Relationship Between Land Use Patterns and Highway Widening

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RELATIONSHIP BETWEEN LAND USE PATTERNS AND HIGHWAY WIDENING

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ABSTRACT

Perhaps one of the most controversial issues a community can face is the question of street widening. This topic has created a continuous debate between local government officials, transportation engineers and taxpayers. However, it is ironic that communities concerned about the costs and impacts of widening often take steps in their land development process that inevitably lead to the widening they oppose.

This report identifies two critical land use factors that lead to highway widening: street connectivity and land use density. Density in this case does not relate to independent variables like population but to the general level of activity in a study area given by the number of dwelling units and the retail and nonretail activities. Street design is evaluated in terms of the traffic present on arterials due to poor connectivity on local streets.

This study deals with three separate but related questions. The first one is what are reasonable thresholds in terms of traffic volumes for roadway widening. The second is how does land use policy specifically densities and dispersal of activities affect thresholds for road widening. Lastly, how does street connectivity affect arterial traffic volumes and widening thresholds.

For the first part a capacity analysis of two lane highways and different type of intersections is performed using the Highway Capacity Manual 2000 and the Highway Capacity Software 2000. Then, a case study using the City of Tallahassee, Florida's traffic network is conducted to develop a methodology to identify the land use activity and the traffic volume reduction on arterials due to the connectivity of residential streets. This report reveals that such traffic reduction highly depends on the relative speed on the arterial and the local roads.
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PART I: INTRODUCTION

People in American cities are continuously changing land use patterns with limited government control. Job opportunities, safety, better education, recreation, privacy and other factors have encouraged people to concentrate in certain points within the urban area and leave other locations with a relatively low level of activity. This phenomenon along with poor street connectivity are some of the principal causes for the inefficient use of a traffic network. Whereas there are several land use factors that affect travel behavior in a network, density and street connectivity are considered the most critical in this study. The evaluation of these two factors in the City of Tallahassee Florida’s traffic network was used as a reference to develop methods to relate density and street connectivity with roadway widening. Roadway widening for the purpose of this study relates to the addition of lanes to the existing roadway configuration.

Land use has become an important issue in the planning and organization of modern cities. Government officials, business people, and the general public are interested in this topic for different reasons. Local government, for example, might think that setting parameters in land use could be an effective way to solve problems of congestion and increase productivity in their cities. Business people would also like to know about land use to locate their businesses in convenient locations where products could reach valuable markets and generate higher revenues. The public in general has interests in land use when choosing a place to live or work.

Most transportation engineers agree that land use is the key for transportation systems to be sustainable in the future. However, lack of understanding of land use transportation interactions from the government has led communities to choose the location for their activities based on patterns contrary to their own particular interests. This phenomenon has generated multiple consequences. This report addresses the dispersal of activities and the inefficient street connectivity as they affect thresholds for roadway widening. It is important to find what levels of land use activity would result in a network that operates at volumes that balance street capacity and use efficient street designs. By doing that, highway widening can be avoided and the transportation network could be used in a more efficient way.
“The hypothesis of this study is that improved connectivity of residential streets will reduce the traffic volumes on nearby arterials.”

INTRODUCTION

The hypothesis of this study is that improved connectivity of residential streets will reduce the traffic volumes on nearby arterials. It is clear however, that there is a critical balance between connectivity and through traffic. Enough connectivity has to be provided so that residents of a neighborhood can easily move to all edges of the neighborhood and adjacent land uses, but not so much that neighborhood streets become attractive choices for through traffic to avoid congestion and delay on arterials.
PART II BACKGROUND AND LITERATURE REVIEW

This literature review includes three sections: The first section: “Land Use Factors that Affect Travel Behavior” gives background information to understand the relationship between land use and highway widening as well as to limit the scope of the study. In the second part, accessibility is analyzed more closely and two street patterns (Neotraditional and Conventional Design) are compared in terms of capacity and their benefits for alternative transportation modes. The last part of the literature review describes the trip table estimation concept. Some background information about this relatively new theory is presented and the model used in this study is explained in detail.

2.1 Land Use Factors that Affect Travel Behavior

Several land use factors affect travel behavior in urban and suburban communities. In the paper “Land Use Impacts on Transport” (Litman, 2003) taken from the TDM Encyclopedia of the Victoria Transport Policy Institute, land use factors are placed together into four different categories: Density and Clustering, Land Use Mix, Roadway Design, and Site and Building Orientation. This portion of the literature attempts to find out which of these land use patterns have the greatest effect on travel behavior so that they can be analyzed in more detail and narrow the scope of this study.

Density and Clustering

“Density refers to the number of people or jobs in a given area whereas Clustering refers to common destinations located closed together.” (Litman, 2003, Pg.1). Density and clustering affect travel behavior through different mechanisms, such as land use accessibility, transportation choice and the implementation of space efficient modes.

Land use accessibility in particular refers to the proximity of origins and destinations within a geographic area. Proximity in this case is not taken as the physical distance between two points but as a measure of the time and convenience to travel from point A to point B. Certainly, communities with increased density and origins closer to destinations favor walking, bicycling and other alternative transportation modes.
“Land use mix not only reduces the travel distance of some trip purposes but also promotes changes in mode split in favor of alternative transportation modes.”

BACKGROUND AND LITERATURE REVIEW

Transportation choice on the other hand, relates to the increased number of transportation options generated in a geographic area due to economies of scale. In downtowns or other high-density areas, for example, transportation facilities can be conveniently located so that people can choose to travel by car, bicycle, walking or transit.

The idea of “space efficient modes” is that in dense areas, where problems of congestion are critical, alternative transportation modes that offer higher occupancy rates are more convenient. Space efficient modes may also be more environmentally friendly.

Land Use Mix

Land use mix not only reduces the travel distance of some trip purposes but also promotes changes in mode split in favor of alternative transportation modes. “Aesthetically-pleasing urban character and amenities at worksites, such as shops and restaurants within walking distance, can reduce errand trips and increase transit and rideshare use, because without these, employees may feel the need to have a car to run errands during brakes [sic].” (Cambridge Systematics, 1994). “One study found that the presence of worksite amenities such as banking services (ATM, direct deposit), on-site childcare, a cafeteria, a gym, and postal services could reduce average weekday car travel by 14%, due to a combination of reduced errand trips and increased ridesharing. (Davidson, 1994).” (Litman, 2003, Pg.5).

Land use mix has a positive impact for trip purposes such as Home to Shopping, Home to Social/Recreation, and Home-to-School but the question about its convenience for Home-to-Work trips remains open. Although some people find it very attractive to live close to their worksites, some researchers argue that few people choose residential locations to minimize commute distances. In that case, even if the conditions for a land use mix are present, the length of home based work trips may not change and more through traffic would be generated in these communities.
BACKGROUND AND LITERATURE REVIEW

Roadway Design

“Traffic modeling by Kulash, Anglin and Marks (1990) predicts that a connected road network reduces VMT within a neighborhood by 75% compared with conventional designs.” (Litman, 2003, Pg.9). Other authors (Knack, 1989) state that trips made on a daily basis are usually completed within an 3000-4000 acres area and for that reason few automobile trips would ever use the arterials in neighborhoods with Neotraditional Design. Some critics argue however, that road networks with improved accessibility might encourage people to make more trips to the point of having the same levels of congestion found in street patterns with poor connectivity.

As it is shown in Table 2.1, Susan L. Handy (1992) selected four case study communities within the San Francisco Bay Area with different levels of local and regional accessibility. She tried to prove that the common belief that accessibility reduces non-work driving trips is not always right.

<table>
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<th>High Local Accessibility</th>
<th>Low Local Accessibility</th>
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<td>High Regional Accessibility</td>
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<tr>
<td>Low Regional Accessibility</td>
<td>Santa Rosa - Junior College</td>
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Table 2.1 Case Study Selection Matrix

Accessibility in these areas was evaluated using available data, planning documents, maps, and extensive field surveys. A phone survey of 100 residents in each area was also conducted to find the relationship between accessibility and travel patterns of the residents in these communities. The study concluded that even though it is true that people living in neighborhoods with higher levels of accessibility make more...
non-work trips and use alternative transportation modes more often, there is still a question of whether these trips replace or are in addition to driving trips. Additionally, “downtown trips did not seem to replace trips to regional shopping centers. It could not be determined to what degree trips to downtown replaced or were made in addition to trips to regional centers.” (Handy, 1992, Pg.17).

Other people like Crane (1999), suggest that accessibility is just one part of the transportation management strategies to discourage the use of automobile. If it is applied without other measures like parking restrictions, gas price and improved transit facilities, it could result in higher levels of congestion.

Site Design and Building Orientation

“Some research indicates that people walk more and drive less in areas with traditional pedestrian-oriented commercial districts where building entrances connect directly to the sidewalk than in areas with automobile-oriented commercial strips where buildings are set back and separated by large parking lots (Moudon, 1996),” (Litman, 2003, Pg.8). Building orientation can either neglect or provide an attractive environment for pedestrians and bicyclists. Large parking lots might disperse activities, which discourage land use mix and therefore make origins and destinations farther away. A study called “Building Orientation - A Supplement to the Pedestrian Environment” by Parsons Brinckerhoff Quade and Douglas, Inc., Cambridge Systematics, Inc. and Calthorpe Associates reveals that an increased number of buildings being set back from front lot lines and from one another will encourage the use of the automobile even for relatively short trips. The study also states that it has been difficult to estimate the effects of traditional building orientation and setback in quantitative terms.

Background

Advocates of New Urbanism and Smart Growth usually point at accessibility as one of their most significant principles. Although accessibility and mobility are similar in some ways, it is important to make a distinction between them. Accessibility is defined as the ability to connect activities, while mobility is a measure of the vehicle-miles or
person-miles involved in travel. In most cases higher values for mobility could be an indication of congestion whereas increasing accessibility is usually associated with reduction of congestion.

Providing a street layout that improves accessibility generates a number of benefits, such as encouraging bicycle and pedestrian trips and decreasing vehicle miles. It can make developments more livable and sustainable in the future.

Accessibility could be as broad as one can imagine because it deals with different topics, such as street connectivity, land use mix and building orientation. This report concentrates in street connectivity where two street designs, Neotraditional Design and Conventional Design, are compared and analyzed in detail.

For the purpose of this study, Neotraditional Design (NTD) will be defined as the interconnected rectilinear grid commonly used before World War II and Conventional Design as the discontinuous patterns of cul-de-sacs preferred since the 1950s.

“Over the past century American conceptions of the residential street network have changed dramatically from the interconnected rectilinear grid of the turn-of-the-century, to the fragmented grid and warped parallel streets of the 1930s and 1940s, to the discontinuous, insular patterns of cul-de-sacs and loops that have preferred since the 1950s.” (Southworth and Ben-Joseph, 1997, Pg.2). See Figures 2.1 to 2.3. However, it has been demonstrated that Neotraditional Design and Conventional Design both have advantages and disadvantages.

An efficient street design should be developed to satisfy the needs of society by taking the benefits of these two concepts.

2.2.1 Street Connectivity
BACKGROUND AND LITERATURE REVIEW

Institutionalization of standards

In 1936 the Federal Housing Administration (FHA) indicated its preference for a hierarchical structure in street layouts by the publication of standards that encouraged curvilinear, cul-de-sacs and courts layouts.

At the same time, the FHA criticized the conventional grid pattern for residential neighborhoods commonly used up until that decade because of the monotony of its appearance and elevated costs of its construction. The following standards were taken from publications of the FHA by that time:

- Layouts should discourage through-traffic;
- Streets should follow the topography to reduce costs, create interesting vistas, and eliminate the monotony of long straight rows of houses;
- Cul-de-sacs are the most attractive street layout for family dwellings. (Southworth and Ben-Joseph, 1997, Pg.92).

Figure 2.1 Evolution of the Street Design

(Southworth and Ben-Joseph, 1997)
BACKGROUND AND LITERATURE REVIEW

The idea of the new street pattern was to locate convenient stores on the neighborhood edges along arterials, whereas schools and common areas would be located in the middle.

In 1965 the Institute of Transportation Engineers published a paper “Recommended Practice for Subdivision Streets” aimed to increase standards of livability. This paper continues ideas of the Federal Housing Administration in 1936, where they criticize grid patterns and support the idea of cul-de-sacs and curvilinear street designs. Some of these principles of the ITE recommendation were as follows:

- Local streets should be designed to discourage excessive speed through the use of curvilinear patterns and discontinuities.
- There should be minimal intersections with preference for T rather than four-leg intersections.
- Local streets should be related to topography. (Southworth and Ben-Joseph, 1997, Pg.93).

Although several variables must be included in a comprehensive comparison of street patterns, this analysis will emphasize the difference in terms of traffic capacity and the benefits for alternative transportation modes between the Neotraditional and the Conventional Design. Accidents, social benefits and economic issues will be described only as a reference.
“Improving connectivity in a network not only makes origins and destinations closer to each other but also can increase traffic capacity of a network.”

Traffic Capacity

Improving connectivity in a network not only makes origins and destinations closer to each other but also can increase traffic capacity of a network. Different authors have mentioned that NTD has superior traffic capacity over Conventional Designs, arguing that traffic capacity in a given network depends almost entirely on its intersections rather than on the capacity of the streets.

The increasing number of intersections available in the NTD, as it is shown in Figure 2.5, allows traffic to spread out in a more uniform manner throughout the entire network and therefore only a small portion of the total volume concentrates at a particular intersection.
BACKGROUND AND LITERATURE REVIEW

Walter Kulash brought up the following example at the 11th Annual Pedestrian Conference in Bellevue WA (Kulash, 1990, Pg.4) to better understand the difference between Neotraditional and Conventional Street Designs in terms of capacity.

Due to the lack of access points in the Conventional Street Design, large traffic volumes meet at intersections like the one shown in Figure 2.4, which commonly have a four-lane divided and six-lane divided arterial street: each having left-turn lanes and protected left-turn signals. If we assume a traffic volume of 3000 vph on the six-lane street and 2000 vph on the four-lane street, and turning movements of 300 and 200 vph, respectively, for the major left turn movements, the intersection would be operating at upper limit of level of service E. The same traffic volume on the same amount of pavement can be accommodated by a pair of two-lane streets intersecting three parallel two-lane streets. (Kulash, 1990, Pg.4).

Figure 2.4 Intersections in a Conventional Street Design

Figure 2.5 Intersections in a Neotraditional Street Design
As it is shown in Figures 2.4 and 2.5 one single intersection in the Conventional design would be replaced by six intersections in the TND using the same number of lanes. “This large number of intersections reduces the turning movement load at any given intersection to a fraction (one-sixth in this example) of the turning movement load that exists in the Conventional Suburban Development Pattern. Consequently, the entire system can carry greater traffic volumes at the same level of traffic service.” (Kulash, 1990, Pg.4).

If it is true that traffic capacity is function of the intersection’s capacity, then the critical point in intersections capacity is the number of left turns that go through the intersection in a certain period of time. As it is shown in Figure 2.6, the increased number of intersections in the NTD provides numerous opportunities for a particular driver to make a left turn. Since traffic is spread out in the network left turns can be easily made using acceptable gaps provided by the opposing traffic flow.

Advantages for turning movements of the NTD over the conventional design could be summarized as follows:

- In the Conventional Design vehicles gather at few intersections, which represents higher traffic volumes and smaller gaps between vehicles in the opposing flow. This situation requires the use of traffic signs and signals, which can create excessive delays for the opposing traffic and reduce capacity.

- Larger intersections in the conventional design mean that more lanes will be introduced at any specific intersection. In order for a gap to be acceptable vehicles must be paired in each lane so that vehicles waiting for the left turn will be able to go through.

- As it is seen in Figure 2.4 and 2.5, while the Conventional Design have three lanes at each approach, the NTD have only two. This means that left turning vehicles in the conventional design will have to clear twice the distance than any turning vehicle in the NTD. This creates longer cycle times and thus more delays at intersections.
“Although some Conventional neighborhoods have pedestrian paths, their designs usually require pedestrians to walk distances greater to what they want to walk.”

**Pedestrian Access**

Although some Conventional neighborhoods have pedestrian paths, their designs usually require pedestrians to walk distances greater to what they want to walk. “The distance Americans will walk for typical daily trips is limited, varying from 400 feet (120m) to about ¼ mile (400m). Untermann found that 70 percent of Americans will walk 500 feet (150 m) for daily errands and that 40 percent will walk about 1/5 mile (320m); only 10 percent will walk ½ mile (800m). Similarly, Barber found that the distance people walked for typical trips varied between 400 and 1200 feet (120-370 m).” (Southworth and Ben-Joseph, 1997, Pg.107). Figure 2.7 shows the environment for pedestrians in a Neotraditional Street Design.
"The problem with cul-de-sacs is not only that pedestrians are forced to walk longer distances but also that they do not have as many path selections as they have in the NTD."

The problem with cul-de-sacs is not only that pedestrians are forced to walk longer distances but also that they do not have as many path selections as they have in the NTD. Accessibility is an issue for pedestrians and non-motorized travel because when their trip purpose is other than pleasure, travelers want to reach their destinations in the fastest and most convenient way.

The principal advantage of the Neotraditional Design over the Conventional Design in terms of pedestrian access is that Neotraditional neighborhoods have more mixed land uses. For this reason, an increased number of origins and destinations are located...
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within a walking distance so that people who want to go to the grocery store, the library or a coffee shop can choose between walking or driving. This would not be possible in neighborhoods with Conventional Street Design since residential developments are isolated from other land uses and most of the trips depend on the automobile.

Other Issues

- **Real-Time Route Selection**

  Another important advantage of NTD is that real-time route selections are most likely to happen. That means that during peak hours, for example, people can change their path selection avoiding traffic congestion. This is more difficult under the street configuration of the conventional design.

- **Accidents**

  Since the 1950 traffic engineers have paid special attention to the relationship between street design and crashes. One of the first traffic studies about safety in residential subdivisions, conducted in Los Angeles between 1951 and 1956, compared crashed rates in grid patterns and curvilinear designs. “The study results showed that accident rates were substantially higher for grid-pattern subdivisions: Fifty percent of all intersections in the grid pattern had at least one accident during the five-year period. In contrast, only 8.8 percent of the intersections in the limited-access pattern had accidents during that period. Overall, T intersections were found to be fourteen times safer than in the grid tracts.” (Southworth and Ben-Joseph, 1997, Pg.92). Although the study was not sensitive to neighborhood density and traffic volume, it became a strong argument to support the hierarchical pattern set by the FHA. Additionally, T intersections can be used as a way to permit good local connectivity while at the same time making it more difficult for through traffic.

  In a more recent study, (1995) Eran Ben-Joseph compared nine different neighborhoods in California in terms of safety and residents’ perception of their street’s livability. Although these neighborhoods have different street layouts: grid, loop and cul-de-sacs, they were matched demographically. The results reveal that people prefer cul-de-sacs, especially the lots at the end, because they feel that streets are safer and
BACKGROUND AND LITERATURE REVIEW

quieter when through traffic volumes are low. They also argue that in the cul-de-sac pattern they get to know their neighbors better, increasing their levels of safety and livability.

Traffic speed, which is one of the principal causes of accidents, is a controversial point for NTD and Conventional Design supporters. Authors like Walter Kulash affirm “the travel speed profile for a NTD generally shows a lower peak speed and shorter, more frequent intersection delays than on a Conventional design. The Conventional Suburban Development trip, made mainly on major arterial streets, is typified by a pattern of high speeds for short segments of road, interspersed with long traffic signal delays at individual traffic signals,” (Kulash, 1990, Pg.8). On the other hand, Conventional Design supporters claim that despite of the speed in the arterial streets, low traffic volumes and reduced speeds in the cul-de-sac make the Conventional Design safer for children playing in the streets.

➢ Social Benefits

One cannot easily compare grid patterns and cul-de-sacs in terms of social benefits because the latter ones have an inherent advantage over the conventional grid design. Factors, such as high speed and aesthetics make grid patterns inconvenient for most people. However, if the evaluation is made between cul-de-sacs and grid patterns built under the concept of New Urbanism, the comparison becomes pertinent. Grid patterns under those conditions promote a civic spirit, encourage multimodal transportation and create areas where kids can play and neighbors have a closer interaction.

Even though benefits of cul-de-sacs are often controversial, it can be argued, for example, that cul-de-sac provide a more efficient way to increase safety not only for kids playing in the streets but also in terms of preventing crimes. It has been demonstrated that criminals prefer neighborhoods with more street choices (grid patterns) where they can escape easily after committing a felony than cul-de-sacs where they spend some more time finding their way out. (Mayo, 1979).
2.2.3 Connectivity and the Future

“Traffic engineers must find the balance between the convenience of NTD and the safety and social benefits offered by Conventional Designs.”

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Street design is an important issue for planners and engineers. “In a recent nationwide survey of public works departments of 75 cities, more than half expressed willingness to reexamine their residential street standards and regulations. Furthermore, almost 70 percent of the cities were either taking or planning some traffic control measures in residential neighborhoods, and about 50 percent of the engineers surveyed knew of the shared street concept and its benefit to the residential setting.” (Southworth and Ben-Joseph, 1997, Pg.132).

Successful street designs that provides connectivity and supply the needs of travelers will be achieved after taking the advantages of both Neotraditional and Conventional Designs. Traffic engineers must find the balance between the convenience of NTD and the safety and social benefits offered by Conventional Designs.

Grid patterns were unsafe in the old set up but concepts like New Urbanism, Traffic Calming and use of T intersections can make Neotraditional neighborhoods safer and more convenient for automobiles and non-motorized modes of transportation. The following concepts will play a vital role in the development of cities in the near future.

The Shared Street Concept

The shared street concept tries to keep the functionality and efficiency of the grid pattern used in the Neotraditional developments and at the same time integrates the safety and livability of the Conventional design. Refer to Figure 2.8.

The main goal of this concept is that vehicles, pedestrians and bicycles will share the space in the streets. “Since this emancipation of the pedestrian environment is done with full integration of vehicular traffic, it is not an anti-car policy.” (Joseph-Ben, 1997, Pg.50).
Figure 2.8 The Shared Street Concept

(Southworth and Ben-Joseph, 1997)
BACKGROUND AND LITERATURE REVIEW

The shared street idea is based on the grid design concept in the sense that, although in different conditions, it promotes accessibility not just for automobiles, but also for pedestrians and bicyclists.

Looking at the evolution of the form since its inception, several design characteristics are typical of a shared street:

- It is a residential, public space.
- Through traffic is discouraged.
- Paved space is shared by pedestrians and cars, with pedestrians having priority over the entire street. Walking and playing are allowed everywhere.
- It can be a single street, a square (or other form), or a combination of connected spaces.
- Its entrances are clearly marked.
- There are no conventional, straight stretches of pavement with raised curbs, and the pavement (carriageway) and sidewalk (footway) are not rigidly demarcated.
- Car speed and movement are restricted by physical barriers and deviations, bends, and undulations.
- Residents have automobile access to their dwelling fronts.
- The area has extensive landscaping and street furnishings. (Southworth and Ben-Joseph, 1997).

Interconnected cul-de-sacs

Interconnected cul-de-sacs provide the convenience of a cul-de-sac and promote other transportation alternatives such as walking and bicycling. Refer to Figure 2.9. The interconnection is achieved by the construction of bicycle/pedestrian paths between cul-de-sacs so that the accessibility neglected to pedestrians and bicyclists by the conventional street design is somewhat improved.
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Interconnected cul-de-sacs have been criticized because they will never provide similar values of accessibility for bicycles and pedestrians than the ones achieved by the grid design and the accessibility problems for automobiles remain unsolved. However, they are substantially better than isolated cul de sacs in that they do allow short cuts between streets and more direct routes.

(Southworth and Ben-Joseph, 1997)

Figure 2.9 Interconnected cul-de-sacs
BACKGROUND AND LITERATURE REVIEW

Street Closures

Street closures used in neighborhoods built under the grid pattern are a way to reduce automobile traffic and promote other transportation modes such as bicycle and walking. As it is shown in Figure 2.10 the idea behind this concept is to keep the connectivity benefits of the grid design for pedestrians and bicyclist whereas restricting connectivity for automobiles so that they must drive slower and therefore safer. Critics of this concept argue that more than decreasing connectivity it is inconvenient for drivers who are not familiar with the area. Besides, street closures usually increase vehicle miles and all the problems associated with it.

Figure 2.10 Street Closures

(Beimborn, 2002)
BACKGROUND AND LITERATURE REVIEW

Variation on a Grid

This street design concept is an alternative to reduce through traffic while promoting transit service in neighborhoods built under a Grid Pattern. The following figures show some examples on how changes in the streets’ geometry can be made to reduce through traffic in local roads while still maintaining connectivity.

Figure 2.11 shows a grid with limited access to the arterials where only few changes from the original layout are necessary. The following alternative, Figure 2.12, introduces cul-de-sacs into the street design. Although it is clear that this street design reduces through traffic it also maintains a high degree of connectivity. (Beimborn and Rabinowitz, 1991, Pg.113).

Figure 2.11 Grid With Limited Access to Arterials

Figure 2.12 Grid With Cul-de-Sacs
BACKGROUND AND LITERATURE REVIEW

Variation on a grid gives more opportunities for alternative transportation modes but especially for transit. Despite the modifications to the grid configuration, pedestrian pathways are direct and the high residential density necessary for a successful transit service remains intact. If no transit service were provided, the patterns can still be used to improve connectivity without attracting through traffic.

The purpose of trip table estimation is to develop origin-destination tables that match traffic counts. The method was developed to provide a tool to find out how much land use activity could occur in different locations to match a network with fixed roadway capacities. In short, the aim is to find out how a community could grow without having to widen highways.

Origin-Destination (O-D) table refinement is a relatively new feature implemented in travel forecasting software packages. In fact, this technique is considered a new area of work and still quite experimental. The trip table estimation concept relies in the idea that a new or adjusted Origin-Destination table can be calculated to match traffic counts encountered in the real world. Although the applicability of this theory to real transportation problems is still under study, the method has potential to use for network calibration and land use forecasting.

The principal problem in trip table refinements is that a large number of different O-D matrices can reproduce the observed traffic counts. It is important to make sure that the adjusted trip table does not deviate much from the original trip table, usually referred as “seed trip table,” and at the same time that the model is giving an acceptable approximation to the traffic counts. “Some models solve this problem by postulating a general model of trip distribution, for example a gravity type model, while other models adopt statistical inference techniques.” (Abrahamsson, 1998, Pg.1).

There are two types of trip tables: Static and Dynamic. When traffic counts only exist for one time period the analysis will be considered Static. Otherwise, the analysis will be Dynamic. Likewise, there are several methods for table refinement. Since the method used in this study is the “General Least Squares (GLS) Fratar Biproportional

---

2.3 Origin-Destination Table Refinements

"The method was developed to provide a tool to find out how much land use activity could occur in different locations to match a network with fixed roadway capacities."
BACKGROUND AND LITERATURE REVIEW

Static Method,” this will be described with more detail and the reason for its selection will be addressed as well.

As Abrahamsson (1998) describes it, there are two modeling approaches to O-D table estimation. The first one is the traffic modeling based approach where the “entropy maximizing” model is the most commonly used. The other group corresponds to the statistical inference approaches where the Generalized Least Squares (GLS) model is the most recognized. It is also one of the models executed by the Quick Response System (QRS II) software, which is used for the trip table estimation in this study.

Traffic Modelling based Approaches

Traffic modelling based approaches are used when the traffic count information is not enough to determine a unique O-D matrix. In these cases it is reasonable to use a minimum information O-D matrix “that adds as little information as possible to the information in the target O-D matrix, while taking the equations relating the observed traffic counts with the estimated O-D volumes into account.” (Abrahamsson, 1998, Pg.6).

The Entropy Maximization method is a popular approach for trip table estimation in this category. Authors like Horowitz (2003) affirm that the Entropy Maximization can produce a nearly perfect fit to traffic counts, but can cause substantial, uncontrolled, distortions to the seed trip table.

Statistical Inference Approaches

This modelling group includes the Maximum Likelihood (ML), Bayesian Inference and the Generalized Least Squares (GLS) approaches. The Fratar Biproportional (Static), which is a GLS approach, is used in this study and it will be covered in the following section. The idea behind all these models is that both the traffic volumes and the target O-D matrix are generated by some probability distributions.
BACKGROUND AND LITERATURE REVIEW

- Fratar Biproportional GLS (Static)

The Generalized Least Squares methods assumed that the refined table is determined from the seed trip table with a probabilistic error term. Similarly, the traffic counts are obtained from a stochastic equation as follows:

\[
\hat{g} = g + \eta \\
\hat{u} = \nu(g) + e
\]  
(Equ 2.1)

Where,
- \(\hat{g}\) is the target OD matrix,
- \(g\) is the original trip table,
- \(\hat{u}\) are the observed traffic counts,
- \(\nu\) is the estimated flow,
- \(\eta\) is the probabilistic error that relates \(\hat{g}\) with \(g\), and
- \(e\) is the error that relates \(\hat{u}\) with \(\nu(g)\).

"Cascetta (1984) concludes that estimations or even “heavy approximations” of the dispersion matrix produced better results than a maximum entropy estimator." (Abrahamsson, 1998, Pg.11).

The Fratar Biproportional GLS Static Method minimizes the following equation:

\[
\min \ P = \sum_{a=1}^{A} W^a \left( V^a - s \sum_{i=1}^{N} \sum_{j=1}^{N} P_{ij}^a x_i y_j T_{ij}^a \right)^2 + z \sum_{i=1}^{N} \sum_{j=1}^{N} T_{ij}^{x^2} (1 - x_i y_j)^2
\]  
(Equ 2.2)
BACKGROUND AND LITERATURE REVIEW

"The Fratar Bipropotional GLS method is appropriate for situations such as peak period analysis where the number of origins from and the number of destinations to a particular zone are likely to be unequal" (Horowitz, 2003, Pg.194). The Tallahassee network, used as a case study in this report, is analyzed for the afternoon peak hour where most of the trips are going from the attraction to the production direction. For that reason the Fratar Bipropotional GLS (static) was chosen for the trip table refinement. Additionally, some authors like Cascetta (1984) conclude that the "heavy approximations" of the production matrix used in the GLS methodology produces better results than a maximum entropy estimator, the other model available in QRSII.

2.4 Summary

As it is described in the first section of this literature review there are several land use factors that affect travel behavior. However, for the purpose of testing the relationship between land use and highway widening, only land use density and street connectivity will be considered. One of the reasons for this selection is that the impact of street connectivity in travel behavior is still under debate. Further research is needed to prove or contradict theories proposed by different authors about this topic. The other reason is that other land use factors, such as land use mix and building orientation are
BACKGROUND AND LITERATURE REVIEW

“More capacity can be attained in a grid pattern since there are more intersections per unit area in a neighborhood with a Neotraditional Design (grid pattern) than in one with Conventional Design (cul-de-sacs).”

part of density and street design. For the case study analyzed in this report, when land use density, represented by the number of households, retail and nonretail activities, increases and the street design provides acceptable levels of accessibility it is very likely to find land use mix and efficient building orientation.

The connectivity of neighborhood streets could have an impact in highway capacity. Authors like Kulash affirm that more capacity can be attained in a grid pattern since there are more intersections per unit area in a neighborhood with a Neotraditional Design (grid pattern) than in one with Conventional Design (cul-de-sacs). The increasing number of intersections available in the NTD makes traffic spread out in a more uniform manner throughout the network and therefore only a small portion of the total volume concentrates at a particular intersection. For that reason, larger gaps between vehicles in the opposing flow are expected and it would be easier for vehicles to make left turns without the use of traffic signals that increase the delay at intersections.

The most appropriate model for O-D trip table estimation for situations such as a peak period analysis where the number of origins and destinations to a particular zone are likely to be unequal is the Fratar Biproportional GLS (Static). This method that belongs to the statistical inference approaches assumes that the refined table is determined from the seed trip table with a probabilistic error term.
PART III: FRAMEWORK

3.1 Capacity Analysis

Before a methodology for relating land use patterns and highway widening is developed, a capacity analysis was necessary to define threshold levels for congestion. The capacity analysis presented in this chapter has two parts. The first deals with the study of two lane highways. This type of arterial was selected for the connectivity analysis and is the most common type found in the City of Tallahassee. However, since the capacity of a roadway also depends on the capacity of its intersections, several types of intersections are also analyzed using the Highway Capacity Software 2000.

The flow chart shown in Figure 3.1 describes the procedure used for this report and presented in this chapter. Two land use factors, street connectivity and land use density, are analyzed and their influence in roadway widening (addition of lanes) is determined. The street connectivity analysis has a network construction phase where local streets are coded with connectivity improvements. The demographic information is subdivided and assigned into multiple centroids for each traffic analysis zone. Finally, traffic volumes on the arterial selected for this analysis are compared before and after connectivity is improved. In the land use density part, a capacity analysis using the Highway Capacity Manual and the Highway Capacity Software is performed to find the threshold volumes and intersection capacity for roadway widening. Then a trip estimation process is used to calculate land use activity adjustments so that the traffic volume on the network does not exceed the threshold values for roadway widening.

“A two-lane highway is an undivided roadway with two lanes, one for use by traffic in each direction. Passing a slower vehicle requires use of the opposing lane as sight distance and gaps in the opposing traffic stream permit.” (Highway Capacity Manual, 2000). Due to its geometric and operational characteristics the level of service in a two-lane highway is measured not only in terms of travel speed but also in the inconvenience generated by the formation of platoons.
FRAMEWORK

Figure 3.1 General Procedure to Find the Relationship Between Land Use Patterns and Highway Widening
Relationship Between Land Use Patterns and Highway Widening

HIGHWAY WIDENING

Street Connectivity

- Network Construction
- Connectivity Improvements
- Demographic Info. Refinement
- Traffic Volumes Comparison (Before and After Connectivity)

Land Use Density

- Capacity Analysis
- Threshold Volumes
- Intersection Capacity
- Trip Estimation Process
- O-D Factors
- No of Vehicles Entering/Leaving the TAZs
- Land Use Activity Adjustment Display

Interpretation and Analysis
"Level of service is calculated in the HCM 2000 based on two parameters: percent time-spent-following (PTSF) and average travel speed (ATS)."

Level of service is calculated in the HCM 2000 based on two parameters: percent time-spent-following (PTSF) and average travel speed (ATS). PTSF reflects the convenience of travel and it is measured as the average percentage of time that vehicles spend following slower vehicles in a platoon. ATS is an indicator of mobility and it can be determined as the length of a highway segment divided by the average travel time of the vehicles present in both directions during a specific period of time.

The HCM also defines two types of two-lane highways. The first one, Class I, is a two-lane highway in which drivers expect to reach high travel speeds. A major intercity route or a primary arterial connecting urban with suburban areas could be taken as an example for this category. Class II corresponds to two-lane highways that provide more accessibility than Class I. In this category drivers do not expect to travel at high speeds.

The case study presented in this report and especially the corridor selected for the connectivity analysis considers principal arterials as two-lane, class I highways. In that case mobility is highly important and the level of service is calculated based on both the percent time-spent-following and the average travel speed using the criteria shown in Table 3.1:

<table>
<thead>
<tr>
<th>LOS</th>
<th>Percent Time-Spent Following</th>
<th>Average Travel Speed (mi/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>= 35</td>
<td>&gt;55</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 35-50</td>
<td>&gt;50-55</td>
</tr>
<tr>
<td>C</td>
<td>&gt;50-65</td>
<td>&gt;45-50</td>
</tr>
<tr>
<td>D</td>
<td>&gt;65-80</td>
<td>&gt;40-45</td>
</tr>
<tr>
<td>E</td>
<td>&gt;80</td>
<td>= 40</td>
</tr>
</tbody>
</table>

Table 3.1 LOS Criteria for Two-Lane Highways in Class I
Source: Exhibit 20-2 HCM

FRAMEWORK

Level of Service
The purpose of the capacity analysis done in this study is to find out a demand volume for the full peak hour \((V)\), for which the level of service is located in the boundary between LOS D and E. This could be considered a threshold for road widening.

For example, a road with a percentage spent following of 40 and an average travel speed of 55 mph will have a level of service B.

Figure 3.2 is the graphical representation of Table 3.1.

**Demand Volume for the Full Peak Hour**

The purpose of the capacity analysis done in this study is to find out a demand volume for the full peak hour \((V)\), for which the level of service is located in the boundary between LOS D and E. This could be considered a threshold for road widening. That means that when traffic volumes exceed this value, consideration should be given to widening as a means to avoid congestion. This volume is calculated for the most probable conditions and therefore it is necessary to perform a sensitivity analysis.
The spreadsheet shown in Figure 3.3 allows the user to calculate the average travel speed, the percent time spend following, and the LOS for different traffic volumes. It is also used for the sensitivity analysis.

Enter the following information:

<table>
<thead>
<tr>
<th>Determining Free-Flow Speed:</th>
<th>Determining Demand Flow Rate:</th>
<th>Calculating ATS and PTSF:</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFFS: (default=60) 60 mi/h</td>
<td>V: (demand volume for the full peak hour) 1500 veh/h</td>
<td>no-passing zones (%): (default=20-50) 20</td>
</tr>
<tr>
<td>Lane Width: (default=12, min=9) 12 ft</td>
<td>PHF: 0.90</td>
<td>Directional Split: (default=50/50) 50/50</td>
</tr>
<tr>
<td>Shoulder Width: (default=6 ft) 6 ft</td>
<td>Type of Terrain: (Level=L / Rolling=R) L</td>
<td></td>
</tr>
<tr>
<td>Acess Points/mi: (max=40) 15</td>
<td>ProportionTrucks: (0-1) (default=0) 0.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proportion RVs: (0-1) 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type of Analysis: (Two Way Highway=T / Directional =D) T</td>
<td></td>
</tr>
</tbody>
</table>

Calculations:

<table>
<thead>
<tr>
<th>FFS: 56.25</th>
<th>Vp (speed): 1683</th>
<th>Vp (Time following): 1667</th>
</tr>
</thead>
<tbody>
<tr>
<td>f_L: 0</td>
<td>f_G: 1.00</td>
<td>f_G: 1.00</td>
</tr>
<tr>
<td>f_A: 3.8</td>
<td>E_T: 1.10</td>
<td>E_T: 1.00</td>
</tr>
<tr>
<td></td>
<td>E_R: 1.00</td>
<td>E_R: 1.00</td>
</tr>
<tr>
<td></td>
<td>f_HV: 0.99</td>
<td>f_HV: 1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ATS: 42.63</th>
<th>PTSF: 79.72</th>
<th>LOS: D</th>
</tr>
</thead>
<tbody>
<tr>
<td>f_np: 0.56</td>
<td>f_dnp: 2.8</td>
<td>BPTSF: 76.9</td>
</tr>
</tbody>
</table>

Figure 3.3 Spreadsheet for Two-Lane Highways Capacity Calculation
Average Travel Speed

The average travel speed is calculated based on the free flow speed (FFS), the demand flow rate ($V_p$) and an adjustment factor for the percentage of no-passing zones as follows:

$$ATS = FFS - 0.00776V_p - f_{np}$$

(Equ 3.1)

Where,

- $ATS$ is the average travel speed for both directions of travel combined (mi/h),
- $f_{np}$ is the adjustment for percentage of no-passing zones (see Exhibit 20-11, HCM 2000) and,
- $V_p$ is the passenger-car equivalent flow rate for peak 15-min period (pc/h).

The free flow speed (FFS) is calculated using the following equation:

$$FFS = BFFS - f_{LS} - f_A$$

(Equ 3.2)

Where,

- $BFFS$ is the base FFS (mi/h),
- $f_{LS}$ is an adjustment for lane width and shoulder width, from Exhibit 20-5 (HCM 2000), and
- $f_A$ is an adjustment for access points, from Exhibit 20-6 (HCM 2000).

The passenger-car equivalent flow rate for peak 15 min period, $V_p$, is determined using Equation 3.3.

$$V_p = \frac{V}{PHF * f_G * f_{HV}}$$

(Equ 3.3)
Where,
\[ V \] is the demand volume for the full peak hour (veh/h),
\[ PHF \] is the peak-hour factor,
\[ f_G \] is the grade adjustment factor, and
\[ f_{HV} \] is the heavy-vehicle adjustment factor.

\[ \text{Percent Time Spent Following} \]

The percent time spent following depends on the demand flow rate, the directional distribution of traffic, and the percentage of no-passing zones and it is calculated as follows:

\[ PTSF = BPTSF + f_{d/np} \]  
(Equ 3.4)

Where,
\[ BPTSF \] is the base percent time-spent-following for both directions of travel combined, and
\[ F_{d/np} \] is an adjustment for the combined effect of the directional distribution of traffic and of the percentage of no-passing zones on percent time-spent-following. Exhibit 20-6 (HCM 2000).

The base percent time-spent-following is calculated with Equation 3.5.

\[ BPTSF = 100\left(1 - e^{-0.000879V_p}\right) \]  
(Equ 3.5)

Where,
\[ V_p \] is the passenger-car equivalent flow rate for peak 15-min period (pc/h) and it is calculated using Equation 3.3. However, it is important to mention that the \( V_p \) calculated for the percent time spent following uses different values for the grade adjustment factor (\( f_G \)) and the heavy-vehicle adjustment factor (\( f_{HV} \)).
Sensitivity Analysis and Demand Volume Selection

The purpose of the sensitivity analysis is to find out how each of the parameters used to calculate the average travel speed and the percent-time-spent-following affect the widening threshold. This is done varying one variable at a time and keeping all the others at a base case. Table 3.2 shows the base case values selected for the calculations. Most of these values are suggested in Chapter 12—Highway Concepts of the HCM 2000.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Free Flow Speed (BFFS)</td>
<td>60 mph</td>
</tr>
<tr>
<td>Lane Width</td>
<td>12 ft</td>
</tr>
<tr>
<td>Shoulder Width</td>
<td>6 ft</td>
</tr>
<tr>
<td>Access Points/mi</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Hour Factor (PHF)</td>
<td>0.90</td>
</tr>
<tr>
<td>Type of Terrain</td>
<td>Level</td>
</tr>
<tr>
<td>Percentage of Trucks</td>
<td>10</td>
</tr>
<tr>
<td>Percentage of Recreational Vehicles (RVs)</td>
<td>0</td>
</tr>
<tr>
<td>Type of Analysis</td>
<td>Two way highway (T)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no-passing zones (%)</td>
<td>20</td>
</tr>
<tr>
<td>Directional split</td>
<td>50/50</td>
</tr>
</tbody>
</table>

Table 3.2 Base Case Values for Sensitivity Analysis
FRAMEWORK

Although some of these parameters remain constant, others like lane width, shoulder width, access points per mile, percentage of trucks, percent of no-passing zones, and directional split take different values depending on the traffic and geometric conditions of the highway. Figures 3.4 through 3.9 show the behavior of each of these variables. Different traffic volumes were tested until a level of service between LOS D and E was achieved. After the sensitivity analysis was completed it was decided that a traffic volume of 1500 veh/h would be used as the threshold volume for the peak hour.

Several conclusions are drawn from Figures 3.4 to 3.9:

• As it is shown in Figure 3.4 and 3.7, lane width and the percentage of trucks do not have an important influence in the calculation of the threshold volume. Despite of the wide range of lane width values and percentages of trucks tested, the traffic volume necessary to reach the threshold volume is always 1514 veh/h. This finding conflict with the common belief that the percentage of trucks has a big influence in the LOS. In the HCM 2000 the passenger-car equivalent for trucks $E_T$, obtained from Exhibit 20-9 or Exhibit 20-10, is very close to 1.0 especially when the flow rate is high and the type of terrain considered in the analysis is “Level.”

• Shoulder width does not have an influence in the LOS estimation either. However, as it is shown in Figure 3.5, when no shoulder width is provided, the traffic volume needed to reach the threshold only 1314 veh/h. For other shoulder width values, such as 2, 4 or 6 ft the traffic volume stabilizes at a number close to 1514 veh/h.

• Access-Point Density has a considerable impact on the threshold estimation when the total number of access points per mile on both sides of the roadway is equal or greater than 30. Figure 3.6 shows that whenever the number of access points is 40 (an average of 264 ft), the traffic volume required to reach the widening threshold drops down to 1044 veh/h.

• The threshold level is also sensitive to the percentage of no-passing zones. As it is seen in Figure 3.8 the threshold traffic volume is inversely proportional to the percentage of no passing zones. When no-passing zones are not used,
FRAMEWORK

the threshold traffic volume is 1646 veh/h while when passing is restricted the volume to reach the threshold level drops to 1320 veh/h.

- Directional Split, which is the last variable analyzed in the sensitivity analysis, does not affect the threshold calculation. When the directional split is equal to 90/10 the threshold is slightly lower (1397 veh/h) than for the other directional split configurations.

Figure 3.4 Traffic Volume Vs Lane Width
FRAMEWORK

Figure 3.5 Traffic Volume Vs Shoulder Width

Figure 3.6 Traffic Volume Vs Access Point Density
Figure 3.7 Traffic Volume Vs Percentage of Trucks

Traffic Volume Vs Percentage of Trucks

![Traffic Volume Vs Percentage of Trucks](image)

Figure 3.8 Traffic Volume Vs Passing Zones

Traffic Volume Vs Passing Zones

![Traffic Volume Vs Passing Zones](image)
“Lane width and the percentage of trucks do not have any relevance; the traffic volume at the threshold level will always be 1514 veh/h. Shoulder width, on the other hand, only affects the traffic volume if it is equal or less than 2 ft.”

“Access Points per mile is one of the most influential factors for the traffic volume selection.”
“The percentage of no-passing zones was also considered as influential.”

The graphics generated from the sensitivity analysis show how to determine the threshold volume. Lane width and the percentage of trucks do not have any relevance; the traffic volume at the threshold level will always be 1514 veh/h. Shoulder width, on the other hand, only affects the traffic volume if it is equal or less than 2 ft. However, since highways with typical conditions have a shoulder width of 6 ft, this variable is not considered for the threshold volume selection either.

Access Points per mile is one of the most influential factors for the traffic volume selection but for a number of 10 to 20 points per mile, which could be considered as a typical range, the traffic volume remains at 1514 veh/h. Access points are considered to be points that contribute to changes in travel speed. Intersections, driveways, or median openings on the opposite side that are expected to have a significant effect on traffic flow in the direction of interest may be included when determining access-point density. The percentage of no-passing zones was also considered as influential but, for typical conditions, for example 20% no-passing zones, the traffic volume needed is equal to 1514 veh/h.
“A conservative estimate for the threshold volume for two-lane highways would be 1500 veh/h. This number represents the traffic volume in both directions of travel during the afternoon peak hour.”

Finally, the threshold volume is very steady for different directional split configurations and for 50/50, considered as the typical condition, the traffic volume is 1514 veh/h.

For all these reasons a conservative estimate for the threshold volume for two-lane highways would be 1500 veh/h. This number represents the traffic volume in both directions of travel during the afternoon peak hour. Using a peak hour ratio one could convert this hourly volume into a 24-hour volume. Table 3.3, for example, shows peak hour ratios calculated from the automatic traffic recorded data for Wisconsin (District 2). The average of all these ratios either by day, functional class or county is close to 8.2. That means that the 1500 veh/h calculated above represent 8.2% of the daily traffic. Then, the daily volume would be 18,293 veh/day. With a consideration for some ride sharing, a useful value for the threshold volume is 20,000 person trips or 18,000 vehicle trips per day.

“The daily volume would be 18,293 veh/day. With a consideration for some ride sharing, a useful value for the threshold volume is 20,000 person trips or 18,000 vehicle trips per day.”
### Table 3.3 Peak Hour Ratios for Wisconsin (District 2)

<table>
<thead>
<tr>
<th>Station</th>
<th>County</th>
<th>Highway</th>
<th>Functional Class</th>
<th>Sun Ratio</th>
<th>Mon Ratio</th>
<th>Tues Ratio</th>
<th>Wed Ratio</th>
<th>Thurs Ratio</th>
<th>Fri Ratio</th>
<th>Sat Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>45-0001, Grafton</td>
<td>Ozaukee</td>
<td>I-43</td>
<td>R Principal Arterial - Interstate</td>
<td>8.1</td>
<td>8.1</td>
<td>8.0</td>
<td>7.9</td>
<td>7.5</td>
<td>8.3</td>
<td>8.1</td>
</tr>
<tr>
<td>45-0239, Port Washington</td>
<td>Ozaukee</td>
<td>I-43</td>
<td>R Principal Arterial - Interstate</td>
<td>7.7</td>
<td>7.7</td>
<td>7.7</td>
<td>8.1</td>
<td>7.7</td>
<td>8.8</td>
<td>7.6</td>
</tr>
<tr>
<td>66-0001, Allenton</td>
<td>Washington</td>
<td>USH 41</td>
<td>R Principal Arterial - Other</td>
<td>7.6</td>
<td>7.8</td>
<td>7.8</td>
<td>8.5</td>
<td>7.6</td>
<td>8.8</td>
<td>7.4</td>
</tr>
<tr>
<td>66-0051, West Bend Freeway</td>
<td>Washington</td>
<td>USH 45</td>
<td>R Principal Arterial - Other</td>
<td>9.3</td>
<td>9.2</td>
<td>9.1</td>
<td>8.8</td>
<td>7.6</td>
<td>8.4</td>
<td>9.3</td>
</tr>
<tr>
<td>67-0001, Menomonee Falls #1</td>
<td>Waukesha</td>
<td>STH 175</td>
<td>U Minor Arterial</td>
<td>8.6</td>
<td>8.5</td>
<td>8.6</td>
<td>8.2</td>
<td>7.9</td>
<td>9.3</td>
<td>9.6</td>
</tr>
<tr>
<td>67-0003, Sunnyslope</td>
<td>Waukesha</td>
<td>I-94</td>
<td>U Principal Arterial - Interstate</td>
<td>7.6</td>
<td>7.3</td>
<td>7.4</td>
<td>7.0</td>
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<td>8.0</td>
<td>7.7</td>
</tr>
<tr>
<td>67-0004, Menomonee Falls #2</td>
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<td>USH 41-</td>
<td>U Principal Arterial - Other Freeways</td>
<td>8.4</td>
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<tr>
<td>67-0005, Menomonee Falls #3</td>
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<td>STH 145</td>
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<td>10.3</td>
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<td>8.3</td>
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<tr>
<td>67-0010, Crowbar Rd</td>
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<td>U Principal Arterial - Interstate</td>
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<td>8.5</td>
<td>8.3</td>
<td>8.4</td>
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<td>8.0</td>
<td>8.3</td>
</tr>
<tr>
<td>67-0011, Busse Rd</td>
<td>Waukesha</td>
<td>I-94</td>
<td>U Principal Arterial - Interstate</td>
<td>8.3</td>
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<td>8.0</td>
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<td>8.3</td>
<td>8.3</td>
</tr>
<tr>
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<td>STH 83</td>
<td>R Minor Arterial - Other</td>
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<td>8.7</td>
<td>8.7</td>
<td>8.7</td>
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<td>8.7</td>
<td>8.6</td>
</tr>
<tr>
<td>67-6113, Poplar Creek</td>
<td>Waukesha</td>
<td>USH 18</td>
<td>U Principal Arterial - other</td>
<td>8.8</td>
<td>8.7</td>
<td>8.7</td>
<td>8.4</td>
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<td>10.7</td>
<td>8.6</td>
</tr>
<tr>
<td>67-6114, Sussex</td>
<td>Waukesha</td>
<td>STH 74</td>
<td>R Principal Arterial - Other</td>
<td>9.9</td>
<td>9.8</td>
<td>9.6</td>
<td>9.1</td>
<td>7.5</td>
<td>7.9</td>
<td>10.0</td>
</tr>
<tr>
<td>64-0002, Lake Geneva</td>
<td>Walworth</td>
<td>USH 12</td>
<td>R Principal Arterial - Other</td>
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<td>9</td>
<td>8.9</td>
<td>8.7</td>
<td>7.7</td>
<td>8.5</td>
<td>8.8</td>
</tr>
<tr>
<td>64-0348, Delavan</td>
<td>Walworth</td>
<td>I-43</td>
<td>R Principal Arterial - Interstate</td>
<td>7.7</td>
<td>7.8</td>
<td>7.7</td>
<td>7.9</td>
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<td>8.3</td>
<td>7.5</td>
</tr>
<tr>
<td>51-0001, Kilbournville</td>
<td>Racine</td>
<td>I-94</td>
<td>R Principal Arterial - Interstate</td>
<td>7.1</td>
<td>7.1</td>
<td>7.0</td>
<td>7.1</td>
<td>7.1</td>
<td>7.7</td>
<td>7.0</td>
</tr>
<tr>
<td>30-0004, State Line</td>
<td>Kenosha</td>
<td>I-94</td>
<td>R Principal Arterial - Interstate</td>
<td>6.9</td>
<td>6.9</td>
<td>6.8</td>
<td>6.9</td>
<td>7.2</td>
<td>7.7</td>
<td>6.8</td>
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<td>30-6109, Salem</td>
<td>Kenosha</td>
<td>STH 50</td>
<td>R Principal Arterial - Other</td>
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<td>8.1</td>
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<td>8.8</td>
<td>7.9</td>
</tr>
<tr>
<td>30-6117, Somers</td>
<td>Kenosha</td>
<td>I-94</td>
<td>R Principal Arterial - Interstate</td>
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<td>6.9</td>
<td>6.7</td>
<td>6.9</td>
<td>7.2</td>
<td>7.8</td>
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</tbody>
</table>

Average: 8.3, 8.3, 8.2, 8.2, 7.6, 8.4, 8.2

---

**Relationship Between Land Use Patterns and Highway Widening**
3.1.2 Intersections

"Once the capacity of a two-lane highway under typical conditions was calculated the next step was to determine the geometry of the intersections needed to handle the traffic volume on the approaching two-way streets."

Once the capacity of a two-lane highway under typical conditions was calculated the next step was to determine the geometry of the intersections needed to handle the traffic volume on the approaching two-way streets. A total of seven intersections were analyzed using the Highway Capacity Software 2000 (HCS). While most of the parameters were kept constant for all the intersections, others like the number of lanes and the phase combinations were modified. The following is a list of values used in this analysis for all the intersections.

- Lane width: 12 ft
- Volume: 1500 veh/h (750 veh/h for each approach).
- Percentage of Heavy Vehicles: 10%
- Peak Hour Factor: 0.90
- Grade: 0%
- Green time: 43 sec
- All Red: 2 sec
- Cycle time: 90 sec

Figures 3.10 through 3.16 show the traffic volumes and the geometric configuration of each of the alternatives. The seven alternatives were developed in such a way so that the first alternatives would have the poorest geometric conditions. Other alternatives have geometric conditions that ensure enough capacity to accommodate the threshold volume calculated in the sensitivity analysis. For example, in alternative 1, the through, left, and right turning movements share one single lane per approach. Alternative 5 on the other hand, has an exclusive lane for through, left and right turning movements.
Figure 3.10 Intersection Type 1

Figure 3.11 Intersection Type 2
Relationship Between Land Use Patterns and Highway Widening
Figure 3.14 Intersection Type 5  
Figure 3.15 Intersection Type 6
“In order to accommodate threshold traffic volumes, two through lanes are needed. The actual type used would be based on economic and operational estimates.”

Table 3.4 is a summary with the results from the capacity evaluation of the intersections. From Table 3.4 it appears that Alternatives 1, 3 and 4 do not have sufficient capacity to handle the demand traffic volume of 1500 veh/h. These intersections all have only one through traffic lane. In order to accommodate threshold traffic volumes, two through lanes are needed. The actual type used would be based on economic and operational estimates. Thus, to accommodate threshold volumes, the intersections would have to provide at least two lanes for the through movement as for intersections in alternatives 2, 5, 6 and 7.

Figure 3.16 Intersection Type 7
3.2 Street Connectivity

“The connectivity analysis will compare the traffic volume on an arterial street before and after the connectivity on the local roads is improved.”

Table 3.4 Intersections Operational Characteristics

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Cycle Length (sec)</th>
<th>Approach Delay (sec/veh)</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>146.9</td>
<td>F</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>22.6</td>
<td>C</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>156.8</td>
<td>F</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>213.6</td>
<td>F</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>27.6</td>
<td>C</td>
</tr>
<tr>
<td>6</td>
<td>90</td>
<td>16.8</td>
<td>B</td>
</tr>
<tr>
<td>7</td>
<td>90</td>
<td>15.1</td>
<td>B</td>
</tr>
</tbody>
</table>

The effectiveness of street connectivity as a measure to reduce congestion in a corridor is seldom seriously considered. However, the hypothesis for the connectivity analysis presented in this report is that improving connectivity in the local roads will provide a greater ability to handle traffic in a corridor and produce a traffic reduction on arterial streets. Figure 3.17 helps to understand the idea of the traffic reduction. A trip between the origin and destination shown in the figure requires a long, convoluted path even though the two points are located very near each other. This illustrates the problem generated by poor connectivity of local roads. Even when origins and destinations are close to each other, there is not a straight and convenient path between them. Rather, travelers are forced to use the arterial street, represented in this case by Monroe St, and need to make longer trips and multiple turns. In Figure 3.17 the approximate distance between the origin and destination using the existing roadway design is 2.2 miles while the direct distance is only 0.3 miles.

The connectivity analysis will compare the traffic volume on an arterial street before and after the connectivity on the local roads is improved.
Figure 3.17 Street Connectivity Concept

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Study Area Selection

The demographic and geographic characteristics of the area selected for the connectivity analysis have a significant influence on the magnitude of the traffic reduction. A reduction in the traffic on the arterials is expected when the following criteria are met:

- Mixed land use. When there is land use mix the trip length for shopping, personal business and recreational trips can decrease. People usually prefer to make those trips where origins are close to destinations, which means that within an ideally connected network these trips could be completed using local roads thereby reducing the traffic volume on the arterial.

- High levels of activity. When an area surrounding an arterial has high levels of activity (number of households, retail and nonretail) more vehicles will use that arterial due to the high number of trips produced and attracted in that area. In this way, the gross reduction of trips after connectivity is improved will be higher.

- Good connectivity. If the area under analysis has poor connectivity of local streets, a large percentage of the traffic has to use the arterials because there is not a direct path in the local roads. With improved connectivity some of those trips will no longer need to use the arterial and a reduction on traffic levels on the arterial will take place.

Based on the criteria described above the corridor displayed in Figure 3.18 was selected for the connectivity analysis. This corridor is located on the west side of Tallahassee, Florida. It was identified as an area with poor connectivity and relatively high levels of activity.
“It was necessary to add detail to the network and draw all roads within the study area.”

Network Construction Considerations

As it is shown in Figure 3.18 the original network of the City of Tallahassee, provided by Mr. Tim Allen, did not have all the local roads coded. It was necessary to add detail to the network and draw all roads within the study area. Figure 3.19 shows this area in more detail before connectivity was changed.
FRAMEWORK

As it can be seen there are numerous cul de sacs in the area that lead to the arterial with very few connections between adjacent roadways.

Local roads were coded using the General Network Editor (GNE) as two-way streets. There were no concerns about capacity restrictions on those links and the speed was set at either 15 or 25 mph. Since the speed on the arterial will have an impact on the routes used, different speeds on the arterial were used: 25 mph, 30 mph, 40 mph and 50 mph.
FRAMEWORK

Major intersections were left as intersections with delay and new intersections connecting local streets were set as intersections without delay. Figure 3.20 shows how the network appears after connectivity was changed.

The connectivity analysis evaluates the traffic impact on arterials under two circumstances: with external-external trips and without them. E-E trips were calculated using the select link analysis technique available in QRS II. Select link analysis calculates the trips between pairs of selected links and places that information in the file “SelectM.txt.” For the purpose of this report the selected links corresponds to the links located at both extremes of the corridor under analysis.
FRAMEWORK

Demographic Information

In order to measure the impact of street connectivity it was necessary to increase the spatial precision in the study area. That meant that the traffic analysis zones had to be subdivided into smaller zones. Multiple centroids were created from the original TAZs so that they contained information that was more spatially detailed. Demographic information in the desired format was found from the City of Tallahassee GIS web site where all this information is available to the public. Figure 3.21 shows how the information for a single parcel was found.

Using the “Property info. Sheet” tab found in the left side of the screen it was possible to get detailed information about a single property. Figure 3.22 shows the property information display given by the GIS Web Site.
Relationship Between Land Use Patterns and Highway Widening

Figure 3.21 Tallahassee GIS Web Site
**Figure 3.22 Property Information Display**

<table>
<thead>
<tr>
<th>General Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property ID:</td>
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<tr>
<td>Site Address:</td>
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<tr>
<td>Mailing Address:</td>
</tr>
<tr>
<td>City, ST, Zip:</td>
</tr>
<tr>
<td>City Limits:</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Property Tax Information</th>
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</thead>
<tbody>
<tr>
<td>Property Tax:</td>
</tr>
<tr>
<td>* For additional information please visit: *</td>
</tr>
<tr>
<td>Leon County Tax Collector</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Property Information</th>
<th>Emergency Services</th>
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<td>$ 116900</td>
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<td>Save Our Homes Value:</td>
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<td>Exempt Value:</td>
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<td>Current Sales:</td>
<td>$ 16600</td>
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<td>* For additional information please visit: *</td>
<td></td>
</tr>
<tr>
<td>Leon County Property Appraiser</td>
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</tr>
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<table>
<thead>
<tr>
<th>Land Use</th>
<th>Elections</th>
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<tr>
<td>Zoning Category:</td>
<td>Single Family Detached R-1</td>
</tr>
<tr>
<td>Site Specific Zoning</td>
<td></td>
</tr>
<tr>
<td>* NOTE: Land Use information can change frequently, please verify with the Tallahassee-Leon County Planning Department 850/891-8600 *</td>
<td></td>
</tr>
<tr>
<td>Voter Precinct:</td>
<td>2359</td>
</tr>
<tr>
<td>Poll Location:</td>
<td>EBENEZER LEON BAPTIST</td>
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<td>Poll Address:</td>
<td>8459 3LOUSTOWN HWY</td>
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</tbody>
</table>

**Relationship Between Land Use Patterns and Highway Widening**
3.3 Land Use Density

“A second analysis was conducted to look at the relationship between land use density and traffic levels. Density in this study is analyzed in terms of the number of households, and the retail and nonretail activities in the study area.”

FRAMEWORK

The item “Zoning Category” that appears at the bottom of Figure 3.22 was used to identify properties with the same land use and group them in separate centroids. The City of Tallahassee has its own zoning system and sometimes categories found in the maps did not match the land use categories presented in a report called “Summary of Site Specific Zoning Districts.” Thus, it was often necessary to look at other items like the owners’ name or the property value to find the land use of a property.

A second analysis was conducted to look at the relationship between land use density and traffic levels. Density in this study is analyzed in terms of the number of households, and the retail and nonretail activities in the study area.

Using the threshold volumes, the idea is to go backwards in the forecasting process to determine the levels of activity that will lead to those levels of traffic. In other words, the forecasting process is used to calculate an adjusted trip table for which the traffic volumes on every link of the network do not exceed the threshold volume.

After some preliminary research it was decided that a case study would be the best approach to understand the trip table estimation problem. Working with real demographic and traffic data and the opportunity to provide a solution to a real transportation problem were some of the reasons for this selection. The next step was to choose a location for the analysis where traffic networks were already coded into the General Network Editor (GNE). The City of Tallahassee Florida’s traffic network was selected for the following reasons:

- City Size. This was considered as a critical factor for the city selection. It cannot be too large because it would make the trip table estimation process computationally difficult and it cannot be too small because a certain level of congestion is required for this analysis. The population of the City of Tallahassee is 202,000 people.

- Network Status. A calibrated network was desired since the calibration process is extremely time consuming and was out of the scope of this study. A calibrated network means that the traffic volumes calculated by a travel
FRAMEWORK

forecasting tool match the traffic counts. The Tallahassee network has a total of 861 zones and 4,545 links.

- Street Design. Since this traffic network is going to be used for the connectivity analysis, it was required to have some areas with poor street connectivity (Conventional Design).

QRS II Table Refinement

The O-D table refinement process adjusts the level of activity on each of the Traffic Analysis Zones (TAZ’s) until the “seed trip table,” which is the trip table calculated in a regular forecasting process, matches ground counts. This process is used to create an O-D table to match traffic counts and can be used as a method to calibrate a travel demand model. In this report the goal of the trip table estimation is somewhat different. In this case, the threshold volumes calculated in the capacity analysis will replace the ground counts, also known as the “target matrix.”

The original Tallahassee network did not have any local residential streets coded and most of the arterial streets correspond to two-lane highways where capacity is equal to 1700 veh/h in each direction or 3400 veh/h combined. However, there are some streets, especially in the downtown area, where capacity is 6800 veh/h and few other cases where capacity is 10,200 for both directions of travel.

The capacity analysis explained in the previous section is only concerned with two lane highways and at this point the threshold volume for roadway widening of multilane highways is unknown. Since two lane highways are the most common type of arterial in the Tallahassee network, it was decided that a separate capacity analysis for multilane highways would not be necessary. Instead, the Highway Capacity Software (HCS) was used to calculate the threshold volumes for roadway widening. All the parameters were kept in a base condition while the demand volume was varied until reaching a level of service between LOS D and E. Table 3.5 summarizes the threshold volumes for roadway widening of the highways found in the City of Tallahassee.
FRAMEWORK

The trip table refinement process is computationally complicated even with a computer with the latest technology. The problem gets computationally difficult when the trip table refinement is done for every single link in a network with the size of the City of Tallahassee. For that reason the trip table estimation process in this study was done only for the links where the traffic volume is at 70% or more of the threshold volume. That means that if the threshold volume for a LOS between LOS D and E is 1500 veh/h, links described as “two-lane highways” have to have a traffic volume of 1050 veh/h or more to be considered in the O-D estimation process. These links were identified using the width function in GNE, the traffic volumes were assigned with the threshold volume as given in Table 3.5.

Figure 3.23 shows the links, with heavier lines that were used in the trip table estimation analysis.

<table>
<thead>
<tr>
<th>Description</th>
<th>Capacity (Veh/h)</th>
<th>Threshold Volume (Veh/h)</th>
<th>70% of the Threshold Volume (Veh/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-lane Highway</td>
<td>3,400</td>
<td>1,500</td>
<td>1,050</td>
</tr>
<tr>
<td>Four-lane Highway</td>
<td>6,800</td>
<td>3,430</td>
<td>2,400</td>
</tr>
<tr>
<td>Six-lane Highway</td>
<td>10,200</td>
<td>5,145</td>
<td>3,600</td>
</tr>
</tbody>
</table>

Table 3.5 Demand Traffic Volumes
Figure 3.23 Traffic Count Links Included in the Refinement Calculation

Relationship Between Land Use Patterns and Highway Widening
FRAMEWORK

This ground count information was loaded into the network using the General Network Editor (GNE) and used in the Quick Response System (QRS II) for the trip table estimation.

The following four methods to estimate O-D tables from traffic counts are available in QRS II:

- Generalized least squares, whole trip table (static and dynamic).
- Generalized least squares, Fratar biproportional (static and dynamic).
- Generalized least squares, Fratar uniproportional (static only).
- Entropy maximization (static only).

As it was mentioned in the literature review the most convenient method when traffic is being analyzed for the peak hour, and where the number of origins and the number of destinations in a particular zone are unequal, is the GLS Fratar Biproportional (static) Method. It is important to pay attention to the following parameters in QRS when doing the trip table refinement.

- Number of equilibrium iterations was set to 13. This parameter is found under Parameters / Trip Distribution / Gravity Model. It is important to pick a number that is not so low that the estimation is inaccurate and not so high making the refinement process extremely long.

- Exclude External Zones. This parameter is found in QRS under Parameters / Trip Distribution / Refinement. The number of trips produced and attracted in the external zones is constant and should not be modified for the trip estimation process. The O-D factors for the external zones must be equal to 1.

- Allow Uniform Scaling of Prior Table. This parameter found in the “Refinement” dialog box under “Trip Distribution” should be checked. It will allow the overall single factor to be different than 1.0 and therefore a more accurate estimation as long as this number does not get too low.
FRAMEWORK

QRS will produce numerous files in a directory selected by the user. The file “ODFactors” will give a factor for each TAZ so that the level of activity can be adjusted and match the traffic counts. If the number is less than 1, it means that less activity for that particular zone is required to match the traffic counts in the forecasting process. This means that the zone is generating an excessive number of trips and that for highways in the network to operate at less than threshold values the zone needs fewer households or less employment. Similarly, if the number is greater than 1, it means that more activity is possible and that the zone could have more households or employment and not cause the highway network to exceed threshold values.

Another key file is “VehTrips” where the total number of trips leaving and entering each of the TAZ is given before and after the refinement process. In this case, when the number of trips leaving or entering the TAZs is smaller after the refinement process, it will be an indicative of excessive land use activity.
PART IV: EVALUATION AND ANALYSIS OF THE RESULTS

4.1 Street Connectivity

“This section provides an analysis of the impacts on flow of a two-lane highway located on the west side of the City of Tallahassee due to the improvement of connectivity on the local roads.”

This chapter presents the results obtained when street connectivity and density are evaluated using the traffic network of the City of Tallahassee. Results from this study will reveal how these land use factors are related to highway widening.

This section provides an analysis of the impacts on flow of a two-lane highway located on the west side of the City of Tallahassee due to the improvement of connectivity on the local roads. The selection of this road was based on three criteria: Mixed land use, a high level of activity and poor connectivity.

The corridor selected for this analysis was divided in 44 segments. Each of these segments corresponds to a road portion between intersections. Figures 4.1 and 4.2 show the western portion of the study area before and after connectivity was improved. The network generated after the new links that are shown as wider lines in Figure 4.2 were added is a hypothetical network. It may be that less connectivity could cause a considerable traffic reduction on the arterial but this was not analyzed in this project.

The geometry configuration for all the 44 segments is constant in both conditions. That means that the principal arterial has the same operational conditions as far as the number and separation of access points is concerned for both conditions. This is an important consideration since traffic volumes are compared before and after connectivity on each of the 44 segments on the arterial.
Figure 4.1 Western Portion of the Study Area Before Connectivity Improvements
Figure 4.2 Western Portion of the Study Area After Connectivity Improvements
EVALUATION AND ANALYSIS OF THE RESULTS

Traffic Volume Results

Figures 4.3 through 4.10 show the traffic volumes before and after connectivity was improved. The traffic volumes in the corridor were calculated for different speed conditions. This was done with a speed on the local roads of 15 or 25 mph while the speed on the arterial was set to 25, 30, 40 and 50 mph.

Figure 4.3 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 25 mph,
On the Local Roads = 15 mph
Figure 4.4 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 30 mph,
On the Local Roads = 15 mph

Figure 4.5 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 40 mph,
On the Local Roads = 15 mph
Figure 4.6 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 50 mph,
On the Local Roads = 15 mph

Figure 4.7 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 25 mph,
On the Local Roads = 25 mph
Figure 4.8 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 30 mph,
On the Local Roads = 25 mph

Figure 4.9 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 40 mph,
On the Local Roads = 25 mph
EVALUATION AND ANALYSIS OF THE RESULTS

Figure 4.10 Traffic Volumes Before and After Connectivity

Speeds:
On the Arterial = 50 mph,
On the Local Roads = 25 mph

“The magnitude of the reduction depends on the relative speed of the arterial vs. that on the local roads.”

When the traffic volume difference is calculated for each of the segments along the arterial it almost always shows a traffic volume reduction on the arterial after connectivity improvements. The magnitude of the reduction depends on the relative speed of the arterial vs. that on the local roads. Very few of these segments experience a traffic volume increase. As the connectivity of the local roads is improved, some segments along the arterial could experience higher levels of congestion. This can be explained with the following example.

Assume that the point A shown in Figure 4.11 is a major trip generator and that 50 vehicle trips are going from point A to point B. The highlighted line shows the shortest path between these two points before connectivity is improved. This path would be used by these 50 vehicles to reach their destination. Note that in this condition “segment n” is not used by any of those vehicles. If the connectivity improvement indicated in Figure 4.11 is implemented, the dashed line will become the shortest path between these two points. Thus, travelers will prefer to use this new path to reach their destination and “segment n” will experience an increment in the traffic volume.
EVALUATION AND ANALYSIS OF THE RESULTS

Figure 4.11 Example of Traffic Volume Increment After Connectivity Improvements

Traffic Impact

The traffic impact along the arterial can be compared by looking to the traffic volume of the 44 segments considered in the analysis. Table 4.1 is a summary of average traffic volumes calculated by QRS II.
EVALUATION AND ANALYSIS OF THE RESULTS

The traffic volumes shown in Table 4.1 confirm the hypothesis that improvements in connectivity of the local streets reduce traffic volumes along the principal arterials. The amount of reduction depends on the relative speed assumed on the arterials vs. that on local streets.

When the speed on the residential streets is considerably high (25 mph), more travelers will use the local streets instead of the arterial to reach their destinations. Consequently, there will be a larger traffic volume reduction on the arterial. In contrast,

Table 4.1 Summary of the Average Traffic Volumes Before and After Connectivity

<table>
<thead>
<tr>
<th>Condition</th>
<th>Assumed Speed on Local Roads = 15 mph</th>
<th>Assumed Speed on Local Roads = 25 mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Including EE trips</td>
<td>Without EE trips</td>
<td>Including EE trips</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 25 mph</td>
<td>1,254</td>
<td>755</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 30 mph</td>
<td>1,370</td>
<td>871</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 40 mph</td>
<td>1,532</td>
<td>1,033</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 50 mph</td>
<td>1,601</td>
<td>1,102</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 25 mph</td>
<td>1,251</td>
<td>752</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 30 mph</td>
<td>1,364</td>
<td>865</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 40 mph</td>
<td>1,519</td>
<td>1,020</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 50 mph</td>
<td>1,597</td>
<td>1,098</td>
</tr>
</tbody>
</table>
EVALUATION AND ANALYSIS OF THE RESULTS

when the speed on the residential street is 15 mph, fewer travelers will take the local roads to complete their trips and there will be a lower traffic reduction on the arterial. Figures 4.12 and 4.13 show this effect.

Figure 4.12 Traffic Volume Before and After Connectivity (Speed Local Roads= 15 mph)
“If external-external trips are excluded from the analysis, the traffic impact on the arterial evaluated as a percentage will seem to be higher after connectivity is improved.”

External-External trips account for an important percentage of the total vehicles traveling along the corridor and if they are not included, it makes a difference in terms of how the results are interpreted. If external-external trips are excluded from the analysis, the traffic impact on the arterial evaluated as a percentage will seem to be higher after connectivity is improved. This can be explained using the following example:

Figure 4.13 Traffic Volume Before and After Connectivity
(Speed Local Roads= 25 mph)
EVALUATION AND ANALYSIS OF THE RESULTS

Traffic volumes when the speed on the local roads is 25 mph and on the arterial 30 mph include 499 external-external trips that use the arterial regardless of the local street connectivity. If these trips are excluded, the impact of connectivity will appear to be greater:

- Including E-E trips:
  - Before connectivity: 1,364 veh/h
  - After Connectivity: 1,087 veh/h
  - Vehicle difference: 277 veh/h
    \[ \Delta = 1,364 - 1,087 = 277 \text{ veh/h} \]
  - % Reduction: 20.30
    \[ \% \text{ Reduction} = 100 - \left( \frac{1,087}{1,364} \right) \times 100 = 20.30\% \]

- Without E-E trips:
  - Before connectivity: 865 veh/h
  - After Connectivity: 588 veh/h
  - Vehicle difference: 277 veh/h
    \[ \Delta = 865 - 588 = 277 \text{ veh/h} \]
  - % Reduction: 32.01
    \[ \% \text{ Reduction} = 100 - \left( \frac{588}{865} \right) \times 100 = 32.01\% \]

Even though the traffic volume difference is the same for both scenarios, excluding the E-E trips make the percentage reduction appear higher at 32.01% compared to 20.30%. Table 4.2 shows the traffic impact on the arterial after connectivity improvements calculated as the traffic volume difference and the percentage reduction:

---

*Relationship Between Land Use Patterns and Highway Widening*
**EVALUATION AND ANALYSIS OF THE RESULTS**

“The traffic volume reduction on the arterial is highly sensitive to the relative speed of the arterial and the residential streets.”

---

### Table 4.2 Summary of the Traffic Volume Reduction After Connectivity Improvements in the Local Roads

<table>
<thead>
<tr>
<th>Condition</th>
<th>Traffic Volume Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Veh/h</td>
</tr>
<tr>
<td>Assumed Speed on Local Roads = 15 mph</td>
<td></td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 25 mph</td>
<td>51</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 30 mph</td>
<td>43</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 40 mph</td>
<td>31</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 50 mph</td>
<td>10</td>
</tr>
<tr>
<td>Assumed Speed on Local Roads = 25 mph</td>
<td></td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 25 mph</td>
<td>644</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 30 mph</td>
<td>277</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 40 mph</td>
<td>161</td>
</tr>
<tr>
<td>Assumed Speed on Arterial = 50 mph</td>
<td>81</td>
</tr>
</tbody>
</table>

As it is shown in Figure 4.14 the traffic volume reduction on the arterial is highly sensitive to the relative speed of the arterial and the residential streets. The highest reduction occurs with an arterial speed of 25 mph and a local roads speed of 25 mph.
When the traffic reduction on the arterial is evaluated as a percentage it is important to consider both scenarios (including E-E trips and without E-E trips). The traffic reduction will seem to be higher when E-E trips are not considered in the analysis. This is illustrated in Figures 4.15 and 4.16:
Figure 4.15 Percentage Reduction of Vehicles on the Arterial After Connectivity Improvements (Speed on Local Roads = 15 mph)

Figure 4.16 Percentage Reduction of Vehicles on the Arterial After Connectivity Improvements (Speed on Local Roads = 25 mph)
4.2 Land Use Density

4.2.1 Origin-Destination Factors

"O-D factors give an idea of how the level of activity in the TAZs should be adjusted so that the traffic volume on the streets does not exceed the threshold volume."

EVALUATION AND ANALYSIS OF THE RESULTS

As it is shown in Figure 4.14 when the speed on the arterial is close to the speed on the local roads, there is a major traffic volume reduction on the arterial. This is because the travel time between origins and destinations is smaller when people use the local roads. When both the speed on the arterial and the local roads is 25 mph the total traffic volume reduction on the arterial is 644 veh/h. In contrast, when the speed on the arterial is 50 mph and the speed on the local roads is 15 mph the traffic volume reduction drops down to only 10 veh/h.

Figure 4.7 provides a different interpretation for the traffic volume reduction on the arterial. In this case the traffic impact is measured as a percentage for the two scenarios: with or without external-external trips. The traffic volume reduction has the same tendency as in Figure 4.14. When the speed in the local roads and the arterial are similar the traffic volume reduction on the arterial is higher. In this case, the most significant traffic reduction on the arterial (85.65%) occurs when the E-E trips are excluded from the analysis and when the speed on the arterial and the local roads is 25 mph. Thus, the effect of connectivity is dependent upon the amount of through traffic on the arterial vs. the amount that takes place within the corridor.

Using the Fratar Biproportional GLS Static Model, QRS II calculates Origin-Destination Factors for each traffic analysis zones to match traffic volumes on the network. The O-D estimator was recently introduced in QRS II and still it is an experimental feature. For a City like Tallahassee the trip table estimation process takes about 3 days on a 2.40GHz computer with 512 MB of RAM memory and using the Windows XP operating system. This time highly depends on how many ground counts are included in the refinement process and the number of iterations for the distribution step. For this study only the links where the traffic volume was 70 % or more of the threshold volume were given a ground count and a total of 13 iterations were used for the distribution step.

These O-D factors give an idea of how the level of activity in the TAZs should be adjusted so that the traffic volume on the streets does not exceed the threshold volume.
**EVALUATION AND ANALYSIS OF THE RESULTS**

The following table shows the first page of the “ODFactors.txt” file found in the results directory of QRS II.

<table>
<thead>
<tr>
<th>OD FACTORS</th>
<th>ORIGIN</th>
<th>DESTINATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Single Factor</td>
<td>O.9101944</td>
<td></td>
</tr>
<tr>
<td>5380 TAZ 439</td>
<td>1.8566523</td>
<td>1.4058760</td>
</tr>
<tr>
<td>5690 TAZ 470</td>
<td>1.1151474</td>
<td>1.0657388</td>
</tr>
<tr>
<td>5700 TAZ 471</td>
<td>1.0106313</td>
<td>0.9545342</td>
</tr>
<tr>
<td>5710 TAZ 472</td>
<td>0.9192878</td>
<td>0.9596142</td>
</tr>
<tr>
<td>5390 TAZ 440</td>
<td>1.8034175</td>
<td>0.9422780</td>
</tr>
<tr>
<td>5720 TAZ 473</td>
<td>1.6561172</td>
<td>1.3859838</td>
</tr>
<tr>
<td>5730 TAZ 474</td>
<td>1.0235468</td>
<td>0.9581783</td>
</tr>
<tr>
<td>6350 TAZ 536</td>
<td>2.3464419</td>
<td>0.3399485</td>
</tr>
<tr>
<td>6360 TAZ 537</td>
<td>1.2269785</td>
<td>1.2346109</td>
</tr>
<tr>
<td>5760 TAZ 477</td>
<td>2.2849009</td>
<td>0.6952983</td>
</tr>
<tr>
<td>5780 TAZ 479</td>
<td>0.8388615</td>
<td>0.9222690</td>
</tr>
<tr>
<td>5740 TAZ 475</td>
<td>1.4652981</td>
<td>1.2688646</td>
</tr>
<tr>
<td>5750 TAZ 476</td>
<td>2.5789174</td>
<td>0.4636640</td>
</tr>
<tr>
<td>5790 TAZ 480</td>
<td>1.0221013</td>
<td>0.9841167</td>
</tr>
<tr>
<td>5400 TAZ 441</td>
<td>1.0221012</td>
<td>1.0084569</td>
</tr>
<tr>
<td>5770 TAZ 478</td>
<td>0.9156820</td>
<td>0.9631584</td>
</tr>
<tr>
<td>5800 TAZ 481</td>
<td>1.4647048</td>
<td>1.1274412</td>
</tr>
<tr>
<td>6380 TAZ 539</td>
<td>1.2918209</td>
<td>1.3169016</td>
</tr>
<tr>
<td>5900 TAZ 491</td>
<td>2.9052567</td>
<td>1.2455936</td>
</tr>
<tr>
<td>5810 TAZ 482</td>
<td>1.7387303</td>
<td>1.3852819</td>
</tr>
<tr>
<td>5820 TAZ 483</td>
<td>0.6389578</td>
<td>0.8665247</td>
</tr>
<tr>
<td>5840 TAZ 485</td>
<td>0.9765342</td>
<td>0.9927628</td>
</tr>
<tr>
<td>5910 TAZ 492</td>
<td>1.8824191</td>
<td>1.4909651</td>
</tr>
<tr>
<td>5830 TAZ 484</td>
<td>0.7444287</td>
<td>0.8496730</td>
</tr>
<tr>
<td>5860 TAZ 487</td>
<td>1.2997139</td>
<td>0.7797904</td>
</tr>
<tr>
<td>6370 TAZ 538</td>
<td>1.4812000</td>
<td>1.5409743</td>
</tr>
<tr>
<td>5410 TAZ 442</td>
<td>1.4637220</td>
<td>0.2204778</td>
</tr>
<tr>
<td>5850 TAZ 486</td>
<td>0.8504966</td>
<td>0.8995422</td>
</tr>
<tr>
<td>5940 TAZ 495</td>
<td>1.0000000</td>
<td>1.0000000</td>
</tr>
<tr>
<td>5880 TAZ 489</td>
<td>0.8178616</td>
<td>1.0118379</td>
</tr>
<tr>
<td>5890 TAZ 490</td>
<td>0.9088160</td>
<td>0.7107534</td>
</tr>
<tr>
<td>5870 TAZ 488</td>
<td>1.0614295</td>
<td>0.9795375</td>
</tr>
<tr>
<td>9923 TAZ 493</td>
<td>2.7237139</td>
<td>0.8760491</td>
</tr>
<tr>
<td>5930 TAZ 494</td>
<td>0.9310234</td>
<td>0.9862409</td>
</tr>
<tr>
<td>6105 TAZ 511</td>
<td>0.8913217</td>
<td>1.0560516</td>
</tr>
<tr>
<td>5420 TAZ 443</td>
<td>2.0695110</td>
<td>0.4334047</td>
</tr>
</tbody>
</table>

**Table 4.3 O-D Factors File**
EVALUATION AND ANALYSIS OF THE RESULTS

The first column in Table 4.3 contains the name of the centroids where the first four digits are used to differentiate centroids located in the same traffic analysis zone. The other two columns show the individual factor calculated by the O-D table refinement process to adjust the number of Origins and Destinations for each traffic analysis zone.

Centroid “6350 TAZ 536,” for example, located in the 8th row of the table has an origin factor of 2.3464419 and a destination factor of 0.3339485. These numbers are multiplied by the overall single factor, in this case, 0.9101944. After this adjustment is made the origin factor will be 2.1357183 and the destination factor 0.3039581. That means that for that particular centroid the number of origins could increase by 113.6% and the number of destinations should decrease by 69.6% in order for the O-D table to give a traffic estimate equal to the specified traffic counts on the network.

O-D Factors Display

Plotting the O-D factors in the Tallahassee network will help to identify areas or specific locations where levels of activity, represented by origins and destinations, should increase or decrease for the traffic on the network to match the specified threshold values. This information can be used as a framework to create alternatives to solve problems of congestion in the city.

“Extract and Update” and the width and color functions available in the General Network Editor (GNE) were used to create the maps shown in Figure 4.17 and 4.18. The map in Figure 4.17 shows the origin display of the trips made in the city of Tallahassee during the afternoon peak hour. The darker (red) dots represent centroids with an excessive level of activity (O-D factor less than 1) while the lighter (green) dots represent centroids where an increased level of activity could occur (O-D factor greater than 1). The size of the circles depends on the magnitude of the level of activity adjustment. Big circles symbolize areas where the level of activity has to either decrease or increase in a significant proportion. Wider links represent the streets where the traffic volume is close or greater than the threshold volume.

Based on the location of the darker (red) circles it is clear that most of the trips during the afternoon peak hour are either generated in the downtown area or along principal arterials that are close or above capacity. This is a reasonable behavior.
considering that at this time of the day most of the people are going back home from work. Although centroids where more activity could occur are mostly spread out in the network, there is also a significant concentration of lighter (green) dots in the east side of downtown.

Figure 4.18 shows the destination display of the trips made in the Tallahassee network during the afternoon peak hour. This map uses the same conventions as the map in Figure 4.17 in terms of the size and color of the centroids. Streets where the traffic volume is close or above the threshold volume are also identified with a darker color.

As it can be seen on this map darker (red) dots that represent the areas with high levels of activity are similarly distributed as the origin display. That means that many trips during the afternoon peak hour have their origins or their destinations in downtown or along arterials with high traffic volumes. Travelers may be doing some shopping, recreational or personal business trips in downtown. For the destination display there are a considerable number of centroids with low levels of activity lighter (green) dots in downtown and the area surround it. They are concentrated to the west of the central business district and along arterials with high traffic volumes to the east of downtown.
EVALUATION AND ANALYSIS OF THE RESULTS

Figure 4.17 Level of Activity Adjustment Calculated from Origin Factors
EVALUATION AND ANALYSIS OF THE RESULTS

Figure 4.18 Level of Activity Adjustment Calculated from Destination Factors
EVALUATION AND ANALYSIS OF THE RESULTS

The feature “Extract and Update” was used in GNE to extract information from a comma-separated file and to assigned it to a node or a link as an attribute. In this case the O-D factors for each of the TAZ were extracted from the file “ODFactors.txt” and inserted on each of the Centroids in the Tallahassee network. The origin factor and the destination factor were placed in the 6th and 7th centroid attribute respectively.

The General Network Editor (GNE) has the capability to change the width and color of any node or link in a network based on expressions given by the user. For display purposes, the size of the centroids was modified based on the following ranges with the idea of differentiating the centroids where large or small adjustments to the level of activity were needed.

<table>
<thead>
<tr>
<th>O-D Factor Range</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 to 0.4</td>
<td>25</td>
</tr>
<tr>
<td>0.4 to 0.6</td>
<td>20</td>
</tr>
<tr>
<td>0.6 to 0.8</td>
<td>15</td>
</tr>
<tr>
<td>0.8 to 1.0</td>
<td>10</td>
</tr>
<tr>
<td>1.0 to 1.2</td>
<td>10</td>
</tr>
<tr>
<td>1.2 to 1.4</td>
<td>15</td>
</tr>
<tr>
<td>1.4 to 1.6</td>
<td>20</td>
</tr>
<tr>
<td>1.6 to 2.2</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 4.4 O-D Factor Ranges for Centroid Size Adjustment

As it is shown in Table 4.4 OD factors representing either a large increase or decrease of activity were assigned with the highest circle size. The ranges are equally distributed so that the size increases constantly with a difference of 5 points between ranges. However, percentages can be misleading. For example, two TAZs with the same O-D factor adjustment could be generating different amounts of trips and therefore the interpretation of the levels of activity in the map may not be the most accurate.
EVALUATION AND ANALYSIS OF THE RESULTS

For that reason it is important to find other ways to represent the adjustments in the levels of activity.

“VehTrips.txt” is another file produced by QRS II after the refinement process is completed and it shows the number of vehicles leaving and entering each of the traffic analysis zones. The difference between vehicle trips before and after the trip estimation process can be used as another way to display the adjustments in the levels of activity.

A vehicle trips file is produced every time QRS II is run and it can be found in a report directory specified by the user. The following table shows the first page of the “VehTrips.txt” file after the refinement process.

The first column in Table 4.5 displays the name of the centroids in the network. The second and third columns contain the total number of trips leaving and entering a traffic analysis zone while the fourth column shows the number of trips made within the TAZ.

**Vehicle Trips Display**

The arithmetical difference between vehicle trips before and after the refinement process can be used as another way to measure the level of activity adjustment needed on each TAZ so that traffic volumes do not exceed the threshold volumes in the network.

The maps generated from O-D factors (Figures 4.17 and 4.18) are similar than the ones generated from the number of vehicle trips leaving and entering each of the TAZs (Figures 4.19 and 4.20). Thus either parameter similarly measures the level of activity adjustment necessary to keep the traffic volumes in the streets lower than the threshold volumes. The interpretation of the results should not change if one or the other set of maps is selected.
**EVALUATION AND ANALYSIS OF THE RESULTS**

**Table 4.5 Vehicle Trips File**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Leaving</th>
<th>Entering</th>
<th>IntraZonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>5380 TAZ 439</td>
<td>38.7</td>
<td>66.9</td>
<td>2.3</td>
</tr>
<tr>
<td>5690 TAZ 470</td>
<td>2.4</td>
<td>6.7</td>
<td>0.0</td>
</tr>
<tr>
<td>5700 TAZ 471</td>
<td>46.6</td>
<td>18.0</td>
<td>1.5</td>
</tr>
<tr>
<td>5710 TAZ 472</td>
<td>16.3</td>
<td>23.3</td>
<td>1.0</td>
</tr>
<tr>
<td>5390 TAZ 440</td>
<td>51.0</td>
<td>72.1</td>
<td>9.9</td>
</tr>
<tr>
<td>5720 TAZ 473</td>
<td>21.2</td>
<td>49.5</td>
<td>0.2</td>
</tr>
<tr>
<td>5730 TAZ 474</td>
<td>10.0</td>
<td>26.4</td>
<td>0.1</td>
</tr>
<tr>
<td>6350 TAZ 536</td>
<td>67.4</td>
<td>22.5</td>
<td>3.5</td>
</tr>
<tr>
<td>6360 TAZ 537</td>
<td>5.8</td>
<td>17.2</td>
<td>0.1</td>
</tr>
<tr>
<td>5760 TAZ 477</td>
<td>244.4</td>
<td>201.1</td>
<td>10.9</td>
</tr>
<tr>
<td>5780 TAZ 479</td>
<td>17.5</td>
<td>54.5</td>
<td>0.4</td>
</tr>
<tr>
<td>5740 TAZ 475</td>
<td>11.9</td>
<td>27.0</td>
<td>0.1</td>
</tr>
<tr>
<td>5750 TAZ 476</td>
<td>232.2</td>
<td>90.1</td>
<td>15.8</td>
</tr>
<tr>
<td>5790 TAZ 480</td>
<td>0.3</td>
<td>0.9</td>
<td>0.0</td>
</tr>
<tr>
<td>5400 TAZ 441</td>
<td>0.4</td>
<td>1.4</td>
<td>0.0</td>
</tr>
<tr>
<td>5770 TAZ 478</td>
<td>203.3</td>
<td>257.8</td>
<td>16.8</td>
</tr>
<tr>
<td>5800 TAZ 481</td>
<td>177.1</td>
<td>332.8</td>
<td>7.8</td>
</tr>
<tr>
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<td>7.8</td>
<td>23.0</td>
<td>0.1</td>
</tr>
<tr>
<td>5900 TAZ 491</td>
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<td>156.9</td>
<td>5.0</td>
</tr>
<tr>
<td>5810 TAZ 482</td>
<td>113.7</td>
<td>235.0</td>
<td>2.2</td>
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<tr>
<td>5820 TAZ 483</td>
<td>36.4</td>
<td>114.0</td>
<td>0.4</td>
</tr>
<tr>
<td>5840 TAZ 485</td>
<td>3.0</td>
<td>8.9</td>
<td>0.0</td>
</tr>
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<td>5910 TAZ 492</td>
<td>133.8</td>
<td>175.0</td>
<td>3.5</td>
</tr>
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<td>5830 TAZ 484</td>
<td>42.1</td>
<td>30.6</td>
<td>0.2</td>
</tr>
<tr>
<td>5860 TAZ 487</td>
<td>11.5</td>
<td>11.3</td>
<td>0.1</td>
</tr>
<tr>
<td>6370 TAZ 538</td>
<td>80.2</td>
<td>167.3</td>
<td>10.6</td>
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<tr>
<td>5410 TAZ 442</td>
<td>25.1</td>
<td>11.2</td>
<td>0.1</td>
</tr>
<tr>
<td>5850 TAZ 486</td>
<td>66.6</td>
<td>53.9</td>
<td>0.7</td>
</tr>
<tr>
<td>5940 TAZ 495</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
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<td>229.0</td>
<td>161.8</td>
<td>4.1</td>
</tr>
<tr>
<td>5870 TAZ 488</td>
<td>0.8</td>
<td>2.3</td>
<td>0.0</td>
</tr>
<tr>
<td>5923 TAZ 493</td>
<td>262.7</td>
<td>158.7</td>
<td>9.0</td>
</tr>
<tr>
<td>5930 TAZ 494</td>
<td>11.0</td>
<td>22.9</td>
<td>0.0</td>
</tr>
<tr>
<td>6105 TAZ 511</td>
<td>37.5</td>
<td>23.2</td>
<td>0.1</td>
</tr>
<tr>
<td>5420 TAZ 443</td>
<td>109.9</td>
<td>63.1</td>
<td>1.0</td>
</tr>
<tr>
<td>5430 TAZ 444</td>
<td>26.2</td>
<td>43.6</td>
<td>0.3</td>
</tr>
<tr>
<td>5921 TAZ 493</td>
<td>182.9</td>
<td>120.2</td>
<td>3.6</td>
</tr>
<tr>
<td>6103 TAZ 511</td>
<td>15.2</td>
<td>50.1</td>
<td>0.0</td>
</tr>
<tr>
<td>6110 TAZ 512</td>
<td>92.6</td>
<td>265.3</td>
<td>2.7</td>
</tr>
</tbody>
</table>

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EVALUATION AND ANALYSIS OF THE RESULTS

One of the differences between these two sets of maps is that maps using vehicle trips are not as dense, in terms of the number of centroids displayed, as the maps using O-D factors. The main cause for this is that in the maps using vehicle trips TAZs with a small land use activity adjustment were assigned with a small centroid size that make them invisible in the display. The other difference between these two set of maps is that for the destination display the map using vehicle trips does not have as many lighter (green) dots as the map using O-D Factors.

Comparing Figures 4.18 and 4.20 one can see that for the destination display using vehicle trips there are not as many lighter (green) dots to the west of downtown as they were in the map using O-D Factors. Areas where more activity is required are still concentrated along principal arterials where traffic volumes are close or greater than the threshold volume for roadway widening.

Both set of maps use the same conventions in terms of the darkness and color of the centroids but for the maps using vehicle trips the size of the centroids was calculated using a different procedure that is explained later.

The map in Figure 4.19 shows the trips leaving the TAZs during the afternoon peak hour and it will be considered the origin display. The map in Figure 4.20 shows the trips entering the TAZs and it will be considered the destination display. As it was described it in the maps using O-D factors, darker (red) dots represent the centroids where the levels of activity have to be reduced to meet the threshold volume limits. Conversely, circles displayed with a lighter (green) color represent centroids, which could have additional trip activity and not affect traffic on constrained links.
Figure 4.19 Level of Activity Adjustment Calculated from Vehicle Trips Leaving the TAZs (Original Display)
EVALUATION AND ANALYSIS OF THE RESULTS

Figure 4.20 Level of Activity Adjustment Calculated from Vehicle Trips Entering the TAZs (Destination Display)
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The extract and update function was used in the same way as for the O-D factors. In this case the file to be extracted was created subtracting the number of trips leaving and entering each of the TAZs from the number of trips leaving and entering those zones after the refinement process.

Figures 4.19 and 4.20 were assigned a darker (red) circle when the number of trips either entering or leaving a TAZ after the refinement process was inferior to the original number of trips entering or leaving that zone. Otherwise, centroids were given a lighter (green) color.

The magnitude of the level of activity adjustment defined by the centroid size was established with a more sophisticated process. This was done to create a useful visual tool to interpret the information displayed in the maps.

One of the considerations was that the ranges to determine the importance of the level of activity adjustment do not necessarily have to be constant. To better understand this concept it is easier to look at the real data. Table 4.6 shows the difference between the number of vehicle trips before and after the trip estimation process for some of the TAZs.

Numbers in the column “leaving” were calculated by comparing the number of trips leaving the TAZ before and after the refinement process. The same process was used to calculate the numbers of trips entering a TAZ.
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Table 4.6 Difference Between the Number of Trips Before and After the Refinement Process

Table 4.7 shows the distribution of the numbers calculated in the previous table but for all the centroids in the Tallahassee network. This will be considered the first data distribution set.
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In this case, the “leaving” and “entering” column represent how often these values occur within each of the 10 ranges.

<table>
<thead>
<tr>
<th>Range No</th>
<th>Range</th>
<th>Leaving</th>
<th>Entering</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-999999</td>
<td>-250</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>-250</td>
<td>-200</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>-200</td>
<td>-150</td>
<td>26</td>
</tr>
<tr>
<td>4</td>
<td>-150</td>
<td>-100</td>
<td>38</td>
</tr>
<tr>
<td>5</td>
<td>-100</td>
<td>-50</td>
<td>72</td>
</tr>
<tr>
<td>6</td>
<td>-50</td>
<td>0</td>
<td>348</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>50</td>
<td>218</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>100</td>
<td>72</td>
</tr>
<tr>
<td>9</td>
<td>100</td>
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</tr>
<tr>
<td>10</td>
<td>120</td>
<td>999999</td>
<td>51</td>
</tr>
</tbody>
</table>

Table 4.7 Distributions of the Difference Between Vehicle Trips Before and After Refinement (First Data Distribution Set)

Figures 4.21 and 4.22 are graphic representations of the distribution calculated in Table 4.7 for both conditions: trips leaving (Figure 4.21) and trips entering (Figure 4.222).
Figure 4.21 Distribution of the Difference between Vehicle Trips Leaving a TAZ Before and After Refinement (First Data Distribution Set)

Figure 4.22 Distribution of the Difference Between Vehicle Trips Entering a TAZ Before and After Refinement (First Data Distribution Set)
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As it is shown in Figures 4.21 and 4.22 most of the data for both conditions (trips entering and trips leaving a TAZ) fall within ranges 6 and 7 (± 50 trips). For that reason and even though the data points contained in ranges 1, 2, 3, 4, 5, 8, 9 and 10 are in ranges where the levels of activity are considerably affected after the refinement process, data in these categories could be grouped into a single range. That means that centroids where the difference between vehicle trips before and after refinement is less than -50 trips or higher than 50 trips should be assigned with the biggest circle size.

Ranges 6 and 7 were analyzed with more detail to find out their data distribution and define more ranges for the magnitude of the level of activity adjustment. The distribution of the TAZs located within these ranges is called the second data distribution set.

Table 4.8 shows the distribution of the difference between the number of vehicles trips before and after the refinement process for TAZs located in ranges 6 and 7.

<table>
<thead>
<tr>
<th>Range No</th>
<th>Range</th>
<th>Leaving</th>
<th>Entering</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-50</td>
<td>-25</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>-25</td>
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<td>275</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>25</td>
<td>136</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>50</td>
<td>82</td>
</tr>
</tbody>
</table>

Table 4.8 Distributions of the Difference Between Vehicle Trips Before and After Refinement (Second Data Distribution Set)

Figures 4.23 and 4.24 are the graphic representation of the second data distribution set calculated in table 4.8.
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Figure 4.23 Distributions of the Difference between Vehicle Trips Leaving Before and After Refinement (Second Data Distribution Set)

Figure 4.24 Distributions of the Difference Between Vehicle Trips Entering Before and After Refinement (Second Data Distribution Set)
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The conditions “vehicle trips leaving” (Figure 4.23) and “vehicle trips entering” (Figure 4.24) have almost the same data distribution; most of the samples fall into ranges number 2 and 3.

Although the magnitude of the level of activity adjustment in ranges 2 and 3 is very small, data points should not be grouped into a single range because an excessive number of “small circles” will make the map visually confusing. For that reason it is better to investigate the data distribution on these ranges and find out a range close to zero for which centroids could be assigned a minimum circle size so that they are not noticeable in the display.

Table 4.9 shows the distribution of the TAZs where the difference between vehicle trips before and after refinement is higher than -25 trips and less than 25 trips. This will be called the third data distribution set.

<table>
<thead>
<tr>
<th>Range No</th>
<th>Range</th>
<th>Leaving</th>
<th>Entering</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>-10</td>
<td>58</td>
</tr>
<tr>
<td>2</td>
<td>-10</td>
<td>-5</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>-5</td>
<td>0</td>
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</tr>
<tr>
<td>4</td>
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<td>5</td>
<td>57</td>
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<tr>
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</tr>
<tr>
<td>6</td>
<td>10</td>
<td>25</td>
<td>61</td>
</tr>
</tbody>
</table>

Table 4.9 Distributions of the Difference Between Vehicle Trips Before and After Refinement (Third Data Distribution Set)

Figures 4.25 and 4.26 show the graphic distribution of the data from Table 4.9.
Figure 4.25 Distributions of the Difference between Vehicle Trips Leaving Before and After Refinement (Third Data Distribution Set)

Figure 4.26 Distributions of the Difference Between Vehicle Trips Entering Before and After Refinement (Third Data Distribution Set)
EVALUATION AND ANALYSIS OF THE RESULTS

Based on this analysis the final range selection for the magnitude of the level of activity adjustment was determined as follows:

<table>
<thead>
<tr>
<th>Range No</th>
<th>Range 1</th>
<th>Range 2</th>
<th>Centroid Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-650</td>
<td>-100</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>-100</td>
<td>-50</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>-50</td>
<td>-5</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
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<td>100</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>650</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 4.10 Final Range Selection of the Level of Activity Adjustment and Centroid Size

The principal reasons for this selection are:

- The data distribution in the first data set indicates that most of the data is located between -50 and 50 trips. It was also determined that the minimum and maximum value in the entire data set was -466 and 630 trips. Based on this information and because the idea is to keep the same ranges for positive and negative numbers it was decided that the TAZs where the vehicle trip difference falls within -650 to -100 and 100 to 650 trips will be assigned the biggest centroid size (30 points).

- Based on the third data distribution set it was decided that values between -5 and 5 trips, which do not represent a significant change in the level of activity will be assigned with a centroid size of 3 points. These centroids are not noticeable in the maps.
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• All the other data was equally distributed with a centroid size of 10 and 20 points.

Interpretation of Maps (Vehicle Trips Entering and Leaving the TAZs)

O-D factors and vehicle trips leaving and entering the TAZs produce similar displays for the level of activity adjustment but since more considerations were used to set ranges for the level of activity and the centroids size using the vehicle trips parameter, this was selected for further analysis.

➢ Vehicle Trips Leaving (Origin Display)

The map in Figure 4.19 shows the level of activity adjustment needed for the network to operate at volumes lower than the threshold values when the trips are leaving the TAZs. Dark (red) dots indicate that too many trips are leaving the TAZs and Light (green) dots that those TAZs could originate more trips during the afternoon peak hour.

This map follows similar patterns as the map using origin factors where lighter (green) dots are mostly spread out in the network. There is only an area to the northwest of downtown with a high concentration of lighter (green) dots. It can also be seen that the darker (red) dots are concentrated in downtown and along corridors with high traffic volumes (darker links).

As it is shown in Figure 4.27 there are seven districts with a high concentration of trip change in the Tallahassee network. Districts 1 through 6 represent areas where most of the trips are originated while District 7 (dotted line) represent an area with low levels of activity.
Figure 4.27 Districts with a High Concentration of Red and Green Dots (Origin Display)
“In order to understand and give some explanations for the results, the demographic characteristics of the centroids with a significant level of activity adjustment located within these districts were analyzed in more detail.”

In order to understand and give some explanations for the results, the demographic characteristics of the centroids with a significant level of activity adjustment located within these districts were analyzed in more detail. Centroids with significant level of activity were those in ranges 1, 2, 7 and 8 (more than 50 trip change per centroid), which are shown with the biggest circle size.

Figure 4.28 shows the total retail and nonretail employment and households on each of the seven districts while Figure 4.29 shows the percentage distribution of these demographic characteristics on each district.
EVALUATION AND ANALYSIS OF THE RESULTS

Figure 4.29 Retail and Nonretail Employment and Household Distribution (Districts 1 - 7)

Figures 4.28 and 4.29 give a general understanding of the origin and destination of the trips during the afternoon peak hour in the City of Tallahassee. These figures can also be used to understand the levels of activity and the travel patterns in those seven districts.

The following conclusions were drawn from Figures 4.28 and 4.29:
EVALUATION AND ANALYSIS OF THE RESULTS

District 1 - This area represents the central business district of downtown Tallahassee. A significant amount of trips originate in this area during the afternoon peak hour (5 pm to 6 pm) when trips are made in the attraction to production direction. People working or doing business in downtown are usually going back home at this time of the day.

Figure 4.29 shows that the retail and the nonretail activities, which reveal the level of employment activity, account for nearly all of the total land use activity in this district. Figure 4.28 shows that there are only 267 dwelling units in this area that corresponds to a 3% of the total land use activity. That indicates that district 1 has a high employment activity and that a significant number of trips will originate in this area during the afternoon peak hour. This excessive level of employment activity is the reason why there is a high concentration of big darker (red) circles in the downtown area.

District 2 - In contrast to district 1, it is quite difficult to come up with conclusions about the travel behavior in this district from its geographic location. District 2 is located near to downtown and it has a large number of households as it is shown in Figure 4.28. The presence of households and the relatively low levels of retail and nonretail employment (Figure 4.29) are probably the reasons why there is not a high concentration of darker (red) circles in this district.

Districts 3, 4, 5 and 6 – These districts are located along principal arterials where the traffic volume is close or greater than the threshold volume for roadway widening. As it is shown in figures 4.28 and 4.29 districts 3, 4, 5 and 6 have a similar land use activity distribution. They have both a large number of dwelling units and a high level of employment activity, as it is the case in the downtown area. For that reason a lot of trips originate in these areas during the afternoon peak hour when people are traveling from their work place back to their houses. The high employment activity is the principal cause of having a high concentration of an oversupply of trips in these districts.

Districts 7 – This area has a high concentration of lighter (green) dots, which means that it could accommodate more activity and still have traffic volumes below the threshold values for roadway widening. As it is shown in Figures 4.28 and 4.29 this district has a large number of dwelling units and a relatively low level of retail and nonretail activities. Based on this information it is clear that some of the employment generators located in the other six districts, where an important amount of trips are being
originated during the afternoon peak hour, could be relocated in District 7. This could also contribute to have a better land use distribution (mixed land use) in District 7.

Vehicle Trips Entering (Destination Display)

The map in Figure 4.20 shows the level of activity adjustment calculated from the vehicle trips entering the TAZs, which is similar to the map in Figure 4.19 calculated from the vehicle trips leaving the TAZs. The similarity is based on the location of areas with TAZs having an excessive level of activity and the tendency for the TAZs with low levels of activity to be spread out in the network. Most of the trips in the Tallahassee network during the afternoon peak hour not only have their origin on areas with high levels of activity but also their destinations. This is indicative of a balance between the number of retail, nonretail and dwelling units in those areas.

As it is shown in Figure 4.20 centroids with high levels of activity are concentrated in the same six districts identified in the origin display (trips leaving the TAZs) with few exceptions. In the downtown area, for example, although there are still some zones generating excessive trips they are not as concentrated as they were in the origin display. The reason for that tendency is that during the afternoon peak hour rather than going to downtown, people are going back home from work.

There are few changes between the origin and the destination display. For the destination display District 5 not only has centroids with excessive levels of activity but also areas that could have more activity.

Two new districts were identified in the destination display for having a high concentration of either darker (red) or lighter (green) dots as it is shown in Figure 4.30. District 8 is one of those new districts and it is located to the northeast side of downtown. It has an important concentration of zones with excessive activity along a principal arterial. District 9, located to the east of downtown, has a high concentration of centroids with low levels of activity (green dots).

Figures 4.31 and 4.32 show the percentage of productions and attractions by trip purpose for districts 8 and 9.
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Figure 4.30 Districts with a High Concentration of Red and Green Dots (Destination Display)

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EVALUATION AND ANALYSIS OF THE RESULTS

Figure 4.31 Retail and Nonretail Employment and Household Size (Districts 8 and 9)

Figure 4.32 Retail and Nonretail Employment Household Distribution (Districts 8 and 9)
“The major benefit of connectivity is that it will help to redistribute the traffic on the network and therefore to provide extra capacity. Consequently, improving the street connectivity of local roads could replace the use of highway widening to provide more capacity in a network.”

EVALUATION AND ANALYSIS OF THE RESULTS

The following conclusions were drawn from figures 4.31 and 4.32:

**District 8** – This area located northwest of downtown has a large number of dwelling units. Figure 4.32 shows that 79% of the land use in this area is residential while only 4% and 18% is dedicated to retail and nonretail activities. Due to this land use distribution several over producing zones are concentrated in this area, which means that a lot of trips made during the afternoon peak hour have their destination in District 8.

**District 9** – In contrast to district 8, this area located to the east of downtown has a high concentration of under producing zones. As it is shown in Figures 4.31 and 4.32 although the land use activity is more balanced, there is a relatively higher number of nonretail businesses in this area. District 9 not only has low levels of activity in the destination display but also in the origin display as it is shown in Figure 4.27. That indicates that it is possible to increase the levels of activity by bringing more households or businesses into the area and still be able to keep traffic volumes lower than the threshold volumes for roadway widening.

Using the results from the connectivity analysis and the demographic characteristics of the districts with a high concentration of potential land use activity, it is possible to do a more comprehensive interpretation of the travel patterns in the City of Tallahassee. The connectivity analysis demonstrated that by improving the connectivity of residential streets, traffic volumes on the arterials can be significantly reduced. There has to be a balance however, between connectivity and through traffic. Enough connectivity has to be provided so that people can reach their destinations in a more efficient way but not to the extreme that neighborhood streets become attractive choices for through traffic to avoid congestion on the arterials. The major benefit of connectivity is that it will help to redistribute the traffic on the network and therefore to provide extra capacity. Consequently, improving the street connectivity of local roads could replace the use of highway widening to provide more capacity in a network.

If one looks at the land use activity distribution of the City of Tallahassee it is clear that most of the trips during the afternoon peak hour have their origins and destinations in districts close to downtown. These areas are characterized for having an interconnected grid pattern, which means, that capacity cannot be improved by providing
“One of the alternative solutions for the problem of congestion in downtown and its surrounding areas would be to redistribute the land use activity based on the adjustments calculated from O-D factors or the vehicle trips leaving and entering the TAZs.”

“EVALUATION AND ANALYSIS OF THE RESULTS

more connectivity. Additionally, a big percentage of the total area in downtown is already dedicated to streets and therefore highway widening cannot be used to provide more capacity. That leads to the conclusion that improving street connectivity is a successful solution to the problem of congestion only in suburban areas but not in the central business district.

When the demographic characteristics of the districts identified as important trip generators were analyzed, it was determined that they have a balance between the number of dwelling units, the retail and the nonretail activities. However, as it can be seen in Figures 4.29 and 4.32 most of the districts have a higher percentage of nonretail and retail employment than dwelling units, which means that employment is still the predominant activity in those areas.

One of the alternative solutions for the problem of congestion in downtown and its surrounding areas would be to redistribute the land use activity based on the adjustments calculated from OD factors or the vehicle trips leaving and entering the TAZs. Policy can be enforced to reduce the levels of activity in some areas so that the network operates at volumes inferior to the threshold values. Growth in households and business from areas with high levels of activity can be shifted to places, which could have additional trip activity and not affect the traffic on constrained links such as Districts 7 and 9. This implies that more people could live in the downtown area and to also move employment generators away the central business district. Land use changes of this proportion, especially relocating employment generators, are difficult because of some other problems associated with it.

Other alternatives to solve the problem of congestion in areas close to downtown are: provide a reliable transit service, increase transit, walking and bicycle use, and better jobs/housing balance. Additionally, a mode split analysis can be performed so that the traffic impact of space inefficient modes of transportation is estimated. Trips made by automobile, for example, have a lower average occupancy during the peak hour periods whereas bus and rapid transit load factors are higher at those times. It may be that prime market areas for transit could be identified with the use of methods developed in this study.
PART V: CONCLUSION

5.1 Summary

Perhaps one of the most controversial issues a community can face is the question of street widening. This topic has created a continuous debate between local government officials, transportation engineers and taxpayers. However, it is ironic that communities concerned about the costs and impacts of widening often take steps in their land development process that inevitably lead to the widening they oppose.

This report identifies two critical land use factors that lead to highway widening: street connectivity and land use density. Connectivity was evaluated by looking at changes in traffic on arterials before and after connectivity improvements on local streets. It was demonstrated that arterials could experience more than a 50 percent traffic reduction with better neighborhood street connectivity depending on the speeds on both the local roads and the arterial. Land use density was related to the general level of activity in a study area given by the number of dwelling units and the retail and nonretail activities.

The major outcome of this study is to develop a methodology to find out how much land use activity could occur throughout a network with fixed roadways capacities by finding optimal levels of activity for particular locations.

5.2 Conclusions

Threshold Analysis

Threshold volume was defined as the boundary between level of service D and E on a two-lane highway. A sensitivity analysis showed that the following factors are critical for getting the most effective use of two-lane highways based on calculated threshold volumes.

- Threshold volumes are sensitive to the number of access points along a two-lane roadway. This number should not be equal or greater than 30 per mile or a separation between access points should be more than an average of 330 ft.
“From the street connectivity case study analysis it was found that the traffic on an arterial could be reduced due to connectivity improvements in the local streets. The magnitude of the effect depends on the speed of the local roads and the arterial.”

“Street Connectivity

From the street connectivity case study analysis it was found that the traffic on an arterial could be reduced due to connectivity improvements in the local streets. The magnitude of the effect depends on the speed of the local roads and the arterial.

For example, when the speed on the local roads is 25 mph and on the arterial 40 mph, the traffic volume reduction including the external-external trips would be 10.59%. If external-external trips are not included in the analysis this traffic reduction is 15.78%. The effect varies from 4.04% when there is a large speed differential to 85.65% when speeds on the local roads and the arterial are equal.

There is a critical balance between connectivity and through traffic. Enough connectivity has to be provided so that residents of a neighborhood can easily move to all edges of the neighborhood and adjacent land uses but not to an extreme so that residential streets become attractive choices for through traffic.”

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• The percentage of no-passing zones should be 20% or lower. Even though this percentage is often set for safety purposes it is the most critical variable in the LOS estimation.

• Shoulder width and directional split do not have a major influence in the LOS as long as the shoulder width is 2 ft or more and the directional split is 80/20 or lower. When the directional split is 90/20 the LOS threshold of a two-lane highway could drop substantially.

With these conditions, it was determined that the threshold volume for a two way street was 1500 vehicles per hour in both directions. Using time of day factors from traffic counts, this translates into a daily volume of 18,293 vehicles per day or about 20,000 person trips per day.

Since the capacity on a network also depends on the capacity of its intersections it is important to find the minimum operational conditions of the intersections required to accommodate the threshold volumes. Using the Highway Capacity Software (HCS) it was determined that for an intersection to accommodate threshold volumes, at least two approach lanes are needed in each direction, one that shares the through and the right turning movement and the other with shared through and left turning movement.
CONCLUSION

This report shows how congestion in urban areas relates to land use activity as based on adjustments in O-D factors or vehicle trips leaving and entering the TAZs. The methodology developed in this study could lead to better land use decisions that indicate how a city could grow without the need to widen highways.

The major benefit of street connectivity is that it redistributes traffic on a network providing an overall increase in the capacity of the system. Consequently, improving street connectivity of residential streets could reduce the need for arterial highway widening by providing more options for local trips.

Based on the results from the case study it is clear that better street connectivity is an alternative to congestion problems and/or can avoid the need for roadway widening in suburban areas. Downtowns and central business districts that have interconnected grid patterns may not be able to make connectivity improvements to provide more capacity. It is also evident that much of the area in downtowns is dedicated to streets and therefore street widening is not normally a feasible solution for the problem of congestion. Other options such as improving the public transit, better job/housing balance, and encouraging shorter trip lengths may be considered.

Land Use Density

The case study in the City of Tallahassee was used to test methods to determine levels of land use activity that result in a network that operates at volumes no greater than the threshold values.

The land use activity distribution of the City of Tallahassee reveals that most of the trips during the afternoon peak hour have their origins and destinations in districts, close to downtown and along principal arterials with high traffic volumes. That could be an indicator of balance between the number of dwelling units and the retail and nonretail activities in those areas. However, when the demographic information was evaluated in detail it was established that employment is the predominant activity in those districts.

This report shows how congestion in urban areas relates to land use activity as based on adjustments in O-D factors or vehicle trips leaving and entering the TAZs. The methodology developed in this study could lead to better land use decisions that indicate how a city could grow without the need to widen highways. Conversely, if road widening does occur, the methods could identify the sources of traffic that require the...
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widening. This may provide a way of assessing impact fees to pay for the costs of widening. While the land use activity adjustment is intended to reduce the overall congestion in the network, it may cause an increment of congestion and the level of activity in some particular locations.

It was also determined that the land use activity adjustments calculated from the difference between vehicle trips leaving and entering the TAZs before and after the refinement process and from origin-destination factors produce similar land use displays. The centroids size calculated from the magnitude of the level of activity adjustment has an important influence on how the maps are interpreted. One has to be very careful with this consideration because the evaluation of the land use activity highly depends on the visual interpretation of the maps.

The selection of the trip table estimation method, in this case the Fratar Biproportional GLS, proved to be a workable technique. The goal of the refinement process is to reproduce the observed traffic counts in the network making sure that the adjusted trip table does not deviate much from the seed trip table. That means that the adjustment factors calculated in the trip table estimation process will not allow big changes in the land use distribution.

The results presented on this report can be used as a framework to develop alternative solutions to the problem of congestion and highway widening. The following considerations, derived from the analysis of land use factors conducted in this study, could help a community to improve levels of service and avoid highway widening:

- Government officials need to understand what is needed to implement the land use activity changes required in an urban area so that the traffic network operates at volumes no greater than the threshold values. In a City like Tallahassee that implies to bring more people to live in downtown and movement of some employment generators from the central business district.

- Growth in households and businesses should avoid areas with high levels of activity and should be relocated in places, where additional trip activity will not affect the traffic on constrained links.
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- If land use changes are not implemented in a proper manner, especially relocating employment generators, they could lead to sprawl and some other problems associated with it.

- Space efficient transportation modes, such as transit, bicycle and walking could replace some of the vehicle trips originated in areas with high levels of activity.

Planning organizations and government officials could adapt the methodology presented in this report to deal with congestion and minimize the use of roadway widening in their own communities. The following steps should be taken as a guideline for urban planning studies and may be adjusted based on the particular conditions of the study area.

Land use factors - It is important to define the land use factors that are going to be included in the analysis. As it was demonstrated in this study street connectivity and land use density have a substantial influence on the need for roadway widening. Other factors such as access point spacing and land use mix may be also considered in the analysis.

Threshold Volumes for Roadway Widening - This number should be selected based on the operational and geometric conditions of the highway facilities in the study area. This parameter has a direct impact on the travel experience and the level of livability in the community.

Network Construction Considerations – Most travel forecasting models do not require a detail traffic network. For the street connectivity analysis, at least in the area where connectivity is being evaluated, residential streets must be coded in the network. Demographic information refinement is also needed to obtain precise information on how street connectivity of the local roads affect the traffic volume on the arterials.

Trip Table Estimation Method – This method should be selected based on the purpose and the conditions of the analysis. For Peak hour conditions the Fratar Biproportional GLS is recommended.
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**Land Use Activity Adjustments** – The analyst must select an adequate parameter to calculate land use activity adjustments. The forecasting tool used in this study (QRS II) provides origin-destination factors and vehicle trips leaving and entering the TAZs that were used for this purpose.

The two principal solutions for the problem of highway widening presented in this report are the improvements of street connectivity on local roads and the redistribution of land use activity throughout an urban area. A mode split analysis should be conducted to understand how trips in areas with high levels of activity concentration would shift between modes with a constrained street network. This could be used to create disincentives for those transportation modes that create congestion and promote the use of space efficient transportation modes, such as transit, bicycle and walking. Trips made by automobile, for example, have a lower average occupancy during the peak hour periods whereas bus and rapid transit load factors are higher at those times.

Based on the trip length distribution information provided by QRS II in the files “LengthDS.txt” before and after the refinement process was completed it was found that the trip estimation model holds the trips length distribution constant in the entire network. By doing that the model may not be taking into account the fact that improvements of connectivity in local streets would allow travelers to find more direct paths to reach their destinations, reducing the trips length substantially. For that reason further research on this topic is needed. A land use model could also be implemented in the analysis so that when trips length change the land use activity could redistribute in the network.

As centroids size was modified based on the range selection for the magnitude of the level of activity adjustment the origin and destination displays would vary substantially. Better ways of analyzing and displaying results are needed since the land use activity evaluation in a urban area relies on the visual interpretation of the maps. Quantitative ways for interpretation of the data and specific measures of spatial information that indicate results while maintaining locational information should be developed.

Finally, results from this study reveal that enough connectivity has to be provided on local streets so that traffic volumes can be spread out more efficiently throughout a network. The question remains open regarding how much traffic neighborhood streets
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could take so that they do not become attractive choices for through traffic. In that respect more studies about safety and livability levels of residential areas with grid patterns (Neotraditional neighborhood design) are needed so that an appropriate level of traffic will occur.
REFERENCES


REFERENCES


