FINAL REPORT

to

THE FLORIDA DEPARTMENT OF TRANSPORTATION
RESEARCH OFFICE

on Project

"Trip Generation Characteristics of Special Generators"

FDOT Contract BDK77, TWO 977-01 (UF Project 00076173)

March 1, 2010

Transportation Research Center
The University of Florida

DISCLAIMER

METRIC CONVERSION CHART

U.S. UNITS TO METRIC (SI) UNITS

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

METRIC (SI) UNITS TO U.S. UNITS

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

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16. Abstract Special generators are introduced in the sequential four-step modeling procedure to represent certain types of facilities whose trip generation characteristics are not fully captured by the standard trip generation module. They are also used in the traffic impact analysis to represent new developments. The objectives of this research project are twofold: 1) to analyze qualitatively trip generation characteristics of special generators and provide recommendations on how to improve the modeling of special generators in the Florida Standard Urban Transportation Model Structure (FSUTMS); 2) to examine the advantages and disadvantages of two modeling approaches, i.e., the link distribution percentage method and the special generator method, for performing traffic impact analyses for proposed developments.			
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EXECUTIVE SUMMARY

Florida Standard Urban Transportation Model Structure (FSUTMS) uses special generators to consider certain types of facilities whose trip generation characteristics are not fully captured by the trip generation sub-model. Those facilities include military bases, universities, hospitals and major shopping centers among others. Those special generators have very different trip generation characteristics and cannot be treated as regular employers. For example, military bases tend not to utilize the transportation network very much. But if treated like a regular employer, the demands that they generate can overwhelm nearby roadways. Universities are unique in that all employees and students never come to campus at the same time. Students attending standard universities such as University of Florida may regularly attend classes and live on campus, but students of community colleges such as Santa Fe College typically do not live on campus and may attend class once or twice a week. Hospitals are open twenty-four hours a day with no apparent peak period. Shopping centers normally attract the largest number of trips on the weekend. These unique characteristics have a major impact on the transportation system, and treating them no different from a state capital or a major downtown employer does not realistically represent the transportation system and how people use the system.

Often special generators are also used in performing traffic impact analysis for proposed developments. A new development may be identified as a special generator whose attractions and possibly productions can be manually input based on the Trip Generation Manual by Institute of Transportation Engineers (ITE), and will then be further adjusted during iterative runs of the FSUTMS model until the trips reported from FSUTMS match the ITE-based trip generation. Traffic assignment will then proceed to quantify the impact of the proposed development on the traffic network. On the other hand, another common practice for traffic impact analysis does not involve the use of special generators. Dwelling unit and employments of the proposed development are estimated and inserted into the conventional ZONEDATA input file, followed by a FSUTMS model run to derive the development traffic percentage for each link in the impact area. The percentages will then be applied to the external ITE trip generation of the proposed development to quantify its traffic impact. Both approaches have pros and cons, and there is no systematic research to show whether two approaches generate similar results or one outperforms

the other.

The objectives of this research project are twofold: 1) to analyze qualitatively trip generation characteristics of special generators, including universities, military bases, hospitals, airports and recreational parks etc, and then provide recommendations on how to improve the modeling of special generators in FSUTMS; 2) to examine the advantages and disadvantages of two modeling methods for performing traffic impact analyses for proposed developments.

Treatment of Special Generators in Travel Demand Modeling

Special generator may be a “necessary evil” in the four-step demand modeling process. It is not a practice that modelers should be encouraged to adopt, because the presence of special generators may affect the transferability and generality of the model. Instead, more efforts could be made to refine the module of trip generation. A well-developed trip generation module is be able to better replicate the real scenario of the modeling area, thereby reducing the need for introducing special generators. Due to the limited time or resource, it is often tempting or inevitable for modelers to introduce special generators, particularly with the presence of activity generators in the region that have significantly different trip generation characteristics.

Inclusion of special generators is a way to force the model to replicate the real scenario of the study area, because special generators can adopt ad hoc attraction rates significantly different from the standard rate. The standard procedure of special generators in FSUTMS and the improved procedure in the lifestyle trip generation models have been successfully applied in many Metropolitan Planning Organization (MPO) models. However, the special generator rates used are mostly those recommended in the Model Update Task B. Those rates are about 30 years old, and there is a need to conduct more attraction-side surveys to update them.

Comparison of Two Methods of Traffic Impact Analyses for Proposed Developments

An empirical study was conducted to compare the two methods for traffic impact analysis, i.e., the link distribution percentage method and the special generator approach. The

Alachua/Gainesville MPO model was used as the test bed. A number of scenarios of new developments were created by changing various characteristics of two hypothetical developments. The traffic impacts of those hypothetical developments were estimated by implementing these two methods respectively.

It was observed from the empirical study that these two methods produced fairly consistent estimates of traffic impacts caused by different hypothetical scenarios. However, the link distribution percentage method is easier to implement. The method makes an implicit assumption that the link distribution percentage pattern remains the same even if a larger number of trips are generated by the new development. The assumption may not be valid, particularly when the network is congested, and the estimates of trip production from FSUTMS and the ITE Trip Generation Manual are substantially different. However, this was not observed in the empirical study. Given the above, the link distribution percentage method is recommended. The report further cautions that the method is based on the "Select Zone Analysis." For the analysis, Cube Voyager stores the path flows during the traffic assignment procedure and then produces the estimates based on the stored path flows. However, since the path flow patterns from traffic assignment are not unique, the estimate of development traffic on each link may only represent one of the many possibilities.

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CHAPTER 1
INTRODUCTION

Florida Standard Urban Transportation Model Structure (FSUTMS) uses special generators to consider certain types of facilities whose trip generation characteristics are not fully captured by the trip generation sub-model. Those facilities include military bases, universities, hospitals and major shopping centers among others. Those special generators have very different trip generation characteristics and cannot be treated as regular employers. For example, military bases tend not to utilize the transportation network very much. But if treated like a regular employer, the demands that they generate can overwhelm nearby roadways. Universities are unique in that all employees and students never come to campus at the same time. Students attending standard universities such as University of Florida may regularly attend classes and live on campus, but students of community colleges such as Santa Fe College typically do not live on campus and may attend class once or twice a week. Hospitals are open twenty-four hours a day with no apparent peak period. Shopping centers normally attract the largest number of trips on the weekend. These unique characteristics have a major impact on the transportation system, and treating them no different from a state capital or a major downtown employer does not realistically represent the transportation system and how people use the system.

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The rest of this report is organized as follows. Chapter 2 assesses the state-of-the-practice on the treatment of special generators in travel demand modeling. A review of the literature on modeling the trip-generation (attraction) patterns associated with special generators is undertaken. The current practices of different metropolitan planning organizations (MPO) both within the state of Florida and elsewhere in the nation are reviewed. Relevant "default" trip-attraction rates available from sources such as the ITE Trip Generation Manual are also summarized. The chapter also discusses the issues associated with the treatment of special generators in FSUTMS and provides recommendations on improving the practice.

Chapter 3 compares the special generator method and the link distribution percentage method for performing traffic impact analyses. The advantages and disadvantages of both methods are qualitatively analyzed, followed by an empirical case study. In the case study, a number of hypothetical scenarios are developed by changing various characteristics of two hypothetic new developments. The traffic impacts of those scenarios are estimated using both methods respectively, and are then compared. Observations on the performances of these two methods are summarized and recommendation on the preferred method is provided.

Chapter 4 presents a summary of all work done and identifies the major results.

CHAPTER 2
TREATMENT OF SPECIAL GENERATORS IN TRAVEL DEMAND MODELING

2.1 Introduction

According to the recent TRB Special Report 288 [1], most of MPOs are still using the sequential four-step modeling procedure for transportation planning practices. In the procedure, the number of daily trips is estimated, and then distributed among different origin and destination zones, further divided according to the mode of travel, and finally assigned to the highway and transit networks. In the first step, the numbers of trips produced and attracted by each travel analysis zone are estimated for each trip purpose by using trip rates from surveys, cross-classification analysis or regression analysis. However, the trip generation patterns of certain major/unique activity centers may not be captured by those general equations or rates. As a remedy, special generators are introduced to represent those major generators and their trip attraction and production are estimated in a different manner. Examples of special generators include military bases, universities, hospitals and major shopping centers.

Special generators can be further classified into three groups in travel demand forecasting: “regular”, “periodic” and “special” [2]. “Regular” special generators produce trips on a regular and weekday basis while the latter two do not. Typical examples for “periodic” special generators are sites with fairs and festivals. Because of their infrequent scheduling, “periodic” special generators are normally not considered in the planning of new investments. The trips generated can be assumed to either make use of the available excess capacity or create acceptable short-lived breakdowns of transportation system. “Special” special generators are those activity generators that cannot be easily classified as regular or periodic. By definition, they are unique and require ad hoc procedures to analyze. The focus of this technical memorandum is to review the treatment of “regular” special generators.

Although most of MPOs have incorporated special generators in their travel demand models and many appear to be interested in developing more effective special generator procedures [1], the published literature is particularly scant on this subject. McKinstry and Nungesser [3] investigated the transferability of the rates for special generators. They compared trip generation rates for two areas in Texas as well as rates from other published sources over time, and concluded that the same land use may have different rates and one rate is not necessarily more correct than another. Several factors, i.e., knowledge of how the rate was calculated, size of the sample, similarity of the study area (in terms of area type, composition of service and activities) to the area in which the rate is to be applied. Benway and McCormick [4] discussed how to establish local trip generation rates for specific generators that are not clearly defined in the ITE Trip Generation Manual and pointed out that some interpretations on trip generation rates can play havoc with major commercial development projects.

Due to a lack of published studies in the open research literature, this chapter mainly reviews current practices by MPOs both within the state of Florida and elsewhere in the nation. Issues associated with the treatment of special generators are discussed and recommendations on improving the practice are provided. The chapter is organized as follows. Sections 2.2 and 2.3 review the treatment of special generators in several models from selected MPOs across the country and within the state of Florida. Section 2.4 presents a summary of the chapter and highlights the major findings.

2.2 Review of Practices by Selected MPOs

2.2.1 Information Collection

The information about MPO models was collected in two stages. In the first stage, information regarding special generators in travel demand models was obtained by searching the Internet. Few complete travel demand models were found. Based on the information from the Internet and the TRB Special Report 288, a list of 40 prospective MPOs, state Departments of Transportation (DOTs) and other transportation planning organizations was complied. Email requests were sent to those agencies and 16 of them replied. Table 2.1 identifies those 16 agencies, four of which indicated that special generators are not introduced in their models.

Table 2.1 List of Responding MPOs/DOTs

ID Number	Name of the MPO/DOT	Special Generators Used
1	Chittenden County Metropolitan Planning Organization, Vermont	Yes
2	Community Planning Association of Southwest Idaho, Idaho	Yes
3	Florida Department of Transportation (FDOT), District IV, Florida	Yes
4	FDOT, District II, Florida	Yes
5	FDOT, District VII, Florida	Yes
6	Michigan Department of Transportation , Michigan	Yes
7	North Central Texas Council of Governments Transportation Department, Texas	Yes
8	North Florida Transportation Planning Organization, Florida	Yes
9	Ohio Department of Transportation, Ohio	Yes
10	Tennessee Department of Transportation, Tennessee	Yes
11	Arizona Department of Transportation, Arizona	Yes
12	North Central Florida Regional Planning Council, Florida	Yes
13	Baltimore Metropolitan Council, Maryland	No
14	Metropolitan Transportation Commission, Oakland, California	No
15	Oregon Department of Transportation, Oregon	No
16	East-West Gateway Council of Governments, Missouri	No

2.2.2 Overview

In the models that have a provision of special generators, special generators are mostly identified as trip attractors and the corresponding trip attractions are estimated by regression models or trip rates as per trip purpose. A special survey may have been conducted to obtain area-specific data on the trip-making characteristics to calibrate trip generation models or determine rates for special generators, particularly those concentrated developments in areas whose demographic characteristics are significantly different from the average. It is found that most of the models treat educational institutes, hospitals, airports, military bases, industrial sites and shopping mall as special generators. General data requirements for estimating trip attractions for special generators are summarized in Table 2.2.

Table 2.2 Data Requirement for Estimating Trip Attractions for Special Generators [5]

Type of Special Generator	**Data Required**
Educational (Universities, colleges and high schools)	Number of employees Number of students Number of students living on campus
Hospitals	Number of employees Number of beds
Airports	Number of employees Number of passengers Number of flights
Military Bases	Number of military personnel Number of civilian employees Number of militaries living in the base
Major Special Attractions/Event Centers	Number of employees
Industrial Sites	Number of employees Acres
Shopping Malls	Number of employees Floor spaces
Casino	Floor space
Bus Terminals	Number of boarding passengers

When empirical data are not available, trip rates for special generators may be estimated from the ITE Trip Generation Manual. The manual was developed based on more than 3750 trip generation studies submitted to ITE by public agencies, developers, consulting firms, and associations. Trip generation rates and equations were developed for an average weekday, Saturday, Sunday and for weekday morning and evening peak hours with respect to land uses. The trip generation equation for one specific land use is the function of one or more independent variables associated with the land use. Therefore, trip rates can be estimated from the manual if the variables for each specific land use are known.

2.2.3 Model Review

For the treatment of special generators, agencies have applied their own trip generation models or trip rates. These treatments are summarized as follows.

Chittenden County MPO Regional Transportation Model [6]

Special generator attraction rates were estimated for IBM Manufacturing Campus in Essex Junction and Williston, University of Vermont (UVM) and Fletcher Allen Health Care (FAHC) in Burlington, Burlington International Airport in South Burlington, University Mall in South Burlington, Saint Michael's College, Camp Johnson and Fanny Allen in Colchester. Special rates were not developed for productions, which have been generated using household data instead. The variations in household trip-making were covered adequately by the sixteen different household-size/vehicle-ownership categories. Therefore, special generator rates were developed for attraction only, as reported in Tables 2.3 and 2.4 for each attraction trip type. These rates were developed by converting vehicle trips based on traffic counts (or ITE rates) into person trips, distributing the person trips into the attraction trip types, and dividing each by the total number of employees within the special generator.

Table 2.3 AM Peak Hour Special Generation Attraction Rates (Person Trips per Employee)

Special Generator	**AM Peak Hour Attraction Trip Types**					
	Home Destination Origin	**Home to Work Destination**	**Home to School Destination**	**Home to Other Destination**	**Non-home-based Origin**	**Non-home-based Destination**
UVM-FAHC	0.0000	0.0854	0.0000	0.0000	0.0018	0.0112
Burlington International Airport	0.0128	0.1549	0.0000	0.0000	0.1292	0.0605
University Mall	0.0000	0.0652	0.0000	0.0000	0.0930	0.0673
IBM	0.0132	0.1454	0.0000	0.0000	0.0100	0.0363
St Mikes/Camp Johnson	0.0106	0.1818	0.0047	0.0047	0.0426	0.1305

Table 2.4 PM Peak Hour Special Generation Attraction Rates (Person Trips per Employee)

Special Generator	**PM Peak Hour Attraction Trip Types**						
	Home to Other Destination	**Work to Home Origin**	**Non-work to Home Origin**	**Work to Non-home Origin**	**Work to Non-home Destination**	**Non-work Non-home Origin**	**Non-work Non-home Destination**
UVM-FAHC	0.0666	0.0342	0.0461	0.0253	0.0439	0.0432	0.0601
Burlington International Airport	0.3250	0.3773	0.3420	0.2594	0.3805	0.2005	0.0872
University Mall	0.3349	0.0974	0.3701	0.2435	0.1739	0.2629	0.2524
IBM	0.0387	0.2018	0.0000	0.0106	0.0008	0.0000	0.0012
St Mikes/Camp Johnson	0.0841	0.0687	0.3204	0.0744	0.0294	0.1087	0.0135

In the trip balancing process, only the attractions not associated with special generators were factored. The balancing adjustment factor is the difference between the total production and the total special-generator attractions divided by the total attractions of regular generators. The procedure is similar to the one used by FDOT District 4 to be reviewed in Section 2.3.

Community Planning Association of Southwest Idaho Travel Demand Forecast Model [7]

During the calibration, nine special generators were included in the model. Additional trips were added to both production and attraction. The trip-purpose distribution rates presented in Table 2.5 for each special generator were estimated using the trip data from the 2002 household data.

Table 2.5 Trip-Purpose Distribution of Special Generators

P/A	Trips Added	Home-Based Work (%)	Home-Based Shop (%)	Home-Based Social (%)	Home-Based School (%)	Home-Based Other (%)	Non-Home-Based (%)	Description
A	5000	4	0	11	12	28	45	Boise High School and YMCA in Downtown Boise
P	5000	0	0	0	0	0	100	
A	2000	16	0	15	0	30	39	Main Post Office
A	5000	16	0	15	0	30	39	St. Likes Meridian Hospital on Eagle Road-employment was only recorded at the Downtown Boise site
P	5000	0	0	0	0	0	100	
A	5000	0	0	30	0	30	40	Boondocks Fun Center and Roaring Springs
P	5000	0	0	0	0	0	100	
A	5000	12	28	2	0	2	56	Crossroads Shopping Center at Eagle Road and Fairview Avenue
P	5000	0	0	0	0	0	100	
A	2000	26	16	11	0	5	42	Outlet Mall and Ice World
A	1000	16	0	30	0	24	30	Canyon County Courthouse and Jail
A	2000	16	0	15	0	30	39	Mercy North Health Center on Garrity Boulevard
P	2000	0	0	0	0	0	100	
A	5000	10	0	30	0	15	25	Commercial Center with Super Walmart, Mercy Medical Hospital, Nampa Recreation Center

Dallas-Fort Worth Regional Travel Demand Model (DFWRTM) [8]

The DFWRTM considers the following three types of special generators:

- Regional shopping malls with over 500,000 square feet
- Universities and colleges with over 1,500 enrolled students
- Hospitals with over 300 service employees

In the DFWRTM, trip attractions of the special generators are first calculated using the standard trip attraction model based on the employment numbers and then another estimate is obtained by using the special generator trip rates. Subsequently, the differences between these two estimates are calculated for each special generator. For home-based work, home-based non-work and other trip purposes, the increments are added to the zonal trip attractions. For non-home-based trips, one half of the increments are added to the trip productions and the other half are added to the trip attractions. DFWRTM does not consider airport trips and external trips in its trip generation module. These are modeled in the trip distribution module. The airport sub-module of gravity models estimates the number of home-based non-work and non-home-based trips to and from the airports based on the number of enplanements at each airport.

Des Moines Area Travel Demand Model [9]

Thirteen zones containing large and unusual sites were selected as special generators and ITE trip generation rates were used to estimate trip generations. The trip purpose distribution for each special generator is shown in Table 2.6.

Table 2.6 Trip Purpose Distributions of Special Generators

Special Generator	**Production**				**Attraction**			
	Home-Based Work	**Home-Based Other**	**Non-Home-Based**	**Commercial Vehicle**	**Home-Based Work**	**Home-Based Other**	**Non-Home-Based**	**Commercial Vehicle**
Lutheran Hospital	0%	0%	5%	5%	55%	25%	5%	5%
Airport Terminal	0%	0%	5%	3%	24%	60%	5%	3%
Truck Stop	0%	0%	3%	40%	7%	7%	3%	40%
Merle Hay Mall	0%	0%	10%	5%	20%	50%	10%	5%
Drake University	3%	5%	5%	3%	55%	21%	5%	3%
Methodist Hospital	0%	0%	5%	5%	55%	25%	5%	5%
Southridge Mall	0%	0%	10%	5%	20%	50%	10%	5%
Truck Stop	0%	0%	3%	40%	7%	7%	3%	40%
Jordan Creek Town Center	0%	0%	10%	5%	20%	50%	10%	5%
DMACC	0%	0%	9%	4%	34%	40%	9%	4%
Adventureland	0%	0%	9%	5%	22%	50%	9%	5%
Retail Area	0%	0%	10%	5%	20%	50%	10%	5%
Valley West Mall	0%	0%	10%	5%	20%	50%	10%	5%

Memphis Travel Demand Model [10]

Memphis International Airport, Federal Express facility at the airport and Graceland were treated as special generators in this model. For the airport, total home-based other and non-home-based trips were calculated based on average enplanements using the results from the Memphis-Shelby

Airport Authority passenger survey. Work trips made by the airport employees were assumed to already be considered in the regular attraction model with the work trip purpose. Special generator trips for the airport were then added to the corresponding person trip attractions as per trip purpose. For Graceland, home-based social/recreational and non-home-based trips were estimated and then added to the person trip attractions. For Federal Express, trip attractions were added to the truck trips generated by the truck trip generation process.

Michigan Statewide Travel Demand Model [11]

Special generators were associated with trip attraction only. Trip attraction rates were developed where the standard rates by employment type do not adequately reflect the trip generation characteristics. The special generators considered in the model include airports, tourist attractions, campgrounds, state parks, golf courses, marinas, motels, hospitals, shopping centers, colleges and universities. Trip attraction rates were developed from the following data sources:

- ITE Trip Generation Manual, 5th Edition (all categories except bus terminals and tourist attractions) and the ITE Trip Generation Manual, 3rd Edition (for community colleges only)
- Intercity Bus Study, Michigan DOT (for bus terminal category)
- Travel & Tourism Report, Michigan DOT (for tourist attractions)

The rates used in the model are provided in Table 2.7.

Table 2.7 Trip Attraction Rates for Special Generators

Special Generators	**Sources of Rates**	**Trip Rate Equations**
Airports	1991 ITE Manual	exp(1.368×ln(registered aircrafts)-0.347) 104.73×(operations)/365
Bus Terminals	Intercity Bus Study	0.631× boarding passengers
Secretary of State	1991 ITE Manual	44.54×employees
Tourist Attractions	Travel & Tourism	2×attendances
Campgrounds	1991 ITE Manual	0.79×camp sites
State Parks	1991 ITE Manual	0.50×acres
Golf Courses	1991 ITE Manual	37.59×holes
Marinas	1991 ITE Manual	1.891×berths+410.795
Motels	1991 ITE Manual	exp(0.713×ln(0.44×rooms+3.945)
Hospitals	1991 ITE Manual	exp(0.634×ln(beds+4.628)
Shopping Centers	1991 ITE Manual	exp(0.756×ln(TSF)+5.154) if TSF>570 exp(0.625×ln(TSF)+5.985) if TSF<570 TSF: Total Square Footage
Colleges and Universities	1991/1987 ITE Manual	2.37× students for University 1.55× students for Community College

The person trips estimated for those activity generators were further separated per trip purpose and then compared with the trips estimated by the regular trip attraction model based on the number of employee. When the difference is large, the activity generator will be represented as a special generator in the model. The additional trip attractions required for every finalized special generator were incorporated into the trip attraction model by trip purpose.

Sacramento Regional Travel Demand Model (SACMET) [12]

At selected zones containing large and unusual sites, trip generation was exogenously calculated, either added to or replacing the trip generation calculated from the household and employment data. Older versions of the SACMET model used special generator trip entries for all major hospitals, colleges and universities and the Sacramento International Airport (SMF). However, SACMET01 uses college/university enrollment and medical employment as a distinct trip generation variable. Therefore, their corresponding special generators were removed. The only remaining special generator is SMF. No airport trip purpose is present in SACMET01 and the trip generation rates for SMF are intended to represent the approximate daily traffic to and from the airport.

Whatcom County Travel Demand Model [13]

Thirteen special generators (six primary types: airport, universities and colleges, casinos, harbors, hospitals and regional shopping centers) were evaluated for addition to the model. The trip rates of these special generators were estimated from the 1997 ITE Trip Generation Manual. For this purpose, the type and size of each identified special generator were determined (Table 2.8).

Table 2.8 Special Generators by Type and Size

Name	**Category**	**Size**	**Units**
Fairhaven Shopping Area	Regional Shopping	468	Employees
Sehome Village Shopping Center	Regional Shopping	729	Employees
Sunset Square Mall	Regional Shopping	326	TSF (thousand square feet)
Meridian Village Shopping Center	Regional Shopping	319	Employees
Bellis Fair Mall	Regional Shopping	922	TSF
Western Washington University	College	12,300	Students
Bellingham Technical College	College	3,682	Students
Whatcom Community College	College	3,832	Students
Nooksack Casino	Casino	20	TSF
Silver Reef Casino	Casino	28	TSF
St. Joseph’s Hospital	Hospital	492	Employees
Bellingham International Airport	Airport	13	Flights
Squalicum Harbor	Harbor	1,417	Slips

The trip attractions of these special generators were calculated using the size variables and then distributed among the appropriate trip purposes. The differences of the estimates from the regular model and ITE rates were added to the former by each trip purpose.

2.3 Treatment of Special Generators in FSUTMS

2.3.1 General Procedure

FSUTMS is a traditional four-step demand model. The first FSUTMS, began in 1978, was built upon a set of mainframe programs called Urban Transportation Planning System (UTPS), distributed by Federal Highway Administration and Urban Mass Transit Administration. The second FSUTMS, began in 1985, was built as a framework around Tranplan, a family of urban transportation planning and related software tools, distributed by Urban Analysis Group and later Citilabs. In the Tranplan version, the GEN module is used to generate person trips for seven trip purposes (home-based work, home-based shop, home-based social/recreation, home-based others, non-home-based, truck-taxi and internal-external). The model makes use of four zonal data files: ZDATA1 (trip production data), ZDATA2 (trip attraction data), ZDATA3 (special generator data) and ZDATA4 (internal-external production data). The model parameters and rates for the GEN module include the dwelling unit weights and the trip production rates. GEN contains a set of default trip attraction rates for all seven trip purposes. Customized rates can also be specified in the second part of the GRATE file. After calculating trip productions and attractions by zone and trip purpose using user-supplied or default trip rates, the GEN module adds the special generator trips specified in the ZDATA3 file. The GEN module then adjusts the number of trip attractions in each travel analysis zone such that total number of trip attractions of each purpose matches the trip production totals for the same purpose. The Current FSUTMS is powered by Cube Voyager, a family of urban transportation planning and related GIS software tools, distributed by Citilabs. The Cube version of FSUTMS uses ZONEDATA for the population, dwelling units, employment and school enrollment data, SPECGEN for the special generators, INTEXT for external station productions, EETRIPS for external-to-external trips, DUWEIGHTS for the weights to distribute population amongst dwelling units, PRODRATES for trip production rates and ATTRRATES for attraction rates. But there are exceptions too. The

Alachua/Gainesville MPO model is a Cube-based model but still uses ZDATA1, ZDATA2, ZDATA3, ZDATA4, GRATES and DUWEIGHT as their input files.

The following land use activities are considered as special generators in FSUTMS models:

- Colleges and Universities
- Large Regional Shopping Malls
- Regional Airports
- Military Bases
- Group Quarters (Dormitories, Barracks)
- Recreational Areas

FDOT recommended the following trip rates for the above special generators:

Table 2.9 Special Generators Trip Rates Recommended by FDOT [14]

Category	**Recommended Attraction Trip Rates**	**Recommended Major Trip Purposes**
Recreational Land Uses		
Community and Regional Park	7.7 Trips/Acre	Home-Based Social/Recreational
State Parks and Public Beaches	28 Trips/Acre	Home-Based Social/Recreational
Marinas	38 Trips/Acre	Home-Based Social/Recreational
Colleges and Universities	3 Trips/Student	Home-Based Other
Military Bases	2.7 Trips/Employee	Home-Based Other/Work
Commercial Airports	24 Trips/Employee	Home-Based Other
General Aviation Airports	22 Trips/Employee	Home-Based Other
Group Quarters	4 Trips/Person	Home-Based Other
Retail Shopping Centers		
200,000 sq. ft. or more	13 Trips/Employee	Home-Based Shop
100,000-200,000 sq. ft.	33 Trips/Employee	Home-Based Shop
50,000-100,000 sq. ft.	30 Trips/Employee	Home-Based Shop

The above procedure has been successfully applied in several MPO models. For example, in the Gainesville urban area model, during the model validation it was found that the model underestimated travel in major shopping areas, near University of Florida (UF) and near the

Santa Fe Community College. Thus, special generators were created for these areas. The adjustment was done through their ZDATA3 file and attractions were added to the Santa Fe Community College, Oaks Mall, Butler Plaza, Retail and Thornbrook and productions were added to UF dormitories.

A survey of MPOs in the state of Florida conducted in 2001 found that special generators have been a concern for many MPOs [15]. Among several suggested improvements, the most welcome one is to update the rates listed in Table 2.9.

2.3.2 Revised Special Generator Procedure

In the above FSUTMS procedure, the trip attractions estimated for special generators will be eventually adjusted up or down during the trip-balancing or trip distribution process. This may be undesirable, particularly after additional efforts have been made to obtain reliable estimates of trip attractions for special generators. One solution is to hold the special generator attractions constant and apply the adjustment to non-special-generator zones. For this purpose, FDOT District 4 has developed a revised procedure for treatments of special generators.

District 4's Lifestyle Trip Generation Model [16]:

In this model, for each trip purpose attractions are balanced so that the sum of attractions becomes equal to the sum of productions. The only exception is the school purpose where productions are adjusted to equal the sum of attractions. The special-generator portion of a zone's attractions is not adjusted during the balancing process while the non-special-generator portion is balanced. The general process of balancing for each trip purpose is as follows:

- The total productions are calculated for each zone;
- The total attractions are calculated for each zone (separate totals are kept for regular and special-generator attractions);
- Adjustment factor = (sum of productions – sum of special-generator attractions)/sum of regular trip attractions;
- Regular trip attractions are multiplied by the adjustment factor;

- The adjusted regular attractions are added to the unadjusted special-generator attractions for each zone.

For home-based trips, only attractions are adjusted while for non-home based trips, both productions and attractions are adjusted.

Another aspect worth noting is an implicit difference in the trip production rates between the "standard" FSUTMS models and the lifestyle trip production model. In the later, the trip production rates are for all the trips, including both the internal-internal and the internal-external /external-internal (IE/EI) trips. The former, however, implicitly includes only the internal trips and consider an IE/EI trip purpose. This difference has a ramification on the trip balancing and distribution processes, as well as specification of special generator, especially when a special generator is close to a model boundary or on an external station.

Tampa Bay Regional Planning Model (TBRPM) [17]

TBRPM also adopts a similar treatment of special generators like District 4's Lifestyle Trip Generation Model. A special generator is used to adjust the productions or attractions of a zone by trip purpose to a desired volume. During the trip balancing, TBRPM Lifestyle Trip Generation model holds special-generator adjustments for zones constant so that the net adjustment cannot spread out over all zones. While the traditional special-generator model only accepts absolute numbers of trips as input, this lifestyle model includes two new functions: one to increase and one to decrease the number of productions or attractions of a zone by percentage and purpose. Special generator adjustments to trip purposes like non-home-based and truck trips are applied to both attractions and productions at the same time. In this case, the total special generator trips for each zone are split as 50% for productions and 50% for attractions and then added to the sum total of productions and attractions and no further balancing will be performed.

Special Generators for Traffic Impact Analysis

Special generators are also often used in performing traffic impact analyses for proposed developments in Florida. In this application, the new development may be identified as a special generator whose attractions and possibly productions can be manually input based on the ITE Trip Generation Manual, and will then be further adjusted during iterative runs of FSUTMS model until the trips reported from FSUTMS match the ITE-based trip generation.

2.4 Summary and Discussion

Special generator may be a "necessary evil" in the four-step demand modeling process. It is not a practice that modelers should be encouraged to adopt, because the presence of special generators may affect the transferability and generality of the model. Instead, more efforts could be made to refine the module of trip generation. A well-developed trip generation module may be able to better replicate the real scenario of the modeling area, thereby reducing the need for introducing special generators. For example, the older versions of the Sacramento Regional Travel Demand Model [12] have treated major hospitals, colleges and universities as special generators. With an improved trip generation module where college/university enrollment and medical employment as distinct trip generation variables, the new version of the model has removed all those relevant special generators. Certainly, due to the limited time or resource, it is often tempting or inevitable for modelers to introduce special generators, particularly with the presence of activity generators in the region that have significantly different trip generation characteristics.

In general, the treatment of special generators can be summarized in following steps:

- Identification of special generators. Recognizing the limitation of the trip production and attraction models, potential special generators can be identified within the study area. When empirical data are not readily available, a survey may be needed to better understand the trip generation characteristics of those generators.

- Justification for introducing special generators. Trip productions may be estimated using cross classification or regression analysis while attractions estimated with regular attraction rates. At the same time, the attractions of special generators may also be estimated using special generator rates. The rates can be determined from the ITE Trip Generation Manual or a special generator survey. These two estimates are then compared for each trip purpose for each potential special generator. If significant difference is observed for one particular zone, it will be incorporated in the model for special generator adjustments.

- Special generator adjustment. The difference of two attraction estimates is added to the model with respect to trip purpose. This can be done in different ways: in most models, the differences of trips are added to attraction only while in some models they are added to both production and attraction. In order to distribute additional trips into appropriate trip purpose category, most of the models have their trip-purpose distributions for each special generator.

- Balancing. After the adjustment for special generators, trip balancing will be performed. In most models, the balancing is done to adjust all attractions (sometime productions). But some models maintain the special-generator attractions constant during the balancing process. In this case, the balancing adjustment factor is the difference between the total production and the total special-generator attractions divided by the total regular-generator attractions.

Attention may be paid to the following issues in the treatment of special generators:

- During the adjustment for special generators, the model should not double count the trips of special generators (one from the regular model and the other from the special generator model).

- If the balancing is performed on total adjusted productions and attractions, significant addition or deletion of trip attractions for special generators will impact trip attractions for zones without special generators.

- When determining special generator rates from the ITE Trip Generation Manual, note that the ITE rates provide vehicle trips while travel demand models deal with person trips.

In summary, the inclusion of special generators is a way to force the model to replicate the real scenario of the study area, because special generators can adopt ad hoc attraction rates significantly different from the standard rate. With a number of special generators within a model, it will lose generality and transferability. Therefore it is good practice to keep the number of special generators in the model to be a minimum. The standard procedure of special generators in FSUTMS and the improved procedure in the lifestyle trip generation models have been successfully applied in many MPO models. However, the special generator rates used are mostly those recommended in the Model Update Task B. Those rates are about 30 years old, and there is a need to conduct more attraction-side surveys to update them.

CHAPTER 3
COMPARISON OF TWO METHODS OF TRAFFIC IMPACT ANALYSES FOR PROPOSED DEVELOPMENTS

3.1 Introduction

Traffic impact analysis is performed for a new development to estimate its impact on the transportation system. The travel demand model is often used for the purpose and the analysis can be generally conducted in two ways: one is called as the link distribution percentage approach and the other is the special generator approach. In the former, dwelling units and employments of a new development are estimated and inserted into the trip generation input file, followed by a travel demand model run to derive the development traffic percentage of each link in the impact area. The percentages will then be applied to the external ITE-based trip generation of the new development to quantify its traffic impact. In the later approach, the new development is treated as a special generator whose attraction and possibly production can be manually calculated based on the ITE Trip Generation Manual, and will then be further adjusted during iterative runs of the model until the trips reported in the model match the ITE-based trip generation. Traffic assignment will then be conducted to quantify the impact of the proposed development on the traffic network. Both approaches have pros and cons, and there is no systematic research to show whether two approaches generate similar results or one outperforms the other. This chapter describes an empirical study that compared these two methods. The Alachua/Gainesville MPO model was used as the test bed. A number of scenarios of new developments were created by changing various characteristics of two hypothetical developments. The traffic impacts of those hypothetical developments were estimated by implementing these two methods respectively.

3.2 Empirical Study Site

The Alachua/Gainesville MPO model was selected given that the research team is most familiar with the region and had no success in obtaining a real-world new development from another region.

In the Alachua/Gainesville MPO model, the region is divided into 446 TAZs. With an intention to find an under-developed TAZ to locate the hypothetical new development, the research team carefully searched the area in Google Map and examined all the TAZs with small amount of trip production and attraction in the model. A few TAZs have been identified as potential sites for our case study, located in the northwestern, southwestern, northeastern and southeastern part of the study area respectively. Among those potential sites, TAZs 225 and 148 were selected for the empirical study. TAZ 225 is located in northeast of the town, near the NE Waldo road, with a total production equal to 243 person trips and total attraction 90 person trips and TAZ 148 is located in southeast of the town, near the SE Williston road and S Main street, with a total production equal to 64 person trips and total attraction 158 person trips. Although both zones are currently under-developed, their surrounding areas and road characteristics are different. TAZ 225 is on the outskirt of the city and the surroundings areas are all under-developed. In contrast, TAZ148 is near downtown where there are a lot of business development and the road network nearby is dense. The study site from Google Map is presented in Figure 3.1 and the TAZ configuration is presented in Figure 3.2.

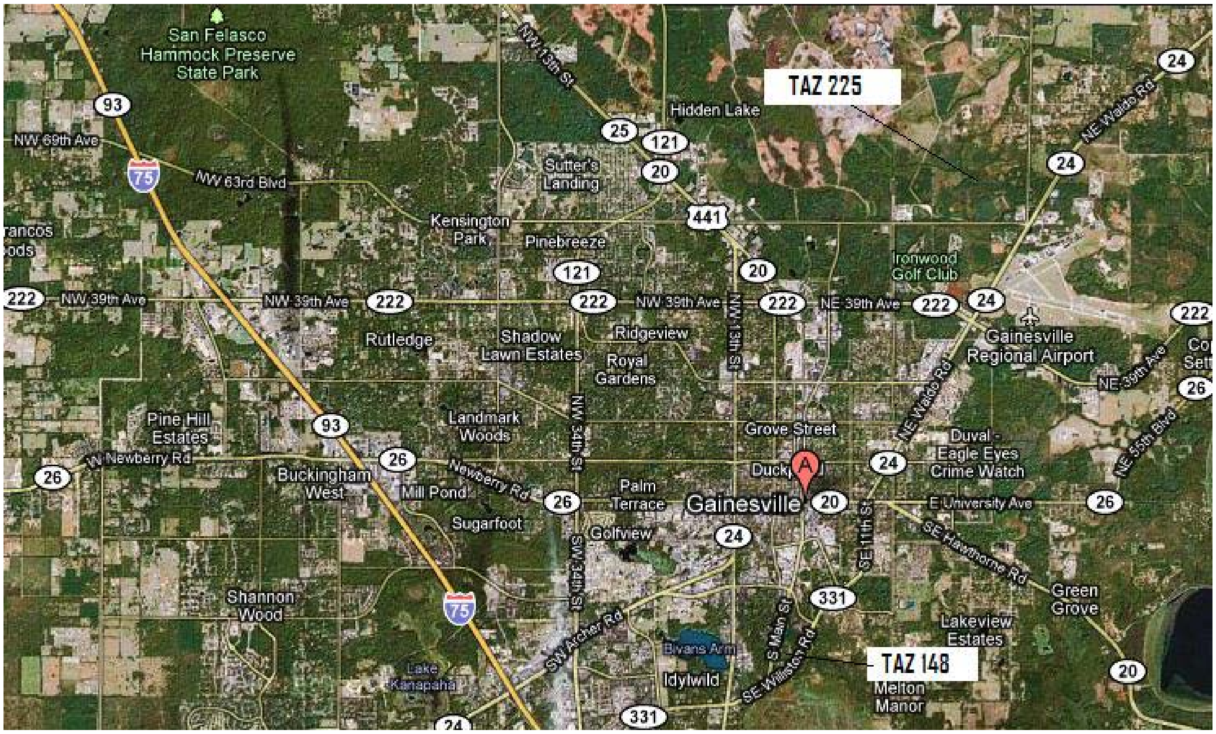

Figure 3.1 Map of the Study Site (From Google Map)

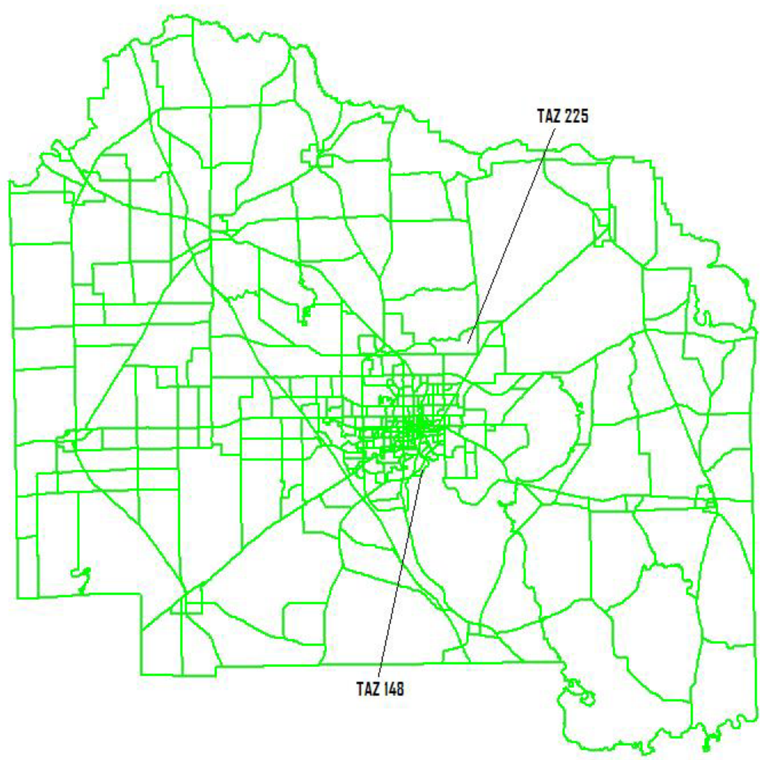

Figure 3.2 TAZ Configuration in the Alachua/Gainesville MPO Model

As the current Alachua/Gainesville MPO model treats only attraction sites as special generators, it was assumed that the new development at either TAZ 225 or 148 is a shopping mall of different sizes. The following input variables (in ZDATA2) are required for attraction sites to run the Alachua/Gainesville model:

SEC	Sector number
TAZ	TAZ number
OIEMP	Other industrial employment by place-of-work (sic 01-19)
MFGEMP	Manufacturing industrial employment by place-of-work (sic 20-51)
COMEMP	Commercial employment by place-of-work (sic 52-59)
SERVEMP	Service employment by place-of-work (sic 60-67, 70-89, and 99)
HOTEL	Hotel employment (not used)
TOTEMP	Total employment by place-of-work (sic 01-99)
SCHENR	School enrollment by school location
SHORTPARK	Short-term (3 hour) parking cost (cents)
LONGPARK	Long-term (8 hour) parking cost (cents)
STUDENTPAR	Student (8 hour) parking cost (cents) at UF

The input variables relevant to a shopping mall are MFGEMP, COMEMP, SERVEMP and TOTEMP. Eight scenarios were created for the new development at either TAZ 225 or 148. The maximum development size was made the same as that of TAZ 237, which contains the Oaks Mall while the other seven were determined arbitrarily with the size of the shopping mall ranging from 50,000 to 100,000 square feet. The current situation of both TAZs and the input data for these eight scenarios are provided in Tables 3.1 and 3.2 respectively.

Table 3.1 Current Situation in TAZs 225 and 148

TAZ	OIEMP	MGEMP	COMEMP	SEREMP	TOTEMP
225	0	6	0	0	6
148	0	0	0	30	30

Table 3.2 Input Data for Hypothetical Development Scenarios

Scenario	OIEMP	MGEMP	COMEMP	SEREMP	TOTEMP
1	0	10	170	20	200
2	0	20	250	30	300
3	0	26	500	50	576
4	0	26	700	70	796
5	0	36	1000	100	1136
6	0	36	1200	130	1366
7	0	36	1500	150	1686
8	0	36	2358	238	2632

3.3 Implementation

The Alachua/Gainesville MPO model was built upon Cube Voyager and has been validated using the Year 2000 data. This is a traditional FSUTMS model, making use of four zonal data files: ZDATA1 (Trip production data), ZDATA2 (Trip attraction data), ZDATA3 (Special generator data) and ZDATA4 (Internal-external production data). In the analyses, the employment data of the new development were updated in ZDATA2 data file. For the special generator method, the adjustment was further done in ZDATA3 input file. Moreover, the "Select Zone Analysis" was used to obtain the flow on each link contributed by the new development.

The implementation of the link distribution percentage method and special generator method are summarized in the following two subsections.

3.3.1 Link Distribution Percentage Method

The employment data of the development site was updated in ZDATA2 file according to a particular development scenario. After running the model, the development traffic on each link attributable to the new development was obtained from the "Select Zone Analysis". The total trip generation of the development site, including both productions and attractions, was retrieved from the "Generation Summary". Consequently, the link percentage, i.e., the percentage of new development trips coming to each link, was calculated as the ratio between the development traffic on each link and the total generation of the site. Finally, the "real" development trips on each link were obtained by multiplying an external estimate of the total trips generated from the new development to the link percentages. The external estimate can be made with reference to the ITE Trip Generation Manual. In the analysis, the estimates were made using the special generator rates recommended by FDOT [14], as described in Chapter 2. The relevant shopping trip rates are summarized in Table 3.3.

Table 3.3 Special Generators Trip Rates Recommended by FDOT

Retail Shopping Centers	**Recommended Attraction Trip Rates**	**Recommended Major Trip Purposes**
200,000 sq. ft. or more	13 Trips/Employee	Home-Based Shop
100,000-200,000 sq. ft.	33 Trips/Employee	Home-Based Shop
50,000-100,000 sq. ft.	30 Trips/Employee	Home-Based Shop

Assuming that the size of the hypothetical shopping center is between 50,000 and 100,000 sq. ft, 30 trips per employee were used to calculate the attractions.

3.3.2 Special Generator Method

Similar to the link distribution percentage approach, the employment data of the development site were updated in ZDATA2 according to a particular development scenario. The new development was then treated as a special generator and its generation was further adjusted in ZDATA3 during iterative runs of the model until the trips reported from the model matched the external estimate of trip generation. In the current Alachua/Gainesville MPO model, large shopping centers are treated as special generators and only attractions are adjusted in the ZDATA3. Moreover, all those attractions are with the home-based shopping trip purpose. Therefore, attractions were only adjusted for the proposed new development in ZDATA3. However, instead of assigning all to be home-based shopping trips, those attractions were distributed them among five trip purposes. Using the attraction rates of the model and the employment data, the numbers of attractions with different trip purposes were calculated manually and then the trip purpose percentages were obtained as follows: 14% for home-based work (HBW), 44% for home-based shopping (HBSH), 4% for home-based social recreation (HBSR), 12% for home-based others (HBO) and 26% for non-home-based (NHB). For comparison, the model was also run with all additional attractions being the HBSH trip purpose.

3.4 Results

The traffic impacts of eight hypothetical scenarios in two different TAZs were estimated by implementing both the link distribution percentage method and the special generator method. The special generator method was implemented with two different trip purpose distributions in the ZDATA 3 file, as shown in Table 3.4.

Table 3.4 Trip Purpose Distributions in ZDATA 3

Distribution (%)	HBW	HBSH	HBSR	HBO	NHB
1	0	100	0	0	0
2	14	44	4	12	26

The link volumes obtained from two different trip purpose distribution patterns are presented in Tables 3.5 to 3.11. As there are 6252 links in this study area, only those top 35 links with large development traffic are presented in the tables. Given that there are significant differences in link volumes with different trip purpose distribution patterns, the comparison between the two methods was based on the proposed trip purpose distribution (Distribution 2). The productions and attractions of the development TAZs and the trip adjustments for the special generator are summarized in Tables 3.12 and 3.13. Graphical representations of flow distribution across the network and the volumes from TAZ 225 or 148 without new development, with the new development before and after the special generator trip adjustments are provided in Figures 3.3 to 3.13. The sum of development trips on each link obtained from those two methods are presented in Tables 3.14 and 3.15, and further illustrated in Figures 3.14and 3.15.

Table 3.5 Development Trips on Links by Special Generator Method (Scenario 1)

Rank	Link		Development Trips on Links	
	Node A	Node B	Distribution1	Distribution 2
1	225	2873	2413	2741
2	2873	225	2413	2741
3	2802	2799	1828	2161
4	2873	2802	1828	2161
5	2799	2802	1826	2159
6	2802	2873	1826	2159
7	2799	2675	1297	1596
8	2675	2799	1301	1582
9	2675	2657	806	1069
10	2657	2675	793	1040
11	2657	2650	752	1007
12	2650	2657	740	978
13	2797	2798	525	577
14	2798	2799	525	577
15	2798	2797	531	565
16	2799	2798	531	565
17	2647	2643	410	557
18	2648	2647	410	557
19	2649	2648	410	557
20	2650	2649	410	557
21	2472	2675	507	542
22	2162	2472	507	541
23	2643	2647	421	539
24	2647	2648	421	539
25	2648	2649	421	539
26	2649	2650	421	539
27	2675	2472	491	527
28	2472	2162	490	525
29	2643	2613	385	522
30	2795	2796	466	509
31	2796	2797	466	509
32	2935	2873	525	507
33	2873	2935	524	505
34	2613	2643	396	504
35	2796	2795	472	497

Table 3.6 Development Trips on Links by Special Generator Method (Scenario 2)

Rank	Link		Development Trips on Links	
	Node A	Node B	Distribution1	Distribution 2
1	225	2873	3691	4072
2	2873	225	3691	4072
3	2802	2799	2757	3184
4	2873	2802	2757	3184
5	2799	2802	2790	3184
6	2802	2873	2790	3184
7	2799	2675	2002	2372
8	2675	2799	1996	2371
9	2675	2657	1212	1552
10	2657	2675	1231	1519
11	2657	2650	1132	1461
12	2650	2657	1151	1428
13	2472	2675	766	851
14	2162	2472	765	850
15	2643	2647	620	823
16	2647	2648	620	823
17	2648	2649	620	823
18	2649	2650	620	823
19	2675	2472	790	820
20	2472	2162	789	818
21	2797	2798	794	813
22	2798	2799	794	813
23	2798	2797	755	812
24	2799	2798	755	812
25	2647	2643	636	811
26	2648	2647	636	811
27	2649	2648	636	811
28	2650	2649	636	811
29	2935	2873	817	781
30	2873	2935	850	781
31	2613	2643	584	772
32	2643	2613	600	759
33	2795	2796	705	714
34	2796	2797	705	714
35	2796	2795	667	713

Table 3.7 Development Trips on Links by Special Generator Method (Scenario 3)

Rank	Link		Development Trips on Links	
	Node A	Node B	Distribution1	Distribution 2
1	225	2873	6775	7224
2	2873	225	6775	7224
3	2799	2802	4748	5196
4	2802	2873	4748	5196
5	2802	2799	4709	5142
6	2873	2802	4709	5142
7	2675	2799	3738	4206
8	2799	2675	3744	4182
9	2675	2657	2235	2587
10	2657	2675	2080	2575
11	2657	2650	2097	2431
12	2650	2657	1943	2419
13	2873	2935	1937	1914
14	2935	2873	1898	1860
15	2472	2675	1658	1631
16	2162	2472	1656	1628
17	2675	2472	1509	1596
18	2472	2162	1508	1593
19	2643	2647	1124	1413
20	2647	2648	1124	1413
21	2648	2649	1124	1413
22	2649	2650	1124	1413
23	2647	2643	1161	1383
24	2648	2647	1161	1383
25	2649	2648	1161	1383
26	2650	2649	1161	1383
27	2613	2643	1059	1326
28	2643	2613	1096	1296
29	2568	2613	883	1120
30	2536	2568	876	1111
31	2613	2568	920	1090
32	2568	2536	913	1081
33	2650	2603	936	1048
34	2534	2535	768	1041
35	2535	2536	768	1041

Table 3.8 Development Trips on Links by Special Generator Method (Scenario 4)

Rank	Link		Development Trips on Links	
	Node A	Node B	Distribution1	Distribution 2
1	225	2873	9118	9717
2	2873	225	9118	9717
3	2799	2802	6422	6643
4	2802	2873	6422	6643
5	2802	2799	6225	6642
6	2873	2802	6225	6642
7	2675	2799	5073	5484
8	2799	2675	5092	5330
9	2657	2675	2896	3217
10	2675	2657	2988	3147
11	2650	2657	2721	3014
12	2657	2650	2812	2944
13	2873	2935	2737	2866
14	2935	2873	2539	2865
15	2472	2675	2177	2266
16	2162	2472	2174	2263
17	2675	2472	2104	2183
18	2472	2162	2101	2180
19	2647	2643	1607	1833
20	2648	2647	1607	1833
21	2649	2648	1607	1833
22	2650	2649	1607	1833
23	2643	2647	1563	1830
24	2647	2648	1563	1830
25	2648	2649	1563	1830
26	2649	2650	1563	1830
27	2643	2613	1521	1719
28	2613	2643	1476	1717
29	2935	2938	1494	1628
30	2938	2927	1494	1628
31	2927	2938	1297	1627
32	2938	2935	1297	1627
33	2901	2899	1432	1532
34	2927	2901	1432	1532
35	2899	2901	1235	1531

Table 3.9 Development Trips on Links by Special Generator Method (Scenario 5)

Rank	Link		Development Trips on Links	
	Node A	Node B	Distribution1	Distribution 2
1	225	2873	12740	13497
2	2873	225	12740	13497
3	2799	2802	8226	8772
4	2802	2873	8226	8772
5	2802	2799	8183	8734
6	2873	2802	8183	8734
7	2675	2799	6235	6730
8	2799	2675	6223	6628
9	2873	2935	4367	4502
10	2935	2873	4324	4463
11	2657	2675	3295	3664
12	2675	2657	3243	3618
13	2650	2657	3069	3393
14	2657	2650	3017	3348
15	2472	2675	2941	3067
16	2162	2472	2937	3062
17	2675	2472	2979	3009
18	2472	2162	2976	3005
19	2935	2938	2724	2804
20	2938	2927	2724	2804
21	2927	2938	2681	2765
22	2938	2935	2681	2765
23	2901	2899	2642	2679
24	2927	2901	2642	2679
25	2899	2901	2599	2641
26	2901	2927	2599	2641
27	2643	2647	2209	2404
28	2647	2648	2209	2404
29	2648	2649	2209	2404
30	2649	2650	2209	2404
31	2647	2643	2126	2347
32	2648	2647	2126	2347
33	2649	2648	2126	2347
34	2650	2649	2126	2347
35	2613	2643	2092	2252

Table 3.10 Development Trips on Links by Special Generator Method (Scenario 6)

Rank	Link		Development Trips on Links	
	Node A	Node B	Distribution1	Distribution 2
1	225	2873	15332	15855
2	2873	225	15332	15855
3	2802	2799	9651	10009
4	2873	2802	9651	10009
5	2799	2802	9626	9998
6	2802	2873	9626	9998
7	2799	2675	7251	7500
8	2675	2799	7145	7494
9	2935	2873	5496	5568
10	2873	2935	5471	5556
11	2675	2657	3652	3942
12	2657	2675	3667	3888
13	2657	2650	3394	3633
14	2472	2675	3477	3606
15	2162	2472	3474	3601
16	2927	2938	3582	3594
17	2938	2927	3557	3583
18	2650	2657	3410	3579
19	2675	2472	3600	3558
20	2472	2162	3596	3553
21	2938	2935	3397	3483
22	2935	2938	3382	3478
23	2899	2901	3488	3453
24	2901	2927	3488	3453
25	2901	2899	3463	3442
26	2927	2901	3463	3442
27	2643	2647	2571	2846
28	2647	2648	2571	2846
29	2648	2649	2571	2846
30	2649	2650	2571	2846
31	2647	2643	2550	2823
32	2648	2647	2550	2823
33	2649	2648	2550	2823
34	2650	2649	2550	2823
35	2613	2643	2436	2673

Table 3.11 Development Trips on Links by Special Generator Method (Scenario 7)

Rank	Link		Development Trips on Links	
	Node A	Node B	Distribution1	Distribution 2
1	225	2873	18110	19084
2	2873	225	18110	19084
3	2802	2799	10984	11500
4	2873	2802	10984	11500
5	2799	2802	10992	11495
6	2802	2873	10992	11495
7	2675	2799	8525	8931
8	2799	2675	8599	8861
9	2935	2873	6885	7266
10	2873	2935	6893	7260
11	2927	2938	4689	4925
12	2938	2927	4697	4919
13	2899	2901	4578	4763
14	2901	2927	4578	4763
15	2901	2899	4586	4758
16	2927	2901	4586	4758
17	2472	2675	4383	4694
18	2162	2472	4379	4688
19	2675	2472	4289	4621
20	2472	2162	4285	4616
21	2675	2657	4309	4240
22	2657	2675	4142	4237
23	2657	2650	4029	3895
24	2650	2657	3862	3892
25	2935	2940	3027	3854
26	2940	2935	3004	3853
27	2885	2888	3352	3456
28	2888	2899	3352	3456
29	2888	2885	3355	3443
30	2899	2888	3355	3443
31	2938	2935	3881	3413
32	2935	2938	3866	3406
33	2648	2647	3023	3184
34	2649	2648	3023	3184
35	2650	2649	3023	3184

Table 3.12 Model Output Before and After the Special Generator Adjustments (TAZ 225)

Scenario	Total Production from Model	Total Attraction from Model	Total ITE Attraction	Special Generator Trips Added	Total Attraction from Model after Sp. Gen. Addition
1	1055	1908	6000	2800	6033
2	1444	2781	9000	4500	9240
3	2620	5388	17280	8000	17190
4	3564	7476	23880	11000	23771
5	2988	10608	34080	16000	34194
6	5954	12724	40980	19000	40832
7	7350	15752	50580	23000	50092
8	11409	24473	78960	36000	78388

Table 3.13 Model Output Before and After the Special Generator Adjustments (TAZ 148)

Scenario	Total Production from Model	Total Attraction from Model	Total ITE Attraction	Special Generator Trips Added	Total Attraction from Model after Sp. Gen. Addition
1	817	1831	6000	3000	6129
2	1205	2703	9000	4300	8910
3	2379	5310	17280	8500	17072
4	3325	7395	23880	11000	23653
5	4748	10530	34080	16000	34072
6	5715	12648	40980	19000	40715
7	7110	15675	50580	23500	50499
8	11169	24395	78960	36000	78266

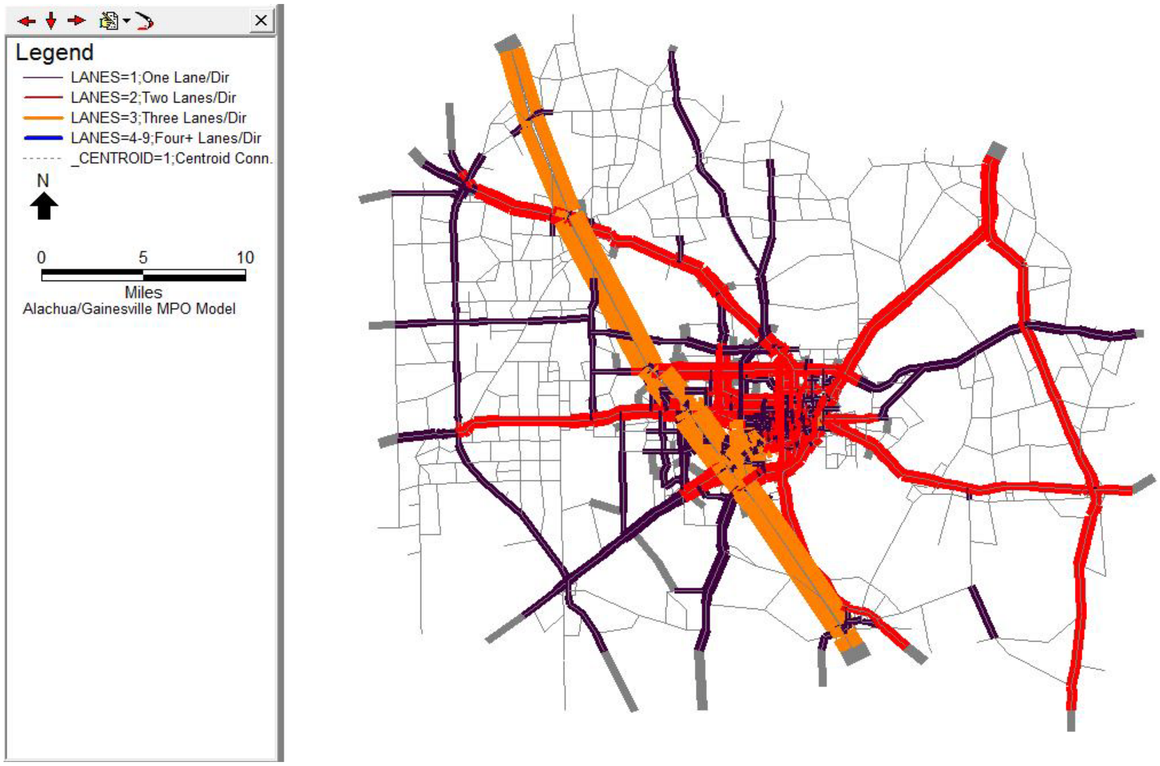

Figure 3.3 Flow Distribution without New Development

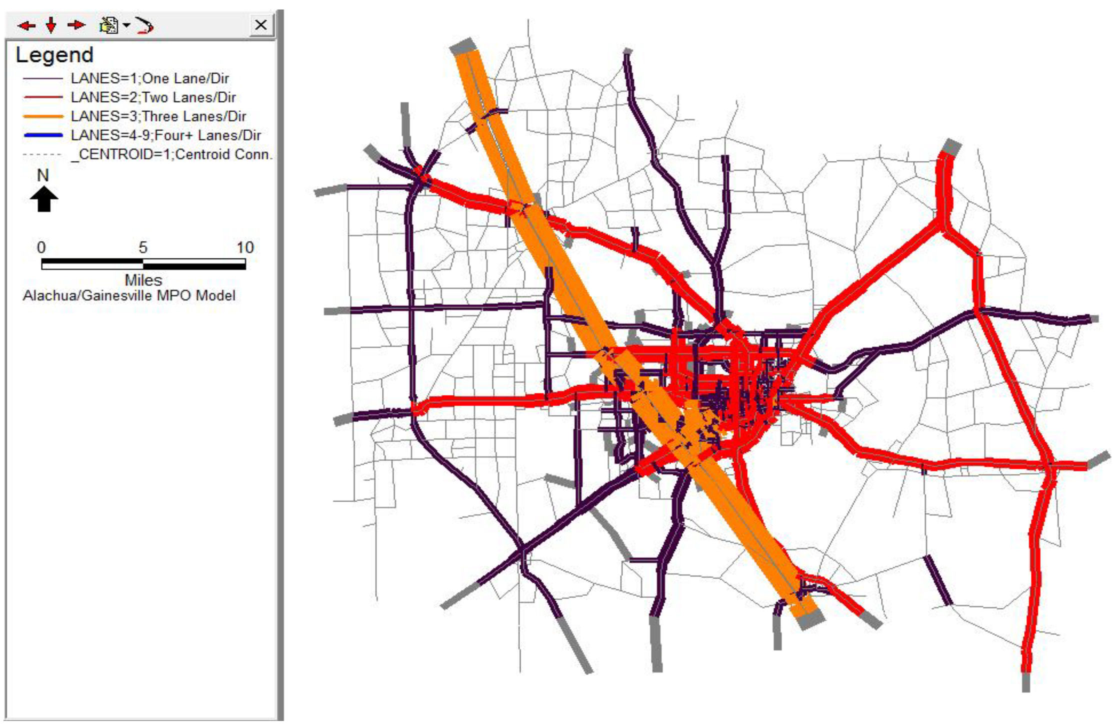

Figure 3.4 Flow Distribution with Development Scenario 8 in TAZ 225 before Special Generator Adjustments

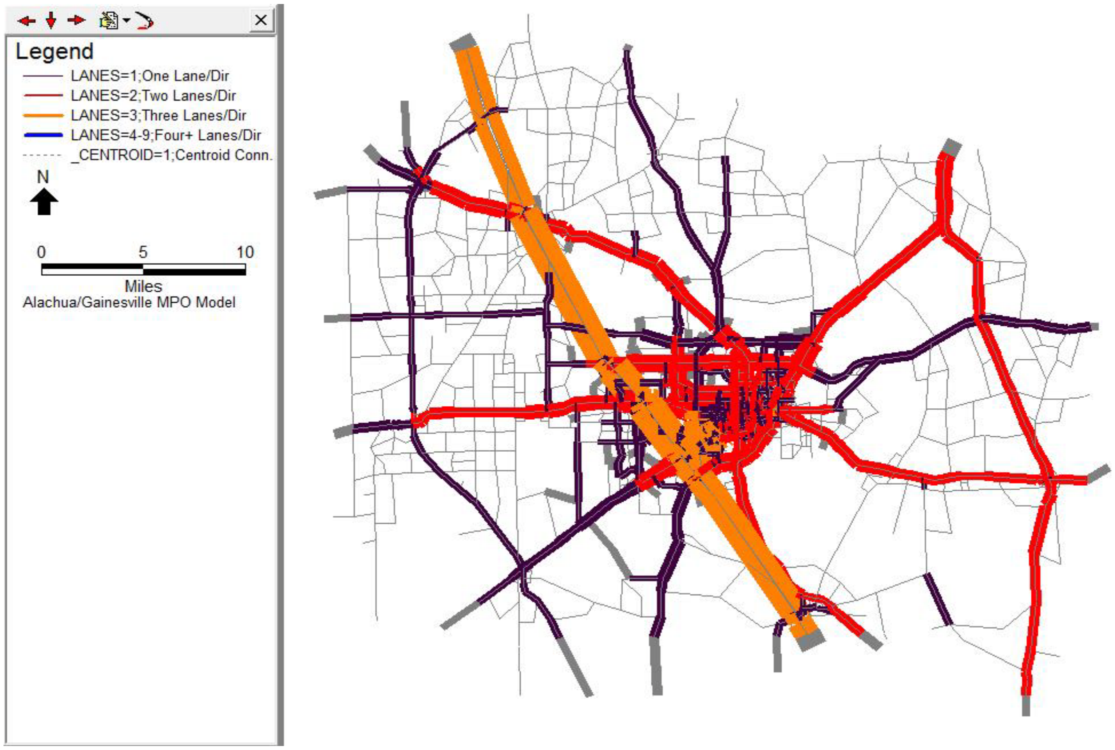

Figure 3.5 Flow Distribution with Development Scenario 8 in TAZ 225 after Special Generator Adjustments

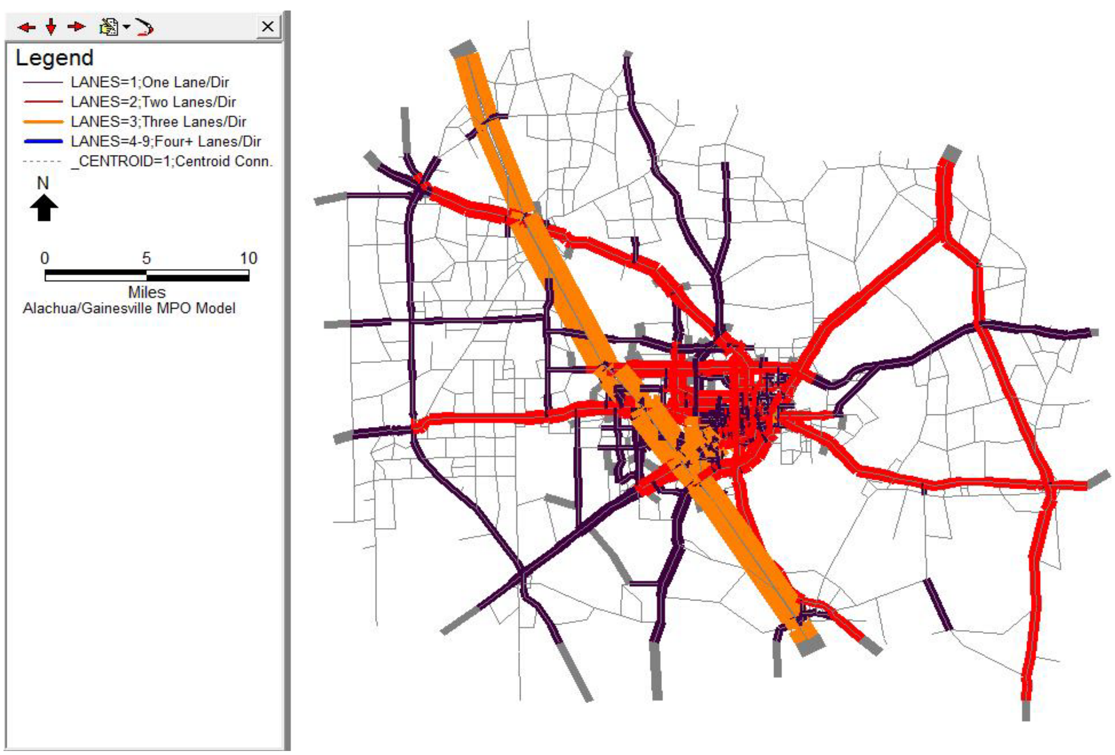

Figure 3.6 Flow Distribution with Development Scenario 8 in TAZ 148 before Special Generator Adjustments

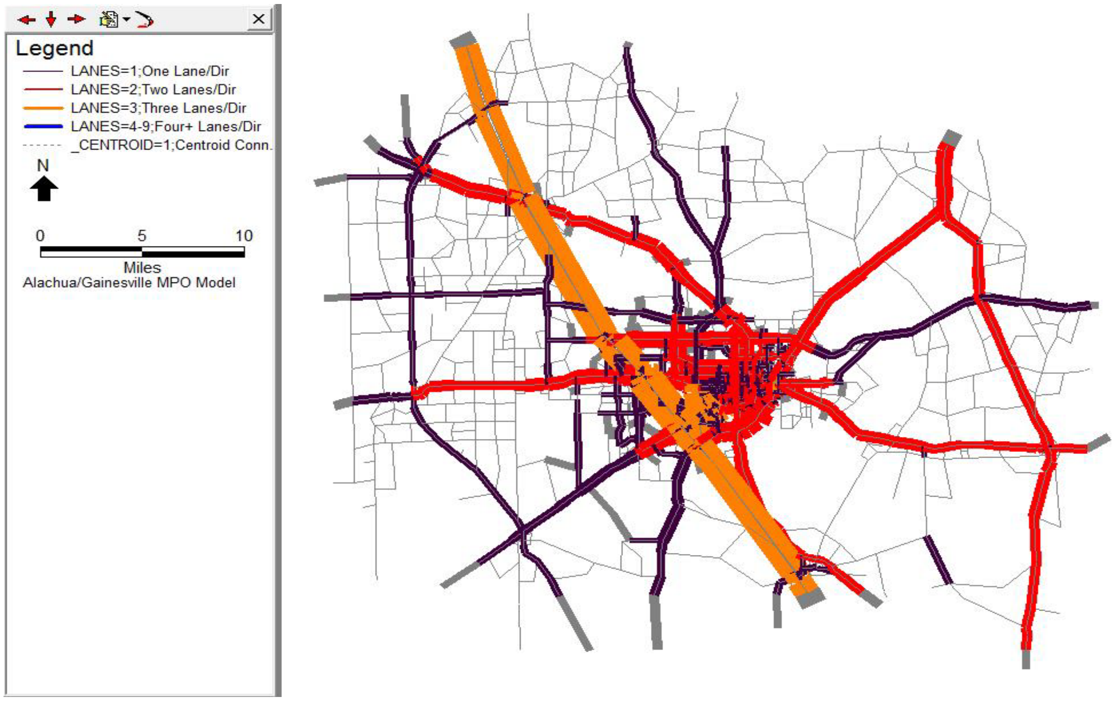

Figure 3.7 Flow Distribution with Development Scenario 8 in TAZ 148 after Special Generator Adjustments

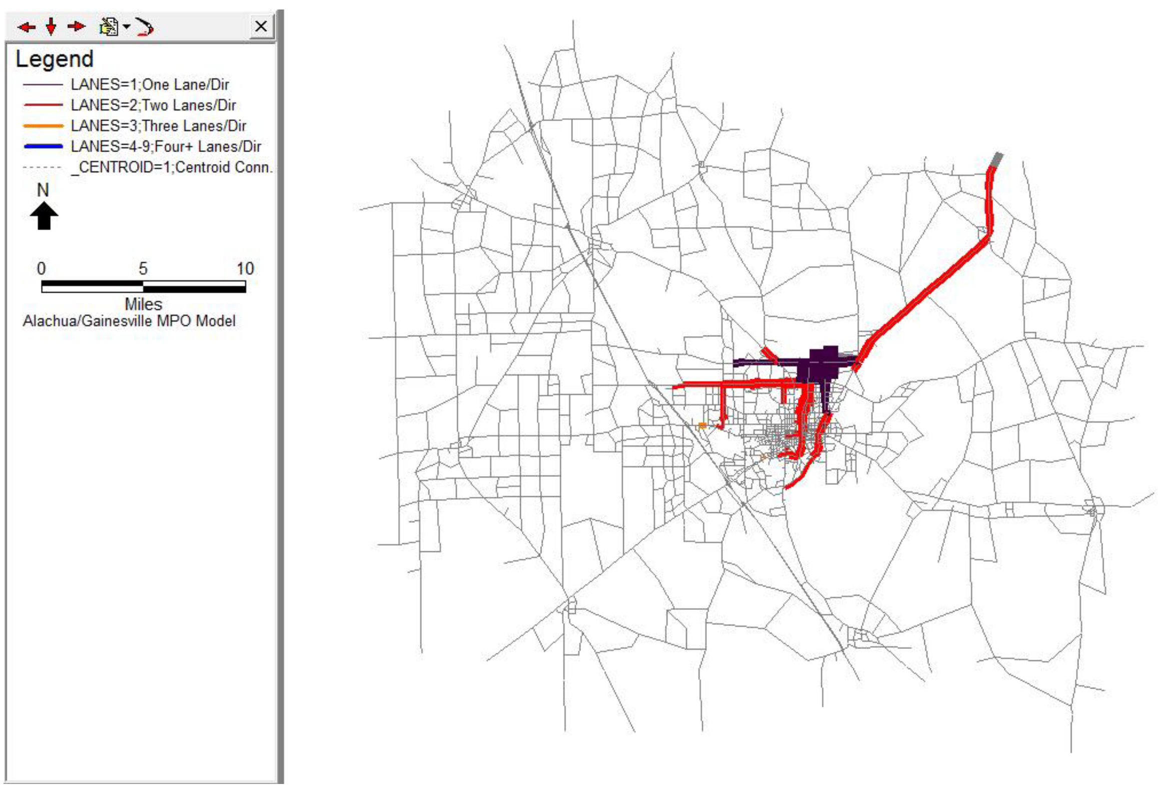

Figure 3.8 Traffic Volumes from TAZ 225 without New Development

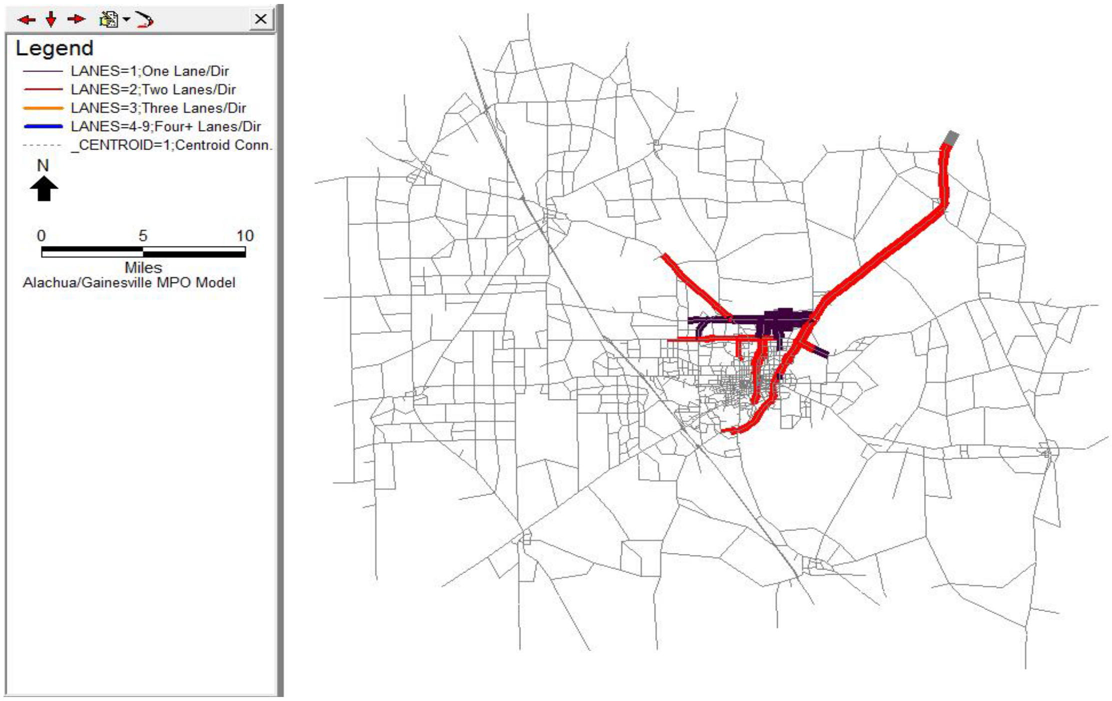

Figure 3.9 Traffic Volumes from TAZ 225 with Development Scenario 8 before Special Generator Adjustments

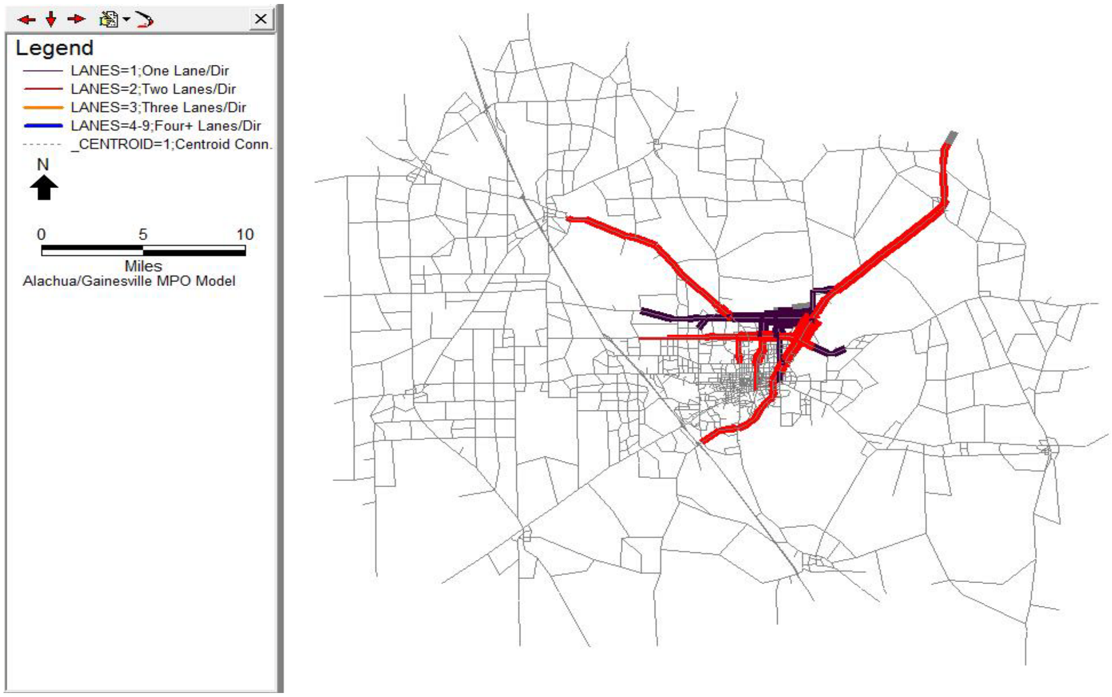

Figure 3.10 Traffic Volumes from TAZ 225 with Development Scenario 8 after Special Generator Adjustments

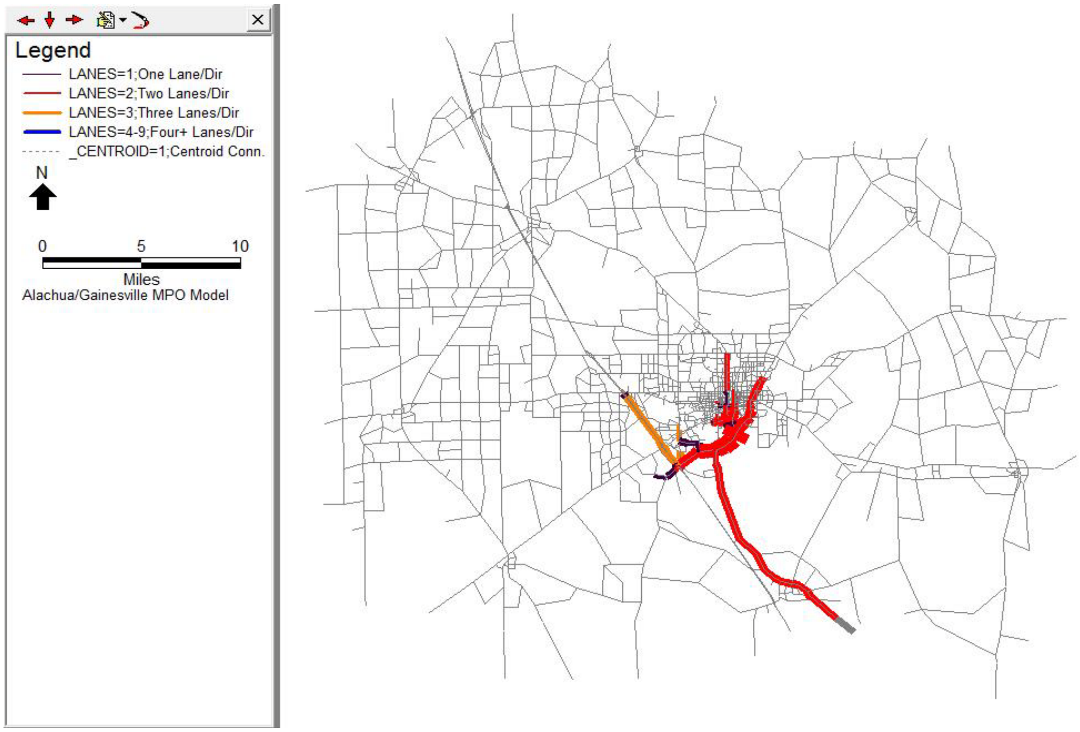

Figure 3.11 Traffic Volumes from TAZ 148 without New Development

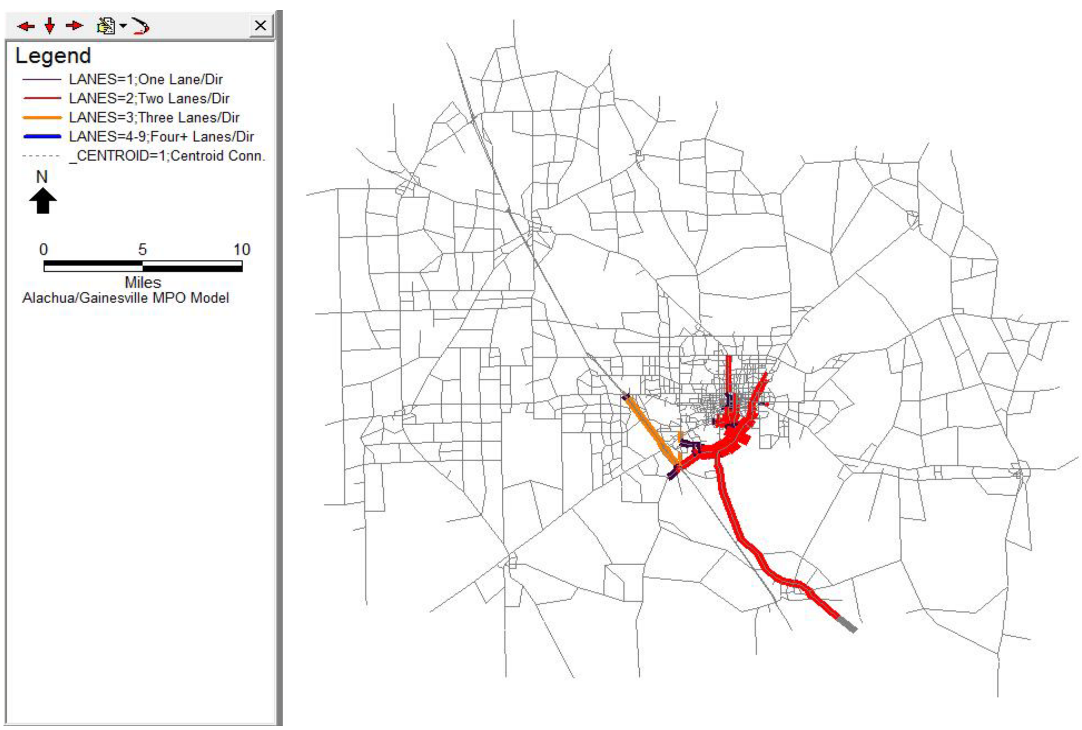

Figure 3.12 Traffic Volumes from TAZ 148 with Development Scenario 8 before Special Generator Adjustments

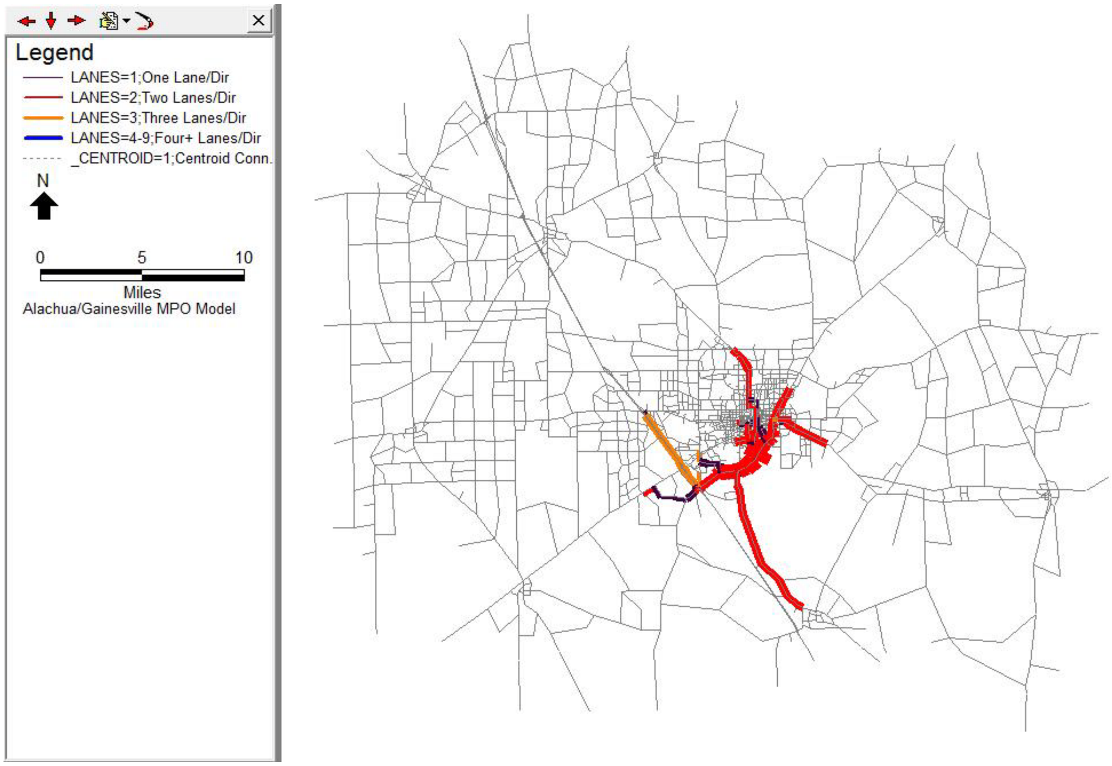

Figure 3.13 Traffic Volumes from TAZ 148 with Development Scenario 8 after Special Generator Adjustments

Table 3.14 Sum of Total Development Trips on Each Link (TAZ 225)

Scenario	Link Distribution Percentage Method	Special Generator Method
1	137879	139387
2	201779	207687
3	368514	368992
4	495303	499519
5	742180	701632
6	802607	831169
7	963182	1014026
8	1429331	1629316

Table 3.15 Sum of Total Development Trips on Each Link (TAZ 148)

Scenario	Link Distribution Percentage Method	Special Generator Method
1	138166	149192
2	205705	214804
3	389945	405600
4	532974	556633
5	750133	796274
6	892270	951532
7	1095832	1171383
8	1631178	1818451

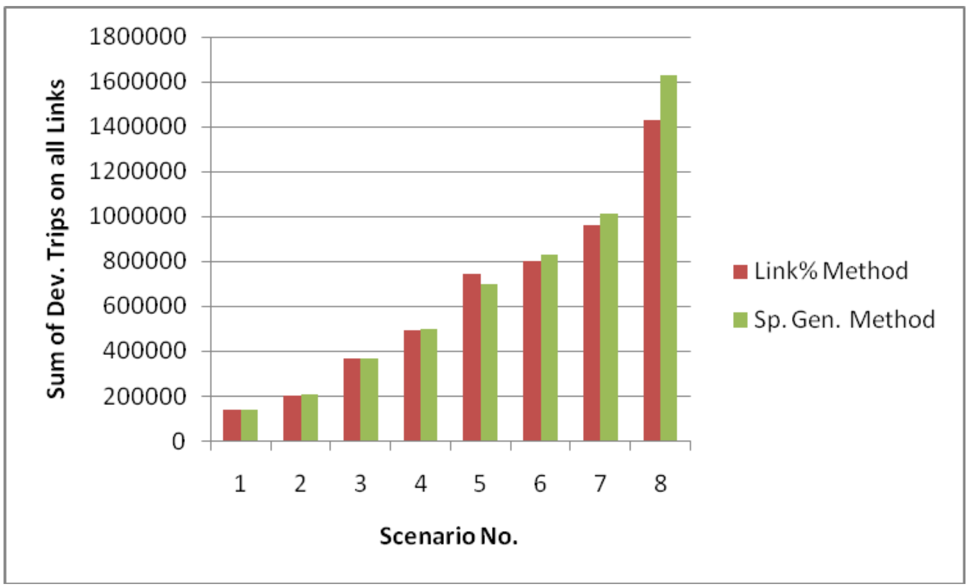

Figure 3.14 Sum of Total Development Trips on Each Link (TAZ 225)

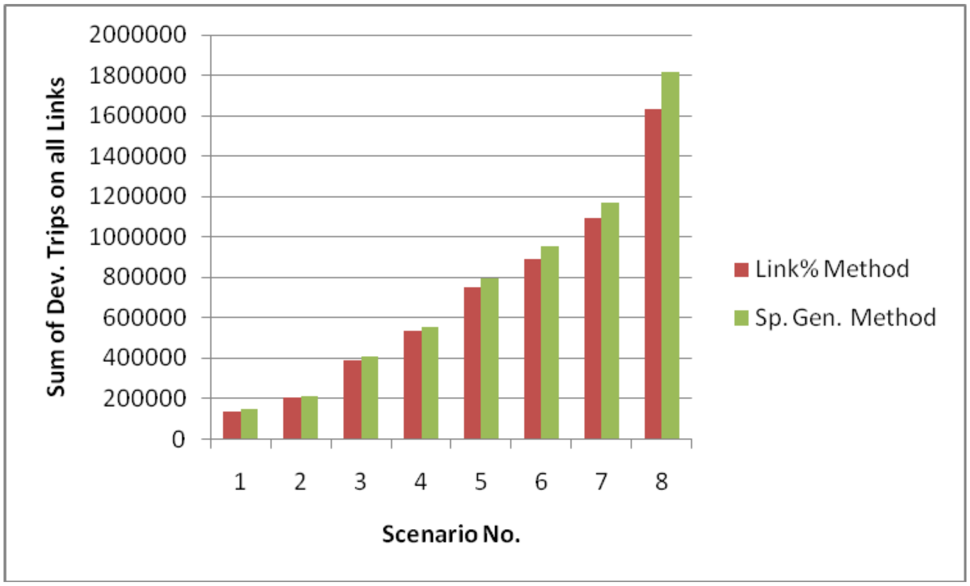

Figure 3.15 Sum of Total Development Trips on Each Link (TAZ 148)

To investigate how the link percentage pattern varies across different scenarios, the link percentages obtained from different scenarios were also compared. For this purpose, the root mean square errors (RMSEs), defined below, were calculated for every scenario against the link percentages from Scenario 1:

$$RMSE = \frac{\sqrt{\sum_a (x_a^1 - x_a^i)^2}}{\sum_a x_a^1}$$

where x_a^1 denotes the link percentage of link a from the development with Scenario 1 (base case) and x_a^i denotes the link percentage of link a from the development with Scenario i = 2,3…7.

The comparisons are presented in Tables 3.16 and 3.17 and further illustrated in Figures 3.16 and 3.17. The link percentages of top 35 links are also presented in Tables 3.18 and 3.19.

Lastly, development trips on each link obtained from those two methods were compared. The top 35 links with development trips are presented in Tables 3.20 to 3.35. RMSE was calculated similarly as above for every scenario using the special generator method as the base case. The results are presented in Tables 3.36 and 3.37 and Figures 3.18 and 3.19.

Table 3.16 Variations of Link Distribution Percentages of Different Scenarios (TAZ 225)

Scenario	RMSE
1	N/A (Base Case)
2	0.0028
3	0.0049
4	0.0063
5	0.0065
6	0.0117
7	0.0147
8	0.0207

Table 3.17 Variations of Link Distribution Percentages of Different Scenarios (TAZ 148)

Scenario	RMSE
1	N/A (Base Case)
2	0.0022
3	0.0027
4	0.0035
5	0.0041
6	0.0049
7	0.0055
8	0.0083

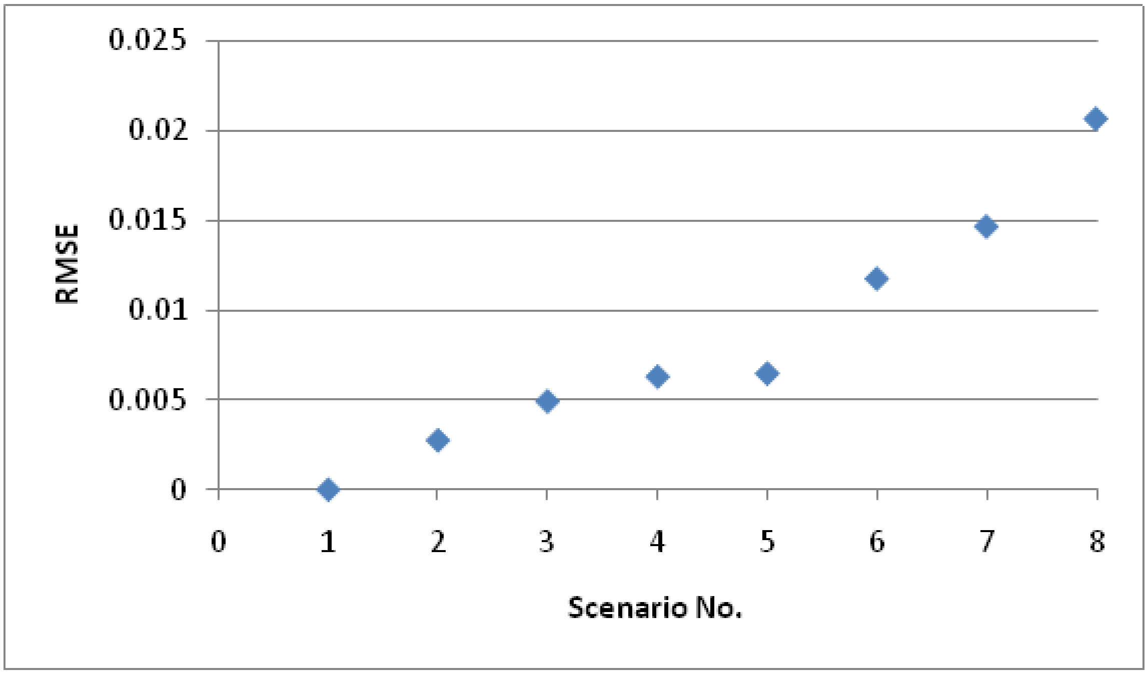

Figure 3.16 Variations of Link Distribution Percentages of Different Scenarios (TAZ 225)

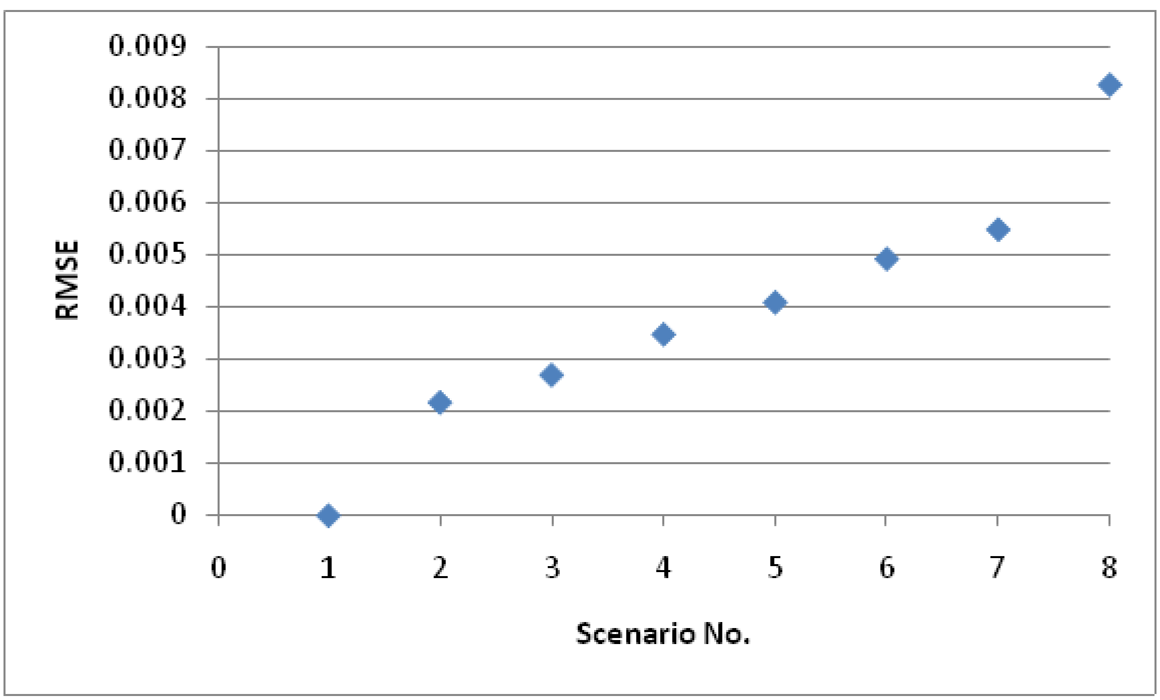

Figure 3.17 Variations of Link Distribution Percentages of Different Scenarios (TAZ 148)

Table 3.18 Link Percentages of Top 35 Links (TAZ 225)

Node A	Node B	Link % (S1)	Link % (S2)	Link % (S3)	Link % (S4)	Link % (S5)	Link % (S6)	Link % (S7)	Link % (S8)
225	2873	37.38	36.94	35.49	34.52	38.25	32.67	31.83	29.99
2873	225	37.38	36.94	35.49	34.52	38.25	32.67	31.83	29.99
2802	2799	29.71	29.24	27.89	26.86	29.11	24.50	22.74	19.98
2873	2802	29.71	29.24	27.89	26.86	29.11	24.50	22.74	19.98
2799	2802	29.70	29.24	27.19	26.86	28.97	23.83	22.62	19.96
2802	2873	29.70	29.24	27.19	26.86	28.97	23.83	22.62	19.96
2799	2675	22.54	22.14	21.10	20.42	22.63	19.27	18.65	14.95
2675	2799	22.41	21.95	21.09	20.44	22.63	19.29	18.71	15.05
2657	2675	16.34	15.88	14.98	14.33	15.36	13.08	12.23	8.92
2675	2657	16.00	16.05	14.89	14.08	14.62	12.35	12.32	8.86
2650	2657	15.50	15.05	14.19	13.57	14.54	12.39	11.56	8.31
2657	2650	15.16	15.22	14.11	13.33	13.80	11.66	11.65	8.25
2643	2647	9.11	8.89	8.44	8.14	9.15	7.53	7.08	6.30
2647	2648	9.11	8.89	8.44	8.14	9.15	7.53	7.08	6.30
2648	2649	9.11	8.89	8.44	8.14	9.15	7.53	7.08	6.30
2649	2650	9.11	8.89	8.44	8.14	9.15	7.53	7.08	6.30
2647	2643	9.11	9.12	8.66	8.19	9.08	7.76	7.23	6.54
2648	2647	9.11	9.12	8.66	8.19	9.08	7.76	7.23	6.54
2649	2648	9.11	9.12	8.66	8.19	9.08	7.76	7.23	6.54
2650	2649	9.11	9.12	8.66	8.19	9.08	7.76	7.23	6.54
2613	2643	8.51	8.30	7.88	7.61	8.57	7.05	6.61	5.87
2643	2613	8.51	8.53	8.10	7.66	8.50	7.27	6.76	6.11
2797	2798	7.29	7.29	6.10	6.42	6.34	4.54	3.91	4.91
2798	2799	7.29	7.29	6.10	6.42	6.34	4.54	3.91	4.91
2613	2568	7.26	7.34	6.98	6.58	7.32	6.27	5.80	5.23
2568	2613	7.24	7.08	6.72	6.43	7.28	6.00	5.61	4.96
2568	2536	7.20	7.29	6.93	6.53	7.27	6.22	5.75	5.19
2536	2568	7.18	7.02	6.67	6.38	7.22	5.95	5.57	4.92
2798	2797	7.17	7.10	6.80	6.44	6.48	5.23	4.09	5.03
2799	2798	7.17	7.10	6.80	6.44	6.48	5.23	4.09	5.03
2534	2535	6.81	6.60	6.30	5.76	6.57	5.60	5.27	4.60
2535	2536	6.81	6.60	6.30	5.76	6.57	5.60	5.27	4.60
2532	2534	6.78	6.56	6.27	5.73	6.54	5.57	5.24	4.57
2529	2532	6.69	6.47	6.18	5.65	6.45	5.49	5.17	4.50
2535	2534	6.66	6.71	6.36	6.04	6.76	5.80	5.34	4.89

Table 3.19 Link Percentages of Top 35 Links (TAZ 148)

Node A	Node B	Link % (S1)	Link % (S2)	Link % (S3)	Link % (S4)	Link % (S5)	Link % (S6)	Link % (S7)	Link % (S8)
148	2445	38.92	38.71	37.99	37.47	36.80	36.38	35.81	34.44
2445	148	38.92	38.71	37.99	37.47	36.80	36.38	35.81	34.44
2583	2445	24.11	23.97	23.64	23.19	22.90	22.44	22.19	21.00
2586	2583	24.11	23.97	23.64	23.19	22.90	22.44	22.19	21.00
2445	2583	23.77	23.61	23.15	22.87	22.49	22.15	21.84	20.72
2583	2586	23.77	23.61	23.15	22.87	22.49	22.15	21.84	20.72
2431	2432	16.60	16.48	16.21	15.76	15.54	15.23	14.98	13.87
2432	2434	16.60	16.48	16.21	15.76	15.54	15.23	14.98	13.87
2434	2586	16.60	16.48	16.21	15.76	15.54	15.23	14.98	13.87
2432	2431	16.22	16.10	15.74	15.54	15.24	14.90	14.60	13.54
2434	2432	16.22	16.10	15.74	15.54	15.24	14.90	14.60	13.54
2586	2434	16.22	16.10	15.74	15.54	15.24	14.90	14.60	13.54
2445	2325	14.66	14.61	14.36	14.14	13.86	13.78	13.54	13.31
2325	2445	14.32	14.25	13.88	13.82	13.45	13.50	13.19	13.03
2201	2185	13.93	13.89	13.65	13.43	13.17	13.10	12.87	12.66
2203	2201	13.93	13.89	13.65	13.43	13.17	13.10	12.87	12.66
2325	2203	13.93	13.89	13.65	13.43	13.17	13.10	12.87	12.66
2201	2203	13.59	13.53	13.16	13.12	12.76	12.81	12.52	12.39
2203	2325	13.59	13.53	13.16	13.12	12.76	12.81	12.52	12.39
2390	2391	11.16	11.47	11.15	10.81	10.65	10.66	9.91	10.29
2391	2431	11.16	11.47	11.15	10.81	10.65	10.66	9.91	10.29
2391	2390	10.56	10.37	10.27	10.40	10.28	10.25	9.71	9.69
2431	2391	10.56	10.37	10.27	10.40	10.28	10.25	9.71	9.69
2185	2201	9.74	9.70	9.23	9.24	8.94	9.03	8.79	8.76
2160	2101	9.56	9.54	9.37	9.21	9.01	8.96	8.78	8.69
2185	2160	9.56	9.54	9.37	9.21	9.01	8.96	8.78	8.69
1997	1995	9.42	9.41	9.23	9.08	8.88	8.86	8.69	8.60
2101	1997	9.42	9.41	9.23	9.08	8.88	8.86	8.69	8.60
2101	2160	9.42	9.38	8.91	8.92	8.63	8.73	8.47	8.48
2160	2185	9.42	9.38	8.91	8.92	8.63	8.73	8.47	8.48
1995	1997	9.25	9.21	8.75	8.77	8.48	8.58	8.35	8.34
1997	2101	9.25	9.21	8.75	8.77	8.48	8.58	8.35	8.34
2586	2642	7.55	7.51	7.42	7.34	7.25	7.25	7.24	7.18
2642	2586	7.51	7.49	7.43	7.42	7.35	7.20	7.21	7.13
2642	2669	7.32	7.29	7.20	7.12	7.04	7.04	7.03	6.99

Table 3.20 Link Volumes of Top 35 Links (TAZ 225 with Scenario 1)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	225	2873	2637	2741
2	2873	225	2637	2741
3	2802	2799	2096	2161
4	2873	2802	2096	2161
5	2799	2802	2095	2159
6	2802	2873	2095	2159
7	2799	2675	1590	1596
8	2675	2799	1581	1582
9	2675	2657	1129	1069
10	2657	2675	1153	1040
11	2657	2650	1069	1007
12	2650	2657	1093	978
13	2797	2798	514	577
14	2798	2799	514	577
15	2798	2797	506	565
16	2799	2798	506	565
17	2647	2643	643	557
18	2648	2647	643	557
19	2649	2648	643	557
20	2650	2649	643	557
21	2472	2675	428	542
22	2162	2472	427	541
23	2643	2647	643	539
24	2647	2648	643	539
25	2648	2649	643	539
26	2649	2650	643	539
27	2675	2472	461	527
28	2472	2162	460	525
29	2643	2613	600	522
30	2795	2796	448	509
31	2796	2797	448	509
32	2935	2873	466	507
33	2873	2935	466	505
34	2613	2643	600	504
35	2796	2795	439	497

Table 3.21 Link Volumes of Top 35 Links (TAZ 225 with Scenario 2)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	225	2873	3858	4072
2	2873	225	3858	4072
3	2802	2799	3054	3184
4	2873	2802	3054	3184
5	2799	2802	3053	3184
6	2802	2873	3053	3184
7	2799	2675	2312	2372
8	2675	2799	2292	2371
9	2675	2657	1677	1552
10	2657	2675	1659	1519
11	2657	2650	1590	1461
12	2650	2657	1572	1428
13	2472	2675	633	851
14	2162	2472	631	850
15	2643	2647	929	823
16	2647	2648	929	823
17	2648	2649	929	823
18	2649	2650	929	823
19	2675	2472	635	820
20	2472	2162	633	818
21	2797	2798	761	813
22	2798	2799	761	813
23	2798	2797	742	812
24	2799	2798	742	812
25	2647	2643	953	811
26	2648	2647	953	811
27	2649	2648	953	811
28	2650	2649	953	811
29	2935	2873	696	781
30	2873	2935	695	781
31	2613	2643	867	772
32	2643	2613	891	759
33	2795	2796	665	714
34	2796	2797	665	714
35	2796	2795	646	713

Table 3.22 Link Volumes of Top 35 Links (TAZ 225 with Scenario 3)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	225	2873	7063	7224
2	2873	225	7063	7224
3	2799	2802	5411	5196
4	2802	2873	5411	5196
5	2802	2799	5550	5142
6	2873	2802	5550	5142
7	2675	2799	4197	4206
8	2799	2675	4198	4182
9	2675	2657	2964	2587
10	2657	2675	2981	2575
11	2657	2650	2807	2431
12	2650	2657	2824	2419
13	2873	2935	1321	1914
14	2935	2873	1461	1860
15	2472	2675	1216	1631
16	2162	2472	1212	1628
17	2675	2472	1234	1596
18	2472	2162	1230	1593
19	2643	2647	1679	1413
20	2647	2648	1679	1413
21	2648	2649	1679	1413
22	2649	2650	1679	1413
23	2647	2643	1723	1383
24	2648	2647	1723	1383
25	2649	2648	1723	1383
26	2650	2649	1723	1383
27	2613	2643	1568	1326
28	2643	2613	1612	1296
29	2568	2613	1337	1120
30	2536	2568	1327	1111
31	2613	2568	1389	1090
32	2568	2536	1379	1081
33	2650	2603	1084	1048
34	2534	2535	1254	1041
35	2535	2536	1254	1041

Table 3.23 Link Volumes of Top 35 Links (TAZ 225 with Scenario 4)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	225	2873	9473	9717
2	2873	225	9473	9717
3	2799	2802	7371	6643
4	2802	2873	7371	6643
5	2802	2799	7371	6642
6	2873	2802	7371	6642
7	2675	2799	5610	5484
8	2799	2675	5605	5330
9	2657	2675	3933	3217
10	2675	2657	3865	3147
11	2650	2657	3725	3014
12	2657	2650	3657	2944
13	2873	2935	1852	2866
14	2935	2873	1853	2865
15	2472	2675	1677	2266
16	2162	2472	1671	2263
17	2675	2472	1740	2183
18	2472	2162	1734	2180
19	2647	2643	2248	1833
20	2648	2647	2248	1833
21	2649	2648	2248	1833
22	2650	2649	2248	1833
23	2643	2647	2235	1830
24	2647	2648	2235	1830
25	2648	2649	2235	1830
26	2649	2650	2235	1830
27	2643	2613	2101	1719
28	2613	2643	2088	1717
29	2935	2938	555	1628
30	2938	2927	555	1628
31	2927	2938	555	1627
32	2938	2935	555	1627
33	2901	2899	401	1532
34	2927	2901	401	1532
35	2899	2901	401	1531

Table 3.24 Link Volumes of Top 35 Links (TAZ 225 with Scenario 5)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	225	2873	14178	13497
2	2873	225	14178	13497
3	2799	2802	10737	8772
4	2802	2873	10737	8772
5	2802	2799	10789	8734
6	2873	2802	10789	8734
7	2675	2799	8389	6730
8	2799	2675	8388	6628
9	2873	2935	3032	4502
10	2935	2873	3084	4463
11	2657	2675	5695	3664
12	2675	2657	5420	3618
13	2650	2657	5389	3393
14	2657	2650	5114	3348
15	2472	2675	2694	3067
16	2162	2472	2686	3062
17	2675	2472	2968	3009
18	2472	2162	2960	3005
19	2935	2938	1039	2804
20	2938	2927	1039	2804
21	2927	2938	1091	2765
22	2938	2935	1091	2765
23	2901	2899	815	2679
24	2927	2901	815	2679
25	2899	2901	867	2641
26	2901	2927	867	2641
27	2643	2647	3391	2404
28	2647	2648	3391	2404
29	2648	2649	3391	2404
30	2649	2650	3391	2404
31	2647	2643	3367	2347
32	2648	2647	3367	2347
33	2649	2648	3367	2347
34	2650	2649	3367	2347
35	2613	2643	3176	2252

Table 3.25 Link Volumes of Top 35 Links (TAZ 225 with Scenario 6)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	225	2873	15332	15855
2	2873	225	15332	15855
3	2802	2799	11499	10009
4	2873	2802	11499	10009
5	2799	2802	11185	9998
6	2802	2873	11185	9998
7	2799	2675	9046	7500
8	2675	2799	9055	7494
9	2935	2873	3770	5568
10	2873	2935	3456	5556
11	2675	2657	5798	3942
12	2657	2675	6141	3888
13	2657	2650	5471	3633
14	2472	2675	2914	3606
15	2162	2472	2905	3601
16	2927	2938	1584	3594
17	2938	2927	1270	3583
18	2650	2657	5814	3579
19	2675	2472	3248	3558
20	2472	2162	3239	3553
21	2938	2935	1584	3483
22	2935	2938	1270	3478
23	2899	2901	1347	3453
24	2901	2927	1347	3453
25	2901	2899	1033	3442
26	2927	2901	1033	3442
27	2643	2647	3536	2846
28	2647	2648	3536	2846
29	2648	2649	3536	2846
30	2649	2650	3536	2846
31	2647	2643	3641	2823
32	2648	2647	3641	2823
33	2649	2648	3641	2823
34	2650	2649	3641	2823
35	2613	2643	3307	2673

Table 3.26 Link Volumes of Top 35 Links (TAZ 225 with Scenario 7)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	225	2873	18437	19084
2	2873	225	18437	19084
3	2802	2799	13171	11500
4	2873	2802	13171	11500
5	2799	2802	13102	11495
6	2802	2873	13102	11495
7	2675	2799	10838	8931
8	2799	2675	10802	8861
9	2935	2873	4898	7266
10	2873	2935	4829	7260
11	2927	2938	2222	4925
12	2938	2927	2153	4919
13	2899	2901	1943	4763
14	2901	2927	1943	4763
15	2901	2899	1874	4758
16	2927	2901	1874	4758
17	2472	2675	3752	4694
18	2162	2472	3742	4688
19	2675	2472	3667	4621
20	2472	2162	3657	4616
21	2675	2657	7135	4240
22	2657	2675	7085	4237
23	2657	2650	6747	3895
24	2650	2657	6697	3892
25	2935	2940	2675	3854
26	2940	2935	2675	3853
27	2885	2888	1304	3456
28	2888	2899	1304	3456
29	2888	2885	1235	3443
30	2899	2888	1235	3443
31	2938	2935	2222	3413
32	2935	2938	2153	3406
33	2648	2647	4187	3184
34	2649	2648	4187	3184
35	2650	2649	4187	3184

Table 3.27 Link Volumes of Top 35 Links (TAZ 225 with Scenario 8)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	2873	225	27106	24150
2	225	2873	27106	23915
3	2802	2799	18055	14585
4	2873	2802	18055	14585
5	2799	2802	18037	14506
6	2802	2873	18037	14506
7	2927	2938	4412	10314
8	2938	2927	4393	10235
9	2899	2901	4025	10099
10	2901	2927	4025	10099
11	2901	2899	4006	10020
12	2927	2901	4006	10020
13	2935	2873	8479	9237
14	2799	2675	13509	9209
15	2675	2799	13599	9115
16	2873	2935	8460	8924
17	2940	2935	4067	8837
18	2935	2940	4067	8818
19	2938	2940	0	7194
20	2940	2938	0	7174
21	2739	2797	2565	6740
22	2797	2739	2618	6652
23	2650	2739	2109	6359
24	2739	2650	2163	6270
25	2650	2603	3715	5752
26	2603	2650	3927	5734
27	2675	2472	5498	5664
28	2472	2162	5484	5658
29	2603	2553	3563	5643
30	2472	2675	5539	5629
31	2553	2603	3775	5625
32	2162	2472	5525	5623
33	2553	2438	3563	5579
34	2438	2553	3775	5560
35	2438	2384	3430	5442

Table 3.28 Link Volumes of Top 35 Links (TAZ 148 with Scenario 1)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	2653	2868
2	2445	148	2653	2868
3	2583	2445	1644	1794
4	2586	2583	1644	1794
5	2445	2583	1621	1772
6	2583	2586	1621	1772
7	2431	2432	1132	1125
8	2432	2434	1132	1125
9	2434	2586	1132	1125
10	2432	2431	1106	1102
11	2434	2432	1106	1102
12	2586	2434	1106	1102
13	2445	2325	999	1041
14	2325	2445	976	1020
15	2201	2185	950	963
16	2203	2201	950	963
17	2325	2203	950	963
18	2201	2203	926	941
19	2203	2325	926	941
20	2390	2391	761	745
21	2391	2431	761	745
22	2185	2201	664	700
23	2160	2101	652	693
24	2185	2160	652	693
25	1997	1995	642	679
26	2101	1997	642	679
27	2101	2160	642	672
28	2160	2185	642	672
29	2586	2642	515	670
30	2642	2586	512	669
31	2391	2390	720	663
32	2431	2391	720	663
33	1995	1997	630	658
34	1997	2101	630	658
35	2642	2669	499	644

Table 3.29 Link Volumes of Top 35 Links (TAZ 148 with Scenario 2)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	3950	4138
2	2445	148	3950	4138
3	2583	2445	2447	2568
4	2586	2583	2447	2568
5	2445	2583	2410	2531
6	2583	2586	2410	2531
7	2431	2432	1682	1601
8	2432	2434	1682	1601
9	2434	2586	1682	1601
10	2432	2431	1643	1567
11	2434	2432	1643	1567
12	2586	2434	1643	1567
13	2445	2325	1491	1530
14	2325	2445	1454	1493
15	2201	2185	1417	1418
16	2203	2201	1417	1418
17	2325	2203	1417	1418
18	2201	2203	1380	1381
19	2203	2325	1380	1381
20	2390	2391	1170	1068
21	2391	2431	1170	1068
22	2185	2201	990	1031
23	2160	2101	974	1029
24	2185	2160	974	1029
25	1997	1995	960	1007
26	2101	1997	960	1007
27	2101	2160	957	993
28	2160	2185	957	993
29	1995	1997	940	970
30	1997	2101	940	970
31	2642	2586	765	967
32	2391	2390	1058	965
33	2431	2391	1058	965
34	2586	2642	766	964
35	2669	2642	742	930

Table 3.30 Link Volumes of Top 35 Links (TAZ 148 with Scenario 3)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	7469	7758
2	2445	148	7469	7758
3	2583	2445	4648	4798
4	2586	2583	4648	4798
5	2445	2583	4552	4747
6	2583	2586	4552	4747
7	2431	2432	3188	2967
8	2432	2434	3188	2967
9	2434	2586	3188	2967
10	2432	2431	3093	2927
11	2434	2432	3093	2927
12	2586	2434	3093	2927
13	2445	2325	2824	2877
14	2325	2445	2728	2826
15	2201	2185	2684	2671
16	2203	2201	2684	2671
17	2325	2203	2684	2671
18	2201	2203	2588	2620
19	2203	2325	2588	2620
20	2390	2391	2192	2052
21	2391	2431	2192	2052
22	2185	2201	1814	1969
23	2160	2101	1842	1942
24	2185	2160	1842	1942
25	1997	1995	1815	1906
26	2101	1997	1815	1906
27	2101	2160	1751	1897
28	2160	2185	1751	1897
29	1995	1997	1720	1856
30	1997	2101	1720	1856
31	2642	2586	1461	1831
32	2586	2642	1459	1819
33	2391	2390	2019	1815
34	2431	2391	2019	1815
35	2669	2642	1418	1765

Table 3.31 Link Volumes of Top 35 Links (TAZ 148 with Scenario 4)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	10194	10587
2	2445	148	10194	10587
3	2583	2445	6308	6554
4	2586	2583	6308	6554
5	2445	2583	6222	6467
6	2583	2586	6222	6467
7	2431	2432	4288	4022
8	2432	2434	4288	4022
9	2434	2586	4288	4022
10	2445	2325	3845	3946
11	2432	2431	4227	3940
12	2434	2432	4227	3940
13	2586	2434	4227	3940
14	2325	2445	3760	3859
15	2201	2185	3654	3669
16	2203	2201	3654	3669
17	2325	2203	3654	3669
18	2201	2203	3569	3582
19	2203	2325	3569	3582
20	2390	2391	2942	2823
21	2391	2431	2942	2823
22	2185	2201	2513	2697
23	2160	2101	2504	2659
24	2185	2160	2504	2659
25	1997	1995	2470	2632
26	2101	1997	2470	2632
27	2101	2160	2428	2602
28	2160	2185	2428	2602
29	1995	1997	2386	2547
30	1997	2101	2386	2547
31	2642	2586	2019	2531
32	2586	2642	1996	2527
33	2391	2390	2829	2515
34	2431	2391	2829	2515
35	2669	2642	1961	2445

Table 3.32 Link Volumes of Top 35 Links (TAZ 148 with Scenario 5)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	14289	14936
2	2445	148	14289	14936
3	2583	2445	8891	9260
4	2586	2583	8891	9260
5	2445	2583	8731	9157
6	2583	2586	8731	9157
7	2431	2432	6036	5647
8	2432	2434	6036	5647
9	2434	2586	6036	5647
10	2445	2325	5382	5550
11	2325	2445	5223	5447
12	2432	2431	5916	5384
13	2434	2432	5916	5384
14	2586	2434	5916	5384
15	2201	2185	5114	5169
16	2203	2201	5114	5169
17	2325	2203	5114	5169
18	2201	2203	4954	5066
19	2203	2325	4954	5066
20	2390	2391	4136	4076
21	2391	2431	4136	4076
22	2185	2201	3470	3827
23	2586	2642	2815	3773
24	2160	2101	3498	3756
25	2185	2160	3498	3756
26	1997	1995	3450	3713
27	2101	1997	3450	3713
28	2101	2160	3350	3680
29	2160	2185	3350	3680
30	2642	2669	2734	3659
31	1995	1997	3293	3620
32	1997	2101	3293	3620
33	2642	2586	2855	3613
34	2669	2642	2773	3499
35	2391	2390	3991	3494

Table 3.33 Link Volumes of Top 35 Links (TAZ 148 with Scenario 6)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	16987	17644
2	2445	148	16987	17644
3	2583	2445	10476	10909
4	2586	2583	10476	10909
5	2445	2583	10342	10798
6	2583	2586	10342	10798
7	2445	2325	6437	6587
8	2325	2445	6302	6476
9	2431	2432	7113	6372
10	2432	2434	7113	6372
11	2434	2586	7113	6372
12	2432	2431	6958	6345
13	2434	2432	6958	6345
14	2586	2434	6958	6345
15	2201	2185	6118	6145
16	2203	2201	6118	6145
17	2325	2203	6118	6145
18	2201	2203	5983	6034
19	2203	2325	5983	6034
20	2390	2391	4976	4587
21	2391	2431	4976	4587
22	2185	2201	4217	4584
23	2642	2586	3364	4536
24	2160	2101	4186	4461
25	2185	2160	4186	4461
26	2586	2642	3383	4453
27	1997	1995	4138	4439
28	2101	1997	4138	4439
29	2669	2642	3267	4406
30	2101	2160	4076	4399
31	2160	2185	4076	4399
32	1995	1997	4007	4343
33	1997	2101	4007	4343
34	2642	2669	3287	4323
35	2391	2390	4788	3914

Table 3.34 Link Volumes of Top 35 Links (TAZ 148 with Scenario 7)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	20660	21551
2	2445	148	20660	21551
3	2583	2445	12799	13182
4	2586	2583	12799	13182
5	2445	2583	12599	13157
6	2583	2586	12599	13157
7	2445	2325	7810	8092
8	2325	2445	7610	8068
9	2432	2431	8423	7637
10	2434	2432	8423	7637
11	2586	2434	8423	7637
12	2201	2185	7423	7566
13	2203	2201	7423	7566
14	2325	2203	7423	7566
15	2431	2432	8640	7553
16	2432	2434	8640	7553
17	2434	2586	8640	7553
18	2201	2203	7222	7542
19	2203	2325	7222	7542
20	2185	2201	5071	5786
21	2642	2586	4159	5628
22	2101	2160	4884	5529
23	2160	2185	4884	5529
24	2586	2642	4175	5521
25	2160	2101	5066	5516
26	2185	2160	5066	5516
27	2390	2391	5715	5502
28	2391	2431	5715	5502
29	1997	1995	5013	5492
30	2101	1997	5013	5492
31	2669	2642	4042	5477
32	1995	1997	4817	5471
33	1997	2101	4817	5471
34	2642	2669	4058	5369
35	2391	2390	5604	4867

Table 3.35 Link Volumes of Top 35 Links (TAZ 148 with Scenario 8)

Rank	Link		Development Volume on Each Link	
	Node A	Node B	Link Percentage Method	Special Generator Method
1	148	2445	31043	32261
2	2445	148	31043	32261
3	2583	2445	18925	19015
4	2586	2583	18925	19015
5	2445	2583	18679	18834
6	2583	2586	18679	18834
7	2445	2325	11995	13028
8	2325	2445	11748	12847
9	2201	2185	11414	11813
10	2203	2201	11414	11813
11	2325	2203	11414	11813
12	2201	2203	11167	11737
13	2203	2325	11167	11737
14	2642	2586	6428	9874
15	2432	2431	12208	9865
16	2434	2432	12208	9865
17	2586	2434	12208	9865
18	2669	2642	6254	9672
19	2185	2201	7897	9195
20	2431	2432	12497	9141
21	2432	2434	12497	9141
22	2434	2586	12497	9141
23	2586	2642	6471	8969
24	2642	2669	6297	8767
25	2160	2101	7830	8323
26	2185	2160	7830	8323
27	1997	1995	7754	8286
28	2101	1997	7754	8286
29	2101	2160	7641	8285
30	2160	2185	7641	8285
31	1995	1997	7520	8247
32	1997	2101	7520	8247
33	2692	2669	5258	7018
34	2714	2692	5241	7001
35	2669	2692	5237	6966

Table 3.36 Comparison of Two Methods (TAZ 225)

Scenario	ITE Attractions of Development Zone	RMSE
1	6000	0.0063
2	9000	0.0063
3	17280	0.0107
4	23880	0.0145
5	34080	0.0185
6	40980	0.0166
7	50580	0.0163
8	78960	0.0219

Table 3.37 Comparison of Two Methods (TAZ 148)

Scenario	ITE Attractions of Development Zone	RMSE
1	6000	0.0064
2	9000	0.0058
3	17280	0.0059
4	23880	0.0063
5	34080	0.0073
6	40980	0.0075
7	50580	0.0081
8	78960	0.0103

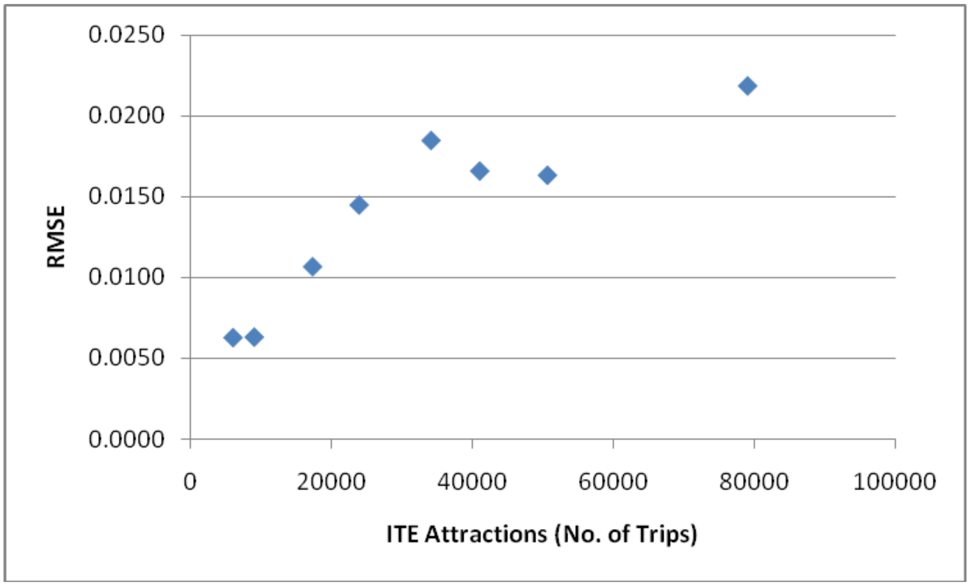

Figure 3.18 RMSE of Development Link Flows from Two Methods (TAZ 225)

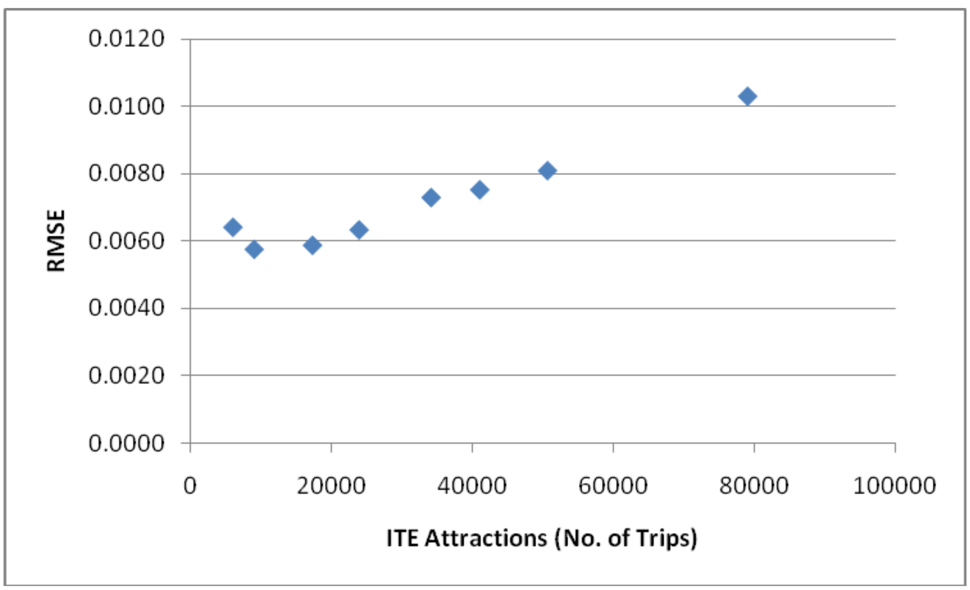

Figure 3.19 RMSE of Development Link Flows from Two Methods (TAZ 148)

3.5 Observations and Recommendations

Observations from this empirical study include:

- The link distribution percentage method is easier to implement than the special generator method. In the latter, the distribution of trip purpose needs to be estimated externally while in the former it is automatically determined by the travel demand model. Moreover, a single model run may be sufficient and the resulting link distribution percentage pattern is applicable in the future. However, in the special generator approach, trips for the special generator need to be adjusted iteratively until the trips reported from the travel model match the estimates based on the ITE rates.

- The link distribution percentage method makes an implicit assumption that the link distribution percentage pattern remains the same if a larger number of trips are generated in the new development. The assumption may not be valid, particularly when the network is congested, and the estimates of trip production from FSUTMS and the ITE Trip Generation Manual are substantially different. However, this was not obvious in this implementation. More specifically, the link percentage patterns obtained for different scenarios were also very consistent with the RMSE ranging from 0.0022 to 0.0207.

- The link distribution percentage method and the special generator method produced fairly consistent estimates of traffic impacts caused by different scenarios created for those two hypothetical developments. The RMSEs between the results from these two approaches were very small, ranging from 0.0058 to 0.0219.

- The difference in link volumes obtained from both methods for scenario 8 in TAZ 225 is much higher than other scenarios. Scenario 8 has the largest scale development and TAZ 225 is located in an under-developed area. With a large scale development, the assumption of the constant link distribution percentage pattern unlikely holds in the link distribution percentage method. On the other hand, the large amount of attraction to the new development may render the special generator approach to produce a distorted trip distribution pattern for the originally under-developed area. Both factors and possibly others acted together and resulted in the observable discrepancy.

Recommendation:

- Many of the above observations were made in this implementation, which may not be applicable to other situations. These two methods should be compared in other networks with different types of development.

- Different MPOs use different special generator adjustment techniques. Therefore, these two methods should be compared with different special generator procedures.

- Both methods are based on the “Select Zone Analysis”. For the analysis, Cube Voyager stores the path flows during the traffic assignment procedure and then produces the estimates based on the stored path flows. However, since the path flow patterns from traffic assignment are not unique, the estimates may only be one of the many possibilities. This issue needs further investigation.

- The numerical experiment suggested both approaches are acceptable and produce similar results. However, given that the link distribution percentage method is easier to implement, it is recommended for traffic impact analysis.

- The quality of the results produced by the link distribution percentage method depends on how well the trip generation module replicates the real scenario of the modeling area. With a well-developed trip generation module, there is no need to rely on the ITE Trip Generation Manual to estimate the trip generation from the new development. Consequently, the link distribution percentage method will produce accurate estimates. Indeed, since there is no need to introduce a special generator to capture the difference, these two methods coincide again.

CHAPTER 4
SUMMARY

4.1 Treatments of Special Generators

The sequential four step modeling procedure is still widely used in the transportation planning practices. In the first step of the procedure, the numbers of trips produced and attracted by each TAZ are estimated for each trip purpose by using trip rates from surveys, cross-classification analysis or regression analysis. However, the trip generation patterns of certain major/unique activity centers, such as military bases, universities, hospitals and major shopping centers, may not be captured by those standard rates or equations. As a remedy, those activity centers are represented as special generators and their trip attractions and productions are estimated in a different manner.

The treatments of special generators can be generally summarized in the following steps:

- Identification of special activity centers. Recognizing the limitation of the trip production and attraction models, potential special generators can be identified within the study area.

- Justification for introducing special generators. Trip productions may be estimated by using cross classification or regression analysis while attractions estimated with regular attraction rates. At the same time, the attractions of special activity centers may also be estimated by using special generator rates. The rates can be determined from the ITE Trip Generation Manual. These two estimates are then compared for each trip purpose for each potential special generator. If significant difference is observed for one particular zone, it will be incorporated in the model for special generator adjustments.

- Special generator adjustment. The difference of two attraction estimates is added to the model with respect to trip purpose. This can be done in different ways: in most models, the differences of trips are added to attraction only while in some models they are added to both production and attraction. In order to distribute additional trips into the appropriate trip purpose category, most models have specific trip-purpose distributions for each special generator.

- Balancing. After the adjustment for special generators, trip balancing will be performed. The balancing can be done to adjust all attractions (sometime production). However, it is feasible to maintain the special-generator attractions constant during the balancing process. In this case, the balancing adjustment factor is the difference between the total production and the total special-generator attractions divided by the total regular-generator attractions.

The inclusion of special generators is a way to force the model to replicate the real scenario of the study area, because special generators may adopt ad hoc attraction rates significantly different from the standard rates. With a number of special generators within a model, the model may lose generality and transferability. Therefore it is good practice to keep the number of special generators in the model to a minimum. The standard procedure of special generators in FSUTMS and the improved procedure in the lifestyle trip generation models have been successfully applied in many MPO models. However, the special generator rates used are mostly those recommended in the Model Update Task B. Those rates are about 30 years old, and there is a need to conduct more attraction-side surveys to update them.

4.2 Comparison of Traffic Impact Analysis Approaches

Traffic impact analysis can be generally performed by two approaches: the link distribution percentage method and the special generator method. In the former, dwelling units and employments of a new development are estimated and inserted into the trip generation input file, followed by a travel demand model run to derive the development traffic percentage of each link in the impact area. The percentages will then be applied to the external ITE-based trip generation of the new development to estimate the development flows and quantify its traffic impact. In the later approach, the new development is treated as a special generator whose attraction and possibly production can be manually calculated based on the ITE Trip Generation Manual, and will then be further adjusted during iterative runs of the model until the trips reported in the model match the ITE-based trip generation. Traffic assignment will then be conducted to quantify the impact of the proposed development on the traffic network. In this study, an empirical study was conducted to compare these two methods. The Alachua/Gainesville MPO model was used as the test bed. A number of scenarios of new developments were created by changing various characteristics of two hypothetical developments. The traffic impacts of those hypothetical developments were estimated by implementing these two methods respectively.

The conclusions from the empirical study include:

- These two methods produced pretty consistent estimates of traffic impacts caused by different hypothetical scenarios.

- The link distribution percentage method makes an implicit assumption that the link distribution percentage pattern remains relatively the same if a larger number of trips are generated in the new development. The assumption may not be valid, particularly when the network is congested, and the estimates of trip production from FSUTMS and the ITE Trip Generation Manual are substantially different. However, in our implementation the link percentages were relatively constant across the hypothetical scenarios.

- The link distribution percentage method is easier to implement than the special generator method.

- Given the above, the link distribution percentage method is recommended. However, we further caution that the estimates of traffic impacts may not be accurate for two reasons: one is due to the assumption of constant link distribution percentages, and the other is due to the use of “Select Zone Analysis”. For the analysis, Cube Voyager stores the path flows during the traffic assignment procedure and then produces the estimates based on the stored path flows. However, since the path flows are not unique, the estimates may only be one of the many possibilities.

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