	80
25	50
26	10
27	80
28	80
29	50
30	70
31	40
32	30
33	70
34	80

ORIGIN ZONE 24

24	10
25	30
26	50
27	50
28	60
29	30
30	50
31	20
32	60
33	50
34	40

ORIGIN ZONE 25

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
25	70
26	20
27	20
28	20
29	20
30	50
31	10
32	90
33	50
34	40

ORIGIN ZONE 26

26	10
27	10
28	10
29	20
30	60
31	30
32	10
33	20
34	20

ORIGIN ZONE 27

27	20
28	10
29	10
30	90
31	40
32	70
33	80
34	70

ORIGIN ZONE 28

28	10
29	10
30	70
31	30
32	80
33	90
34	60

ORIGIN ZONE 29

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
29	0
30	10
31	10
32	30
33	40
34	40

ORIGIN ZONE 30

30	40
31	80
32	80
33	60
34	90

ORIGIN ZONE 31

31	50
32	30
33	40
34	20

ORIGIN ZONE 32

32	20
33	60
34	40

ORIGIN ZONE 33

DESTINATION ZONE	PERCENT DISTANCE TRAVELED ON ARTERIALS
33	50
34	10

ORIGIN ZONE 34

34	20

APPENDIX C

LINKS FALLING ON THE SHORTEST PATH USED IN QRS

FROM	TO	LINK NUMBER
1	1	3
1	2	64 77 78 79
1	3	23 24
1	4	23 24 46 81
1	5	23 24 25
1	6	23 24 80
1	7	3 4
1	8	3 4 84
1	9	9 10 11 23 24 25 26 121 122
1	10	3 4 8 85
1	11	23 24 25 26
1	12	23 24 25 35
1	13	23 24 25 47 87
1	14	23 24 25 87 88
1	15	23 24 25 35 36 37 38 39 126 127 128 129 130 131
1	16	23 24 25 35 36 37 38 39 126 127 128 129 130
1	17	23 24 25 35 36 37 109 110 111
1	18	23 24 25 35 36 37 38
1	19	23 24 25 26 29 30 31 93
1	20	23 24 25 26 27
1	21	23 24 25 26 27 28
1	22	3 4 8 85 91
1	23	3 4 8 9 10 85 113
1	24	1 3 4 5 8 85 90 121
1	25	3 4 8 9 10 11 12 13 85 132
1	26	3 4 8 9 10 11 33 85 123 124
1	27	23 24 25 35 36 37 38 39 40 135
1	28	23 24 25 35 36 37 38 39 126 127 128
1	29	23 24 25 35 36 37 38 39 40 41 42 43 152 153
1	30	23 24 25 35 36 37 38 39 40 41 42 43
1	31	23 24 25 35 36 37 38 39 40 41 42 43 56 57
1	32	3 4 8 9 10 11 12 13 14 15 16 150
1	33	3 4 5 6 7 85 90
1	34	1 2 3 4 8 9 10 11 85 121 122
1	35	23 24 25 35 36 37 38 39 126 127 128 129 130 131
1	36	23 24 25 35 36 37 38 39 40 41 42 43 56 57
1	37	9 10 11 23 24 25 26 120 121 122
1	38	23
1	39	23 37
1	40	23
2	2	44
2	3	44 45
2	4	44 45 46
2	5	44 45 80 81
2	6	44 45 80 81

FROM	TO	LINK NUMBER
2	7	44 45 46 84 85 86 87
2	8	44 45 46 84 85 86 87
2	9	44 45 46 47 48 49 50 121 122 123 124 125 126
2	10	44 45 46 47 90 91 92 93 94 95
2	11	44 45 46 47 93 94 95
2	12	44 45 46 47
2	13	44 45 46 47
2	14	64 65 66
2	15	64 65 66 67 68 69 70 130 131
2	16	64 65 66 67 68 69 70 130
2	17	64 65 66 67 68 111 112
2	18	44 45 46 47 48 49 50
2	19	44 45 46 47 48 49 50 115 116
2	20	27 28 44 45 46 47 93 94 95
2	21	24 25 26 27 28 64 78 79
2	22	44 45 46 47 91 92 93 94 95
2	23	18 19 20 44 45 46 47 92 93 94 95 113
2	24	1 44 45 46 47 48 49 50 51 121 122 123 124 125 126
2	25	22 44 45 46 47 48 49 50 51 124 125 126 132
2	26	33 44 45 46 47 48 49 50 51 125 126
2	27	44 45 46 47 48 49 50 51 52 135
2	28	44 45 46 47 48 49 50 51 52
2	29	44 45 46 47 48 49 50 51 52 53 54 55 152 153
2	30	44 45 46 47 48 49 50 51 52 53 54 55
2	31	44 45 46 47 48 49 50 51 52 53 54 55 56 57
2	32	44 45 46 47 48 49 50 51 52 53 54 55 150 151
2	33	6 7 44 45 46 47 48 49 50 51 122 123 124 125 126
2	34	1 2 44 45 46 47 48 49 50 51 121 122 123 124 125 126 148
2	35	44 45 46 47 48 49 50 51 127 128 129 130 131
2	36	44 45 46 47 48 49 50 51 52 53 54 55 56 57
2	37	44 45 46 47 48 49 50 51 120 121 122 123 124 125 126
2	38	23 78 79
2	39	44
2	40	23 78 79
3	3	24 45
3	4	45 46
3	5	24 25
3	6	80 81
3	7	24 25 84 85 86
3	8	24 25 84 85 86
3	9	5 24 25 26 90 91 92 121
3	10	8 24 25 86
3	11	24 25 26
3	12	24 25 26
3	13	45 46 47

FROM	TO	LINK NUMBER
3	14	45 46 88
3	15	45 46 47 48 49 50 51 127 128 129 130 131
3	16	45 46 47 48 49 50 51 127 128 129 130
3	17	45 46 47 48 49 110 111
3	18	45 46 47 48 49 50
3	19	24 25 35 36 37 38
3	20	24 25 26 27
3	21	24 25 26 27 28
3	22	24 25 26 91 92
3	23	18 19 20 24 25 26 92
3	24	1 45 46 47 48 49 50 51 121 122 123 124 125 126
3	25	27 45 46 47 48 49 50 51 124 125 126 132
3	26	45 46 47 48 49 50 51 52 133 134 135
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3	29	45 46 47 48 49 50 51 52 53 54 55 152 153
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3	37	45 46 47 48 49 50 51 120 121 122 123 124 125 126
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3	39	44 45
3	40	23 24
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4	6	46 80 81
4	7	4 46 85 86 87
4	8	46 84 85 86 87
4	9	46 47 89 90 91 92 93 94 95
4	10	8 86 87 88
4	11	35 87
4	12	46 87
4	13	46 47
4	14	46 88
4	15	46 47 48 49 50 51 127 128 129 130 131
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4	22	46 47 91 92 93 94 95
4	23	18 19 20 46 47 92 93 94 95

FROM	TO	LINK NUMBER
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4	36	46 47 48 49 50 51 52 53 54 55 56 57
4	37	46 47 89 90 91 92 93 94 95
4	38	23 45 46 78
4	39	44 45 46
4	40	23 45 46 78
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5	6	80
5	7	84 85 86
5	8	84 85 86
5	9	8 86 89 90
5	10	8 86
5	11	25 26
5	12	23 35
5	13	86 87 88
5	14	86 87 88
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5	18	25 35 36 37 38
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5	23	18 19 20 25 26 92
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5	25	8 9 10 113
5	26	18 19 20 25 26 92 113
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5	28	25 35 36 37 38 39 40 135
5	29	25 35 36 37 38 39 40 41 42 43 152 153
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5	31	25 35 36 37 38 39 40 41 42 43 56 57
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FROM	TO	LINK NUMBER
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5	39	24 25 44 78
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6	8	8 89 90
6	9	8 9 10 11 121 122
6	10	8
6	11	26 85 86
6	12	25 35 80
6	13	85 86 87 88
6	14	85 86 87 88
6	15	47 48 49 50 51 85 86 87 127 128 129 130 131
6	16	47 48 49 50 51 85 86 87 127 128 129 130
6	17	47 48 49 85 86 87 110 111
6	18	35 36 37 38 85 86 109
6	19	26 29 30 31 85 86 93
6	20	25 26 27 80
6	21	26 27 28 85 86
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6	23	8 9 10 85 107
6	24	1 8 9 10 11 121 122
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6	26	8 9 10 11 33 123 124
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6	28	35 36 37 38 39 85 86 126 127
6	29	8 9 10 11 12 13 14 15 16 150 151 152 153
6	30	8 9 10 11 12 13 14 15 16 150 151
6	31	25 35 36 37 38 39 40 41 42 43 56 57 80
6	32	8 9 10 11 12 13 14 15 16 17
6	33	8 9 10 11 12 13 14 15 146
6	34	2 8 9 10 11 12 13 14 141 142 148
6	35	47 48 49 50 51 85 86 87 127 128 129 130 131
6	36	25 35 36 37 38 39 40 41 42 43 44 45 56 57 80
6	37	8 9 10 11 120 121 122
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7	7	4
7	8	84
7	9	89
7	10	8 84 85
7	11	26 84 85 86
7	12	84 85 86 87
7	13	84 85 86 87 88
7	14	84 85 86 87 88

FROM	TO	LINK NUMBER
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7	16	67 68 69 70 84 85 86 87 88 130
7	17	47 48 49 84 85 86 87 110 111
7	18	4 35 36 37 38 85 86
7	19	4 26 29 30 31 85 86 93
7	20	26 27 84 85 86
7	21	26 27 28 84 85 86
7	22	4 8 9 85
7	23	4 8 9 10 107
7	24	1 5 8 85
7	25	8 9 10 11 12 84 85 132
7	26	8 9 10 11 33 84 85 123 124
7	27	4 35 36 37 38 39 40 85 86
7	28	47 48 49 50 51 52 84 85 86 87
7	29	47 48 49 50 51 52 53 54 55 84 85 86 87 152 153
7	30	35 36 37 38 39 40 41 42 43 84 85 86
7	31	35 36 37 38 39 40 41 42 43 56 57 84 85 86
7	32	8 9 10 11 12 13 14 15 16 17 84 85
7	33	4 5 6 7 146
7	34	1 2 4 8 9 10 11 121 122
7	35	67 68 69 70 84 85 86 87 88 130 131
7	36	35 36 37 38 39 40 41 42 43 56 57 84 85 86
7	37	5 120 121
7	38	4 23 27
7	39	4 44 77 78
7	40	23 76 77
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8	11	89 90 91 92 93
8	12	89 90 91 92 93 94 95
8	13	89 90 91 92 93 94 95 96 97
8	14	89 90 91 92 93 94 95 96 97 98 99
8	15	74 89 90 91 92 93 94 95 96 97 98 99 131
8	16	68 69 70 89 90 91 92 93 94 95 96 97 98 130
8	17	58 89 90 91 92 93 94 95 96 111
8	18	36 37 38 89 90 91 92 93 94
8	19	29 30 31 89 90 91 92 93
8	20	27 89 90 91 92 93
8	21	27 28 89 90 91 92
8	22	9 89 90
8	23	9 10 89 90 113
8	24	1 120
8	25	9 10 11 12 13 89 90
8	26	29 30 31 32 33 89 90 91 92 93
8	27	36 37 38 39 40 41 89 90 91 92 93 94
8	28	120 121 122 123 124 125 126 127 128
8	29	36 37 38 39 40 41 42 43 89 90 91 92 93 94 152 153

FROM	TO	LINK NUMBER
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8	31	5 6 7 8 56 57 89 149 150 151
8	32	9 10 11 12 13 14 15 16 17 89 90
8	33	5 6 7 89 146
8	34	1 21 120 148
8	35	74 89 90 91 92 93 94 95 96 97 98 99 131
8	36	5 6 7 8 56 57 89 149 150 151
8	37	120
8	38	23 24 25 84 85 86
8	39	23 24 25 84 85 86
8	40	44 45 46 84 85 86 87
9	9	120 121
9	10	8 9 10 11 121 122
9	11	5 90 91 92 93
9	12	5 90 91 92 93 94
9	13	47 48 49 50 51 121 122 123 124 125 126
9	14	67 68 69 70 121 122 123 124 125 126 127 128 129
9	15	121 122 123 124 125 126 127 128 129 130 131
9	16	121 122 123 124 125 126 127 128 129 130
9	17	59 60 121 122 123 124 125 126 127
9	18	39 116 121 122 123 124 125
9	19	32 121 122 123 124 125
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9	22	9 10 11 121 122
9	23	11 113 121 122
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9	26	33 121 122 123 124
9	27	40 41 121 122 123 124 125
9	28	121 122 123 124 125 126 127 128
9	29	52 53 54 55 121 122 123 124 125 126 152 153
9	30	6 7 8 149 150 151
9	31	40 41 42 43 56 57 121 122 123 124 125
9	32	12 13 14 15 16 17 121 122
9	33	5 6 7
9	34	1 2 148
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9	36	52 53 54 55 56 57 121 122 123 124 125 126
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FROM	TO	LINK NUMBER
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10	17	58 90 91 92 93 94 95 96 111
10	18	36 37 38 90 91 92 93 94 116
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10	21	27 28 91 92
10	22	8 9
10	23	8 9 107
10	24	1 8 9 10 11 121 122
10	25	8 9 10 11 12 132
10	26	9 10 11 33 123 124
10	27	8 9 10 11 40 123 124 125 135
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10	32	8 9 10 11 12 13 14 15 16 17
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10	34	1 2 121 122
10	35	74 90 91 92 93 94 95 96 97 98 99 131
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10	37	9 10 11 120 121 122
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10	39	8 44 45 46 86 87
10	40	8 23 24 25 86
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11	14	67 93 94 95 96
11	15	35 74 95 96 97 98 99 131
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FROM	TO	LINK NUMBER
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12	32	9 10 11 12 13 14 15 16 17 91 92 93 94 95
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13	15	67 68 69 70 130 131
13	16	67 68 69 70 130
13	17	47 48 49 110 111
13	18	47 48 49 50 116
13	19	47 48 49 50 115 116
13	20	27 93 94 95 96 97
13	21	27 28 93 94 95 96 97
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13	23	47 48 49 108 109 113 114
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FROM	TO	LINK NUMBER
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13	26	33 47 48 49 50 51 125 126
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13	28	47 48 49 50 51 52
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13	30	47 48 49 50 51 52 53 54 55
13	31	67 68 69 70 130 131
13	32	9 10 11 12 13 14 15 16 17 91 92 93 94 95 96 97
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13	34	1 2 47 48 49 50 51 121 122 123 124 125 126 148
13	35	67 68 69 70 130 131
13	36	47 48 49 50 51 52 53 54 55 56 57
13	37	5 90 91 92 93 94 95 96 97 120 121
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13	39	44 45 46 47
13	40	23 24 25 87 88
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14	16	74 130
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14	19	36 37 38 95 96 97 98 99
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14	21	27 28 93 94 95 96 97 98 99
14	22	91 92 93 94 95 96 97 98 99
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14	27	52 67 68 69 70 127 128 129 130 135
14	28	67 68 69 70 71 139
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14	32	55 67 68 69 70 71 72 144 150 150
14	33	5 6 7 90 91 92 93 94 95 96 97 98 99
14	34	1 2 67 68 69 70 121 122 123 124 125 126 127 128 129 148
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14	36	48 49 50 51 52 53 54 55 56 57 96 97 98 99
14	37	67 68 69 70 120 121 122 123 124 125 126 127 128 129
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14	39	64 65 66
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15	16	130 131
15	17	62 63 111 130 131

FROM	TO	LINK NUMBER
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15	19	31 32 125 126 127 128 129 130 131
15	20	27 74 93 94 95 96 97 98 99 131
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15	22	9 10 11 123 124 125 126 127 128 129 130 131
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15	32	52 53 54 55 127 128 129 130 131 150 151
15	33	6 7 122 123 124 125 126 127 128 129 130 131
15	34	1 2 121 122 123 124 125 126 127 128 129 130 131 148
15	35	131
15	36	52 53 54 55 56 57 127 128 129 130 131
15	37	120 121 122 123 124 125 126 127 128 129 130 131
15	38	23 24 25 35 36 37 38 39 126 127 128 129 130 131
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16	17	62 111 129 130
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16	19	31 32 126 127 128 129 130
16	20	27 68 69 70 93 94 95 96 97 98
16	21	27 28 68 69 70 93 94 95 96 97 98
16	22	9 10 11 123 124 125 126 127 128 129 130
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16	25	22 124 125 126 127 128 129 130 132
16	26	33 125 126 127 128 129 130
16	27	52 127 128 129 130 135
16	28	128 129 130
16	29	52 53 54 55 127 128 129 130 152 153
16	30	52 53 54 55 127 128 129 130
16	31	52 53 54 55 127 128 129 130
16	32	12 13 14 15 16 17 123 124 125 126 127 128 129 130
16	33	6 7 122 123 124 125 126 127 128 129 130
16	34	1 2 121 122 123 124 125 126 127 128 129 130 148
16	35	130 131
16	36	52 53 54 55 56 57 127 128 129 130
16	37	120 121 122 123 124 125 126 127 128 129 130
16	38	23 24 25 35 36 37 38 39 126 127 128 129 130
16	39	44 45 46 47 48 49 50 51 127 128 129 130

FROM	TO	LINK NUMBER
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17	17	59 62 111 118
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17	19	31 108 109 110 111
17	20	27 58 93 94 95 96 111
17	21	27 28 58 93 94 95 96 111
17	22	58 91 92 93 94 95 96 111
17	23	108 109 110 111 113 114
17	24	1 59 60 121 122 123 124 125 126 127
17	25	32 33 115 116 117 118 132 133
17	26	31 32 33 108 109 110 111
17	27	50 51 52 110 111 135
17	28	62 63 111
17	29	50 51 52 53 54 55 110 111 152 153
17	30	50 51 52 53 54 55 110 111
17	31	51 52 53 54 55 56 57 117 118
17	32	51 52 53 54 55 56 57 117 118 150 151
17	33	6 7 59 60 122 123 124 125 126 127
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17	36	51 52 53 54 55 56 57 117 118
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18	18	38 116
18	19	115 116
18	20	37 38 104 105
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18	22	37 38 102 103 104 105
18	23	108 109 113 114
18	24	1 39 116 121 122 123 124 125
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18	29	50 51 52 53 54 55 152 153
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18	31	50 51 52 53 54 55 56 57
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18	33	6 7 121 122 123 124 125 126
18	34	1 2 38 39 121 122 123 124 125
18	35	50 51 127 128 129 130 131
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18	37	39 116 120 121 122 123 124 125
18	38	23 24 25 35 36 37 38
18	39	44 45 46 47 48 49 50
18	40	23 24 25 35 36 37 38

FROM	TO	LINK NUMBER
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19	22	102 103 104 105
19	23	31 113 114
19	24	1 32 121 122 123 124
19	25	21 22 114 132
19	26	31 32 33
19	27	38 39 40 41
19	28	31 32 33 134 135
19	29	39 40 41 42 43 115 152 153
19	30	38 39 40 41 42 43
19	31	38 39 40 41 42 43 56 57
19	32	39 40 41 42 43 150 151
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19	37	32 120 121 122 123 124
19	38	23 24 25 35 36 37 38
19	39	36 37 38 44 45 46 47 95
19	40	23 24 25 35 36 37 38
20	20	27
20	21	27 28
20	22	102 103
20	23	19 20 103 113
20	24	1 10 11 101 102 103 121 122
20	25	19 20 21 22 27 103 132
20	26	27 30 31 32 33 104
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20	30	27 37 38 39 40 41 42 43 104 105
20	31	27 37 38 39 40 41 42 43 56 57 104 105
20	32	10 11 12 13 14 15 16 17 101 102 103
20	33	10 11 12 13 14 15 27 101 102 103 146
20	34	1 2 9 10 27 101 102 103 121 122 148
20	35	27 49 50 51 103 104 105 106 130 131
20	36	27 37 38 39 40 41 42 43 56 57 104 105
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20	39	44 45 46 47 93 94 95
20	40	23 24 25 26 27
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21	22	28 102 103
21	23	19 20 113
21	24	1 19 20 21 121 122 123
21	25	19 20 21 22 132

FROM	TO	LINK NUMBER
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21	27	19 20 21 22 133 134 135
21	28	28 49 50 51 52 104 105 106
21	29	38 39 40 41 42 43 108 152 153
21	30	28 37 38 39 40 41 42 43 104 105
21	31	20 21 52 53 54 55 56 57 124 125 126
21	32	13 14 15 16 17 19 20 21 22 132
21	33	6 7 9 10 28 101 102 103
21	34	1 2 9 10 28 101 102 103 121 122
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21	38	23 24 25 26 27 28
21	39	28 44 45 46 47 48 104 105 106
21	40	23 24 25 26 27 28
22	22	101 102
22	23	107 110
22	24	1 10 11 101 121 122
22	25	10 11 12 101 132
22	26	30 31 32 33 102 103 104
22	27	37 38 39 40 41 102 102 103 105
22	28	49 50 51 52 53 102 103 104 105 106
22	29	37 38 39 40 41 42 43 102 103 104 105 152 153
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23	24	1 11 113 121 122
23	25	20 21 22
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23	35	21 113 123 124 125 126 127 128 129 130 131

FROM	TO	LINK NUMBER
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23	39	19 20 44 45 46 47 48 103 104 105 106
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24	26	1 33 121 122 123 124
24	27	1 40 41 121 122 123 124 125
24	28	1 121 122 123 124 125 126 127 128
24	29	1 15 16 141 142 150 151 152 153
24	30	1 7 8 141 149 150 151
24	31	1 7 8 56 57 141 149 150 151
24	32	1 15 16 17 141 142
24	33	7 141
24	34	1 2 148
24	35	1 121 122 123 124 125 126 127 128 129 130 131
24	36	1 7 8 56 57 141 149 150 151
24	37	1 120
24	38	1 23 24 25 35 36 37 38 39 121 122 123 124 125
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25	26	132 133
25	27	132 133 134 135
25	28	136 137 138 139
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25	31	42 43 56 57 136 137
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25	39	44 45 46 47 48 49 50 51 52 132 133 134 135
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26	28	134 135
26	29	34 42 43 137 152 153
26	30	41 42 43 134
26	31	41 42 43 56 57 134
26	32	13 14 15 16 17 132 133
26	33	7 14 34 136 142

FROM	TO	LINK NUMBER
26	34	32 13 14 132 133 141 142
26	35	52 127 128 129 130 131 134 135
26	36	41 42 43 56 57 134
26	37	33 120 121 122 123 124
26	38	23 24 25 35 36 37 38 39 40 134
26	39	44 45 46 47 48 49 50 51 52 134 135
26	40	23 24 25 35 36 37 38 39 40 134
27	27	135 138
27	28	135
27	29	53 54 55 152 153
27	30	41 42 43
27	31	53 54 55 56 57
27	32	41 42 43 150 151
27	33	7 14 136 137 138 142
27	34	2 13 14 132 133 134 135 141 142
27	35	52 53 127 128 129 130 131
27	36	53 54 55 56 57
27	37	40 41 120 121 122 123 124 125
27	38	23 24 25 35 36 37 38 39 40 135
27	39	44 45 46 47 48 49 50 51 52 53
27	40	23 24 25 35 36 37 38 39 40 135
28	28	139
28	29	53 54 55 152 153
28	30	53 54 55
28	31	53 54 55 56 57
28	32	53 54 55 56 150 151
28	33	7 14 136 137 138 139 142
28	34	2 14 136 137 138 139 141 142 148
28	35	71 130 131
28	36	53 54 55 56 57
28	37	52 120 121 122 123 124 125 126
28	38	23 24 25 47 48 49 50 51 52 87
28	39	44 45 46 47 48 49 50 51 52
28	40	23 24 46 47 48 49 50 51 52 81
29	29	153
29	30	151 152 153
29	31	56 57 152 153
29	32	150 151 152 153
29	33	8 149 150 151 152 153
29	34	148 149
29	35	52 53 54 55 127 128 129 130 131 152 153
29	36	56 57 152 153
29	37	6 7 8 120 121 149 150 151 152 153
29	38	23 24 25 35 36 37 38 39 40 41 42 43 152 153
29	39	44 45 46 47 48 49 50 51 52 53 54 55 152 153
29	40	23 24 25 35 36 37 38 39 40 41 42 43 152 153

FROM	TO	LINK NUMBER
30	30	43 55
30	31	56 57
30	32	150 151
30	33	7 8 149 150 151
30	34	2 7 8 148 149 150 151
30	35	52 53 54 55 127 128 129 130 131
30	36	56 57
30	37	40 41 42 43 120 121 122 123 124 125
30	38	23 24 25 35 36 37 38 39 40 41 42 43
30	39	44 45 46 47 48 49 50 51 52 53 54 55
30	40	23 24 25 35 36 37 38 39 40 41 42 43
31	31	57
31	32	56 57 150 151
31	33	43 56 57 146 147
31	34	56 57 148 149 150 151
31	35	52 53 54 55 56 57 127 128 129 130 131
31	36	57
31	37	53 54 55 56 57 120 121 122 123 124 125 126
31	38	23 24 25 35 36 37 38 39 40 41 42 43 56 57
31	39	44 45 46 47 48 49 50 51 52 53 54 55 56 57
31	40	23 24 25 35 36 37 38 39 40 41 42 43 56 57
32	32	150
32	33	8 149 150
32	34	2 15 16 17 141 142
32	35	52 53 54 55 127 128 129 130 131 150 151
32	36	56 57 150 151
32	37	12 13 14 15 16 17 120 121 122
32	38	8 9 10 11 12 13 14 15 16 23 24 25 86
32	39	44 45 46 47 48 49 50 51 52 53 54 55 150 151
32	40	8 9 10 11 12 13 14 15 16 17 23 24 25 86
33	33	7 8 146
33	34	2 7 141 148
33	35	43 56 57 146 147
33	36	4 6 122 123 124 125 126 127 128 129 130 131
33	37	6 7 120 121
33	38	5 6 7 23 24 25 26 90 91 92
33	39	6 7 44 45 46 47 48 49 50 51 122 123 124 125 126
33	40	5 6 7 23 24 25 26 90 91 92
34	34	148
34	35	15 16 56 57 141 142 150 151
34	36	1 2 121 122 123 124 125 126 127 128 129 130 131
34	37	1 20 120
34	38	1 2 23 24 25 35 36 37 38 39 121 122 123 124 125
34	39	1 2 44 45 46 47 48 49 50 51 121 122 123 124 125 126
34	40	1 2 23 24 25 35 36 37 38 39 121 122 123 124 125

FROM	TO	LINK NUMBER
35	36	52 53 54 55 56 57 127 128 129 130 131
35	37	120 121 122 123 124 125 126 127 128 129 130 131
35	38	23 24 25 35 36 37 38 39 126 127 128 129 130 131
35	39	44 45 46 47 48 49 50 51 127 128 129 130 131
35	40	23 24 25 35 36 37 38 39 126 127 128 129 130 131
36	37	52 53 54 55 56 57 120 121 122 123 124 125 126
36	38	23 24 25 35 36 37 38 39 40 41 42 43 56 57
36	39	44 45 46 47 48 50 51 52 53 54 55 56 57
36	40	23 24 25 35 36 37 38 39 40 41 42 43 56 57
37	38	10 11 23 24 25 26 27 101 102 103 120 121 122
37	39	44 45 46 47 48 49 50 51 120 121 122 123 124 125 126
37	40	10 11 23 24 25 26 27 101 102 103 120 121 122
38	39	44
38	40	23 24
39	40	23

APPENDIX D

TRIP DISTRIBUTION MATRIX FOR QRS

HBW TRIP DISTRIBUTION FOR THE YEAR 2010

ORIGIN ZONE 1

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		2	1	9	7	0	2	1	0	0
10	0	2	4	2	0	1	0	4	1	1
20	0	8	1	1	7	2	2	1	1	0
30	0	0	1	2	0	1	1	1	1	0
40	0									

ORIGIN ZONE 2

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		7	4	54	37	1	8	1	0	2
10	1	7	22	9	1	1	2	20	7	5
20	0	41	1	6	27	12	6	7	3	0
30	2	1	1	7	1	4	6	5	3	0
40	1									

ORIGIN ZONE 3

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		13	8	102	82	2	17	3	0	3
10	5	14	49	21	3	2	4	43	16	11
20	0	82	2	12	55	24	12	17	4	1
30	5	1	3	16	1	8	10	10	4	1
40	1									

ORIGIN ZONE 4

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		10	7	90	78	2	14	2	0	2
10	4	14	50	22	3	2	4	45	15	11
20	0	85	2	12	52	23	12	16	4	1
30	5	1	3	14	1	8	8	9	3	1
40	1									

ORIGIN ZONE 5

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		20	9	143	114	4	32	4	1	4
10	8	24	79	33	4	3	7	73	25	19
20	0	145	5	19	95	42	21	27	8	1
30	8	2	6	28	2	12	13	15	6	1
40	2									

ORIGIN ZONE 6

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	0	5	3	0	1	0	0	1
10	0	1	2	1	0	0	0	3	0	1
20	0	4	1	0	3	1	1	1	0	0
30	0	0	1	0	0	1	0	1	0	0
40	0									

ORIGIN ZONE 7

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		6	2	35	24	1	8	1	1	1
10	2	6	18	7	1	1	1	16	6	4
20	0	35	2	5	30	10	5	7	2	0
30	2	1	1	7	1	3	4	3	2	1
40	0									

ORIGIN ZONE 8

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	0	3	2	0	1	0	0	1
10	0	0	2	1	0	0	0	2	1	0
20	0	4	0	0	4	2	0	1	0	0
30	0	0	1	1	0	0	0	1	0	0
40	0									

ORIGIN ZONE 9

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	0	5	4	0	2	0	0	0
10	1	1	2	2	0	0	0	3	1	1
20	0	7	0	1	7	2	1	1	0	0
30	1	0	0	2	0	0	1	1	0	0
40	0									

ORIGIN ZONE 10

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		14	7	100	80	2	25	3	1	5
10	8	18	62	24	3	3	4	55	21	16
20	0	140	5	19	89	39	18	24	6	2
30	7	2	5	24	2	9	11	11	5	1
40	1									

ORIGIN ZONE 11

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		5	4	45	40	1	9	2	0	1
10	3	10	37	13	2	1	2	29	12	8
20	0	65	2	9	36	16	9	11	3	1
30	3	1	2	9	1	4	5	5	2	0
40	1									

ORIGIN ZONE 12

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		8	5	69	64	1	13	2	1	2
10	4	16	48	21	2	2	4	42	16	12
20	0	87	2	11	45	23	12	16	5	1
30	4	1	3	13	1	6	6	8	3	0
40	1									

ORIGIN ZONE 13

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		32	18	260	240	5	47	6	2	8
10	12	51	181	80	10	7	15	188	61	41
20	0	301	9	40	153	82	43	61	18	3
30	18	4	10	49	4	24	24	29	11	2
40	3									

ORIGIN ZONE 14

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		6	4	48	43	1	8	2	0	1
10	2	8	29	14	2	2	3	33	10	7
20	0	50	1	7	28	14	8	10	3	1
30	3	1	2	8	1	6	5	8	2	0
40	1									

ORIGIN ZONE 15

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		2	1	11	12	0	2	1	0	0
10	1	2	7	4	1	0	1	10	3	2
20	0	14	0	2	8	4	2	4	1	0
30	1	1	0	3	0	2	1	2	1	0
40	0									

ORIGIN ZONE 16

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		12	7	86	82	2	16	2	1	3
10	4	18	60	27	5	4	8	76	23	16
20	0	111	3	14	62	32	18	27	9	2
30	8	2	5	21	1	12	10	12	5	1
40	1									

ORIGIN ZONE 17

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		25	14	199	184	5	38	5	1	7
10	11	42	137	71	9	7	15	168	59	42
20	0	292	8	38	145	77	44	63	20	4
30	18	4	10	44	3	22	20	25	10	2
40	2									

ORIGIN ZONE 18

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		4	3	38	32	1	7	1	1	1
10	2	8	28	12	1	1	3	30	11	9
20	0	58	1	8	28	16	9	12	4	1
30	3	1	2	9	0	4	4	5	1	1
40	0									

ORIGIN ZONE 19

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		15	9	114	100	3	23	3	1	5
10	7	28	86	34	5	3	8	96	38	26
20	0	183	5	25	95	54	31	39	11	2
30	10	3	6	30	2	11	12	13	6	1
40	1									

ORIGIN ZONE 20

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		3	2	23	21	1	5	0	0	2
10	1	6	18	7	1	0	2	16	6	5
20	0	39	1	5	20	10	5	7	1	1
30	2	0	1	6	0	3	2	2	2	0
40	0									

ORIGIN ZONE 21

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		49	29	369	344	9	78	11	2	17
10	27	92	277	112	13	11	22	288	110	79
20	0	648	19	82	327	175	90	117	32	6
30	34	7	22	96	7	38	40	46	17	3
40	5									

ORIGIN ZONE 22

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	4	60	55	2	13	2	1	3
10	4	14	41	16	2	2	3	40	15	12
20	0	95	3	13	53	26	14	16	4	1
30	5	1	4	15	2	5	6	7	3	0
40	1									

ORIGIN ZONE 23

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		19	11	142	125	3	28	5	1	6
10	11	32	98	40	6	3	8	102	39	30
20	0	226	7	32	132	73	35	41	11	2
30	13	3	9	38	3	15	14	16	7	1
40	2									

ORIGIN ZONE 24

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		14	7	82	71	2	17	3	1	6
10	6	17	47	19	3	2	4	47	18	14
20	0	109	4	16	120	41	17	22	6	1
30	8	2	6	34	2	9	9	11	4	1
40	1									

ORIGIN ZONE 25

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		20	10	140	119	3	27	4	1	7
10	10	29	92	38	4	4	8	95	38	30
20	0	219	7	33	155	77	36	47	13	3
30	14	4	9	46	4	15	14	17	7	1
40	2									

ORIGIN ZONE 26

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		6	4	47	42	1	10	1	1	2
10	3	11	35	14	2	1	3	40	15	12
20	0	80	2	12	44	26	13	19	5	1
30	5	2	3	15	1	6	5	7	2	0
40	1									

ORIGIN ZONE 27

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		3	2	26	21	1	4	1	0	1
10	2	5	18	7	1	1	2	21	8	6
20	0	40	1	5	23	12	8	10	3	1
30	3	0	2	7	0	3	3	3	1	1
40	0									

ORIGIN ZONE 28

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	4	60	57	2	11	2	0	3
10	3	14	44	19	2	3	5	57	20	14
20	0	92	2	13	53	30	18	25	7	2
30	7	1	4	15	1	7	7	8	4	0
40	1									

ORIGIN ZONE 29

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	1	7	6	0	1	1	0	0
10	0	2	5	2	1	0	1	6	2	1
20	0	11	0	1	7	4	2	2	1	0
30	1	0	1	2	0	1	1	1	1	0
40	0									

ORIGIN ZONE 30

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	4	60	52	1	12	1	1	3
10	3	13	39	18	2	3	4	49	17	13
20	0	92	3	12	64	31	16	24	7	1
30	10	2	5	19	1	8	7	9	4	0
40	1									

ORIGIN ZONE 31

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	1	7	7	0	2	0	0	0
10	1	2	4	3	0	0	1	6	2	2
20	0	12	0	2	9	4	2	3	1	0
30	1	0	1	3	0	1	1	1	1	0
40	0									

ORIGIN ZONE 32

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		12	5	75	64	2	14	3	0	4
10	5	16	47	20	3	3	5	54	21	15
20	0	115	3	17	89	39	20	26	7	1
30	10	3	6	30	2	9	9	10	4	1
40	1									

ORIGIN ZONE 33

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		14	7	88	73	2	18	3	1	6
10	6	17	53	23	3	2	5	55	22	16
20	0	123	4	18	129	47	20	25	7	2
30	8	3	7	36	3	9	11	11	5	1
40	1									

ORIGIN ZONE 34

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	1	7	5	0	1	1	0	0
10	1	1	4	1	0	1	0	4	1	1
20	0	8	1	1	10	3	1	2	1	0
30	0	0	1	3	0	1	1	0	1	0
40	0									

ORIGIN ZONE 35

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		5	3	33	27	1	6	1	0	1
10	2	5	18	9	1	2	2	19	7	5
20	0	35	1	5	24	11	6	8	2	1
30	3	0	2	7	0	54	5	14	2	0
40	1									

ORIGIN ZONE 36

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		7	4	38	29	0	7	1	0	2
10	2	5	18	8	1	1	2	17	7	4
20	0	35	1	5	24	11	5	7	2	0
30	3	0	2	7	0	5	58	7	7	1
40	2									

ORIGIN ZONE 37

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		6	3	42	33	1	7	1	0	2
10	2	6	22	9	2	2	2	22	8	5
20	0	41	1	6	28	12	6	10	2	1
30	3	1	2	8	1	13	6	79	3	0
40	1									

ORIGIN ZONE 38

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		4	1	18	13	0	4	0	0	1
10	1	2	9	3	1	0	1	8	3	2
20	0	16	0	2	12	5	2	3	1	1
30	1	0	1	3	0	2	7	3	13	0
40	1									

ORIGIN ZONE 39

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	0	3	2	0	1	0	0	0
10	0	1	1	1	0	0	0	1	1	0
20	0	3	0	0	2	1	0	1	0	0
30	0	0	1	0	0	1	1	0	0	1
40	0									

ORIGIN ZONE 40

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		1	0	5	3	1	0	1	0	0
10	0	1	2	1	0	0	0	2	1	1
20	0	4	0	1	3	1	1	1	0	0
30	0	0	1	0	0	1	2	1	1	0
40	1									

HBNW TRIP DISTRIBUTION FOR THE YEAR 2010

ORIGIN ZONE 1

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		31	15	26	17	15	4	8	0	6
10	11	6	25	29	6	3	10	35	16	20
20	1	12	7	12	21	26	16	17	10	1
30	9	2	10	16	2	6	10	7	6	1
40	2									

ORIGIN ZONE 2

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		98	79	180	106	64	15	21	2	19
10	44	36	138	136	35	16	52	176	94	98
20	8	67	32	64	84	123	80	91	46	5
30	42	7	40	60	7	30	41	37	22	5
40	7									

ORIGIN ZONE 3

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		162	161	319	242	152	38	50	4	41
10	104	81	307	330	66	27	105	391	211	205
20	17	130	61	125	160	250	163	196	93	11
30	92	14	82	127	15	52	63	62	34	8
40	10									

ORIGIN ZONE 4

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		117	106	271	236	129	26	37	2	33
10	90	84	339	364	66	32	112	418	193	201
20	17	140	65	122	154	233	162	183	99	10
30	90	14	80	115	13	46	48	55	26	6
40	8									

ORIGIN ZONE 5

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		236	154	405	308	290	73	86	5	65
10	203	144	508	480	90	42	180	657	330	344
20	33	238	126	210	285	424	300	312	159	18
30	144	26	146	246	26	70	83	86	44	9
40	14									

ORIGIN ZONE 6

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	5	13	8	10	2	4	0	3
10	8	4	15	14	3	1	5	19	10	11
20	1	7	4	6	9	12	9	8	5	0
30	5	0	4	7	1	2	3	3	1	1
40	0									

ORIGIN ZONE 7

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		83	35	92	60	60	19	34	2	27
10	62	31	108	99	20	11	36	138	74	83
20	7	58	29	55	101	111	72	76	36	4
30	37	7	39	69	9	19	24	23	13	3
40	4									

ORIGIN ZONE 8

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		7	4	8	5	5	2	3	1	4
10	6	3	10	11	2	1	4	13	8	8
20	1	6	3	7	13	14	9	8	4	0
30	5	1	4	9	1	2	3	2	1	1
40	0									

ORIGIN ZONE 9

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		11	6	13	9	8	3	4	1	6
10	10	5	17	15	3	2	6	25	13	15
20	2	11	6	10	28	23	13	15	7	0
30	8	2	9	17	2	3	3	4	2	0
40	1									

ORIGIN ZONE 10

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		166	96	252	192	184	53	82	5	73
10	222	105	372	340	59	31	119	473	255	311
20	27	257	137	246	276	414	271	277	133	15
30	147	25	131	218	23	55	63	64	34	7
40	10									

ORIGIN ZONE 11

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		54	43	108	101	73	16	23	2	21
10	59	62	270	205	31	15	63	267	153	183
20	14	117	47	97	103	163	122	129	66	6
30	58	9	57	74	7	25	25	29	13	3
40	4									

ORIGIN ZONE 12

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		84	69	171	169	105	24	33	2	28
10	86	112	318	342	49	24	99	388	224	232
20	21	148	60	124	119	219	177	187	96	10
30	85	13	69	100	11	35	35	41	18	4
40	6									

ORIGIN ZONE 13

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		339	237	643	633	351	81	105	8	94
10	275	296	1197	1284	230	104	406	1911	840	764
20	60	486	184	411	389	763	588	703	361	39
30	318	54	262	376	36	142	129	158	69	16
40	21									

ORIGIN ZONE 14

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		66	58	121	109	62	15	20	2	16
10	45	44	165	218	58	29	103	325	123	127
20	10	76	30	73	71	127	104	115	64	9
30	61	11	48	62	6	50	30	47	16	4
40	5									

ORIGIN ZONE 15

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		18	13	27	27	16	3	5	1	5
10	12	11	42	52	15	11	35	84	37	35
20	2	21	9	17	21	37	31	39	22	3
30	23	4	18	18	2	12	8	14	4	1
40	1									

ORIGIN ZONE 16

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		118	86	193	184	124	26	37	2	35
10	91	87	328	383	102	65	268	739	288	274
20	20	161	65	133	156	290	239	313	207	25
30	164	30	126	157	14	72	53	70	29	6
40	9									

ORIGIN ZONE 17

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		237	173	432	410	272	59	83	5	85
10	217	218	769	1080	194	96	443	1608	810	842
20	50	468	169	392	351	694	641	768	451	42
30	337	53	260	317	30	119	103	130	55	13
40	17									

ORIGIN ZONE 18

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		39	33	84	68	49	12	16	1	16
10	42	46	159	171	27	14	63	291	147	189
20	11	97	35	81	73	155	134	159	82	7
30	61	9	51	67	6	22	19	22	10	2
40	3									

ORIGIN ZONE 19

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		138	103	239	209	151	35	53	4	54
10	151	158	488	458	80	43	174	892	556	578
20	36	298	121	285	239	544	504	489	218	21
30	187	30	166	222	20	57	56	65	31	7
40	9									

ORIGIN ZONE 20

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		32	22	54	49	40	8	13	1	13
10	37	34	119	98	17	8	35	145	84	100
20	9	79	30	60	56	102	76	80	35	4
30	35	5	33	45	4	13	12	14	6	2
40	2									

ORIGIN ZONE 21

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		91	73	159	150	109	25	38	3	42
10	129	105	322	303	50	25	107	515	297	309
20	30	243	92	188	173	360	269	282	126	13
30	124	20	110	146	14	41	40	46	20	4
40	7									

ORIGIN ZONE 22

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		92	65	139	133	108	24	36	2	40
10	131	80	249	215	37	21	81	349	200	238
20	21	173	81	166	152	277	207	191	90	9
30	95	14	97	129	12	33	33	36	18	4
40	6									

ORIGIN ZONE 23

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		184	147	318	278	200	47	77	6	84
10	259	184	568	535	101	44	184	906	521	621
20	49	395	185	378	371	828	542	495	224	22
30	231	39	241	317	30	79	74	87	41	9
40	12									

ORIGIN ZONE 24

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		162	91	195	168	130	30	68	6	105
10	139	93	260	244	47	26	103	389	223	250
20	21	174	82	177	464	457	238	261	124	16
30	162	32	168	368	41	54	58	61	31	7
40	10									

ORIGIN ZONE 25

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		196	137	311	259	198	42	76	6	90
10	214	151	492	487	86	48	196	784	488	579
20	40	369	151	404	466	885	579	606	272	27
30	289	49	257	420	40	85	78	90	42	9
40	14									

ORIGIN ZONE 26

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		55	42	96	86	66	14	23	2	24
10	66	53	188	177	33	19	76	343	197	254
20	14	131	53	125	115	274	179	265	136	10
30	102	15	90	114	12	33	27	31	14	3
40	4									

ORIGIN ZONE 27

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		28	22	52	44	31	7	11	0	12
10	31	26	90	96	17	10	46	186	108	111
20	7	62	23	52	57	130	120	145	74	6
30	63	7	44	49	5	16	13	18	7	2
40	2									

ORIGIN ZONE 28

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		79	54	121	117	78	17	26	2	26
10	72	64	225	242	45	29	148	535	269	245
20	14	137	51	115	133	285	302	362	150	16
30	138	21	92	106	11	38	33	43	18	4
40	6									

ORIGIN ZONE 29

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	7	15	13	9	2	4	0	4
10	9	7	28	29	7	6	20	55	25	27
20	2	15	6	13	19	33	25	34	18	3
30	21	4	14	16	2	7	5	7	3	0
40	1									

ORIGIN ZONE 30

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		81	52	125	109	73	17	28	2	33
10	83	59	206	221	46	31	122	415	209	218
20	14	139	56	122	181	315	234	321	144	19
30	228	36	155	156	15	45	37	50	21	5
40	6									

ORIGIN ZONE 31

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		11	7	16	14	10	3	4	0	5
10	12	7	25	30	6	5	17	53	25	27
20	2	18	7	16	29	43	28	28	17	3
30	29	7	22	25	2	7	6	7	2	1
40	1									

ORIGIN ZONE 32

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		113	69	159	139	107	21	42	3	52
10	106	81	244	261	51	34	133	459	247	277
20	20	176	83	184	267	402	299	315	138	18
30	222	40	226	283	28	52	47	60	26	5
40	8									

ORIGIN ZONE 33

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		154	84	199	161	146	31	59	5	82
10	143	87	283	303	53	30	134	452	268	298
20	22	190	88	197	473	530	305	292	127	17
30	181	35	229	376	42	58	60	69	32	7
40	10									

ORIGIN ZONE 34

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		13	7	17	12	11	2	5	1	7
10	10	6	21	21	3	3	8	31	17	19
20	1	13	6	13	38	36	22	20	9	1
30	13	2	16	30	4	5	5	6	3	0
40	1									

ORIGIN ZONE 35

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		34	26	48	39	24	6	10	1	9
10	22	17	60	68	25	12	36	101	51	46
20	4	32	13	29	42	63	53	55	27	5
30	30	6	26	34	4	1143	23	82	11	3
40	3									

ORIGIN ZONE 36

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		60	35	59	40	30	7	12	1	11
10	24	17	59	62	15	8	27	88	44	45
20	4	31	13	28	44	59	42	47	23	3
30	27	4	23	36	4	23	1190	28	58	9
40	30									

ORIGIN ZONE 37

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		40	30	58	46	30	7	11	1	10
10	25	20	68	75	23	13	35	109	51	52
20	4	34	15	32	46	67	50	61	30	5
30	33	6	29	40	5	81	27	1528	15	3
40	5									

ORIGIN ZONE 38

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		35	19	33	22	16	4	7	1	5
10	14	9	32	34	9	4	15	48	25	25
20	2	16	7	16	25	32	22	26	14	1
30	16	2	13	20	2	11	60	15	348	4
40	10									

ORIGIN ZONE 39

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		7	4	7	5	4	1	1	0	1
10	3	2	8	7	2	1	4	11	5	6
20	0	4	1	4	5	8	5	5	3	1
30	3	1	2	5	0	3	9	4	4	18
40	2									

ORIGIN ZONE 40

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		10	6	10	7	5	1	2	1	1
10	4	3	10	11	3	1	4	15	8	8
20	0	6	2	5	7	11	7	8	4	1
30	4	1	4	6	1	3	31	5	9	2
40	34									

NHB TRIP DISTRIBUTION FOR THE YEAR 2010

ORIGIN ZONE 1

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		103	56	141	102	70	24	31	2	24
10	59	37	128	148	30	15	58	192	83	99
20	9	140	35	71	125	138	78	88	51	6
30	54	9	54	87	10	37	52	44	28	4
40	8									

ORIGIN ZONE 2

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		56	48	145	93	51	14	17	2	14
10	39	30	104	110	25	12	43	146	69	76
20	7	113	26	57	83	102	62	67	37	4
30	38	7	37	56	6	29	35	35	18	3
40	5									

ORIGIN ZONE 3

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		140	145	385	304	170	50	54	4	43
10	124	95	336	371	72	31	125	439	212	219
20	21	311	72	158	226	297	178	204	107	13
30	114	19	107	163	18	76	86	90	43	9
40	12									

ORIGIN ZONE 4

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		102	93	305	281	134	34	39	3	32
10	98	89	325	360	66	29	114	424	178	196
20	19	300	70	141	196	242	156	167	97	11
30	97	16	92	136	13	61	64	73	32	6
40	9									

ORIGIN ZONE 5

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		70	50	170	134	110	33	31	2	22
10	77	55	181	184	34	15	68	246	111	123
20	13	188	48	88	128	162	104	104	57	8
30	57	11	59	96	10	35	40	43	21	3
40	6									

ORIGIN ZONE 6

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		23	15	50	34	33	9	12	0	8
10	26	15	49	51	9	5	18	65	31	34
20	3	52	13	25	36	44	27	29	15	2
30	17	3	16	26	3	10	12	12	6	1
40	2									

ORIGIN ZONE 7

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		31	17	55	38	31	11	15	2	11
10	30	17	54	56	11	6	21	77	36	42
20	4	62	15	31	57	59	35	37	19	3
30	21	4	22	37	4	13	16	15	8	2
40	2									

ORIGIN ZONE 8

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		2	2	4	3	2	0	2	0	1
10	2	2	4	5	1	0	2	6	3	3
20	0	6	1	3	5	6	3	3	1	1
30	1	1	2	3	0	2	1	1	1	0
40	0									

ORIGIN ZONE 9

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		23	14	42	32	22	8	11	1	12
10	25	15	45	45	9	5	18	69	33	38
20	3	59	15	30	71	58	32	34	18	2
30	21	4	22	42	4	12	12	13	6	1
40	2									

ORIGIN ZONE 10

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		59	39	124	99	77	26	31	2	25
10	94	46	153	147	28	13	55	199	97	122
20	12	211	59	107	130	171	102	103	52	7
30	61	10	58	94	9	31	35	37	18	3
40	5									

ORIGIN ZONE 11

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		38	30	94	88	55	15	17	1	14
10	47	48	188	148	24	11	46	190	98	124
20	12	177	35	77	87	122	80	84	45	5
30	44	7	43	60	6	25	25	28	13	2
40	4									

ORIGIN ZONE 12

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		126	103	335	324	181	50	54	4	45
10	152	189	514	568	82	38	163	624	319	350
20	37	496	103	224	255	370	263	275	150	18
30	142	23	128	190	19	80	79	93	40	8
40	11									

ORIGIN ZONE 13

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		147	110	369	359	183	51	55	5	45
10	147	148	568	628	107	46	195	908	352	344
20	31	487	97	227	260	385	266	304	166	19
30	158	27	142	210	20	91	87	105	44	9
40	12									

ORIGIN ZONE 14

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		31	25	72	66	33	10	11	1	9
10	28	23	83	106	27	13	47	155	56	62
20	5	82	18	42	52	72	48	54	31	4
30	33	5	29	39	4	27	20	28	10	2
40	3									

ORIGIN ZONE 15

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		15	12	31	29	16	4	6	0	5
10	13	11	38	47	12	8	28	73	29	30
20	2	41	9	19	27	37	25	31	18	3
30	19	3	16	21	2	12	10	14	5	1
40	1									

ORIGIN ZONE 16

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		57	43	125	114	67	18	21	2	19
10	55	47	163	196	47	28	125	346	128	131
20	11	174	37	80	110	156	110	136	91	12
30	77	14	67	90	8	44	37	47	19	4
40	5									

ORIGIN ZONE 17

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		191	146	436	422	245	64	77	6	69
10	199	190	623	906	154	73	345	1309	595	653
20	45	792	151	357	385	591	471	539	344	34
30	267	42	222	303	29	131	122	149	61	12
40	17									

ORIGIN ZONE 18

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		82	68	212	177	112	31	36	3	32
10	96	97	318	352	56	29	127	595	270	356
20	23	420	75	183	191	315	250	287	156	14
30	121	19	107	149	14	60	55	64	28	5
40	8									

ORIGIN ZONE 19

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		98	75	217	195	123	34	41	4	37
10	121	125	349	343	61	30	130	652	356	392
20	29	461	93	234	220	389	331	314	147	15
30	133	21	126	174	15	61	59	69	31	6
40	8									

ORIGIN ZONE 20

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	7	21	19	13	3	4	1	3
10	12	12	37	31	5	3	11	45	23	29
20	3	50	10	21	21	31	22	21	11	1
30	11	2	10	15	2	5	6	6	3	0
40	1									

ORIGIN ZONE 21

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		139	112	308	299	187	51	61	6	58
10	211	177	495	487	82	40	174	791	421	462
20	50	788	154	332	323	553	390	381	185	20
30	189	30	178	248	23	90	89	102	43	8
40	13									

ORIGIN ZONE 22

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		35	27	72	70	48	13	15	2	14
10	58	36	103	97	18	9	37	152	75	92
20	10	154	36	78	76	116	78	73	37	4
30	39	7	41	59	5	20	19	23	10	2
40	3									

ORIGIN ZONE 23

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		71	56	157	141	88	24	31	3	30
10	107	76	224	227	41	19	80	357	182	235
20	21	333	78	168	175	329	198	172	86	9
30	91	15	97	134	12	44	43	50	22	4
40	6									

ORIGIN ZONE 24

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		124	83	226	196	129	36	57	5	72
10	130	88	255	261	52	27	110	388	192	221
20	20	325	76	176	421	391	193	214	111	15
30	140	26	146	303	30	66	69	76	36	7
40	10									

ORIGIN ZONE 25

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		137	102	295	242	162	43	58	6	57
10	171	121	371	385	72	37	156	591	316	391
20	31	554	115	329	391	640	386	377	183	20
30	202	34	189	307	27	86	82	95	42	8
40	12									

ORIGIN ZONE 26

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		78	61	178	155	103	27	35	3	32
10	102	80	262	265	49	25	110	470	251	330
20	21	390	78	198	192	385	232	319	174	14
30	132	21	124	169	16	59	53	63	26	5
40	7									

ORIGIN ZONE 27

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		87	67	203	166	104	29	37	3	34
10	103	83	275	304	54	31	135	539	287	315
20	21	381	73	172	213	376	320	365	200	17
30	170	21	131	158	15	63	57	73	29	6
40	8									

ORIGIN ZONE 28

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		50	37	105	97	57	15	20	1	17
10	53	45	150	166	31	17	91	344	156	147
20	11	185	37	86	110	183	174	199	91	9
30	83	13	62	79	8	34	31	39	16	3
40	5									

ORIGIN ZONE 29

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		6	4	14	10	7	2	3	0	2
10	7	5	17	19	5	3	11	34	14	15
20	1	21	4	10	15	20	14	18	10	1
30	12	2	8	12	1	5	4	6	2	0
40	1									

ORIGIN ZONE 30

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		54	38	113	97	58	17	21	2	21
10	61	43	143	158	32	19	78	267	122	133
20	11	189	39	91	139	202	132	171	83	11
30	131	20	94	104	10	39	34	44	19	3
40	5									

ORIGIN ZONE 31

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	7	19	16	10	3	4	1	4
10	10	7	23	27	6	3	14	43	19	21
20	2	30	7	15	26	34	20	21	12	3
30	20	4	17	20	2	7	7	7	4	0
40	1									

ORIGIN ZONE 32

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		54	37	107	92	59	16	22	1	23
10	57	43	128	142	29	16	67	222	108	126
20	11	178	42	98	145	190	125	131	63	9
30	93	17	100	130	12	35	32	40	16	3
40	5									

ORIGIN ZONE 33

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		87	56	163	136	95	26	37	4	42
10	93	61	191	210	40	20	91	304	150	175
20	15	249	58	134	303	307	170	158	80	12
30	104	20	131	217	22	49	50	58	26	5
40	7									

ORIGIN ZONE 34

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		9	6	18	14	9	3	4	0	5
10	9	5	19	20	4	2	8	29	14	15
20	2	23	5	12	30	28	15	15	8	1
30	10	2	12	22	2	5	6	6	3	0
40	1									

ORIGIN ZONE 35

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		38	30	78	64	36	11	14	1	11
10	33	26	82	95	28	12	46	136	62	63
20	5	94	20	46	68	89	63	65	36	5
30	40	8	36	50	5	699	30	75	15	3
40	4									

ORIGIN ZONE 36

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		55	36	89	66	42	12	16	2	12
10	36	26	83	91	21	9	39	127	57	62
20	6	93	21	44	72	86	55	59	32	4
30	37	6	34	53	5	31	736	38	48	7
40	21									

ORIGIN ZONE 37

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		45	36	94	76	45	12	16	2	13
10	39	30	97	109	29	15	48	155	67	73
20	6	106	23	52	79	99	66	76	40	6
30	46	8	42	60	6	76	37	963	19	4
40	5									

ORIGIN ZONE 38

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		28	18	44	33	21	6	8	1	6
10	18	13	41	45	11	5	19	63	29	31
20	3	44	11	23	36	42	27	30	17	2
30	19	3	17	26	3	14	48	19	184	3
40	7									

ORIGIN ZONE 39

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		5	3	9	6	4	1	2	0	1
10	3	3	8	9	2	1	3	13	5	6
20	1	8	2	4	7	8	6	5	3	1
30	3	1	3	5	1	3	6	4	3	7
40	1									

ORIGIN ZONE 40

DEST ZONE	0	1	2	3	4	5	6	7	8	9
00		8	5	12	9	6	2	2	0	2
10	5	4	11	13	3	1	6	17	8	9
20	1	13	3	6	10	13	7	9	4	1
30	5	1	4	8	1	4	20	5	7	1
40	15									

APPENDIX E

CAPACITY ANALYSIS USING THE NCHRP REPORT 187 APPROACH

TABLE 44

DETERMINATION OF LOS USING QRS
ASSIGNMENT OUTPUT

LINK	DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
1	Country Club	11	2013	1032	1.90	F
2	Country Club	11	146	1032	.14	A
3	Sangre	9	276	845	.33	A
4	Sangre	12	389	1126	.33	A
5	Sangre	12	578	1126	.51	A
6	Sangre	10.5	1024	985	1.04	E
7	Sangre	10.5	1582	985	1.61	F
8	Western	11.5	1776	1080	1.64	F
9	Western	12	1414	1126	1.26	F
10	Western	26	1655	2585	.64	B
11	Western	26	1508	2585	.58	A
12	Western	15	1164	1408	.83	D
13	Western	15	1322	1408	.94	E
14	Western	12	1283	1126	1.14	F
15	Western	11.5	1172	1080	1.09	F
16	Western	11.5	831	1080	.77	C
17	Western	11.5	776	1080	.72	C
18	Monroe	13	466	1220	.38	A
19	Monroe	15	1472	1455	1.01	E
20	Monroe	18	1809	1690	1.07	E
21	Monroe	18	1604	1690	.95	E
22	Monroe	11	1379	1032	1.33	F
23	HWY 177	26	995	2585	.28	A
24	HWY 177	26	1791	2585	.50	A
25	Washington	26	2410	2585	.93	E
26	Washington	26	1193	2585	.46	A
27	Washington	26	1867	2585	.72	C
29	Duck	20	411	1875	.22	A
30	Duck	20	652	1875	.35	A
31	Duck	24	1519	2330	.65	B
32	Duck	24	1113	2330	.48	A
33	Duck	24	1430	2330	.61	B
34	Duck	24	177	2330	.08	A
35	Boomer	32	2520	3230	.78	C
36	Main	32	2020	3230	.63	B
37	Main	32	2336	3230	.72	C
38	Main	25	2408	2430	.99	E

TABLE 44 (Continued)

LINK	DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
39	Main	25	2078	2430	.86	D
40	Main	18	1858	1690	1.10	F
41	Main	18	1373	1690	.80	C
42	Main	12	1000	1126	.89	D
43	Main	12	1062	1126	.94	E
44	Perkins	12	720	1126	.64	B
45	Perkins	12	2060	1126	1.80	F
46	Perkins	22	3608	2135	1.69	F
47	Perkins	26	5986	2585	2.31	F
48	Perkins	26	4724	2585	1.83	F
49	Perkins	26	4881	2585	1.89	F
50	Perkins	26	4093	2585	1.58	F
51	Perkins	26	3503	2585	1.35	F
52	Perkins	26	2424	2585	.94	E
53	Perkins	26	1554	2585	.60	A
54	Perkins	26	1315	2585	.51	A
55	Perkins	24	1364	2330	.53	A
56	HWY 177	12	1092	1800	.61	B
57	Hwy 177	12	1092	1800	.61	B
58	Burdick	11	676	1032	.66	B
59	Burdick	11	391	1032	.38	A
60	Burdick	11	391	1032	.38	A
61	Stallard	13	82	1220	.07	A
62	Stallard	13	432	1220	.35	A
63	Stallard	13	246	1220	.20	A
64	Jardot	10	164	938	.17	A
65	Jardot	10	102	938	.11	A
66	Jardot	10	105	938	.11	A
67	Jardot	10	439	938	.47	A
68	Jardot	10	506	938	.54	A
69	Jardot	10	457	938	.49	A
70	Jardot	10	450	938	.48	A
71	Jardot	11	112	1032	.11	A
72	Jardot	11	16	1032	.01	A
73	Jardot	10	--	938	--	A
74	Brush Creek	10	92	938	.10	A
75	Brush Creek	10	--	938	--	A

TABLE 44 (Continued)

LINK	DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
76	Richmond	12	--	1126	--	-
77	Richmond	12	23	1126	.02	A
78	Richmond	12	85	1126	.08	A
79	Richmond	10	71	938	.08	A
80	Airport	11	145	1032	.14	A
81	Airport	18	141	1690	.18	A
82	Airport	12	48	1126	.04	A
83	Airport	10	--	938	--	-
84	Lakeview	10	314	938	.33	A
85	Lakeview	10	763	938	.81	C
86	Lakeview	11.5	841	1080	.78	C
87	Lakeview	11	927	1032	.90	D
88	Lakeview	9	566	845	.67	B
89	McElroy	12	80	1126	.07	A
90	McElroy	12	999	1126	.89	D
91	McElroy	12	1578	1126	1.40	F
92	McElroy	12	1955	1126	1.74	F
93	McElroy	12	2849	1126	2.53	F
94	McElroy	12	2596	1126	2.31	F
95	McElroy	26	2470	2585	.96	E
96	McElroy	26	1619	2585	.63	B
97	McElroy	26	863	2585	.33	A
98	McElroy	26	419	2585	.16	A
99	McElroy	10	318	938	.34	A
100	McElroy	10	--	938	--	-
101	Hall of Fame	26	325	2585	.13	A
102	Hall of Fame	26	485	2585	.19	A
103	Hall of Fame	26	504	2585	.20	A
104	Hall of Fame	26	694	2585	.27	A
105	Hall of Fame	26	535	2585	.21	A
106	Hall of Fame	26	121	2585	.05	A
107	Farm	12	250	1126	.22	A
108	Miller	12	791	1126	.70	B
109	Miller	12	1340	1126	1.19	F
110	Virginia	16	2741	1500	1.83	F
111	Virginia	16	3944	1500	2.62	F
112	Virginia	16	150	1500	.10	A
113	University	15	1380	1410	.98	E
114	University	18	762	1690	.45	A
115	3 rd	18	724	1690	.43	A

TABLE 44 (Continued)

LINK	DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
116	3 rd	12.5	1178	1175	1.00	E
117	3 rd	12.5	426	1175	.36	A
118	3 rd	12.5	447	1175	.38	A
119	3 rd	12.5	--	1175	--	-
120	HWY 51	26	835	2585	.23	A
121	HWY 51	26	2990	2585	.83	D
122	6 th	26	3008	2585	1.16	F
123	6 th	26	2623	2585	1.01	E
124	6 th	30	3073	2980	1.03	E
125	6 th	26	2957	2585	1.14	F
126	6 th	26	2537	2585	.98	E
127	6 th	26	2038	2585	.79	C
128	6 th	26	1708	2585	.66	B
129	6 th	26	1770	2585	.69	B
130	6 th	26	2360	2585	.91	E
131	HWY 51	12	1050	1800	.58	A
132	9 th	15	2295	1408	1.63	F
133	9 th	15	1540	1408	1.09	F
134	9 th	34	1065	3430	.31	A
135	9 th	16	1658	1500	1.10	F
136	12 th	13	644	1220	.53	A
137	12 th	22	424	2135	.20	A
138	12 th	15	392	1408	.28	A
139	12 th	10	276	938	.29	A
140	19 th	10	--	--	--	-
141	19 th	10	381	938	.41	A
142	19 th	11	294	1032	.28	A
143	19 th	11	--	--	--	-
144	19 th	8.5	16	798	.02	A
145	19 th	8.5	--	798	--	-
146	26 th	9	451	845	.53	A
147	26 th	9	28	845	.03	A
148	32 nd	9	130	845	.15	A
149	32 nd	8	287	750	.38	A
150	32 nd	10	874	938	.93	E
151	32 nd	9.5	756	890	.85	D
152	32 nd	9.5	209	890	.23	A
153	32 nd	7	159	660	.24	A

TABLE 45

REQUIRED APPROACH WIDTH BASED ON
QRS ASSIGNED VOLUMES

LINK	DESCRIPTION	V/C RATIO	EXISTING WIDTH, FT	REQUIRED WIDTH, FT
1	Country Club	1.95	11	25
6	Sangre	1.04	9	13
7	Sangre	1.61	9	20
8	Western	1.64	11.5	23
9	Western	1.26	12	19
12	Western	0.83	15	15
13	Western	0.94	15	18
14	Western	1.14	12	17
15	Western	1.09	11.5	16
19	Monroe	1.01	15	19
20	Monroe	1.07	18	23
21	Monroe	0.95	18	21
22	Monroe	1.33	11	18
25	Washington	0.93	26	30
38	Main	0.99	25	30
39	Main	0.86	25	26
40	Main	1.10	18	24
42	Main	0.89	12	13
43	Main	0.94	12	14
45	Perkins	1.80	12	25
46	Perkins	1.69	22	44
47	Perkins	2.31	26	60
48	Perkins	1.83	26	56
49	Perkins	1.89	26	58
50	Perkins	1.58	26	49
51	Perkins	1.35	26	42
52	Perkins	0.94	26	30
87	Lakeview	0.90	11	12
90	McElroy	0.89	12	13
91	McElroy	1.40	12	20
92	McElroy	1.74	12	25
93	McElroy	2.53	12	35
94	McElroy	2.31	12	32
95	McElroy	0.96	26	30
109	Miller	1.19	12	18
110	Virginia	1.83	16	34
111	Virginia	2.62	16	47
113	University	0.98	15	18
116	3rd	1.00	12.5	16

TABLE 45 (Continued)

LINK	DESCRIPTION	V/C RATIO	EXISTING WIDTH, FT	REQUIRED WIDTH, FT
122	6th	1.16	26	37
123	6th	1.01	26	32
124	6th	1.03	30	38
125	6th	1.14	26	36
126	6th	0.98	26	31
132	9th	1.63	15	29
133	9th	1.09	15	20
135	9th	1.10	16	21
150	32nd	0.93	10	12
151	32nd	0.85	9.5	10

TABLE 46

DETERMINATION OF LOS USING QRS II
ASSIGNMENT OUTPUT

LINK DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
Country Club 1	11	205	1032	.20	A
Country Club 2	11	0	1032	-	-
Sangre 1	9	0	845	-	-
Sangre 2	12	234	1126	.21	A
Sangre 3	12	19	1126	.02	A
Sangre 4	10.5	1172	985	1.19	F
Sangre 5	10.5	1332	985	1.35	F
Sangre 6	10.5	33	985	.03	A
Western 1	11	780	1032	.76	C
Western 2	12	913	1126	.81	C
Western 3	26	3151	2585	1.22	F
Western 4	26	3626	2585	1.40	F
Western 5	15	1161	1408	.82	C
Western 6	15	816	1408	.58	A
Western 7	12	885	1126	.79	C
Western 8	11.5	1029	1080	.95	E
Western 9	11.5	905	1080	.84	D
Monroe 1	13	0	1220	-	-
Monroe 2	15.5	242	1455	.17	A
Monroe 3	18	736	1690	.44	A
Monroe 4	18	1332	1690	.79	C
Monroe 5	11	1031	1032	1.00	E
HWY 177 1	26	364	3600	.10	A
HWY 177 2	26	897	3600	.25	A
Washington 3	26	1752	2585	.68	B
Washington 4	26	1705	2585	.66	B
Washington 5	26	2207	2585	.85	D
Duck 1	20	1320	1875	.70	C
Duck 2	20	472	1875	.25	A
Duck 3	24	995	2332	.43	A
Duck 4	24	1154	2332	.49	A
Duck 5	24	283	2332	.12	A
Duck 6	24	798	2332	.34	A
Boomer 1	32	714	3230	.22	A
Main 2	32	0	3230	-	-
Main 3	32	649	3230	.20	A
Main 4	25	667	2430	.27	A

TABLE 46 (Continued)

LINK DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
Main 5	25	508	2430	.21	A
Main 6	18	482	1690	.29	A
Main 7	18	569	1690	.34	A
Main 8	12	707	1126	.63	B
Main 9	12	51	1126	.05	A
Perkins 1	12	168	1126	.15	A
Perkins 2	12	772	1126	.69	B
Perkins 3	22	1352	2135	.63	B
Perkins 4	26	2199	2585	.85	D
Perkins 5	26	4522	2585	1.75	F
Perkins 6	26	3763	2585	1.14	F
Perkins 7	26	3763	2585	1.46	F
Perkins 8	26	3763	2585	1.46	F
Perkins 9	26	2857	2585	1.10	F
Perkins 10	26	2406	2585	.93	E
Perkins 11	26	1904	2585	.74	C
Perkins 12	24	1806	2332	.78	C
HWY 177 13	12	884	1800	.49	A
HWY 177 14	12	869	1800	.48	A
Burdick 1	11	0	1032	-	-
Burdick 2	11	1198	1032	1.16	F
Burdick 3	11	1198	1032	1.16	F
Stallard 1	13	0	1220	-	-
Stallard 2	13	0	1220	-	-
Stallard 3	13	0	1220	-	-
Jardot 1	10	0	938	-	-
Jardot 2	10	68	938	.07	A
Jardot 3	10	51	938	.05	A
Jardot 4	10	534	938	.57	A
Jardot 5	10	244	938	.26	A
Jardot 6	10	244	938	.26	A
Jardot 7	10	244	938	.26	A
Jardot 8	11	31	1032	.03	A
Jardot 9	11	31	1032	.03	A
Jardot 10	10	0	938	-	-

TABLE 46 (Continued)

LINK DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
Richmond 1	12	0	1126	-	-
Richmond 2	12	610	1126	.61	B
Richmond 3	12	138	1126	.12	A
Richmond 4	10	0	938	-	-
Airport 1	11	211	1032	.20	A
Airport 2	18	144	1690	.09	A
Airport 3	12	63	1126	.06	A
Airport 4	10	0	938	-	-
Lakeview 1	10	9	938	-	-
Lakeview 2	10	692	938	.74	C
Lakeview 3	11.5	602	1080	.56	A
Lakeview 4	11	350	1032	.34	A
Lakeview 5	9	146	845	.17	A
McElroy 1	12	0	1126	-	-
McElroy 2	12	37	1126	.03	A
McElroy 3	12	18	1126	.02	A
McElroy 4	12	693	1126	.62	B
McElroy 5	12	693	1126	.62	B
McElroy 6	12	326	1126	.29	A
McElroy 7	26	1656	2585	.64	B
McElroy 8	26	2152	2585	.83	D
McElroy 9	26	1683	2585	.65	B
McElroy 10	26	289	2585	.11	A
McElroy 11	10	289	938	.31	A
Hall of Fame	26	1918	2585	.74	C
Hall of Fame	26	2160	2585	.83	D
Hall of Fame	26	2554	2585	.99	E
Hall of Fame	26	1931	2585	.75	C
Hall of Fame	26	1895	2585	.73	D
Farm 1	12	510	1126	.45	A
University 1	15	0	1408	-	-
University 2	18	894	1690	.53	A
Knoblock 1	10	894	938	.95	E
Miller 1	12	2594	1126	2.30	F
Miller 2	12	2261	1126	2.00	F
Miller 3	12	1225	1126	1.09	F
Virginia 1	16	1347	1500	.90	E
Virginia 2	16	0	1500	-	-
Virginia 3	16	0	1500	-	-

TABLE 46 (Continued)

LINK DESCRIPTION	APPROACH WIDTH,FT	VOLUME VPH	CAPACITY VPH	V/C	LOS
3rd 1	12.5	159	1175	.14	A
3rd 2	12.5	0	1175	-	-
3rd 3	12.5	0	1175	-	-
3rd 4	12.5	0	1175	-	-
3rd 5	12.5	0	1175	-	-
HWY 51 1	26	1035	3600	.29	A
HWY 51 2	26	1337	3600	.37	A
6th 3	26	3868	2585	1.50	F
6th 4	26	1349	2585	.52	A
6th 5	26	1580	2585	.61	B
6th 6	30	1350	2980	.45	A
6th 7	26	1324	2585	.51	A
6th 8	26	3456	2585	1.34	F
6th 9	26	2537	2585	.98	E
6th 10	26	2537	2585	.98	E
6th 11	26	1140	2585	.44	A
HWY 51 12	12	852	1800	.47	A
9th 1	15	99	1408	.07	A
9th 2	15	1549	1408	1.10	F
9th 3	26	1044	2585	.40	A
9th 4	16	957	1500	.64	B
12th 1	13	72	1220	.06	A
12th 2	22	870	2140	.41	A
12th 3	15	711	1408	.51	A
12th 4	10	0	938	-	-
19th 1	10	0	938	-	-
19th 2	10	45	938	.05	A
19th 3	11	311	1032	.30	A
19th 4	11	0	1032	-	-
19th 5	8.5	98	798	.12	A
19th 6	8.5	0	798	-	-
26th 1	9	0	845	-	-
26th 2	9	227	845	.27	A
32nd 1	9	0	845	-	-
32nd 2	8	34	750	.05	A
32nd 3	10	651	938	.69	B
32nd 4	9.5	953	890	1.10	F
32nd 5	9.5	31	890	.03	A
32nd 6	7	0	650	-	-

TABLE 47

REQUIRED APPROACH WIDTH BASED ON
QRS II ASSIGNED VOLUMES

LINK DESCRIPTION	V/C RATIO	EXISTING WIDTH, FT	REQUIRED WIDTH, FT
Sangre 4	1.19	10.5	16
Sangre 5	1.35	10.5	18
Western 3	1.22	26	39
Western 4	1.40	26	44
Western 8	.95	11.5	14
Western 9	.84	11.5	12
Monroe 5	1.00	11	14
Washington 5	.85	26	28
Perkins 4	.85	26	28
Perkins 5	1.75	26	54
Perkins 6	1.14	26	44
Perkins 7	1.46	26	41
Perkins 8	1.46	26	41
Perkins 9	1.10	26	35
Perkins 10	.93	26	30
Burdick 2	1.16	11	16
Burdick 3	1.16	11	16
McElroy 8	.83	26	27
Hall of Fame 2	.83	26	27
Hall of Fame 3	.99	26	32
Knoblock 1	.95	10	12
Miller 1	2.30	12	32
Miller 2	2.00	12	28
Miller 3	1.09	12	16
Virginia 1	.90	16	18
Sixth 3	1.50	26	47
Sixth 8	1.34	26	42
Sixth 9	.98	26	31
Sixth 10	.98	26	31
Nineth 2	1.10	15	20
32nd 4	1.10	9.5	13

APPENDIX F

CAPACITY ANALYSIS USING THE HCM APPROACH

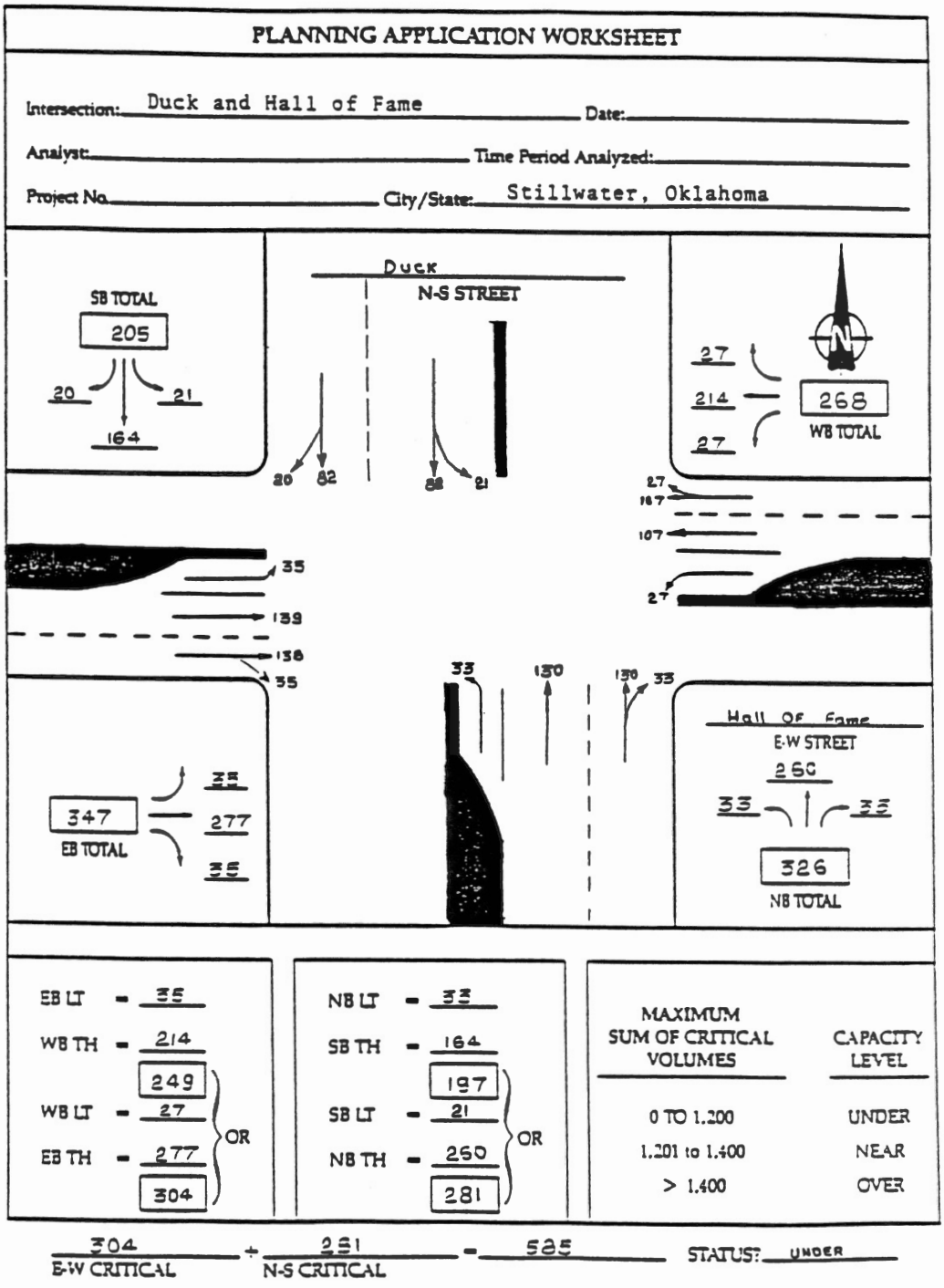

Figure 24. Intersection Capacity Analysis Using QRS Assigned Volumes (Duck and Hall of Fame)

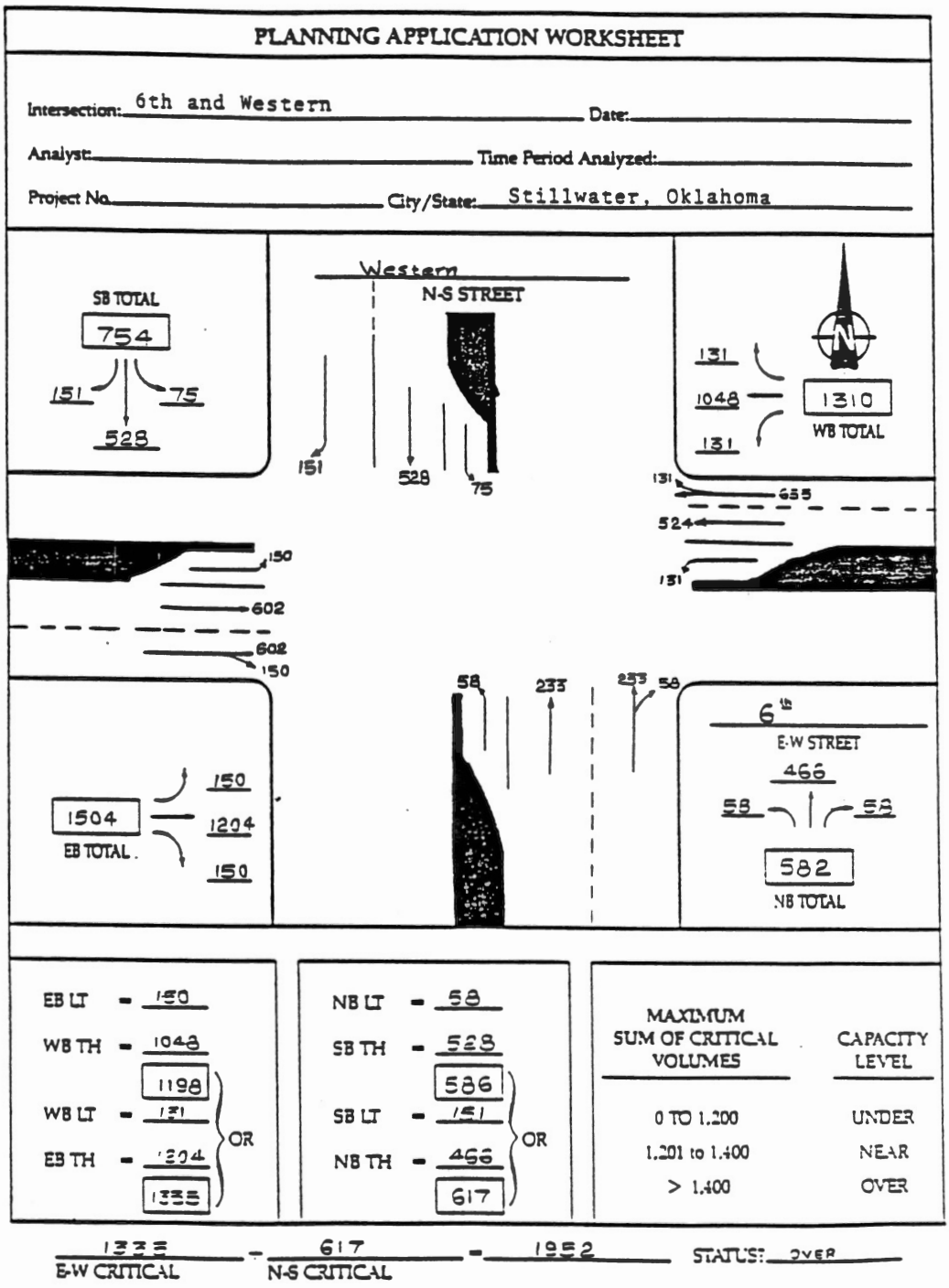

Figure 25. Intersection Capacity Analysis Using QRS Assigned Volumes (6th and Western)

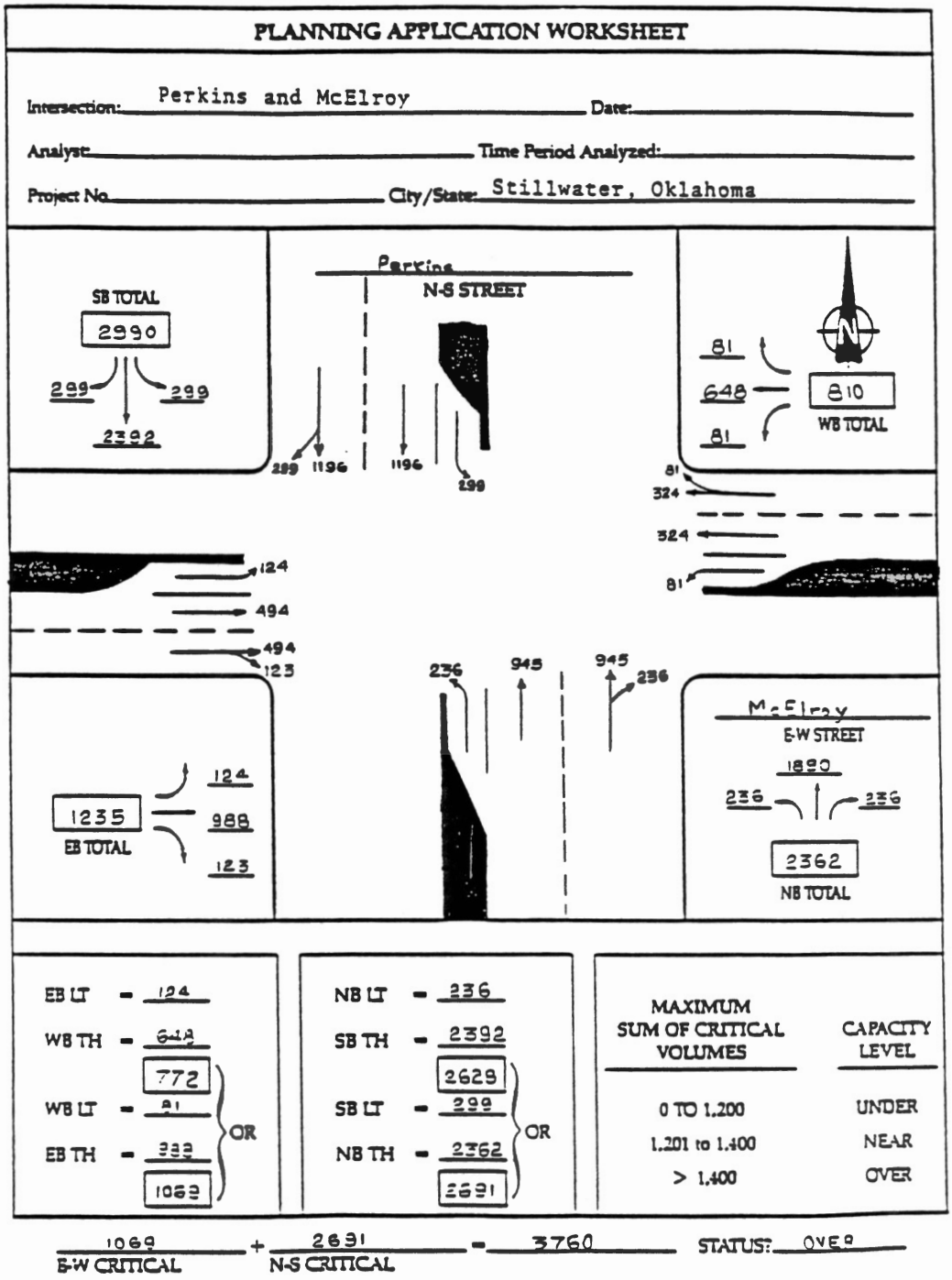

Figure 26. Intersection Capacity Analysis Using QRS Assigned Volumes (Perkins and McElroy)

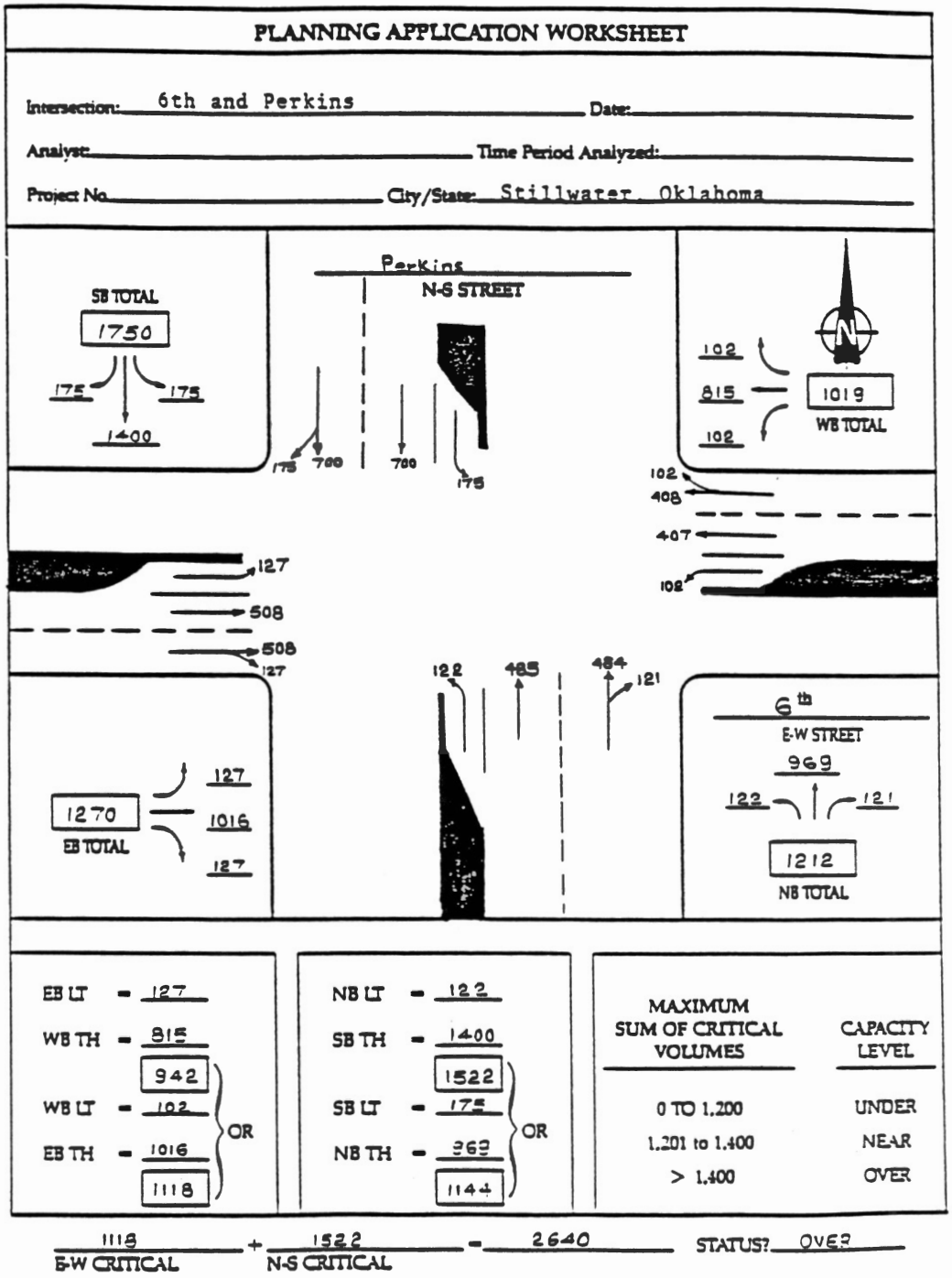

Figure 27. Intersection Capacity Analysis Using QRS Assigned Volumes (6th and Perkins)

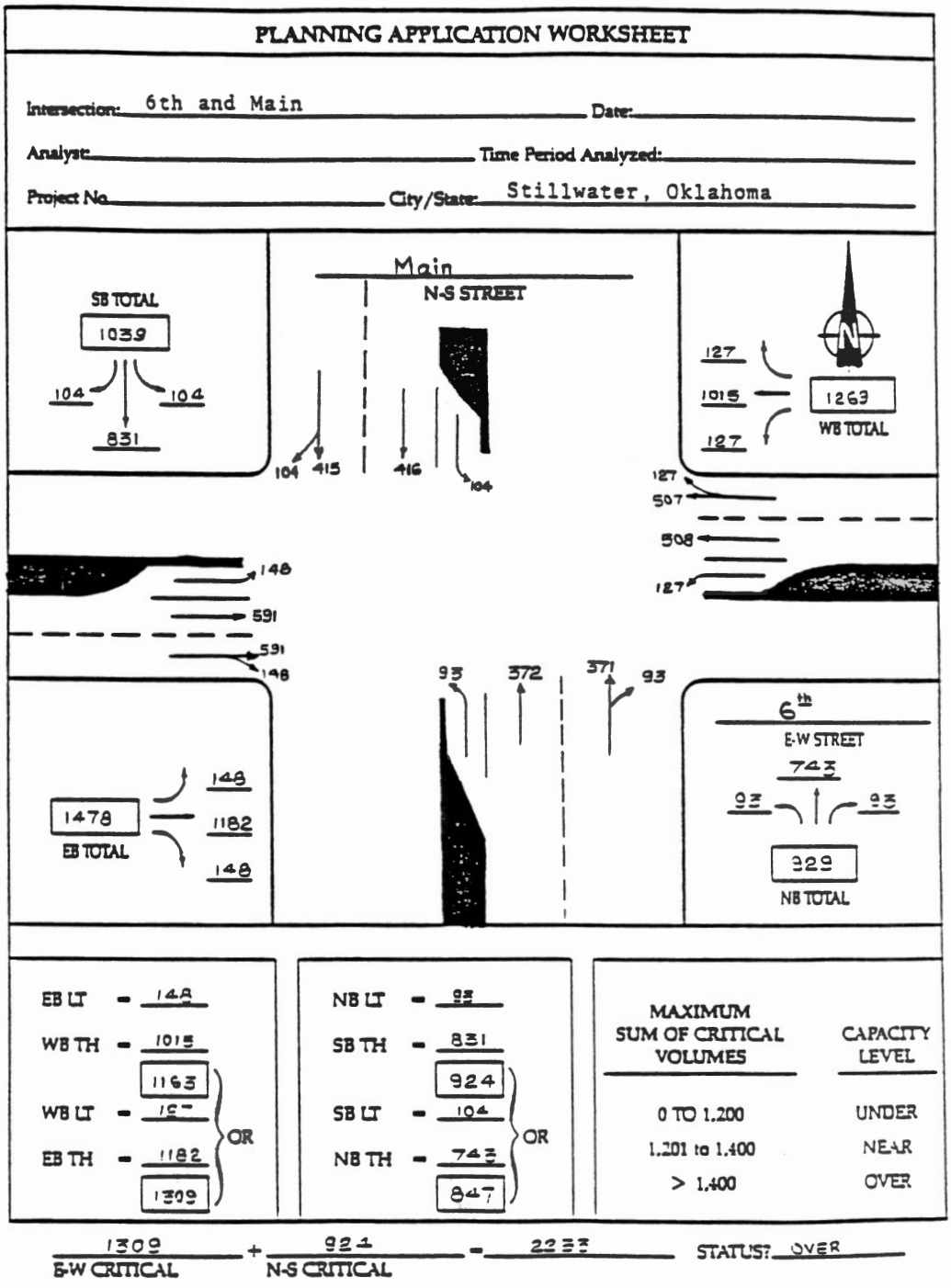

Figure 28. Intersection Capacity Analysis Using ORS Assigned Volumes (6th and Main)

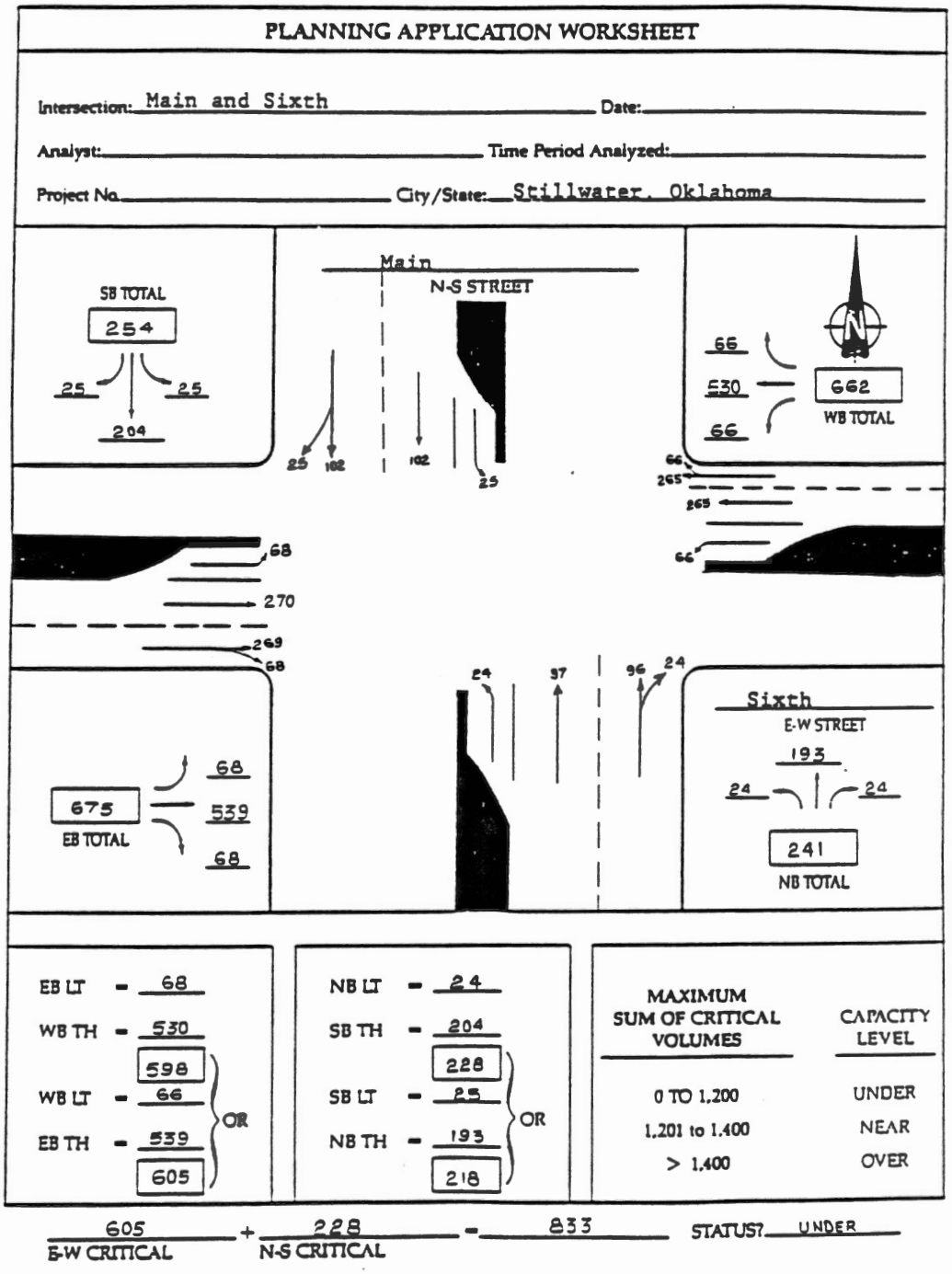

Figure 29. Intersection Capacity Analysis Using QRS II Assigned Volumes (Main and Sixth)

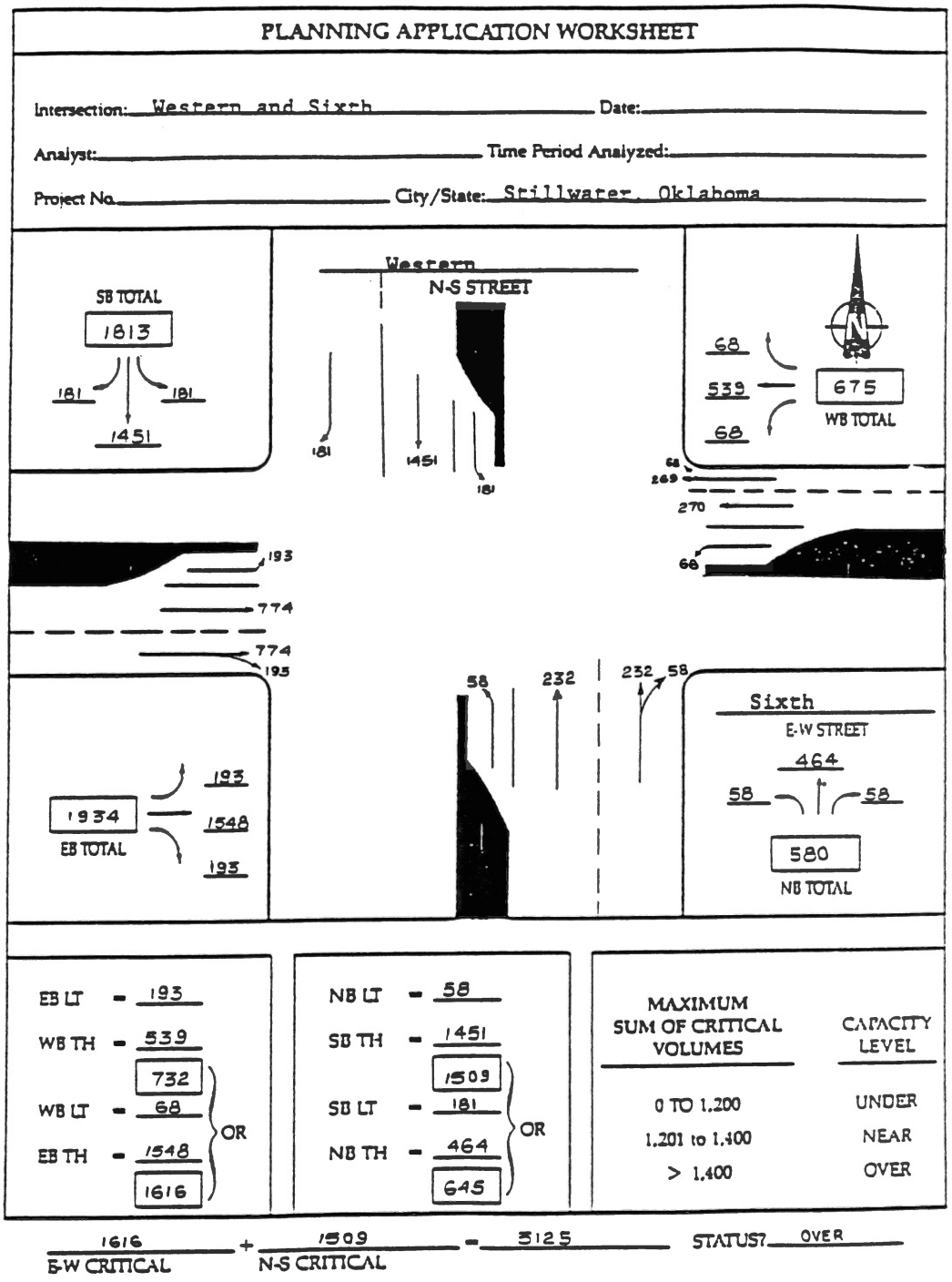

Figure 30. Intersection Capacity Analysis Using QRS II Assigned Volumes (Western and Sixth)

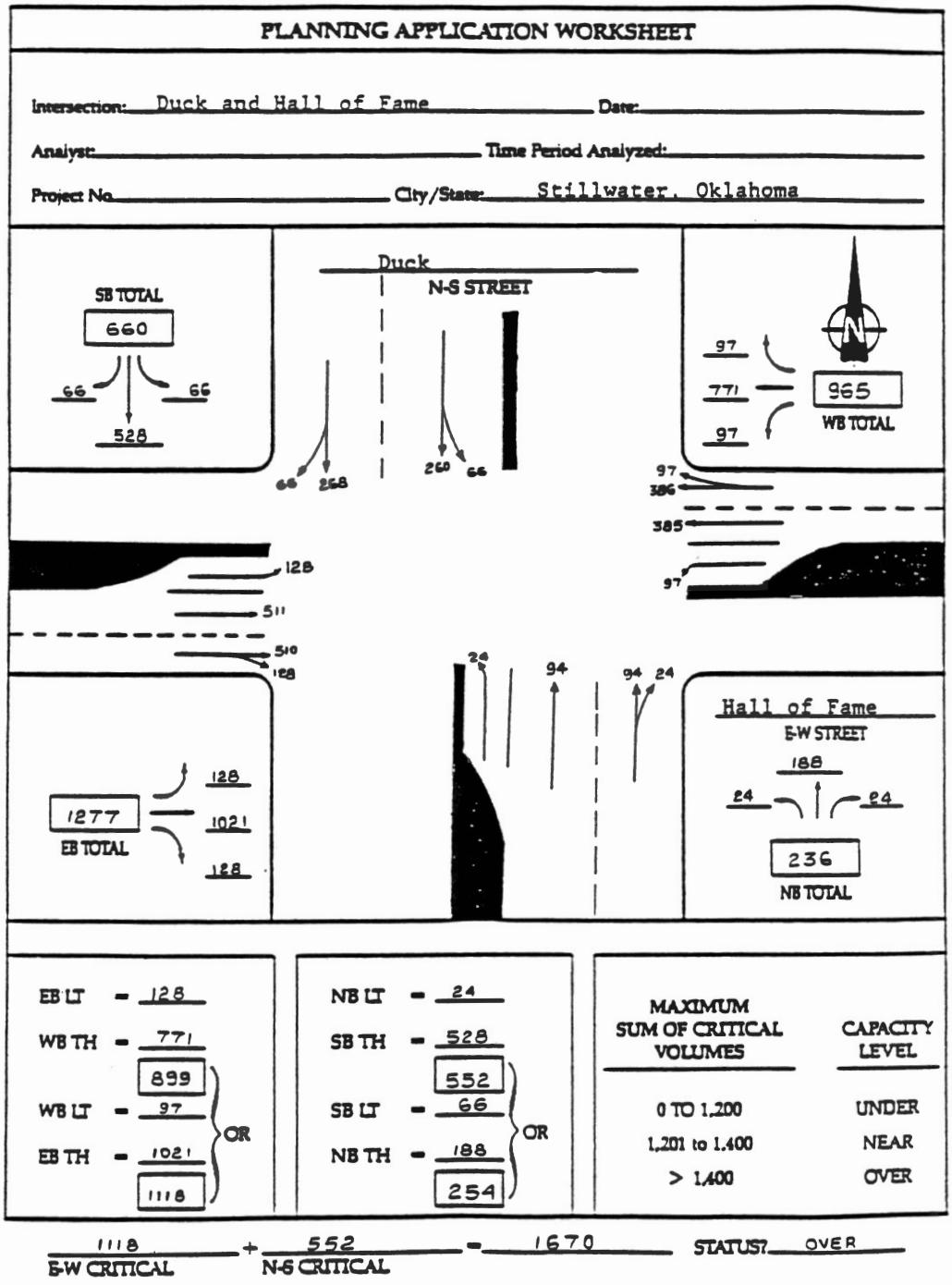

Figure 31. Intersection Capacity Analysis Using QRS II Assigned Volumes (Duck and Hall of Fame)

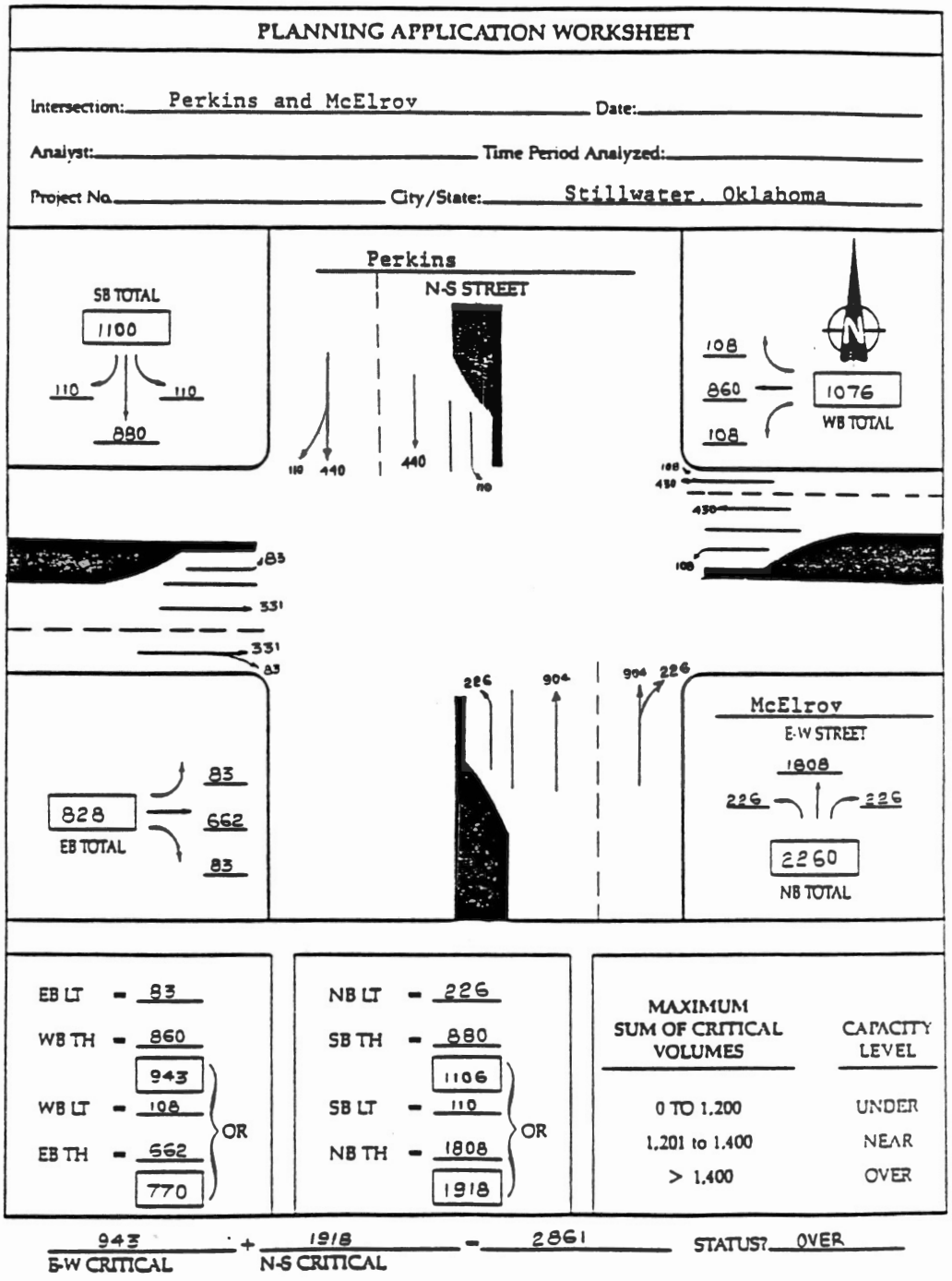

Figure 32. Intersection Capacity Analysis Using QRS II Assigned Volumes (Perkins and McElroy)

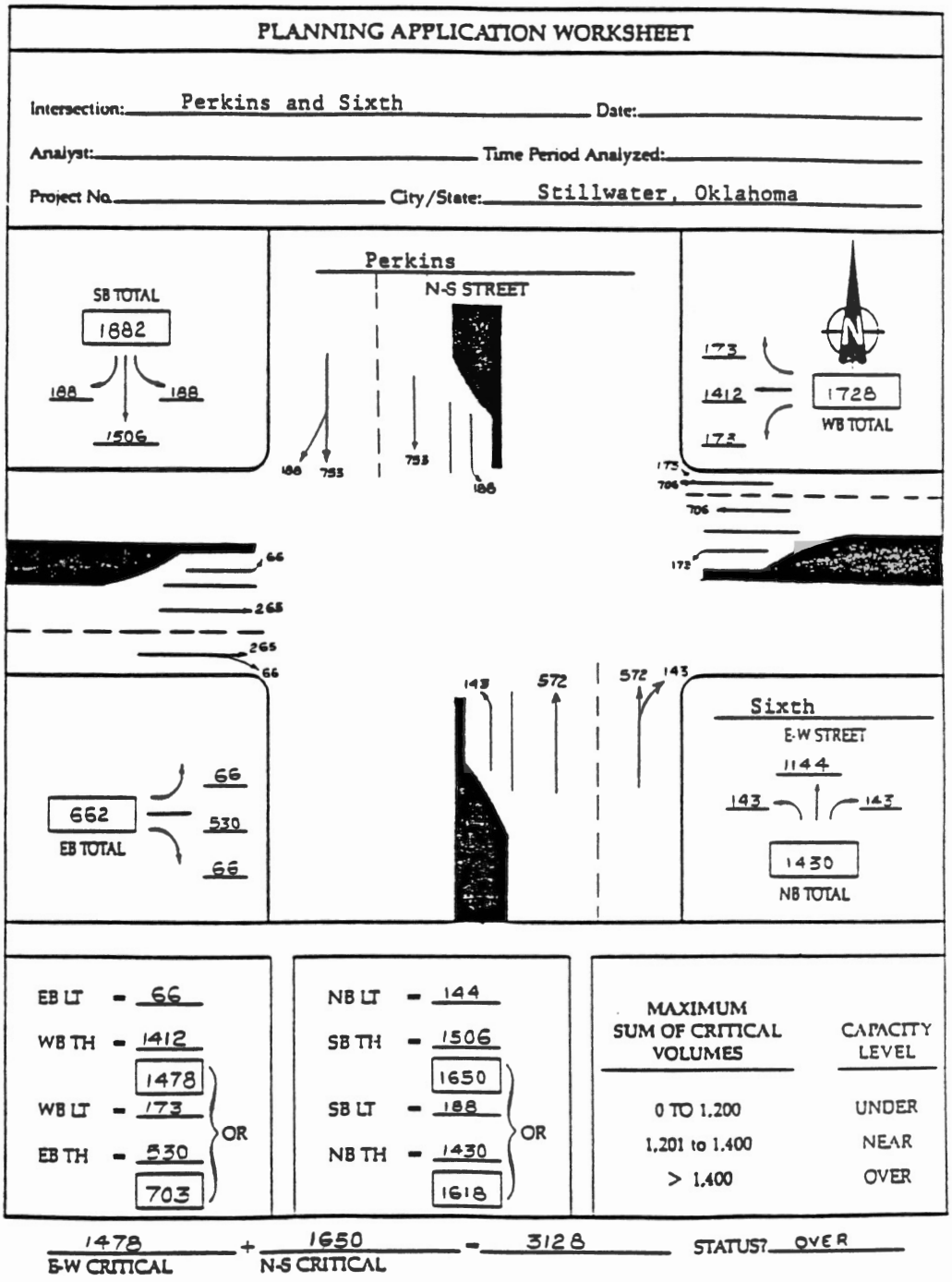

Figure 33. Intersection Capacity Analysis Using QRS II Assigned Volumes (Perkins and Sixth)

VITA[2]

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