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# Optimal Detour Planning Around Blocked Construction Zones

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# OPTIMAL DETOUR PLANNING AROUND BLOCKED CONSTRUCTION ZONES

by

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# ABSTRACT

Construction zones are traffic way areas where construction, maintenance or utility work is identified by warning signs, signals and indicators, including those on transport devices that mark the beginning and end of construction zones. Construction zones are among the most dangerous work areas, with workers facing workplace safety challenges that often lead to catastrophic injuries or fatalities.

In addition, daily commuters are also impacted by construction zone detours that affect their safety and daily commute time. These problems represent major challenges to construction planners as they are required to plan vehicle routes around construction zones in such a way that maximizes the safety of construction workers and reduces the impact on daily commuters.

This research aims at developing a framework for optimizing the planning of construction detours. The main objectives of the research are to first identify all the decision variables that affect the planning of construction detours and secondly, implement a model based on shortest path formulation to identify the optimal alternatives for construction detours.

The ultimate goal of this research is to offer construction planners with the essential guidelines to improve construction safety and reduce construction zone hazards as well as a robust tool for selecting and optimizing construction zone detours.

To my mother

# ACKNOWLEDGMENTS

There are too many people and too little space. I would like to express my deepest gratitude to my mentor and academic advisor, Dr. Ahmed Khalafallah, for all his valuable advice, constructive guidance and solid support throughout my masters program. I give special appreciation to all my committee members; Dr. Ahmed Khalafallah, Dr. Essam Radwan, and Dr. Noor Elmitiny. There are no words that can express my appreciation to them.

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Very special thanks to my mother for her patience, support and continuous encouragement throughout my entire life especially during my graduate years. I would also like to thank my siblings Hadil, MJ, and Rana for their helpful advice and support.

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# CHAPTER ONE: INTRODUCTION

## 1.1 Overview

Many commuters go through traffic detours on a daily basis. Traffic detour, or rerouting, is a process that forces the through traffic to follow an alternate path to promote safety and efficiency. This process promotes the orderly movement of all road users on streets and highways throughout construction and work zones. There are many reasons to have the need for a traffic detour such as lane closure due to adverse weather conditions, road maintenance, utility construction work activities, etc. Traffic detours are typically identified by warning signs, signals and indicators, including those on mobile transport devices that guide the commuters through the detour. If road construction work will affect the flow of traffic and will require a detour, local authorities usually require plans to contain a detailed process for the traffic detour. The requirement of such traffic detours vary from state to state, county to county or city to city.

Most local authorities and municipalities pay close attention to make sure that detour signs are easily understood by both local residents and daily commuters, who are only familiar with the main traffic path. Selection of detour links (road segments), however, do not have specific guidelines other than to avoid detouring traffic into roads known to be at or exceeding road traffic capacity, and therefore fail to achieve the desirable level of service.

## 1.2 Importance of Detours

Detours are usually associated with complete blockage of the roadway. The total blockage of the construction zone allows faster completion of the task in order to shorten the traffic disturbance period. Safety is also a major concern, and road blockage provides a comfortable work environment for workers. Moreover, detours allow the use of unutilized road capacity that is already in the transportation network.

### 1.2.1 Cost Associated with Construction Detours

When it comes to economic feasibility, the dilemma is between the cost of blocking the whole road for the total duration of the project versus a partial blocking of the road. While the former allows faster completion of the specific task, the latter option requires less detour planning. In addition to these factors, the cost of the delay due to construction should be considered in evaluating the more feasible choice.

### 1.2.2 Construction Detour Safety

Many studies have tried to evaluate the safety of highway construction zones in several locations throughout the United States. Harb, in a 2009 study, concluded that these studies confirmed that work zones produce a significantly higher rate of crashes when compared to non-work zone locations. He also cited that work zones are responsible for a 26% increase in motor vehicle crashes during construction or roadway maintenance (Harb, 2009 ).

## 1.3 Problem Statement

There are many problems associated with detours. For instance, detours can lead commuters to unfamiliar traffic networks that can create a disturbance and discomfort with the commuter and their surroundings. Secondly, detours may cause the alternate path (detour) to reach maximum capacity, which causes a decline in the level of service. The scarcity of guidelines and tools to help engineers plan efficient detours can lead to overlooking available detour choices. Engineers can potentially overlook these valuable choices due to the lack of adequate and accurate methods to compare different available detour options. The main goal of this research is to use machine-learning and optimization techniques to develop tools and guidelines that can help engineers optimize detour plans. These tools could potentially offer a better utilization of the available capacity in the entire traffic network.

## 1.4 Research Objectives

As mentioned above, the main objective of this research is to address the pressing need for a tool to help in the optimization of detour planning. Modern advances in machine-learning techniques and high-computing capacity has contributed in many ways to find optimal solutions for many problems.

This research endeavored to use the shortest path formulation technique to help facilitate the detour planning process for the purpose of creating a tool to help engineers better plan an efficient, capacity-utilizing detour without compromising the safety of workers or motorists. In order to achieve this objective the following sub-objectives need to be fulfilled.

Sub-Objective 1:

The first sub-objective that needed to be considered is to identify all the decision variables that affect the planning of construction detours.

Research Questions:

The research questions that are related to the first sub- objective are

(a) What links should be removed from the network? (b) How do we identify the various design variables? (c) What effects could the identified variables have on detours? (d) What factors have significant impact on construction detour?

Hypothesis:

The variables that have the most significant impact on selecting the optimal route for construction detour can be identified form data collection and observations.

Sub-Objective 2:

Implement a model based on shortest path formulation to identify the optimal alternatives for construction detours that are be capable of (i) reducing travel time associated with detours around blocked construction zones based on commuter point of view; (ii) reducing travel cost associated with detours around blocked construction zones based on commuter point of view.

Research Questions:

In order to accomplish this sub- objective, the following research questions need to be addressed:

(a) How to build a model that can identify all the alternatives? (b) How can the selected alternatives be simultaneously optimized using the model? (c) What are the required software tools for implementing a model based on shortest path formulation?

Hypothesis:

To formulate linear models that are able of optimizing routes in order to (i) minimize the travel cost and (ii) minimize the travel time for commuter.

# CHAPTER TWO: LITERATURE REVIEW

An extensive literature review was performed on available references. These references address similar issues or issues related to this area of research. This research serves to develop new research approaches and alternatives followed in the research included in this study. The most relevant resources of literature are summarized as follows.

## 2.1 Rerouting Vehicles around Transportation Networks

Elmitiny, in his thesis about creating an evacuation route, said that simulating the traffic is considered one of the most useful techniques in organizing and coordinating traffic flow. Elmitiny added that with modern advanced computers and machine learning, it is possible to model multiple networks and roadways. Elmitiny suggests that by simulating these networks, one can come up with a favorable alternative that is considered the best fit or solution for the situation (Elmitiny, 2006).

Radwan et al. mentioned the values of new techniques for tackling traffic incidents, whether these incidents are natural, such as hurricane floods, or man-made, such as road construction or car accidents. Radwan mentioned the importance of having a good detour around the incident location (Radwan et al., 2003).

Hu et al. presented an intellectual solution system for vehicle routing problems (VRP). This intellectual or intelligent solution is comprised of three main phases. The first phase uses the collected data analysis from data mining to organize all customers by a number of characteristics, such as distance, demand level, city layout and other factors. The second phase initiates how to create feasible routing schemes for each vehicle type. The third and last phase is to create a programming model that is built to identify the optimal routing schemes. Xiangpei Hu and his colleagues also demonstrated an actual vehicle routing problem showing how to solve the VRP. For example, Figure 1: The Structure of the Intelligent Solution System for VRP (Hu et al., 2007) illustrates what steps are followed after collecting the problem information. One first inputs the problem information and then inputs the information into Geographical Information System (GIS)-based classification. After that, finding the feasible vehicle routing scheme requires generating, then inputting these schemes and integrating them to identify optimal routing schemes (Hu et al., 2007).

Snelder et al. described how a disturbance of even a small section of a network can cause a major disruption on that network as a whole, such as congestion and delays.

Snelder and his colleagues used a method that consists of a analysis of the specification of the design standards and process next to analysis of the road network and testing the quality of the network (Snelder et al., 2009).

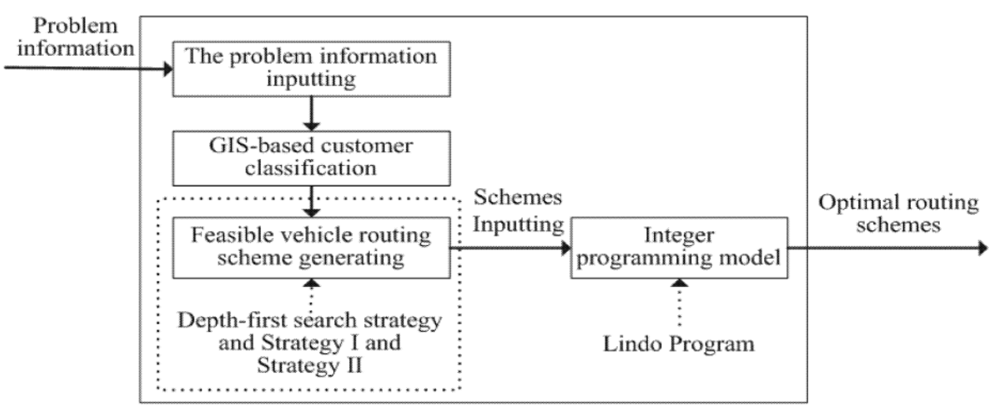



Figure 1: The Structure of the Intelligent Solution System for VRP (Hu et al., 2007)

Peralta et al. in their assessment of the impact of high rise buildings on the electric and transportation infrastructure did a study that simulated and analyzed the operating condition of critical infrastructure. Their study consists of two main parts. One of them consists of user equilibrium analysis of the transportation infrastructure. One of their findings was dependant on the configuration of the network and the location of blackouts that caused the ratio of capacity to volume to go down to a point where total traffic jam occurs (Peralta et al., 2009).

## 2.2 Computational Methods for Routing Problems

Khushaba et al. claim that even though ant colony optimization showed that it is a very good technique in diverse types of optimization problems, it still needs some development when applied to a specific problem. Rami N. Khushaba and his colleagues combined the use of ant colony optimization and differential evolution to get a better, more well- rounded result in their work and research (Khushaba et al., 2008).

Cai et al. in their book *Time Varying Network Optimization* said that network flow optimization problems appears in many significant fields such as telecommunication, transportation, computer networking, chain management and many other felids They also mentioned that many important and accountable results have been achieved (Cai et al., 2007).

Yen said that finding the shortest path in network is a primary problem in network theory and has many applications in operation research and allied or associated fields (Yen, 1975).

Ruszczynski said optimization can be applied to many different applications. He also mentioned that optimization is mainly and widely used in fields such as engineering, statistics, and computer science. What makes Ruszczynskis' book different than other books is that he provided a new way to help understand the area of optimization and understand it in the modern way (Ruszczynski, 2006).

Du and Pardalos described how the major technological development which happened in the late 1980's gave a boost in all areas of human enterprise, but especially in the information field. They also mentioned how machine learning played an important role in providing fast, reliable and a cost effective method of communication and problem solving (Du and Pardalos, 1993).

One of the developed professional software in the field of transportation is TransCAD. TransCAD is Geographic Information System- Based Software capable of analyzing, and managing transportation data. One of the neat features of TransCAD is the ability to combine both the geographic information system with transportation modeling in a single model. TransCad can be used as a powerful geographic information system. In addition, TransCad has the ability to map, visualize, and analyze tools that designed for transportation applications (Caliper, 2011).

### 2.2.1 Linear Programming

Anderson, in *An Introduction to Management Science, Quantitative Approaches to Decision Making*, gives a good introduction about transportation, assignment, transshipment, and shortest route problems. He categorized these kinds of problems into one special category of linear programming called network flow problem. Anderson and his colleagues conclude that the network model for such a problem consist of nodes and arcs (Anderson, 2007). Focusing on the shortest route problems, they concluded that the main goal is to find the shortest path or route between two nodes of a route problem. These problems can be expressed as a transshipment problem with one origin and one destination. By transporting one unit from one point (the origin) to another point (the destination) the solution will determine the shortest route through the network.

### 2.2.2 Ant Colony Optimization

Dorigo and Caro said that one of the most successful examples of swarm intelligent system is ant algorithms. Dorigo and DiCaro defined ant algorithms as “multi-agent systems in which the behavior of each single agent called ‘artificial ant’ is inspired by the behavior of real ants” (Dorigo and Caro, 1999).

Socha presented a way to extend the Ant Colony Optimization Metaheuristic to continuously search domains. He applied the study to both continuous and mixed discrete-continuous optimization problems (Socha, 2004).

Becker concluded that ant colony optimization belongs to a class of biologically motivated computing that includes such metaheuristic-like reproduction of neural networks, evolutionary algorithms, and artificial immune systems. He added details about how ant colonies have achieved a way to discover solutions to complicated problems that would otherwise use many resources to solve using traditional techniques (Becker, 2006).

El-Nashar and El-Kilany discussed modeling and simulation in different kinds of problems. They found that the best solutions use modeling and simulation. A good data-based library should be built, making sure that this library contains multiple mechanisms and components (El-Nashar and El-Kilany, 2007).

### 2.2.3 Shortest Path Problem

In their book Path *Problems in Networks*, Baras and Theodorakopoulos said that the algebraic path problem is a generalization of the shortest path problem in graphs. A variety of instances of path problems have appeared in the literature, and similar solutions have been separately discovered and rediscovered. They showed how path problems in networks may be theoretically divided into two parts. They also said that the shortest path problem is presented to fix terminology and concepts: existence and uniqueness of solutions, strength to parameter changes, and centralized and distributed computation algorithms (Baras, 2010).

Bast et al. introduced the concept of transit nodes as a means for preprocessing a road network. By introducing the concept of transit nodes, they assisted in making the point to point shortest path queries solvable and answerable very quickly. In short, the transit nodes are a set of nodes with the property that every “none- local” shortest path passes through at least one of these nodes (Bast et al., 2009).

Sanders and Schultes developed a new observation which is when someone drives somewhere, he or she will pass via only few important traffic junctions. They presented a genetic framework for transit routing which permits constant time routing (Sanders and Schultes, 2009)

Barret et al. presented extension of a familiar speed up technique for the standard shortest path formulation and they conducted wide-ranging studies of those techniques performance. Their results showed that the search speed is based on the network type (Barret et al., 2009).

Santos said that the shortest path problem is one of the most studied optimization problem. J.L. Santos also mentioned that it has wide range of application and it could be used in direct or indirect ways to support other optimization techniques (Santos, 2009).

Lauther presented a method that is based on preprocessing and best suited for static graph to find the most efficient algorithm for quick and accurate calculations of the shortest path in graphs with geometrical information in nodes, coordinates (Lauther, 2009).

# CHAPTER THREE: METHODOLOGY

Most local authorities and municipalities pay close attention to ensure that the detour signs are easily understood by both local residents who are familiar with the area and daily commuters who are familiar with just the main traffic path. There are no specific guidelines for defining the path of the detour other than not to detour traffic into roads that are known to be at or exceeding road capacity (i.e., roads that failed to achieve the desirable level of service). The lack of guidelines and tools to help construction planners in selecting an efficient detour can lead to overlooking potentially good alternatives of available traffic detours. As such, there is a need for a system to specify detour guidelines and help construction planners in identifying optimal traffic routes that maximizes the safety of construction workers and commuters, while efficiently maximizing traffic flow.

## 3.1 Task 1: Network Planning

When it comes to network planning, the planner needs to deeply study the entire network, and evaluate all available alternatives to come up with the most optimal model. Also the network planner must make sure that the new proposed network meets the needs of the commuter as well as the local area residents and municipality. For such a reason, road networks could be modeled as a group of links and nodes. Moreover, the proposed network will have variety of variables such as single lane and multi-lane highways, freeways, toll roads, and roads with critical facilities such as a hospital or a fire station. For the proposed network, using the concept which was mentioned in the literature review section, the point of each intersection will be considered a node and each road that connects two nodes will be considered a link (arc). Each link can represent one or more of the following variables (i) travel distance, (ii) traveling time or (iii) traveling cost.

## 3.2 Task 2: Modeling Decision Objectives and Variables

There are many factors the daily commuter looks at when choosing an alternative, such as the type of road whether it be a multi-lane road, toll road, or freeway. Some commuters believe the most optimal detour is the one that has the highest capacity and/ or the highest speed limit. Since the parameters that humans can control are cost, distance or time, they will be considered as the main design objective of this research.

### 3.2.1 Distance

The length of each link can be determined by using s number of available software packages such as Google Earth or Mappoint. In this research, Google Earth will be used as it is a free and readily available tool

### 3.2.2 Time

The time for each link will be calculated based on the Bureau of Public Roads formula (Kockelman, 2004)

$$t(V) = t_f\left(1 + 0.15\left(\frac{V}{C}\right)^4\right) \qquad (1)$$

Where:

V is the traffic volume,

C is the practical capacity, corresponding to approximately 80 percent of the true capacity,

$t(V)$ is the actual travel time, as a function of demand volume V, and

$t_f$ is the free-flow travel time*

*The free travel time will be calculated by driving on each link at the exact speed limit during non rush hour for three times and finding the average of those three times.

### 3.2.3 Cost

There is more than one way to calculate the cost. Cost could be calculated based on the number of hours, number of miles, type of car, and other methods. The speed of the vehicles is expected to fluctuate within the zone of detour, so for this model the vehicle operating cost will be considered the main factor. In addition to the operation cost the model takes into account critical facilities. Critical facilities include, but are not limited to shelters, hospitals, and fire stations. Those facilities must be considered when selecting a new route for the detour. In many cases detours can disturb and jam the whole area or network, which may prevent emergency vehicles from reaching the critical facilities. Also, the model takes into account the cost of toll roads if applicable.

The graphical illustration below shows the main steps of the proposed optimization model for selecting the optimal route for detours.

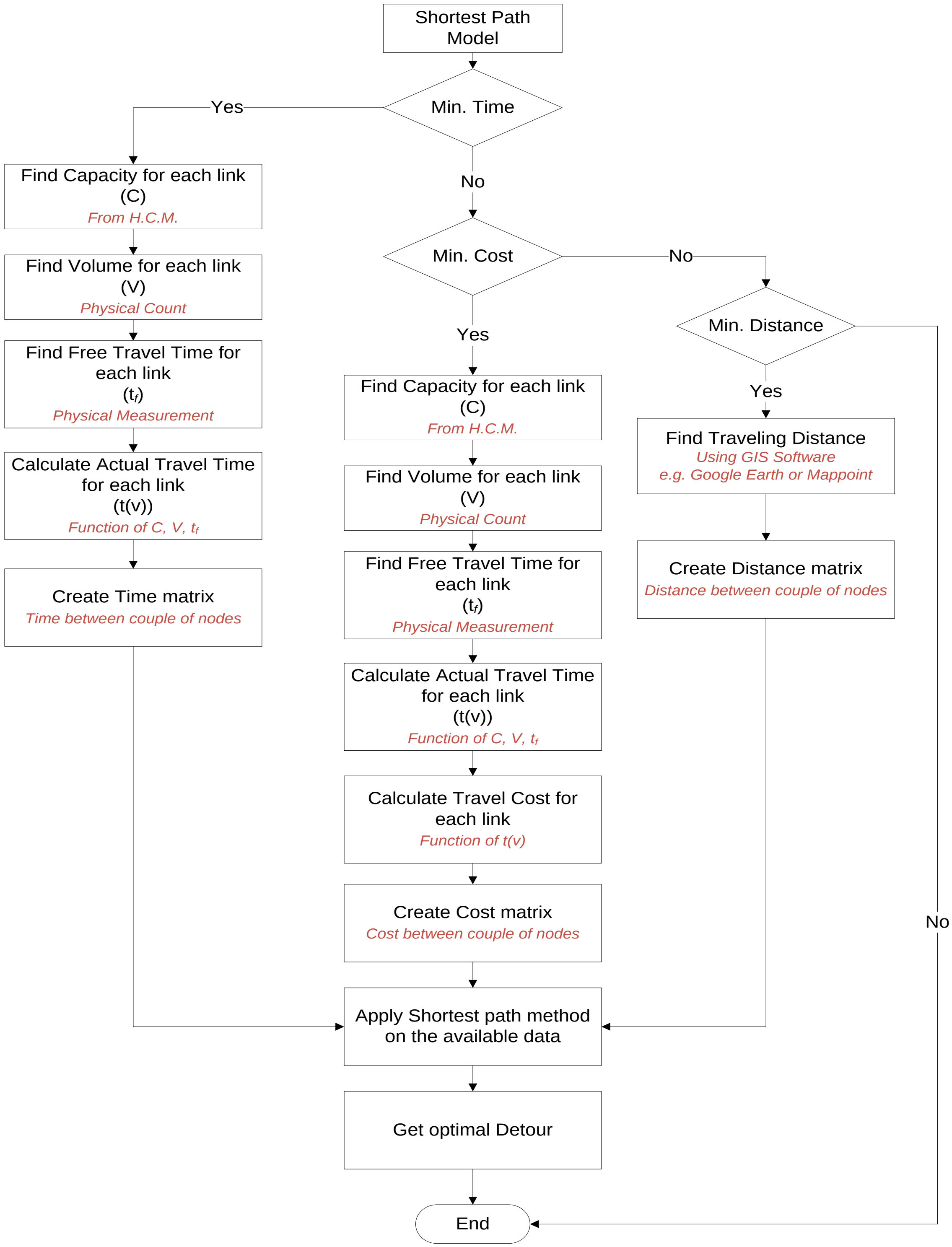



Figure 2: Optimization Model Formulation

### 3.3 Task 3: Selection Criteria

We have two main selection criteria which are traveling cost or traveling time. Depending on the designer and the decision maker this tool will help him/her to choose the optimal detour which will satisfy the community and the commuter needs. Note that the selection criteria dropped the distance as a factor, and that is due to the possibility of the distance to be a deceiving factor.

### 3.4 Research Example

#### 3.4.1 Description

In order to illustrate the dynamics of the research methodology, a research example is selected to discuss the previous tasks in more detail. The common route for traveling to the east campus of Valencia Community College is selected as a research example.

#### 3.4.2 Common Route (Route 1)

After a careful study of the city of Orlando roads, and specifically Orange County roads, it was observed that many daily commuters who work and/or study at Valencia Community College, drive through the intersection of South Goldenrod Road (SR 551) and Lake Underhill Road. The common route for those commuters is first heading north on Goldenrod Road (SR 551) until reaching the intersection of Goldenrod Road (SR 551) with Valencia College Lane (distance is 1 mile). Commuters then head east on Valencia College Lane (distance 2.1 miles) until reaching their destination, Valencia Community College, a total distance of 3.1 miles, as illustrated in Figure 3.

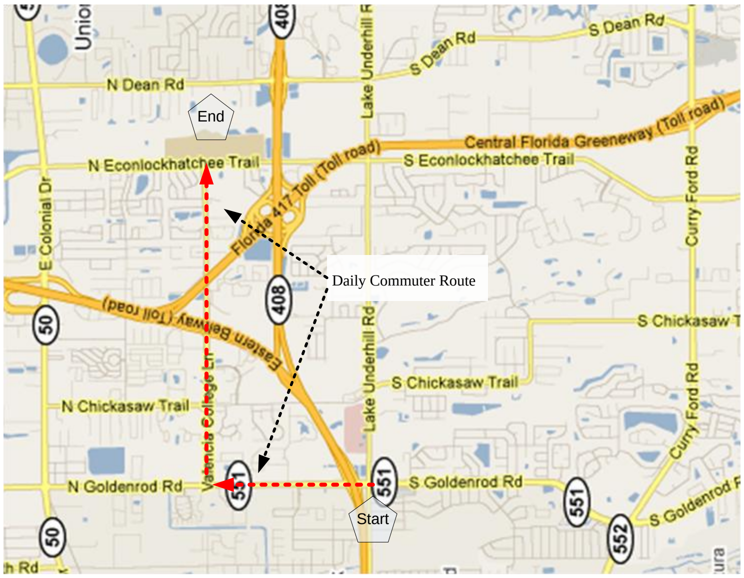


Figure 3: Daily Commuter Route to Valencia Community College.

### 3.4.3 Common Route with Closed Link

To implement the shortest path formulation, it was decided to close one section (link) of the daily commuter route (Route 1). After closing one specific link in the daily commuter route, we show as many realistic alternative routes as possible, then examine each one of those routes using machine-learning techniques and shortest path formulation. After finding those realistic alternatives, we will scale each one of those alternatives based on many factors to find the most feasible route as an alternative route for common route (Route 1).

The closed section or link was the link from the beginning of Valencia College Lane to the intersection of Valencia College Lane with North Chickasaw Trail. This link is considered a very important link in the daily commuter route. Since passing through the chosen link is a must for the daily commuter to reach his or her destination, it was hypothesized that closing this link would generate a major disturbance in the daily commuter route. The closed link was measured to be approximately half a mile, as illustrated in Figure 4.

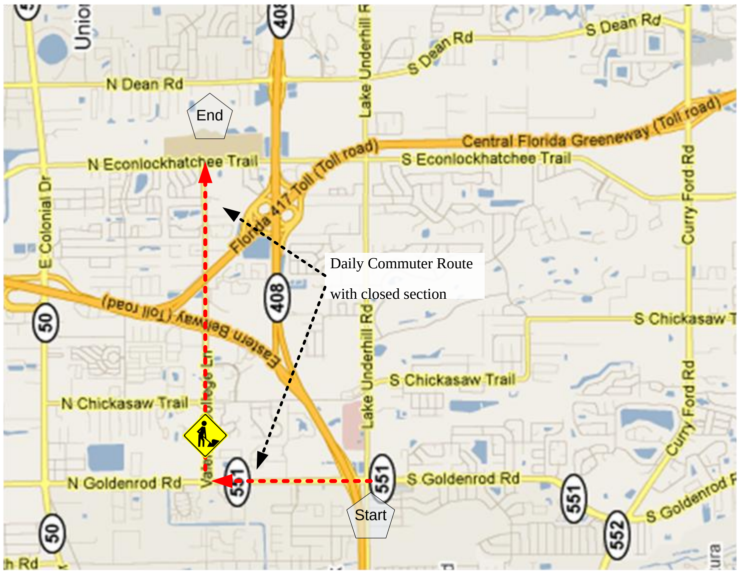


Figure 4: Daily Commuter Route Showing the Closed Section

### 3.4.4 Reroute Alternatives

#### 3.4.4.1 Detour Route A

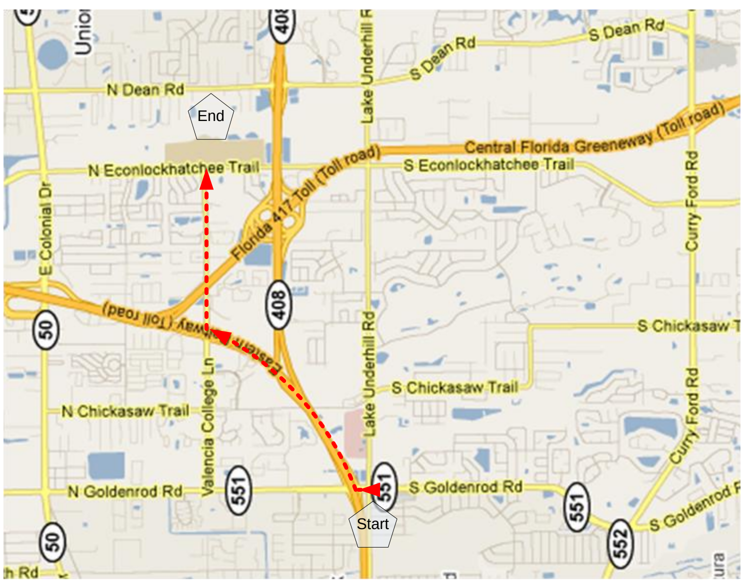


Figure 5: Detour Route A

This route started like the original route, by heading north on FL-551 N/S Goldenrod Road for approximately 0.35 mile, then turning right to merge onto FL-408 E toward Titusville, a distance of approximately 0.7 mile. The route then merged a slight left at Central Florida

Greeneway/Eastern Beltway/Florida 417 North, a distance of approximately 0.4 miles. Then the detour took the Valencia College Lane exit, a distance of approximately 0.3 mile. Finally, the detour turns right at Valencia College Lane, for a distance of approximately 1.3 mile, arriving at Valencia Community College after approximately four minutes. The main advantages for this route are distance and time (shortest distance and shortest time). On the other hand, this route's main disadvantage is cost. Since this route requires the commuter to take a toll road, it is a high-cost alternative.

3.4.4.2 Detour Route B

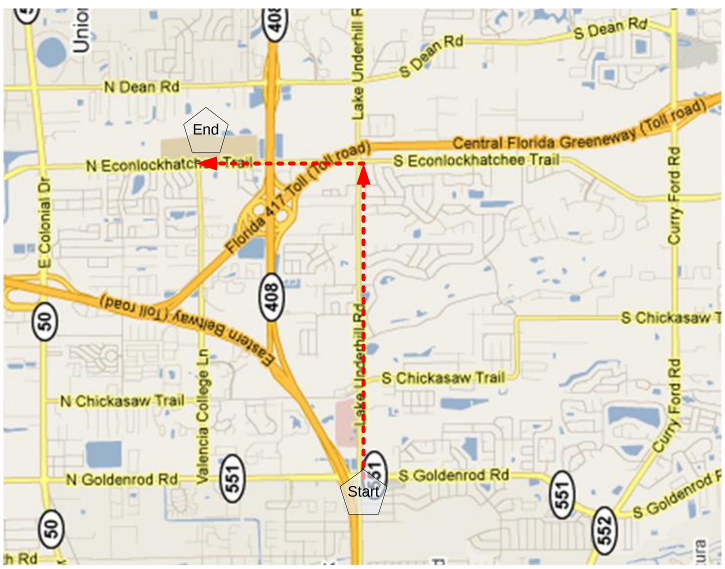


Figure 6: Detour Route B

This route starts by having the commuter heading east on Lake Underhill Road toward South Chickasaw Trail, a distance of approximately 2.0 miles. Drivers then turn left at South Econlockhatchee Trail, and follow it until they reach the main entrance of Valencia Community College at Valencia College Lane. The main advantage of this route is the distance, since this route is considered the second shortest distance between the points. The main disadvantage for this route is the presence of critical facility (a hospital, in our case).

3.4.4.3 Detour Route C

This route starts just like the original route by heading north on FL-551 N/S Goldenrod Road approximately 2.0 miles, then turning right at FL-50 E/E Colonial Drive, for a distance of 0.5 miles. Then, the route turns right at North Chickasaw Trail for 1.0 miles, and finally back on the original route by turning left on Valencia College Lane for approximately 1.7 miles. This route takes the daily commuter a total time of 12 minutes from point A, the intersection of Lake Underhill Road with Goldenrod Road, until reaching the final destination, Valencia Community College. The main disadvantage is the time this route takes, which is almost triple the time that the daily commuter is used to.

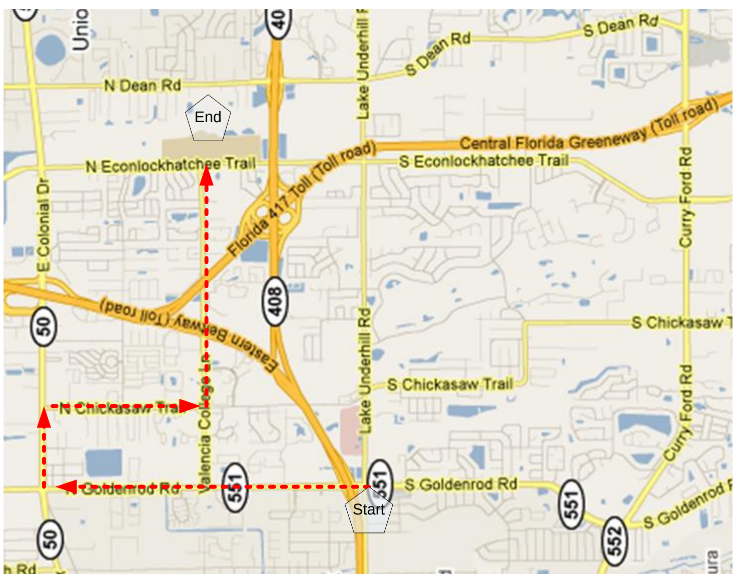


Figure 7: Detour Route C

3.4.4.4 Detour Route D

This route starts like the original route, by heading north on FL-551 N/S Goldenrod Road for approximately 2.0 miles, then turning right at FL-50 E/E Colonial Drive for a distance of 2.0 miles. The route then turns right at North Econlockhatchee Trail, for distance of 1 mile. This route takes about 11 minutes to complete.

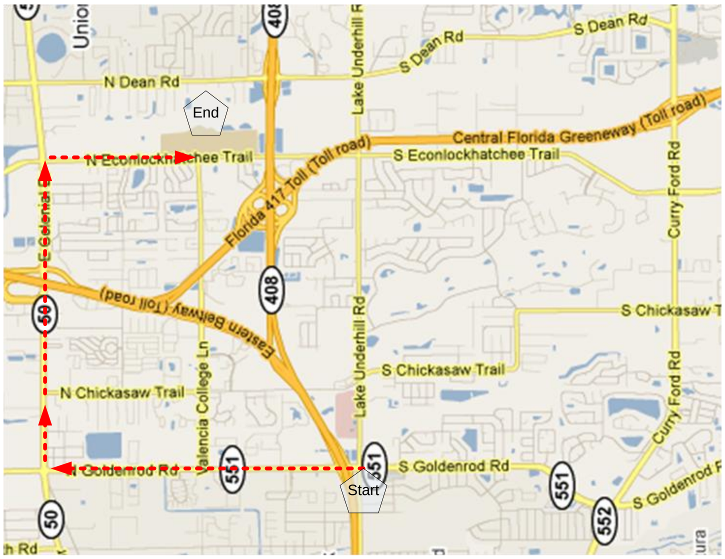


Figure 8: Detour Route D

3.4.4.5 Detour Route E

This route begins by first heading south on FL-551 S/S Goldenrod Road for approximately 1.7 miles, then turns left at Curry Ford Road and continues for distance of 2.1 miles. The route then turns left at South Econlockhatchee Trail for 3.1 miles, then finally turns at Valencia College Lane. This detour takes approximately 17 minutes to complete, with total distance of 7.2 miles.

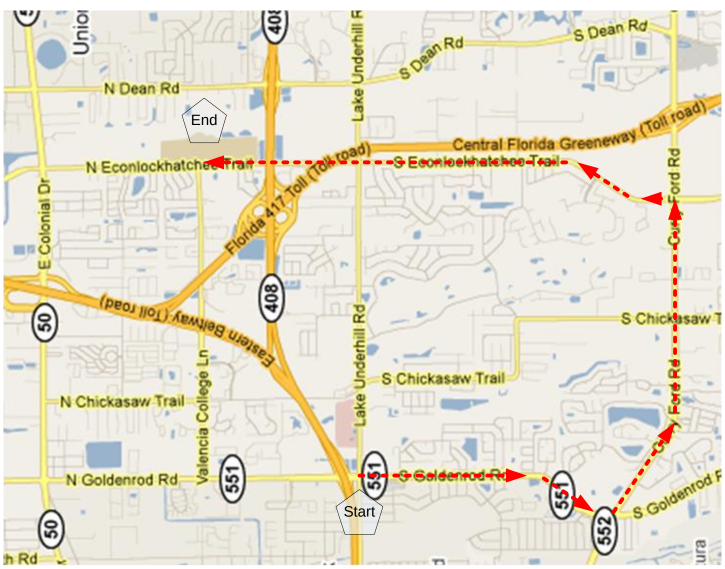


Figure 9: Detour Route E

3.4.4.6 Detour Route F

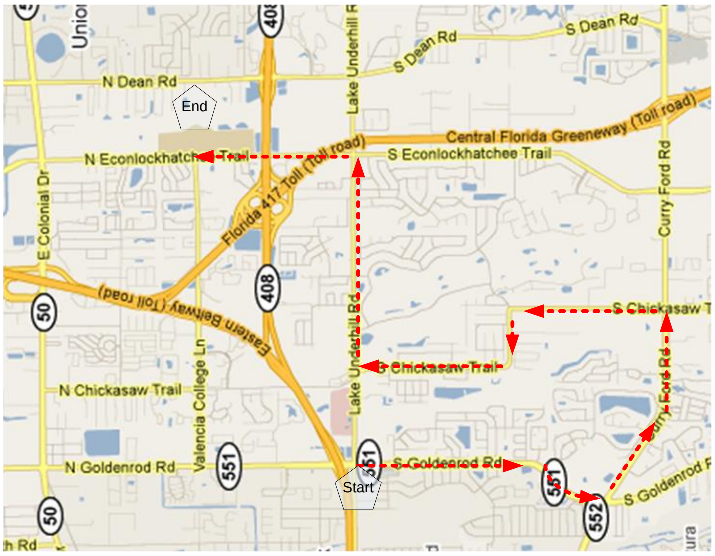


Figure 10: Detour Route F

This route starts in the opposite way of the original route, in a similar way to Route E. Due to that reason, when it came to designing this route, driver confusion factor must be taken into consideration. The route starts by heading south on FL-551 S/S Goldenrod Road for approximately 1.7 miles, then turning left at Curry Ford Road for a distance approximately 1.4 miles. The route then turns left at South Chickasaw Trail for approximately 1.0 mile, and then turns left at El Prado Avenue for 0.4 miles. The route then continues onto South Chickasaw Trail for another 1 mile, and finally turns left at South Econlockhatchee Trail and arrives at Valencia Community College. This route takes approximately 16 minutes to complete.  Below table number 1 summaries all possible routes.

Table 1 Routes Summary

| Route | Total Distance(Mile) | Total Time Minutes | Toll |
|---|---|---|---|
| A | 3.05 | 4 | Yes |
| B | 3.04 | 6 | No |
| C | 2.7 | 12 | No |
| D | 5 | 11 | No |
| E | 6.9 | 17 | No |
| F | 5.5 | 16 | No |

# CHAPTER FOUR: MODELING THE IMPACT OF TRAVEL TIME ON SELECTING THE OPTIMAL DETOUR ROUTE

## 4.1 Introduction

The objective of this chapter is to present a linear formulation to aid construction planners and decision makers in modeling the impact of travel time on the selection of the optimal detour route. The main objective when it comes to determining the impact of travel time on selecting the optimal route is developing a linear model such as shortest path formulation to find a route that will take the least amount of time from start point to end point.

For instance, when a daily commuter or traveler chooses a specific option (route) he/she will receive a payoff (travel time), based on his/her belief that this route will serve his/her need in an optimal way. For example, travelers facing stochastic network situations are assumed to minimize their expected travel time (Avineri and Prashker, 2006).

## 4.2 Travel Time-Based Optimization Model

After researching, no such a program or clear guidelines were designed or found when it comes to assisting construction detour planners in generating a set of optimal construction site layout plans that minimize the travel time. The only thing that was found was a small section in the *Plans Preparation Manual*, chapter 10, *Transportation Management Plan*. For such a reason, a model was created to help the construction detour planner in order to help aid when it comes to planning a construction detour while considering the shortest travel time.

This model is based on shortest path formulation which is a technique that uses machine-learning and optimization techniques to develop a tool and guidelines that can help engineers make better detour plans based on the shortest time. This model could potentially offer a better utilization of the available capacity in the entire traffic network while considering time as a main factor.

## 4.3 Data Collection

Data was collected at ten different locations. These ten locations are considered critical points that the driver has to pass by in order to take one of the alternative routes in case of a detour. The data was collected on regular days for three consecutive hours, and they were analyzed every 15 minutes in order to provide precise results and more extensive information. The analysis also identified the peak hour precisely. Another way of collecting data for this research was done by interviewing government officials from the Florida Department of Transportation.

### 4.3.1 Interview with the local officials

To better understand the procedure and the process when designing a detour, an interview with Mr. James Harkrider from the Florida Department of Transportation (FDOT) was conducted in August, 2010. The questionnaire form for Mr. Harkrider read as follows:

### 4.3.2 Interview Questionnaire, Main purpose, and Answers

**Question 1**

Who is responsible for planning the detour, the Department of Transportation or the contactor?

**Purpose of Question 1**

The main purpose of this question is to find out who is responsible for planning the detour and choosing the new route. It is also to find out who is responsible for making sure the new route will be able to accommodate the new capacity of motor vehicle traffic in addition to the current vehicle capacity.

**Answer to Question 1**

The main person responsible for planning the detour is the designer.

**Question 2**

Is there any publication that the Department of Transportation or the contactor relies on?

If yes, what is it? If no, what strategy is being implemented to ensure the most efficient detour?

**Purpose of Question 2**

The main purpose of this question is to find out if the Department of Transportation or the private contractor relies on any publication when it comes to choosing the new route or detour. We also need to know what strategy is being taken into consideration to have the most efficient detour.

**Answer to Question 2**

Yes. Department's Plans Preparation Manual, section 10.12.9, also gives guidelines.

**Question 3**

When designing the detour, are any of the following tasks taken into consideration?

| Task | Yes, it is taken into consideration | No, it is not taken into consideration |
|---|---|---|
| **Level of service ( L.O.S)** | | |
| **Driver confusion** | | |
| **Number of Lanes** | | |
| **Type of Road: City, county, highway, freeway** | | |
| **Expected delays** | | |
| **Other, please add** | | |

**Purpose of Question 3:**

The main purpose of this question is to know if:

A. The new route, based on the highway capacity manual, will keep a reasonable level of service based on the amount of new flow coming from the closed road?
B. Driver confusion taken into consideration (e.g. Turning left instead of turning right, or going west instead of going east)?
C. The number of lanes taken into consideration?
D. The type of road being taken into consideration. For example, if the closed road is a county road, can I detour the traffic to a state road?
E. The expected delay of the new route and the costs associated with the potential delay?

**Answer to Question 3**

| Task | Yes it is taken into consideration | No it is not taken into consideration |
|---|---|---|
| **Level of service ( L.O.S)** | YES | |
| **Driver confusion** | YES | |
| **Number of Lanes** | YES | |
| **Type of Road City, county, high way, Freeway** | YES | |
| **Expected delays** | YES | |
| **Other please add** | Capacity of the detour road<br>Number of trucks that use/may use the detour<br>Turning radius<br>Overhead clearance<br>The structural capacity of the detour pavement should also be considered. | |

**Question 4**

Is there a limit for the number of detours per distance?

**Purpose of Question 4:**

The main purpose of this question is to find out if there is a limit of number of detours per distance. For example, there can be no more than two detours per one mile, or not having more than one detour in the same area.

**Answer to Question 4**

Not too close together. For example, not to have two successive detours at the same time.

**Question 5**

Is there any optimization technique in use?

**Purpose of Question 5**

The main purpose of this question is to know if there is there is any optimization technique in use, such as ant colony optimization or shortest path algorithm used to determine the design of the detour.

**Answer to Question 5**

No optimization technique is used.

**Question 6**

Who calculates the cost of the detours? How do they do it?

**Purpose of Question 6**

The main purpose of this question is to know who performs the cost analysis when it comes to calculating the cost associated with detours, such as the delay cost per hour. Also, this question attempts to discover who performs the cost analysis when it comes to calculating the cost of new signs or signals, if needed, or the cost of tolls if the detour forces the commuter to use a toll road.

**Answer to Question 6**

Each municipality has a method of calculation.

**Question 7**

Do you use any simulation software?

If Yes, please see table:

| Software Name | Yes, it is in use | No, it is not in use |
|---|---|---|
| **Vissim** | | |
| **Corsim** | | |
| **Paramics** | | |

**Purpose of Question 7**

The main purpose of this question is to find out if any simulation software is implemented when designing the detour, such as Vissim, Corsim, or Paramics.

**Answer to Question 7**

No simulation software is used.

### 4.3.3 Free Travel Time Data Collection and Calculation

To calculate free travel time, we must first understand free flow speed. The free flow speed is a term that describes the average speed that a vehicle can travel without any congestion or any kind of unfavorable conditions, such as snow storms, heavy rains, fog, brush fires, etc.

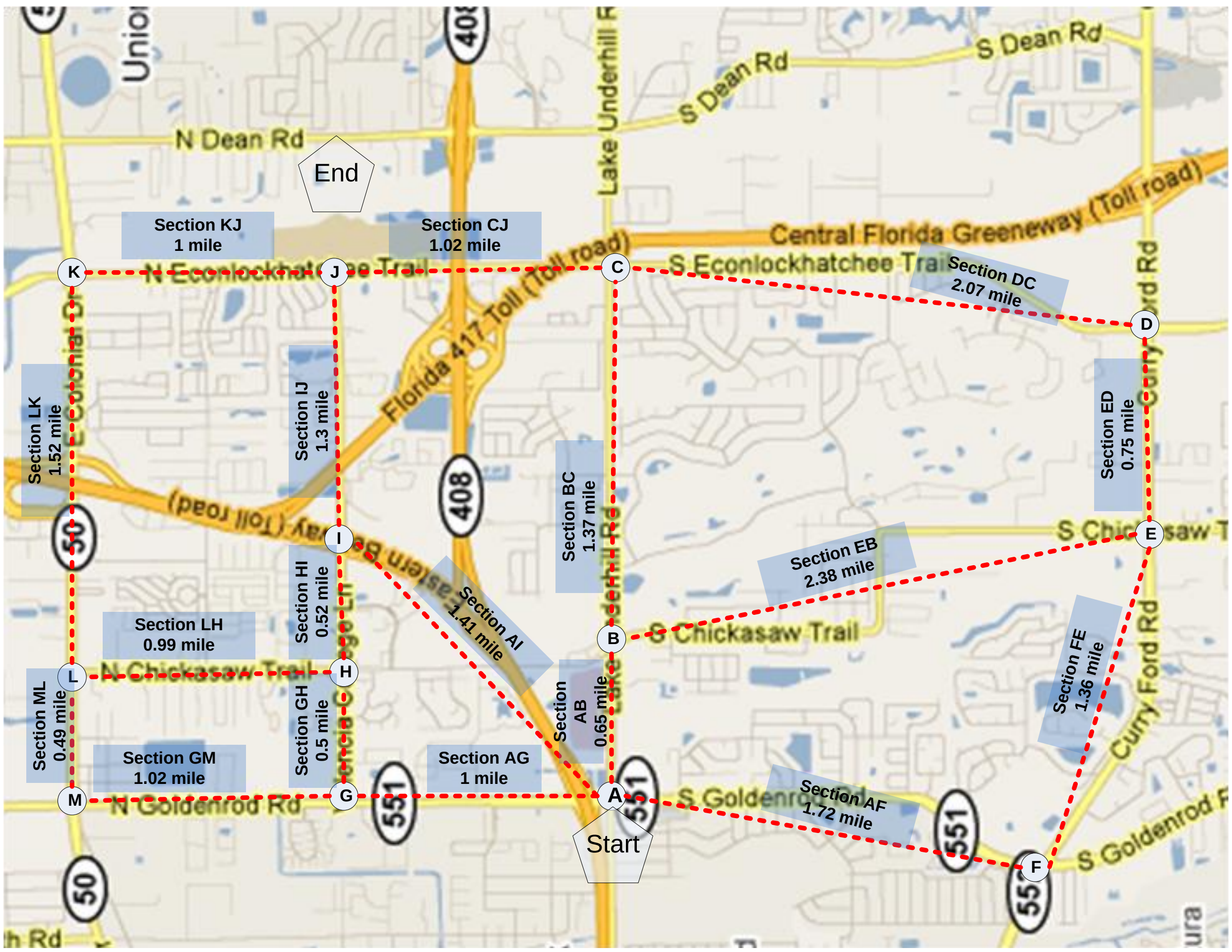


Figure 11 Road Network

Table 2: Calculating Free Travel Time

| *Route (link)* | *Number of Traffic Lights and Stop Signs* | *Distance (mile)* | *Posted Speed limit (mile/hr)* | *Free Travel Time (min:sec)* |
|---|---|---|---|---|
| **AF** | 0 | 1.72 | 45 | 2:33 |
| **FE** | 1 | 1.36 | 45 | 2:18 |
| **ED** | 0 | 0.75 | 45 | 1:11 |
| **DC** | 0 | 1:40 | 45 | 3:23 |
| **EB** | 1 | 2.38 | 45 | 4:08 |
| **AB** | 0 | 0.65 | 45 | 1:25 |
| **BC** | 3 | 1.37 | 45 | 2:20 |
| **CJ** | 0 | 1.02 | 45 | 1:29 |
| **AI** | 1(TOLL) | 1.41 | 55 | 2:02 |
| **AG** | 2 | 1.0 | 45 | 3:14 |
| **GH** | 0 | 0.5 | 45 | 0:48 |
| **HI** | 0 | 0.52 | 45 | 0:51 |
| **IJ** | 0 | 1.0 | 45 | 2:45 |
| **KJ** | 1 | 1.0 | 45 | 1:43 |
| **LH** | 0 | 0.99 | 45 | 1:46 |
| **GM** | 0 | 1.02 | 45 | 1:30 |
| **ML** | 0 | 0.49 | 45 | 0:43 |
| **LK** | 2 | 1.52 | 45 | 3:48 |

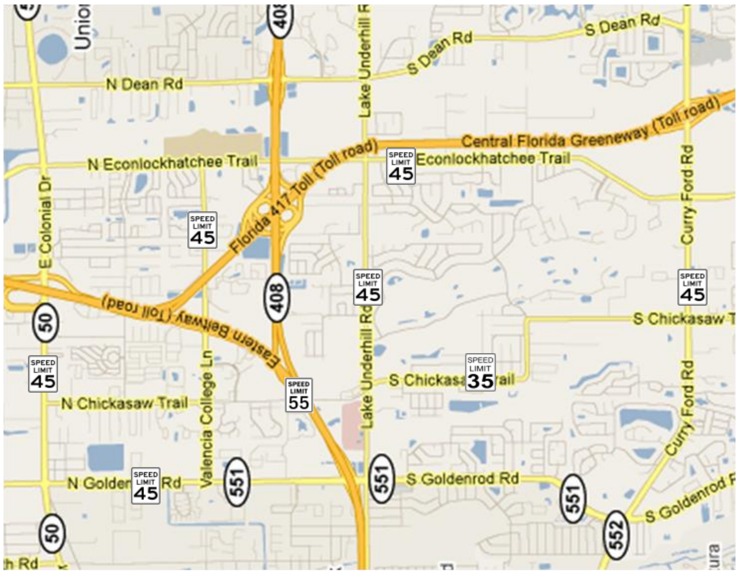


Figure 12: Posted Speed

### 4.3.4 Vehicles Count and Class Data

Data was collected on ten different locations. These ten locations are considered critical points that the driver has to pass by in order to take one of the alternative routes in case of a detour. When collecting the data, not only were the number of vehicles counted, but also the type of vehicle (whether it was a regular passenger car, sport utility vehicle, or heavy vehicle).

**Location 1**

In case traffic had to be detoured to either of Routes E or F, the point of Curry Ford Road (SR 552) crossing with Goldenrod Road (SR 551) would be a must-pass point for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 1 was selected. A total of three consecutive hours of data collection was conducted at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact locations of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15 minutes increments.

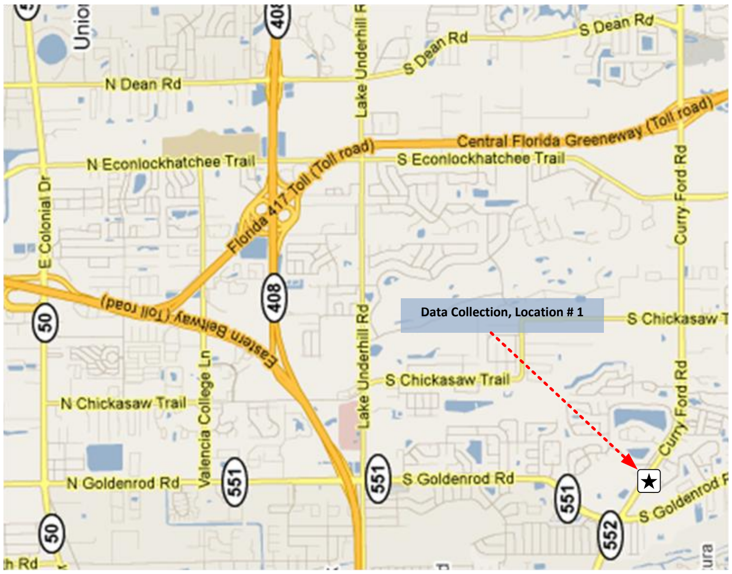



Figure 13: Data Collection, Location 1

Table 3: Number of Vehicles, Location 1

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 145 | 64 | 1 | 210 |
| 6:15 AM | 6:30 AM | 142 | 63 | 9 | 214 |
| 6:30 AM | 6:45 AM | 147 | 58 | 8 | 213 |
| 6:45 AM | 7:00 AM | 149 | 64 | 8 | 221 |
| 7:00 AM | 7:15 AM | 147 | 66 | 14 | 227 |
| 7:15 AM | 7:30 AM | 145 | 68 | 11 | 224 |
| 7:30 AM | 7:45 AM | 149 | 65 | 12 | 226 |
| 7:45 AM | 8:00 AM | 146 | 66 | 13 | 225 |
| 8:00 AM | 8:15 AM | 142 | 52 | 6 | 200 |
| 8:15 AM | 8:30 AM | 140 | 56 | 14 | 210 |
| 8:30 AM | 8:45 AM | 140 | 59 | 9 | 208 |
| 8:45 AM | 9:00 AM | 137 | 58 | 5 | 200 |

**Location 2:**

In case traffic had to be detoured to Route F, the point of Curry Ford Road (SR 552) crossing with South Chickasaw Trail would be a must-pass point for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 2 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

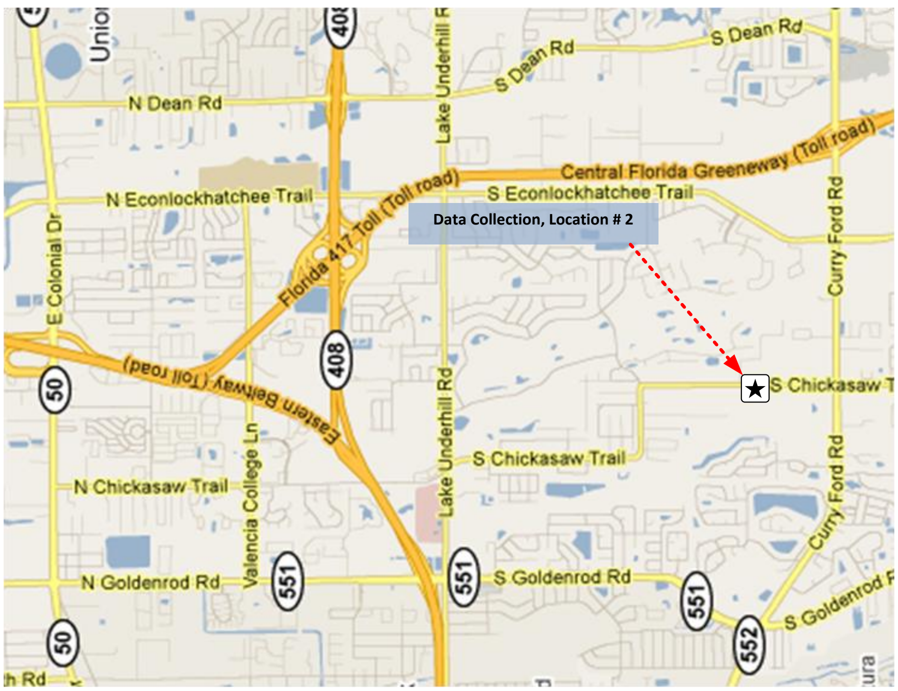



Figure 14: Data Collection, Location 2

Table 4: Number of Vehicles, Location 2

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 82 | 30 | 0 | 112 |
| 6:15 AM | 6:30 AM | 86 | 31 | 19 | 136 |
| 6:30 AM | 6:45 AM | 118 | 24 | 7 | 149 |
| 6:45 AM | 7:00 AM | 106 | 30 | 12 | 148 |
| 7:00 AM | 7:15 AM | 115 | 35 | 14 | 164 |
| 7:15 AM | 7:30 AM | 103 | 46 | 7 | 156 |
| 7:30 AM | 7:45 AM | 99 | 32 | 24 | 155 |
| 7:45 AM | 8:00 AM | 85 | 16 | 1 | 102 |
| 8:00 AM | 8:15 AM | 75 | 20 | 5 | 100 |
| 8:15 AM | 8:30 AM | 68 | 25 | 8 | 101 |
| 8:30 AM | 8:45 AM | 77 | 35 | 3 | 115 |
| 8:45 AM | 9:00 AM | 85 | 30 | 3 | 118 |

**Location 3**:

In case traffic had to be detoured to Route E, the intersection of Curry Ford Road (SR 552) and South Econlockhatchee Trail would be a must-pass point for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 3 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

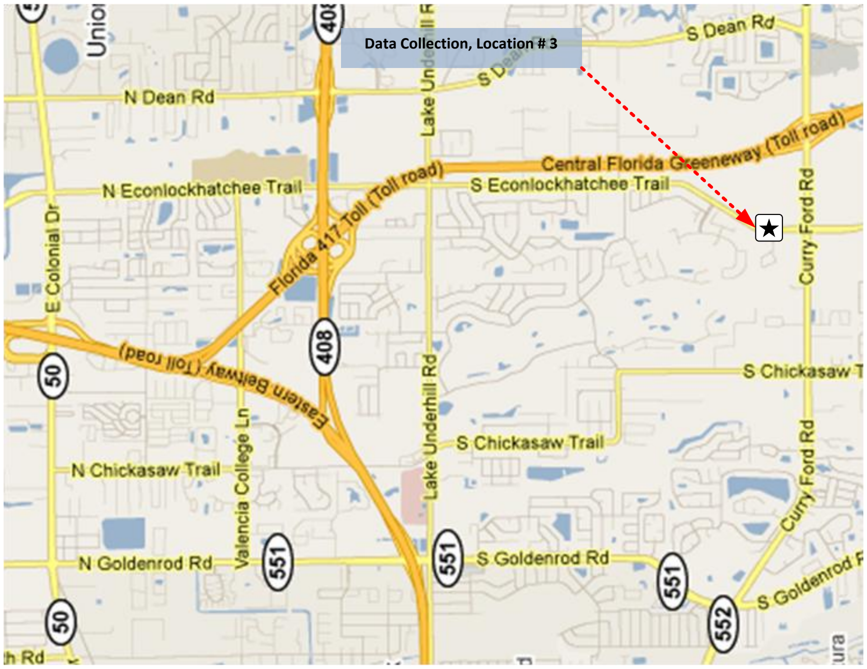


Figure 15: Data Collection, Location 3

Table 5: Number of Vehicles, Location 3

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 59 | 18 | 1 | 78 |
| 6:15 AM | 6:30 AM | 63 | 35 | 2 | 100 |
| 6:30 AM | 6:45 AM | 55 | 30 | 1 | 86 |
| 6:45 AM | 7:00 AM | 70 | 39 | 0 | 109 |
| 7:00 AM | 7:15 AM | 68 | 42 | 2 | 112 |
| 7:15 AM | 7:30 AM | 72 | 20 | 9 | 101 |
| 7:30 AM | 7:45 AM | 75 | 31 | 5 | 111 |
| 7:45 AM | 8:00 AM | 60 | 29 | 2 | 91 |
| 8:00 AM | 8:15 AM | 51 | 27 | 2 | 80 |
| 8:15 AM | 8:30 AM | 60 | 28 | 5 | 93 |
| 8:30 AM | 8:45 AM | 53 | 37 | 6 | 96 |
| 8:45 AM | 9:00 AM | 76 | 29 | 3 | 108 |

**Location 4:**

In case traffic had to be detoured to Route B, the intersection of South Goldenrod Road (SR 551) and Lake Underhill Road would be a must-pass location for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 4 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15 minutes increments.

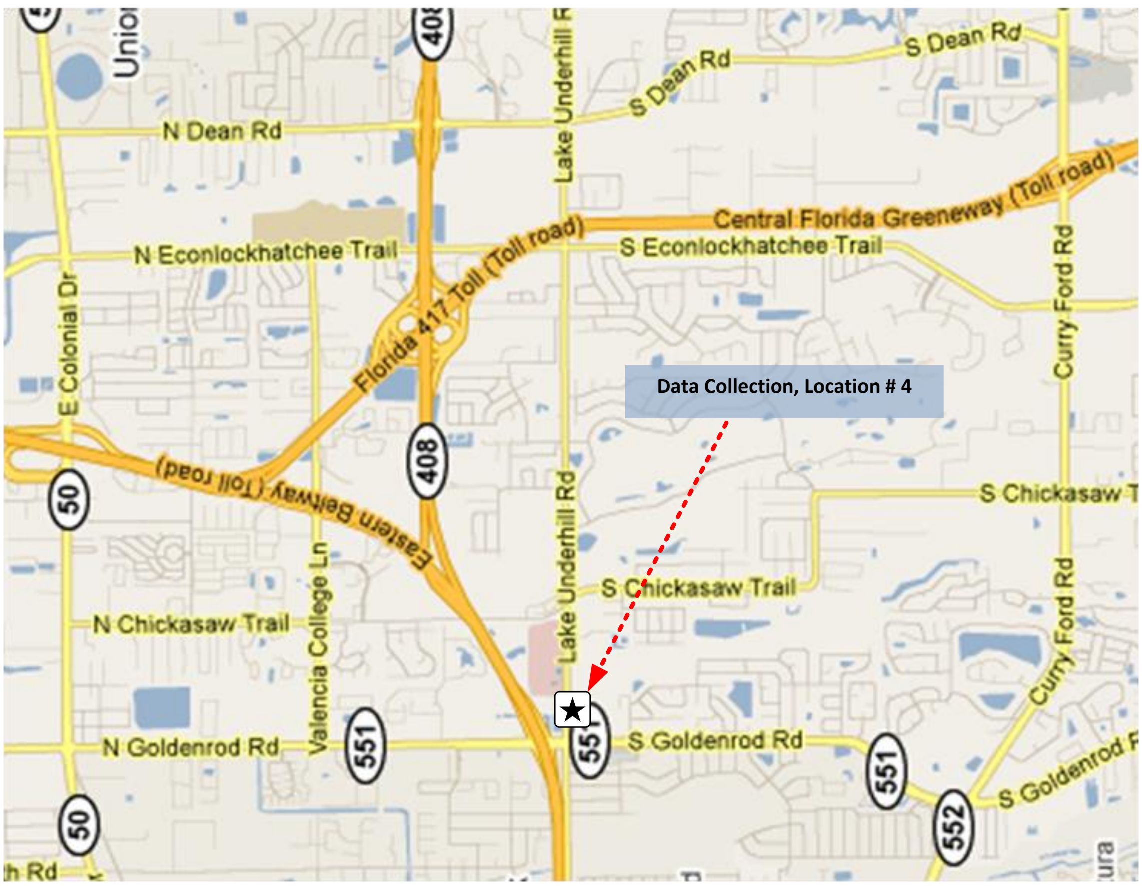



Figure 16: Data Collection, Location 4

Table 6: Number of Vehicles, Location 4

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 175 | 72 | 0 | 247 |
| 6:15 AM | 6:30 AM | 153 | 75 | 0 | 228 |
| 6:30 AM | 6:45 AM | 191 | 70 | 7 | 268 |
| 6:45 AM | 7:00 AM | 201 | 81 | 2 | 284 |
| 7:00 AM | 7:15 AM | 189 | 77 | 3 | 269 |
| 7:15 AM | 7:30 AM | 203 | 75 | 3 | 281 |
| 7:30 AM | 7:45 AM | 177 | 87 | 4 | 268 |
| 7:45 AM | 8:00 AM | 184 | 65 | 2 | 251 |
| 8:00 AM | 8:15 AM | 176 | 79 | 6 | 261 |
| 8:15 AM | 8:30 AM | 165 | 66 | 0 | 231 |
| 8:30 AM | 8:45 AM | 129 | 73 | 3 | 205 |
| 8:45 AM | 9:00 AM | 150 | 81 | 0 | 231 |

**Location 5:**

This location is one of the most important locations. The main reason is that this route is the main route that daily commuters have to take in order to reach their final destination, Valencia Community College. Based on the importance of this point, location 5 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

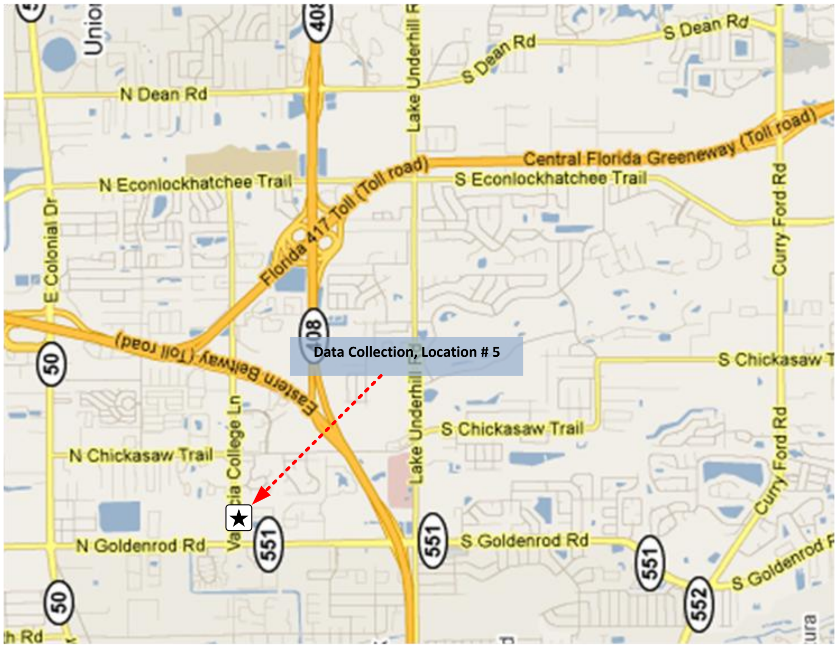


Figure 17: Data Collection, Location 5

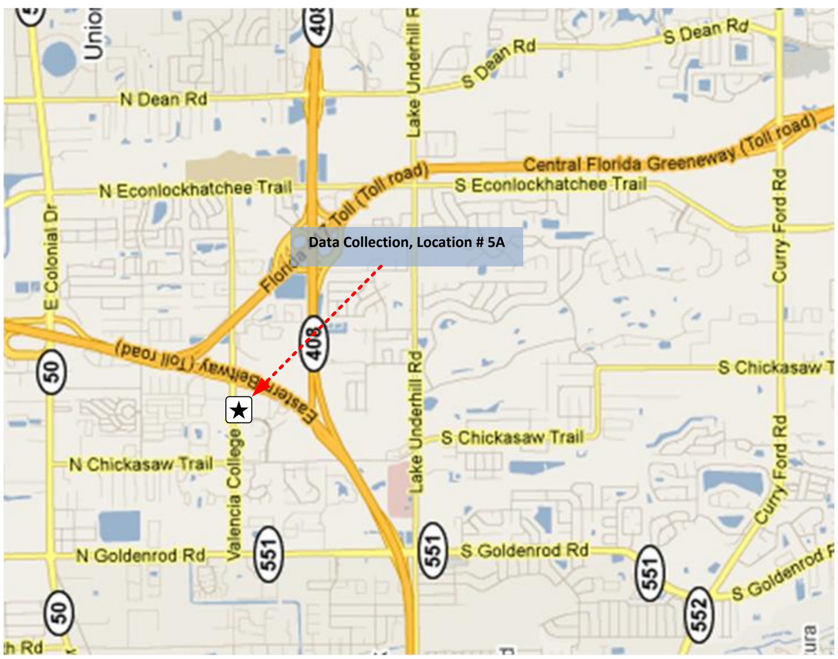


Figure 18: Data Collection, Location 5A

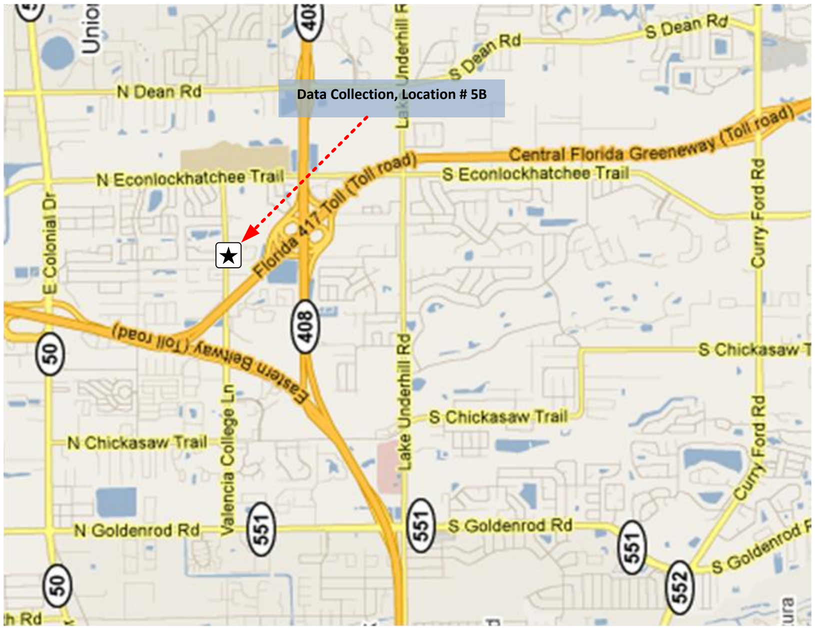



Figure 19: Data Collection, Location 5B

Table 7: Number of Vehicles, Location 5

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 63 | 19 | 6 | 88 |
| 6:15 AM | 6:30 AM | 60 | 7 | 3 | 70 |
| 6:30 AM | 6:45 AM | 69 | 28 | 6 | 103 |
| 6:45 AM | 7:00 AM | 87 | 24 | 4 | 115 |
| 7:00 AM | 7:15 AM | 78 | 24 | 6 | 108 |
| 7:15 AM | 7:30 AM | 87 | 26 | 0 | 113 |
| 7:30 AM | 7:45 AM | 81 | 16 | 3 | 100 |
| 7:45 AM | 8:00 AM | 72 | 27 | 0 | 99 |
| 8:00 AM | 8:15 AM | 66 | 24 | 1 | 91 |
| 8:15 AM | 8:30 AM | 76 | 8 | 3 | 87 |
| 8:30 AM | 8:45 AM | 36 | 3 | 1 | 40 |
| 8:45 AM | 9:00 AM | 44 | 6 | 0 | 50 |

Table 8: Number of Vehicles, Location 5A

| Time Period | | Number of Cras | Number of SUV's | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 63 | 19 | 6 | 88 |
| 6:15 AM | 6:30 AM | 60 | 7 | 3 | 70 |
| 6:30 AM | 6:45 AM | 69 | 28 | 6 | 103 |
| 6:45 AM | 7:00 AM | 87 | 24 | 4 | 115 |
| 7:00 AM | 7:15 AM | 78 | 25 | 6 | 109 |
| 7:15 AM | 7:30 AM | 87 | 28 | 2 | 117 |
| 7:30 AM | 7:45 AM | 82 | 21 | 3 | 106 |
| 7:45 AM | 8:00 AM | 72 | 27 | 1 | 100 |
| 8:00 AM | 8:15 AM | 66 | 24 | 1 | 91 |
| 8:15 AM | 8:30 AM | 76 | 8 | 3 | 87 |
| 8:30 AM | 8:45 AM | 36 | 3 | 1 | 40 |
| 8:45 AM | 9:00 AM | 44 | 6 | 0 | 50 |

Table 9: Number of Vehicles, Location 5B

| Time Period | | Number of Cras | Number of SUV's | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 63 | 19 | 6 | 88 |
| 6:15 AM | 6:30 AM | 60 | 7 | 3 | 70 |
| 6:30 AM | 6:45 AM | 69 | 28 | 6 | 103 |
| 6:45 AM | 7:00 AM | 87 | 24 | 4 | 115 |
| 7:00 AM | 7:15 AM | 85 | 29 | 6 | 120 |
| 7:15 AM | 7:30 AM | 87 | 28 | 3 | 118 |
| 7:30 AM | 7:45 AM | 90 | 30 | 3 | 123 |
| 7:45 AM | 8:00 AM | 83 | 27 | 2 | 112 |
| 8:00 AM | 8:15 AM | 66 | 24 | 1 | 91 |
| 8:15 AM | 8:30 AM | 76 | 8 | 3 | 87 |
| 8:30 AM | 8:45 AM | 36 | 3 | 1 | 40 |
| 8:45 AM | 9:00 AM | 44 | 6 | 0 | 50 |

**Location 6:**

In case traffic had to be detoured to either Routes C or D, the intersection of East Colonial Drive (HW 50) and Goldenrod Road (SR 551) would be a must-pass location for the daily commuter in order to reach the final destination Valencia Community College. Based on the importance of this point, location 6 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

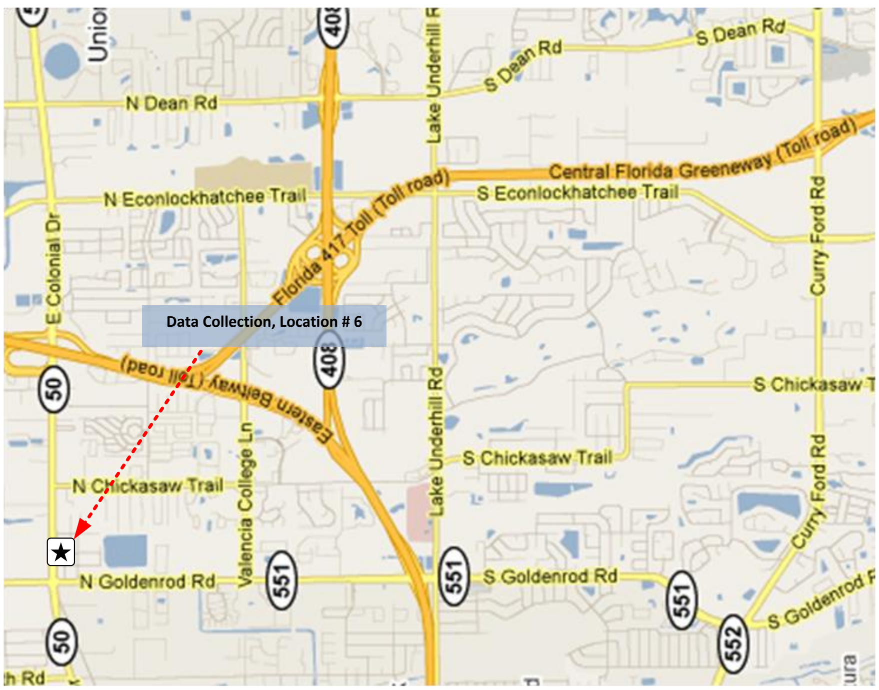


Figure 20: Data Collection, Location 6

Table 10: Number of Vehicles, Location 6

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 245 | 99 | 12 | 356 |
| 6:15 AM | 6:30 AM | 251 | 94 | 17 | 362 |
| 6:30 AM | 6:45 AM | 265 | 99 | 20 | 384 |
| 6:45 AM | 7:00 AM | 264 | 101 | 15 | 380 |
| 7:00 AM | 7:15 AM | 259 | 92 | 21 | 372 |
| 7:15 AM | 7:30 AM | 262 | 87 | 23 | 372 |
| 7:30 AM | 7:45 AM | 264 | 95 | 22 | 381 |
| 7:45 AM | 8:00 AM | 258 | 100 | 18 | 376 |
| 8:00 AM | 8:15 AM | 252 | 78 | 20 | 350 |
| 8:15 AM | 8:30 AM | 251 | 84 | 16 | 351 |
| 8:30 AM | 8:45 AM | 258 | 78 | 1 | 337 |
| 8:45 AM | 9:00 AM | 249 | 88 | 7 | 344 |

**Location 7:**

In case traffic had to be detoured to either Routes E or F, the intersection of Goldenrod Road (SR 551) midway between Lake Underhill Road and Goldenrod Road crossing and Curry Ford Road and Goldenrod Road crossing would be a must-pass point for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 7 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

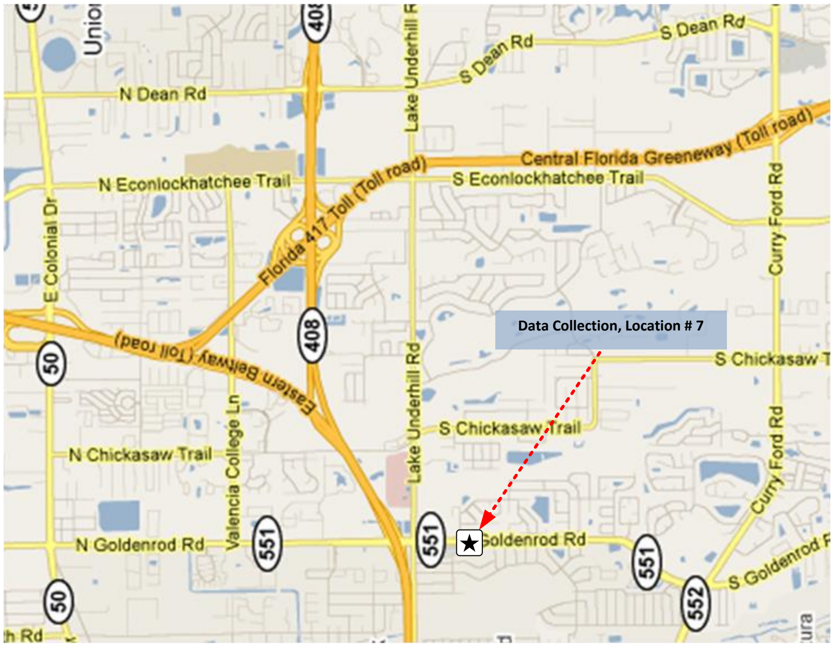


Figure 21: Data Collection, Location 7

Table 11: Number of Vehicles, Location 7

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 297 | 102 | 6 | 405 |
| 6:15 AM | 6:30 AM | 267 | 135 | 9 | 411 |
| 6:30 AM | 6:45 AM | 306 | 129 | 8 | 443 |
| 6:45 AM | 7:00 AM | 318 | 117 | 6 | 441 |
| 7:00 AM | 7:15 AM | 294 | 136 | 8 | 438 |
| 7:15 AM | 7:30 AM | 315 | 120 | 9 | 444 |
| 7:30 AM | 7:45 AM | 306 | 132 | 9 | 447 |
| 7:45 AM | 8:00 AM | 291 | 129 | 4 | 424 |
| 8:00 AM | 8:15 AM | 288 | 126 | 2 | 416 |
| 8:15 AM | 8:30 AM | 294 | 117 | 3 | 414 |
| 8:30 AM | 8:45 AM | 288 | 93 | 1 | 382 |
| 8:45 AM | 9:00 AM | 285 | 99 | 4 | 388 |

**Location 8:**

In case traffic had to be detoured to Route D, the intersection of East Colonial Drive (HW 50) with north Econlockhatchee Trail would be a must-pass point for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 8 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

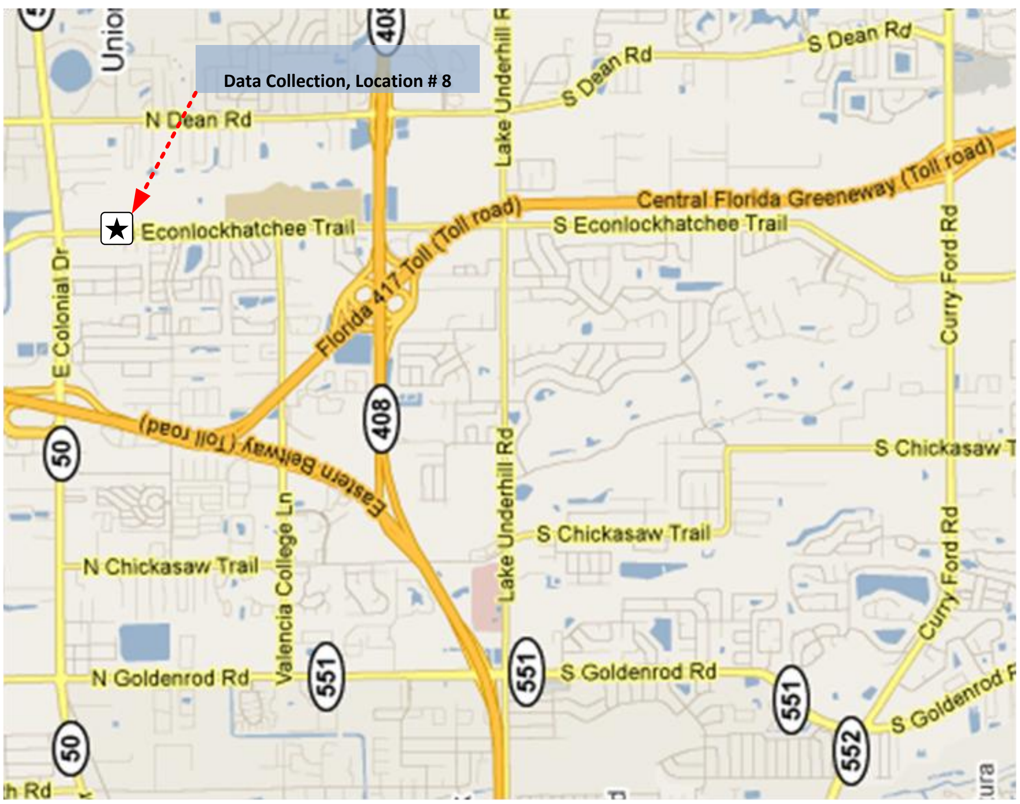



Figure 22: Data Collection, Location 8

Table 12: Number of Vehicles, Location 8

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 120 | 30 | 0 | 150 |
| 6:15 AM | 6:30 AM | 123 | 39 | 0 | 162 |
| 6:30 AM | 6:45 AM | 132 | 42 | 6 | 180 |
| 6:45 AM | 7:00 AM | 141 | 54 | 3 | 198 |
| 7:00 AM | 7:15 AM | 147 | 45 | 3 | 195 |
| 7:15 AM | 7:30 AM | 138 | 54 | 3 | 195 |
| 7:30 AM | 7:45 AM | 141 | 42 | 3 | 186 |
| 7:45 AM | 8:00 AM | 135 | 57 | 0 | 192 |
| 8:00 AM | 8:15 AM | 126 | 45 | 3 | 174 |
| 8:15 AM | 8:30 AM | 129 | 39 | 0 | 168 |
| 8:30 AM | 8:45 AM | 123 | 30 | 4 | 157 |
| 8:45 AM | 9:00 AM | 113 | 25 | 1 | 139 |

**Location 9:**

In case traffic had to be detoured to Route A, the 408/417 near exit 16 is considered a must-pass point for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 9 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

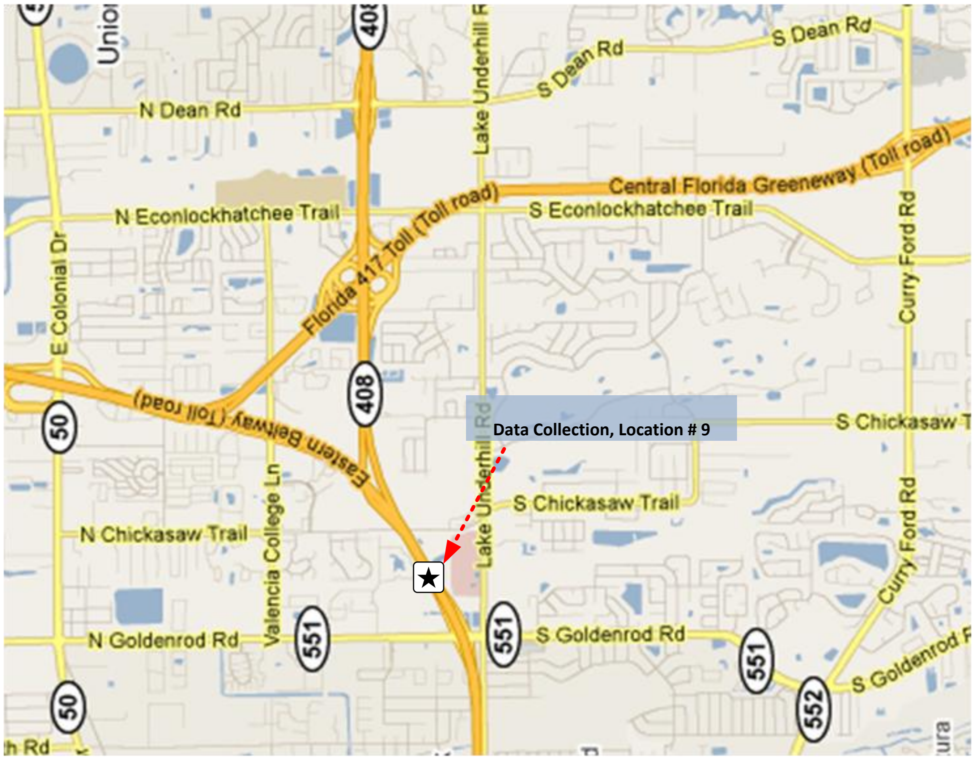



Figure 23: Data Collection, Location 9

Table 13: Number of Vehicles, Location 9

| Time Period | | Number of Cars | Number of SUVs | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 486 | 186 | 15 | 687 |
| 6:15 AM | 6:30 AM | 498 | 231 | 27 | 756 |
| 6:30 AM | 6:45 AM | 549 | 210 | 33 | 792 |
| 6:45 AM | 7:00 AM | 573 | 252 | 42 | 867 |
| 7:00 AM | 7:15 AM | 546 | 273 | 36 | 855 |
| 7:15 AM | 7:30 AM | 546 | 282 | 33 | 861 |
| 7:30 AM | 7:45 AM | 561 | 258 | 42 | 861 |
| 7:45 AM | 8:00 AM | 540 | 288 | 30 | 858 |
| 8:00 AM | 8:15 AM | 549 | 216 | 45 | 810 |
| 8:15 AM | 8:30 AM | 558 | 264 | 30 | 852 |
| 8:30 AM | 8:45 AM | 573 | 246 | 51 | 870 |
| 8:45 AM | 9:00 AM | 558 | 216 | 33 | 807 |

**Location 10:**

In case traffic had to be detoured to Route C, the point of East Colonial Drive (HW 50) and Chickasaw Trail would be a must-pass point for the daily commuter in order to reach the final destination, Valencia Community College. Based on the importance of this point, location 10 was selected. Three consecutive hours of data were collected at that point between the hours of 6:00am and 9:00am. Below are demonstration maps showing the exact location of the data collection points and a table showing the numbers of vehicles that passed through the collection points, divided into 15-minute increments.

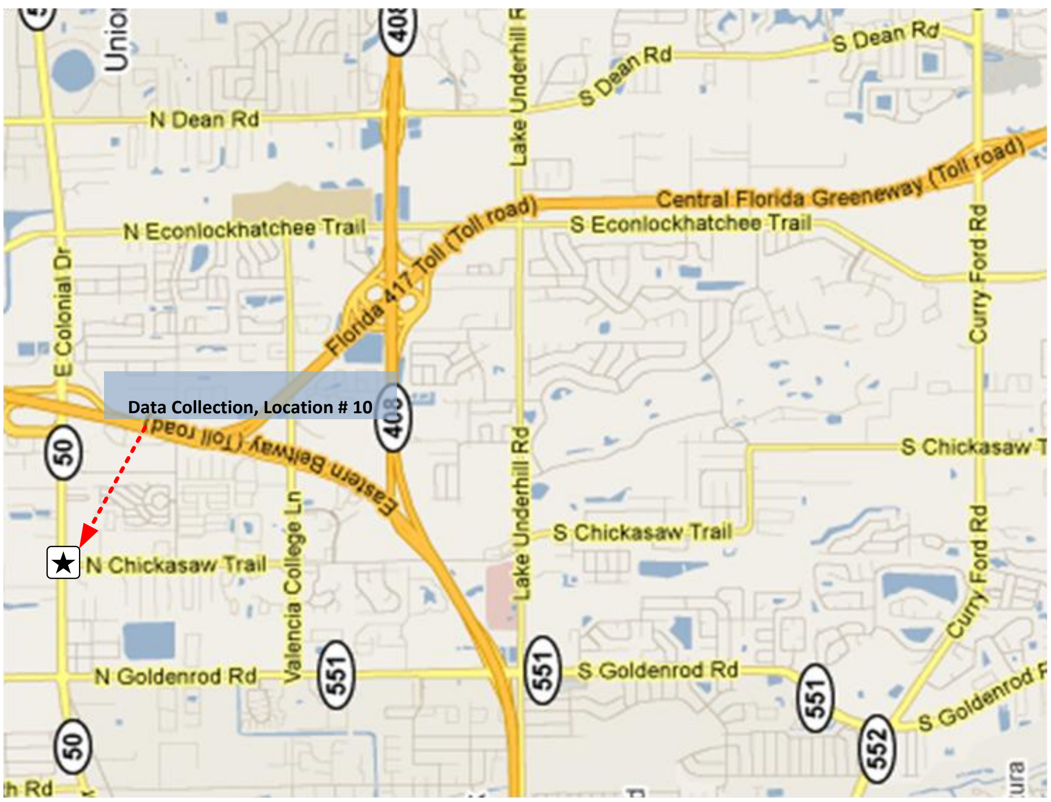


Figure 24: Location 10

Table 14: Number of Vehicles, Location 10

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | Total |
|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 66 | 21 | 0 | 87 |
| 6:15 AM | 6:30 AM | 57 | 24 | 0 | 81 |
| 6:30 AM | 6:45 AM | 78 | 21 | 3 | 102 |
| 6:45 AM | 7:00 AM | 78 | 18 | 5 | 101 |
| 7:00 AM | 7:15 AM | 84 | 21 | 2 | 107 |
| 7:15 AM | 7:30 AM | 83 | 27 | 0 | 110 |
| 7:30 AM | 7:45 AM | 76 | 19 | 0 | 95 |
| 7:45 AM | 8:00 AM | 66 | 21 | 3 | 90 |
| 8:00 AM | 8:15 AM | 60 | 28 | 1 | 89 |
| 8:15 AM | 8:30 AM | 57 | 12 | 3 | 72 |
| 8:30 AM | 8:45 AM | 60 | 23 | 1 | 84 |
| 8:45 AM | 9:00 AM | 51 | 19 | 1 | 71 |

## 4.4 Data Analysis

Gathering and formatting data, running a model and documenting and reporting results is the main step of this research. In order to relate the most accurate results, data was collected at ten different locations. The primary objective of collecting this data was to select the best alternative route and detour solution. Such a problem falls among three fields: Construction, Transportation, and Optimization. There is no specific software related to how alternatives should be developed in order to find the optimal solution. Thus, the best alternative, or the most optimal solution, should be a factor of more than one input and the consideration of many factors. Since this part, data analysis, strongly depends on many factors, customized software was developed to fit the process of solving this problem.

### 4.4.1 Road Capacity

Many books and many journals define road capacity in different ways. However in my research I am defining the highway capacity based on the dictionary of *Military and Associated Terms, US Department of Defense*, 2005. Highway capacity is the maximum traffic flow obtainable on a given roadway using all available lanes, usually expressed in vehicles per hour or vehicles per day.

#### 4.4.1.1 Highway Capacity and Level of Service

Not only has the peak hour been taken into consideration in this framework,but several other factors are also considered to have an effect on selecting the optimal solution using the modified shortest path formulation. The desired level-of-service, or quality, of the connections in the network needs to be defined clearly. An acceptable Volume-capacity ratio (capacity) is needed as a prerequisite (see Figure 26 and Table 15). However, the capacity should be considered separately from the desired quality (Kockelman, 2004).

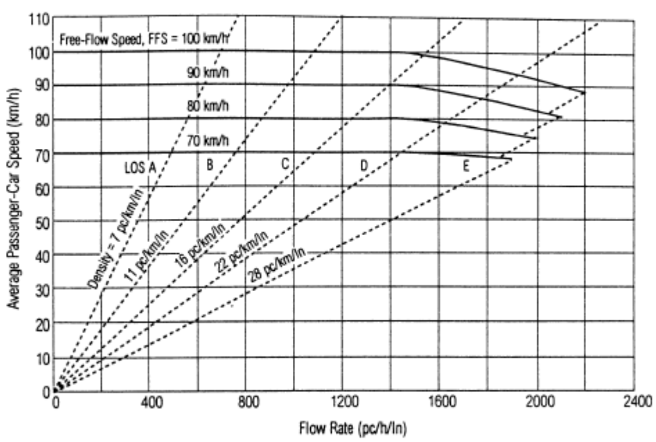



Figure 25: Speed-Flow Models for Four Classes of Multilane (TRP, 2000)

In order to find the capacity for each road and each link in our case, we need to know the exact speed limit for that link, as illustrated in Figure 26: Network with Posted Speed Limits map of the network which shows the posted speed limit of each link that the commuter might take in order to reach his/her destination.

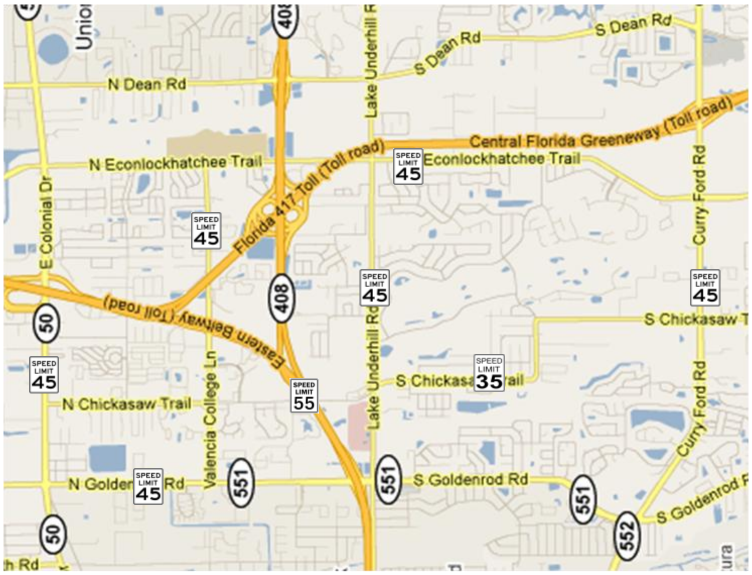


Figure 26: Network with Posted Speed Limits

Table 15: Level of Service Definitions for Basic Freeway Segments(TRP, 2000)

| *Level of service (LOS)* | *Density, pc /km/ ln* |
|---|---|
| A | 0–7 |
| B | 7–11 |
| C | 11–16 |
| D | 16–22 |
| E | 22–28 |
| F | >28 |

Calculation for the Level of Service (LOS) based on the HCM 2000 procedure is composed of the following steps:

Step 1: Calculation of FFS

Step 2: Determination of Flow Rate

Step 3: Calculation of LOS

In this analysis it was considered that level of service E is acceptable in case of a detour, thus the capacity was calculated based on highway capacity manual 2000, Level of service E. see Table 16, and also Table 18.Table 16: LOS Criteria for Multilane Highways (TRP, 2000)Table 16: LOS Criteria for Multilane Highways (TRP, 2000)

| | | LOS | | | | |
|---|---|---|---|---|---|---|
| Free-Flow Speed | Criteria | A | B | C | D | E |
| 60 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 40 |
| | Average speed (mi/h) | 60.0 | 60.0 | 59.4 | 56.7 | 55.0 |
| | Maximum volume to capacity ratio (v/c) | 0.30 | 0.49 | 0.70 | 0.90 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 660 | 1080 | 1550 | 1980 | 2200 |
| 55 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 41 |
| | Average speed (mi/h) | 55.0 | 55.0 | 54.9 | 52.9 | 51.2 |
| | Maximum v/c | 0.29 | 0.47 | 0.68 | 0.88 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 600 | 990 | 1430 | 1850 | 2100 |
| 50 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 43 |
| | Average speed (mi/h) | 50.0 | 50.0 | 50.0 | 48.9 | 47.5 |
| | Maximum v/c | 0.28 | 0.45 | 0.65 | 0.86 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 550 | 900 | 1300 | 1710 | 2000 |
| 45 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 45 |
| | Average speed (mi/h) | 45.0 | 45.0 | 45.0 | 44.4 | 42.2 |
| | Maximum v/c | 0.26 | 0.43 | 0.62 | 0.82 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 490 | 810 | 1170 | 1550 | 1900 |

Based on the Highway Capacity Manual 2000, when it comes to highway capacity of multi lane highways each truck or bus is equivalent to a value. This value is between 1.2 up to 4.5 based on the terrain and type of vehicle whether it is a bus, truck, or RV. This equivalent number is illustrated in Table 17: Passenger-Car Equivalents on Extended General Highway Segments.

Table 17: Passenger-Car Equivalents on Extended General Highway Segments

| | Type of Terrain | | |
|---|---|---|---|
| Factor | Level | Rolling | Mountainous |
| $E_T$ (trucks and buses) | 1.5 | 2.5 | 4.5 |
| $E_R$ (RVs) | 1.2 | 2.0 | 4.0 |

Table 18: LOS Criteria for Basic Freeway Segments (TRP, 2000)

EXHIBIT 23-2. LOS CRITERIA FOR BASIC FREEWAY SEGMENTS

| Criteria | LOS | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| FFS = 75 mi/h | | | | | |
| Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 45 |
| Minimum speed (mi/h) | 75.0 | 74.8 | 70.6 | 62.2 | 53.3 |
| Maximum v/c | 0.34 | 0.56 | 0.76 | 0.90 | 1.00 |
| Maximum service flow rate (pc/h/ln) | 820 | 1350 | 1830 | 2170 | 2400 |
| FFS = 70 mi/h | | | | | |
| Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 45 |
| Minimum speed (mi/h) | 70.0 | 70.0 | 68.2 | 61.5 | 53.3 |
| Maximum v/c | 0.32 | 0.53 | 0.74 | 0.90 | 1.00 |
| Maximum service flow rate (pc/h/ln) | 770 | 1260 | 1770 | 2150 | 2400 |
| FFS = 65 mi/h | | | | | |
| Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 45 |
| Minimum speed (mi/h) | 65.0 | 65.0 | 64.6 | 59.7 | 52.2 |
| Maximum v/c | 0.30 | 0.50 | 0.71 | 0.89 | 1.00 |
| Maximum service flow rate (pc/h/ln) | 710 | 1170 | 1680 | 2090 | 2350 |
| FFS = 60 mi/h | | | | | |
| Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 45 |
| Minimum speed (mi/h) | 60.0 | 60.0 | 60.0 | 57.6 | 51.1 |
| Maximum v/c | 0.29 | 0.47 | 0.68 | 0.88 | 1.00 |
| Maximum service flow rate (pc/h/ln) | 660 | 1080 | 1560 | 2020 | 2300 |
| FFS = 55 mi/h | | | | | |
| Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 45 |
| Minimum speed (mi/h) | 55.0 | 55.0 | 55.0 | 54.7 | 50.0 |
| Maximum v/c | 0.27 | 0.44 | 0.64 | 0.85 | 1.00 |
| Maximum service flow rate (pc/h/ln) | 600 | 990 | 1430 | 1910 | 2250 |

4.4.1.2 Data adjustment for all ten locations

Below are tables showing the number of vehicle for each location after the adjustment for trucks and buses. The peak hour is highlighted with yellow

Table 19: Location 1 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of cars during peak hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 145 | 64 | 1 | 1.5 | 210 | 210.5 | |
| 6:15 AM | 6:30 AM | 142 | 63 | 9 | 13.5 | 214 | 218.5 | |
| 6:30 AM | 6:45 AM | 147 | 58 | 8 | 12 | 213 | 217 | |
| 6:45 AM | 7:00 AM | 149 | 64 | 8 | 12 | 221 | 225 | |
| 7:00 AM | 7:15 AM | 147 | 66 | 14 | 21 | 227 | 234 | 927 |
| 7:15 AM | 7:30 AM | 145 | 68 | 11 | 16.5 | 224 | 229.5 | |
| 7:30 AM | 7:45 AM | 149 | 65 | 12 | 18 | 226 | 232 | |
| 7:45 AM | 8:00 AM | 146 | 66 | 13 | 19.5 | 225 | 231.5 | |
| 8:00 AM | 8:15 AM | 142 | 52 | 6 | 9 | 200 | 203 | |
| 8:15 AM | 8:30 AM | 140 | 56 | 14 | 21 | 210 | 217 | |
| 8:30 AM | 8:45 AM | 140 | 59 | 9 | 13.5 | 208 | 212.5 | |
| 8:45 AM | 9:00 AM | 137 | 58 | 5 | 7.5 | 200 | 202.5 | |

Table 20: Location 2 Data Adjustment

| Time Period | | Number of Cras | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 82 | 30 | 0 | 0 | 112 | 112 | |
| 6:15 AM | 6:30 AM | 86 | 31 | 19 | 28.5 | 136 | 145.5 | |
| 6:30 AM | 6:45 AM | 118 | 24 | 7 | 10.5 | 149 | 152.5 | |
| 6:45 AM | 7:00 AM | 106 | 30 | 12 | 18 | 148 | 154 | |
| 7:00 AM | 7:15 AM | 115 | 35 | 14 | 21 | 164 | 171 | 600 |
| 7:15 AM | 7:30 AM | 103 | 46 | 7 | 10.5 | 156 | 159.5 | |
| 7:30 AM | 7:45 AM | 99 | 32 | 24 | 36 | 155 | 167 | |
| 7:45 AM | 8:00 AM | 85 | 16 | 1 | 1.5 | 102 | 102.5 | |
| 8:00 AM | 8:15 AM | 75 | 20 | 5 | 7.5 | 100 | 102.5 | |
| 8:15 AM | 8:30 AM | 68 | 25 | 8 | 12 | 101 | 105 | |
| 8:30 AM | 8:45 AM | 77 | 35 | 3 | 4.5 | 115 | 116.5 | |
| 8:45 AM | 9:00 AM | 85 | 30 | 3 | 4.5 | 118 | 119.5 | |

Table 21: Location 3 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 59 | 18 | 1 | 1.5 | 78 | 78.5 | |
| 6:15 AM | 6:30 AM | 63 | 35 | 2 | 3 | 100 | 101 | |
| 6:30 AM | 6:45 AM | 55 | 30 | 1 | 1.5 | 86 | 86.5 | |
| 6:45 AM | 7:00 AM | 70 | 39 | 0 | 0 | 109 | 109 | |
| 7:00 AM | 7:15 AM | 68 | 42 | 2 | 3 | 112 | 113 | 424 |
| 7:15 AM | 7:30 AM | 72 | 20 | 9 | 13.5 | 101 | 105.5 | |
| 7:30 AM | 7:45 AM | 75 | 31 | 5 | 7.5 | 111 | 113.5 | |
| 7:45 AM | 8:00 AM | 60 | 29 | 2 | 3 | 91 | 92 | |
| 8:00 AM | 8:15 AM | 51 | 27 | 2 | 3 | 80 | 81 | |
| 8:15 AM | 8:30 AM | 60 | 28 | 5 | 7.5 | 93 | 95.5 | |
| 8:30 AM | 8:45 AM | 53 | 37 | 6 | 9 | 96 | 99 | |
| 8:45 AM | 9:00 AM | 56 | 29 | 3 | 4.5 | 88 | 89.5 | |

Table 22: Location 4 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of cars during peak hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 175 | 72 | 0 | 0 | 247 | 247 | |
| 6:15 AM | 6:30 AM | 153 | 75 | 0 | 0 | 228 | 228 | |
| 6:30 AM | 6:45 AM | 191 | 70 | 7 | 10.5 | 268 | 271.5 | |
| 6:45 AM | 7:00 AM | 201 | 81 | 2 | 3 | 284 | 285 | |
| 7:00 AM | 7:15 AM | 189 | 77 | 3 | 4.5 | 269 | 270.5 | 1075 |
| 7:15 AM | 7:30 AM | 203 | 75 | 3 | 4.5 | 281 | 282.5 | |
| 7:30 AM | 7:45 AM | 177 | 87 | 4 | 6 | 268 | 270 | |
| 7:45 AM | 8:00 AM | 184 | 65 | 2 | 3 | 251 | 252 | |
| 8:00 AM | 8:15 AM | 176 | 79 | 6 | 9 | 261 | 264 | |
| 8:15 AM | 8:30 AM | 165 | 66 | 0 | 0 | 231 | 231 | |
| 8:30 AM | 8:45 AM | 129 | 73 | 3 | 4.5 | 205 | 206.5 | |
| 8:45 AM | 9:00 AM | 150 | 81 | 0 | 0 | 231 | 231 | |

Table 23: Location 5 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 63 | 19 | 6 | 9 | 88 | 91 | |
| 6:15 AM | 6:30 AM | 60 | 7 | 3 | 4.5 | 70 | 71.5 | |
| 6:30 AM | 6:45 AM | 69 | 28 | 6 | 9 | 103 | 106 | |
| 6:45 AM | 7:00 AM | 87 | 24 | 4 | 6 | 115 | 117 | |
| 7:00 AM | 7:15 AM | 78 | 24 | 6 | 9 | 108 | 111 | 424.5 |
| 7:15 AM | 7:30 AM | 87 | 26 | 0 | 0 | 113 | 113 | |
| 7:30 AM | 7:45 AM | 81 | 16 | 3 | 4.5 | 100 | 101.5 | |
| 7:45 AM | 8:00 AM | 72 | 27 | 0 | 0 | 99 | 99 | |
| 8:00 AM | 8:15 AM | 66 | 24 | 1 | 1.5 | 91 | 91.5 | |
| 8:15 AM | 8:30 AM | 76 | 8 | 3 | 4.5 | 87 | 88.5 | |
| 8:30 AM | 8:45 AM | 36 | 3 | 1 | 1.5 | 40 | 40.5 | |
| 8:45 AM | 9:00 AM | 44 | 6 | 0 | 0 | 50 | 50 | |

Table 24: Location 5A Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 63 | 19 | 6 | 9 | 88 | 91 | |
| 6:15 AM | 6:30 AM | 60 | 7 | 3 | 4.5 | 70 | 71.5 | |
| 6:30 AM | 6:45 AM | 69 | 28 | 6 | 9 | 103 | 106 | |
| 6:45 AM | 7:00 AM | 87 | 24 | 4 | 6 | 115 | 117 | |
| 7:00 AM | 7:15 AM | 78 | 25 | 6 | 9 | 109 | 112 | 438 |
| 7:15 AM | 7:30 AM | 87 | 28 | 2 | 3 | 117 | 118 | |
| 7:30 AM | 7:45 AM | 82 | 21 | 3 | 4.5 | 106 | 107.5 | |
| 7:45 AM | 8:00 AM | 72 | 27 | 1 | 1.5 | 100 | 100.5 | |
| 8:00 AM | 8:15 AM | 66 | 24 | 1 | 1.5 | 91 | 91.5 | |
| 8:15 AM | 8:30 AM | 76 | 8 | 3 | 4.5 | 87 | 88.5 | |
| 8:30 AM | 8:45 AM | 36 | 3 | 1 | 1.5 | 40 | 40.5 | |
| 8:45 AM | 9:00 AM | 44 | 6 | 0 | 0 | 50 | 50 | |

Table 25: Location 5B Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 63 | 19 | 6 | 9 | 88 | 91 | |
| 6:15 AM | 6:30 AM | 60 | 7 | 3 | 4.5 | 70 | 71.5 | |
| 6:30 AM | 6:45 AM | 69 | 28 | 6 | 9 | 103 | 106 | |
| 6:45 AM | 7:00 AM | 87 | 24 | 4 | 6 | 115 | 117 | |
| 7:00 AM | 7:15 AM | 85 | 29 | 6 | 9 | 120 | 123 | 480 |
| 7:15 AM | 7:30 AM | 87 | 28 | 3 | 4.5 | 118 | 119.5 | |
| 7:30 AM | 7:45 AM | 90 | 30 | 3 | 4.5 | 123 | 124.5 | |
| 7:45 AM | 8:00 AM | 83 | 27 | 2 | 3 | 112 | 113 | |
| 8:00 AM | 8:15 AM | 66 | 24 | 1 | 1.5 | 91 | 91.5 | |
| 8:15 AM | 8:30 AM | 76 | 8 | 3 | 4.5 | 87 | 88.5 | |
| 8:30 AM | 8:45 AM | 36 | 3 | 1 | 1.5 | 40 | 40.5 | |
| 8:45 AM | 9:00 AM | 44 | 6 | 0 | 0 | 50 | 50 | |

Table 26: Location 6 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 245 | 99 | 12 | 18 | 356 | 362 | |
| 6:15 AM | 6:30 AM | 251 | 94 | 17 | 25.5 | 362 | 370.5 | |
| 6:30 AM | 6:45 AM | 265 | 99 | 20 | 30 | 384 | 394 | |
| 6:45 AM | 7:00 AM | 264 | 101 | 15 | 22.5 | 380 | 387.5 | 1545.5 |
| 7:00 AM | 7:15 AM | 259 | 92 | 21 | 31.5 | 372 | 382.5 | |
| 7:15 AM | 7:30 AM | 262 | 87 | 23 | 34.5 | 372 | 383.5 | |
| 7:30 AM | 7:45 AM | 264 | 95 | 22 | 33 | 381 | 392 | |
| 7:45 AM | 8:00 AM | 258 | 100 | 18 | 27 | 376 | 385 | |
| 8:00 AM | 8:15 AM | 252 | 78 | 20 | 30 | 350 | 360 | |
| 8:15 AM | 8:30 AM | 251 | 84 | 16 | 24 | 351 | 359 | |
| 8:30 AM | 8:45 AM | 258 | 78 | 1 | 1.5 | 337 | 337.5 | |
| 8:45 AM | 9:00 AM | 249 | 88 | 7 | 10.5 | 344 | 347.5 | |

Table 27: Location 7 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 297 | 102 | 6 | 9 | 405 | 408 | |
| 6:15 AM | 6:30 AM | 267 | 135 | 9 | 13.5 | 411 | 415.5 | |
| 6:30 AM | 6:45 AM | 306 | 129 | 8 | 12 | 443 | 447 | |
| 6:45 AM | 7:00 AM | 318 | 117 | 6 | 9 | 441 | 444 | 1786 |
| 7:00 AM | 7:15 AM | 294 | 136 | 8 | 12 | 438 | 442 | |
| 7:15 AM | 7:30 AM | 315 | 120 | 9 | 13.5 | 444 | 448.5 | |
| 7:30 AM | 7:45 AM | 306 | 132 | 9 | 13.5 | 447 | 451.5 | |
| 7:45 AM | 8:00 AM | 291 | 129 | 4 | 6 | 424 | 426 | |
| 8:00 AM | 8:15 AM | 288 | 126 | 2 | 3 | 416 | 417 | |
| 8:15 AM | 8:30 AM | 294 | 117 | 3 | 4.5 | 414 | 415.5 | |
| 8:30 AM | 8:45 AM | 288 | 93 | 1 | 1.5 | 382 | 382.5 | |
| 8:45 AM | 9:00 AM | 285 | 99 | 4 | 6 | 388 | 390 | |

Table 28: Location 8 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 120 | 30 | 0 | 0 | 150 | 150 | |
| 6:15 AM | 6:30 AM | 123 | 39 | 0 | 0 | 162 | 162 | |
| 6:30 AM | 6:45 AM | 132 | 42 | 6 | 9 | 180 | 183 | |
| 6:45 AM | 7:00 AM | 141 | 54 | 3 | 4.5 | 198 | 199.5 | 780 |
| 7:00 AM | 7:15 AM | 147 | 45 | 3 | 4.5 | 195 | 196.5 | |
| 7:15 AM | 7:30 AM | 138 | 54 | 3 | 4.5 | 195 | 196.5 | |
| 7:30 AM | 7:45 AM | 141 | 42 | 3 | 4.5 | 186 | 187.5 | |
| 7:45 AM | 8:00 AM | 135 | 57 | 0 | 0 | 192 | 192 | |
| 8:00 AM | 8:15 AM | 126 | 45 | 3 | 4.5 | 174 | 175.5 | |
| 8:15 AM | 8:30 AM | 129 | 39 | 0 | 0 | 168 | 168 | |
| 8:30 AM | 8:45 AM | 123 | 30 | 4 | 6 | 157 | 159 | |
| 8:45 AM | 9:00 AM | 113 | 25 | 1 | 1.5 | 139 | 139.5 | |

Table 29: Location 9 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 486 | 186 | 15 | 22.5 | 687 | 694.5 | |
| 6:15 AM | 6:30 AM | 498 | 231 | 27 | 40.5 | 756 | 769.5 | |
| 6:30 AM | 6:45 AM | 549 | 210 | 33 | 49.5 | 792 | 808.5 | |
| 6:45 AM | 7:00 AM | 573 | 252 | 42 | 63 | 867 | 888 | |
| 7:00 AM | 7:15 AM | 546 | 273 | 36 | 54 | 855 | 873 | 3505.5 |
| 7:15 AM | 7:30 AM | 546 | 282 | 33 | 49.5 | 861 | 877.5 | |
| 7:30 AM | 7:45 AM | 561 | 258 | 42 | 63 | 861 | 882 | |
| 7:45 AM | 8:00 AM | 540 | 288 | 30 | 45 | 858 | 873 | |
| 8:00 AM | 8:15 AM | 549 | 216 | 45 | 67.5 | 810 | 832.5 | |
| 8:15 AM | 8:30 AM | 558 | 264 | 30 | 45 | 852 | 867 | |
| 8:30 AM | 8:45 AM | 573 | 246 | 51 | 76.5 | 870 | 895.5 | |
| 8:45 AM | 9:00 AM | 558 | 216 | 33 | 49.5 | 807 | 823.5 | |

Table 30: Location 10 Data Adjustment

| Time Period | | Number of Cars | Number of SUV's | Number of Heavy Vehicles | H.V. Adjusted | Total | Total With Adjstemt | Total Number of Cars During Peak Hour |
|---|---|---|---|---|---|---|---|---|
| 6:00 AM | 6:15 AM | 66 | 21 | 0 | 0 | 87 | 87 | |
| 6:15 AM | 6:30 AM | 57 | 24 | 0 | 0 | 81 | 81 | |
| 6:30 AM | 6:45 AM | 78 | 21 | 3 | 4.5 | 102 | 103.5 | 425 |
| 6:45 AM | 7:00 AM | 78 | 18 | 5 | 7.5 | 101 | 103.5 | |
| 7:00 AM | 7:15 AM | 84 | 21 | 2 | 3 | 107 | 108 | |
| 7:15 AM | 7:30 AM | 83 | 27 | 0 | 0 | 110 | 110 | |
| 7:30 AM | 7:45 AM | 76 | 19 | 0 | 0 | 95 | 95 | |
| 7:45 AM | 8:00 AM | 66 | 21 | 3 | 4.5 | 90 | 91.5 | |
| 8:00 AM | 8:15 AM | 60 | 28 | 1 | 1.5 | 89 | 89.5 | |
| 8:15 AM | 8:30 AM | 57 | 12 | 3 | 4.5 | 72 | 73.5 | |
| 8:30 AM | 8:45 AM | 60 | 23 | 1 | 1.5 | 84 | 84.5 | |
| 8:45 AM | 9:00 AM | 51 | 19 | 1 | 1.5 | 71 | 71.5 | |

### 4.4.2 Traffic Volume

#### 4.4.2.1 Peak Hour

Road Volume and Peak Hour Data were collected over ten different locations for a total of three hours per location. An analysis for each location was performed in order to find the time where the peak hours occurred at each specific location.

#### 4.4.2.2 Location 1

The first location was the intersection of Curry Ford Road (SR 552) and Goldenrod Road (SR 551). A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. A primary graph of the collected data is shown below in Figure 27: Location 1, Data Results.

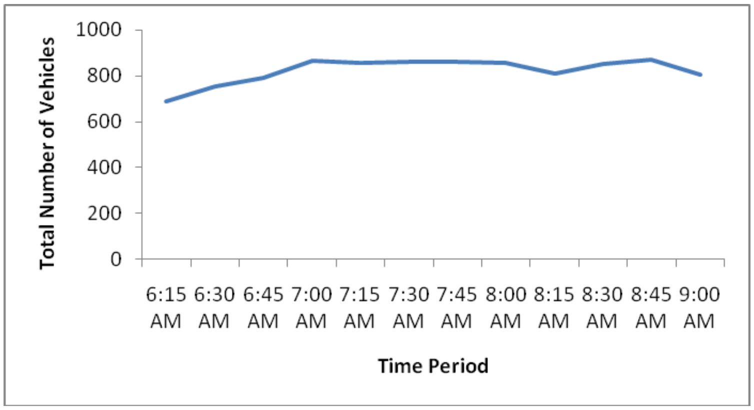



Figure 27: Location 1, Data Results

After the primary analysis for the data was performed, a detailed analysis was evaluated to find the exact peak traffic hour for that location. The analysis showed that the time between 7:00am and 8:00am is the time where the highest number of vehicles passed through that point. Figure 28: Location 1 with Peak Hour highlights the peak hour in red.

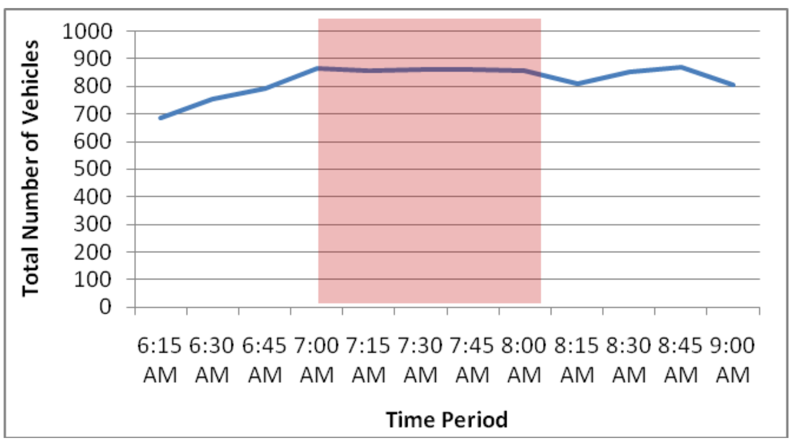



Figure 28: Location 1 with Peak Hour

4.4.2.3 Location 2 Data Results

The intersection of Curry Ford Road (SR 552) and South Chickasaw Trail was the location of point 2. A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. Primary graph of the collected data is shown below. Figure 29: Location 2, Data results.

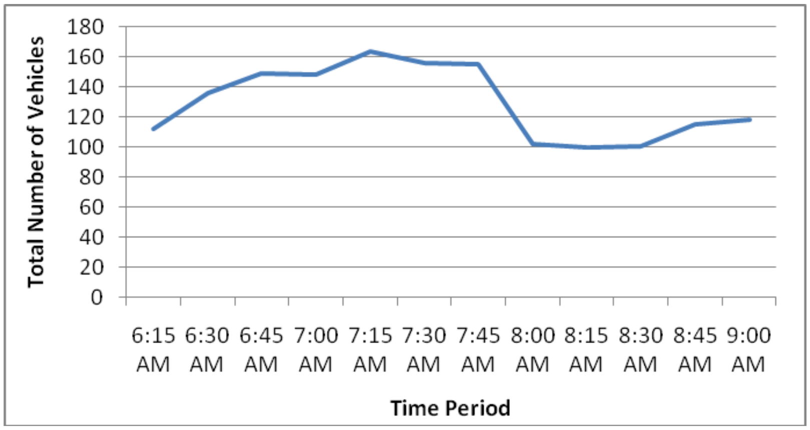


Figure 29: Location 2, Data results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour of that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 30: Location 2 with Peak Hour highlights the peak hour in light red.

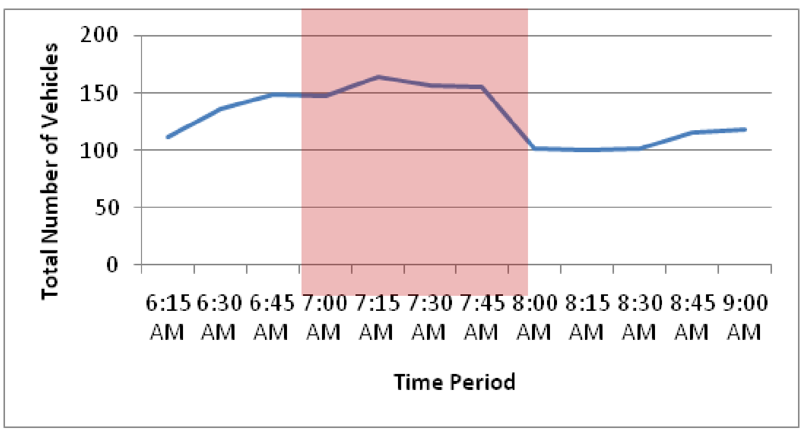


Figure 30: Location 2 with Peak Hour

4.4.2.4 Location 3 Data Results

The intersection of Curry Ford Road (SR 552) crossing with South Econlockhatchee Trail was the location of data point 3. A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. A primary graph of the collected data is shown below. Figure 31: Location 3, Data Results.

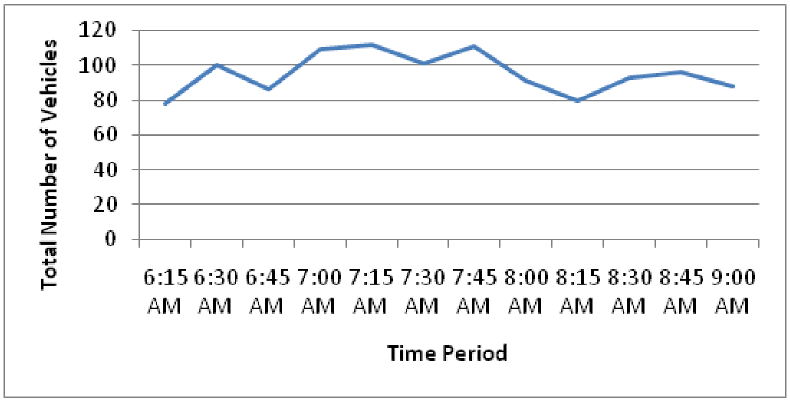


Figure 31: Location 3, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour of that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 32: Location 3 with Peak Hour highlights the peak hour in light red.

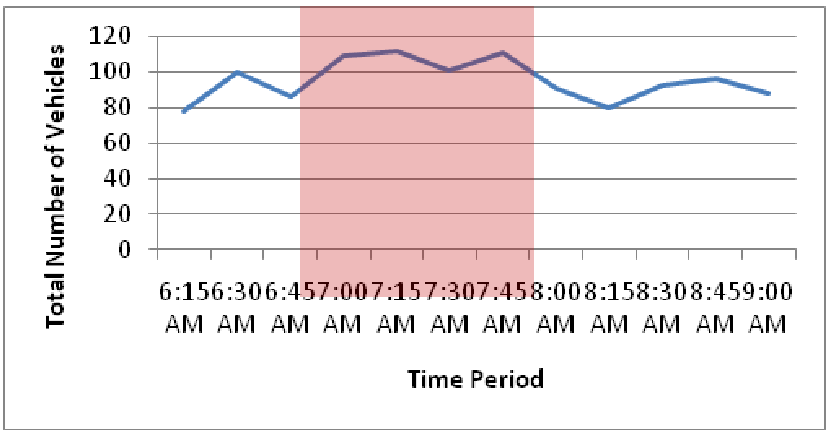


Figure 32: Location 3 with Peak Hour

4.4.2.5 Location 4 Data Results

Location 4 was the intersection of South Goldenrod Road (SR 551) and Lake Underhill Road. A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. A primary graph of the collected data is shown below. Figure 33: Location 4, Data Results.

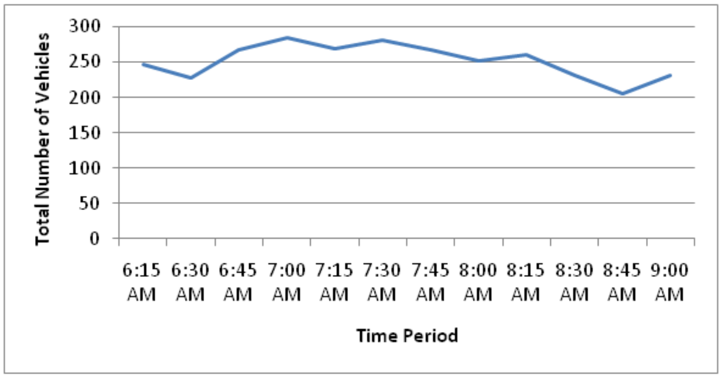



Figure 33: Location 4, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour for that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 34: Location 4 with Peak Hour highlights the peak hour in light red.

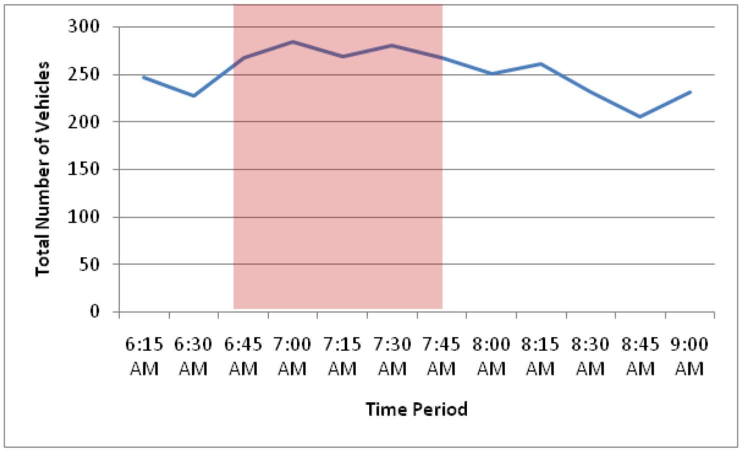



Figure 34: Location 4 with Peak Hour

4.4.2.6 Location 5 Data Results

A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. A primary graph of the collected data is shown below in Figure 35: Location 5, Data Results, and Figure 36: Location 5A, Data Results and Figure 37: Location 5B, Data Results.

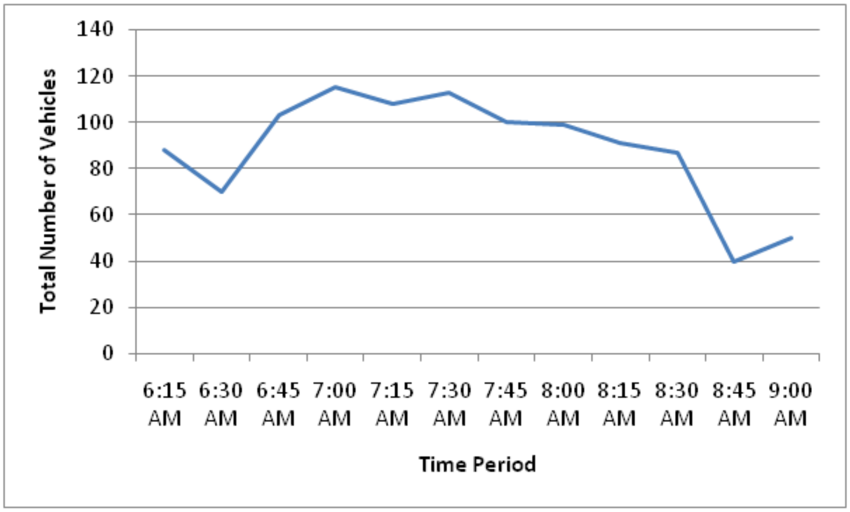



Figure 35: Location 5, Data Results

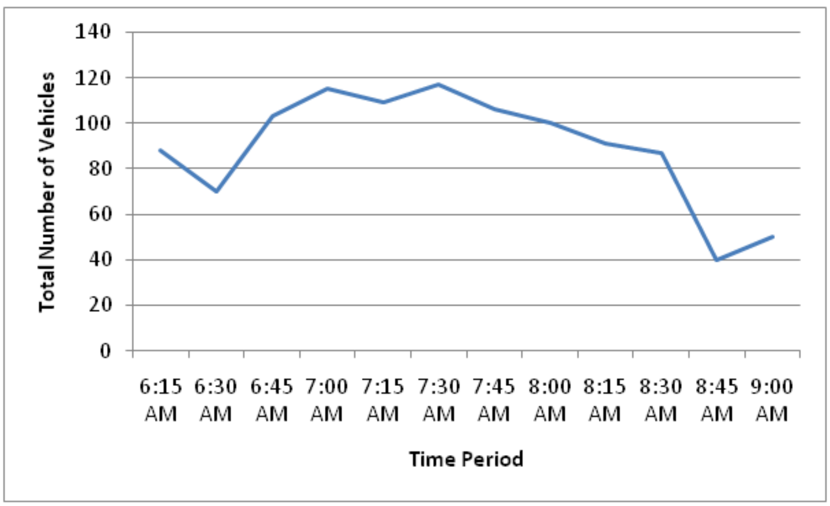



Figure 36: Location 5A, Data Results

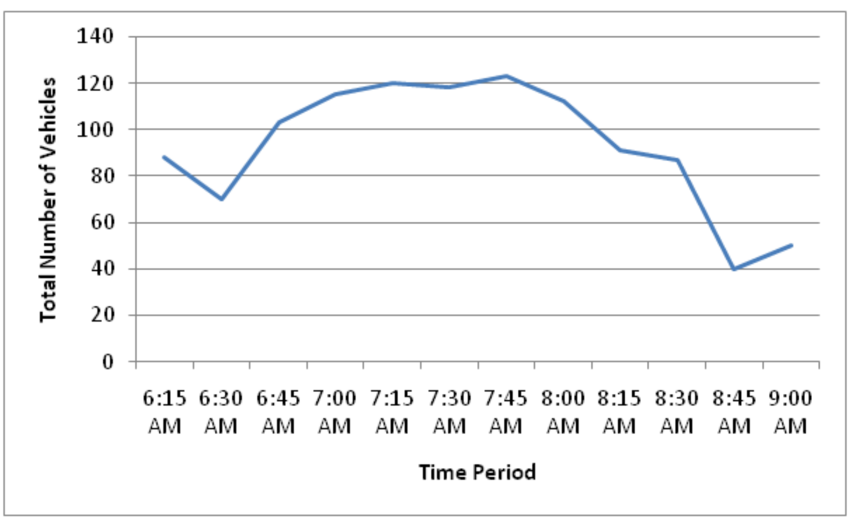


Figure 37: Location 5B, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour for that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 38: Location 5 with Peak Hour highlights the peak hour in light red. As well as Figure 39: Location 5A with Peak Hour and Figure 40: Location 5B with Peak Hour

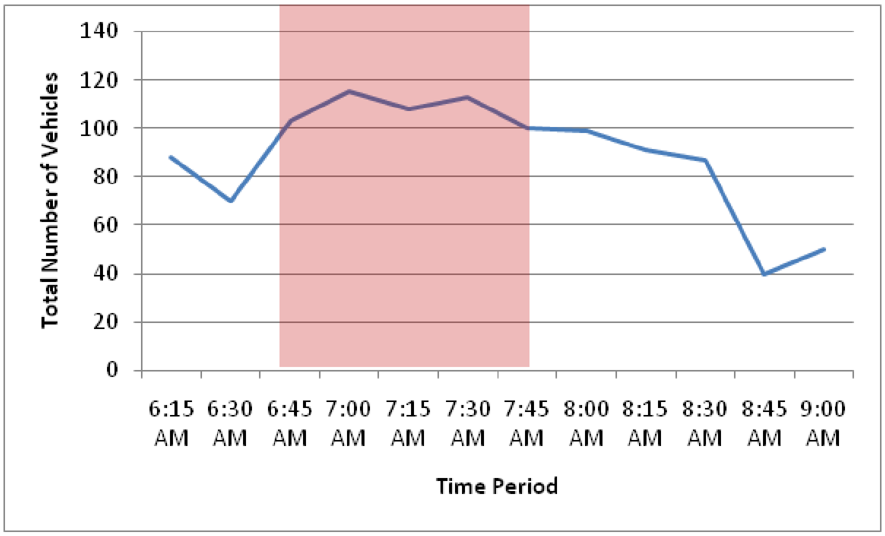



Figure 38: Location 5 with Peak Hour

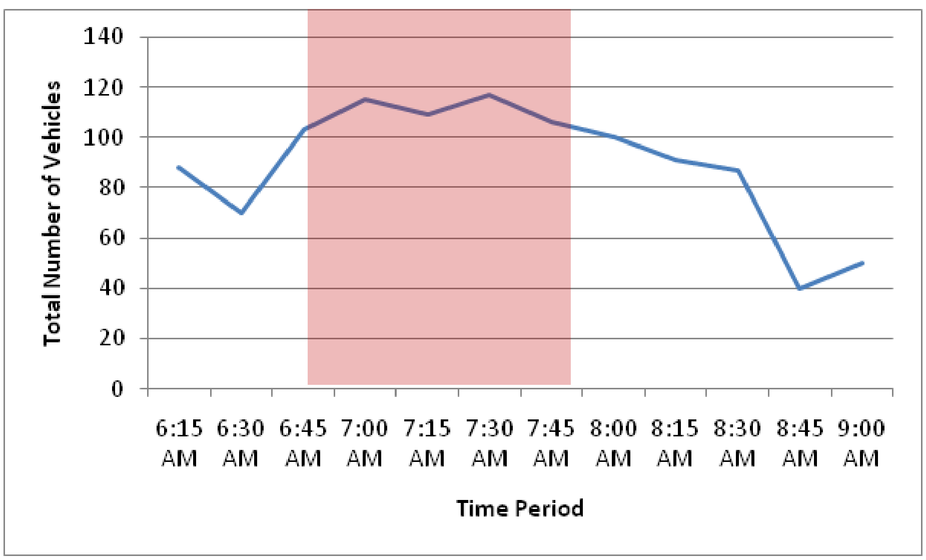



Figure 39: Location 5A with Peak Hour

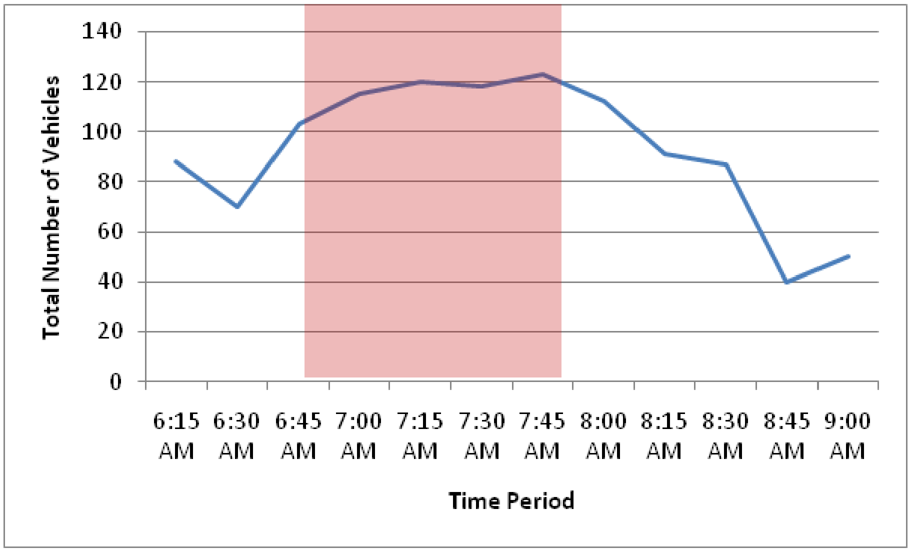



Figure 40: Location 5B with Peak Hour

4.4.2.7 Location 6 Data Results

Location 6 was the intersection of East Colonial Drive (HW 50) crossing with Goldenrod Road (SR 551). A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. A primary graph of the collected data is shown below. Figure 41: Location 6, Data Results.

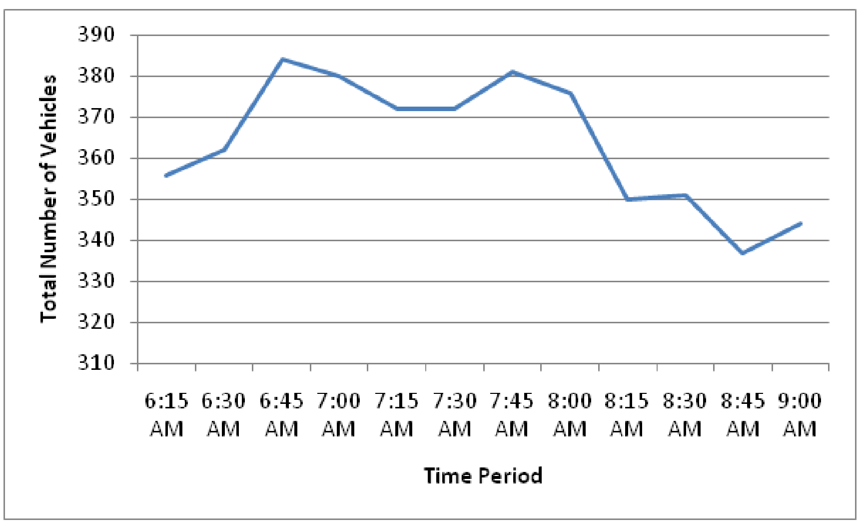



Figure 41: Location 6, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour of that location. The analysis showed that the time between

7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 42: Location 6 with Peak Hour highlights the peak hour in light red.

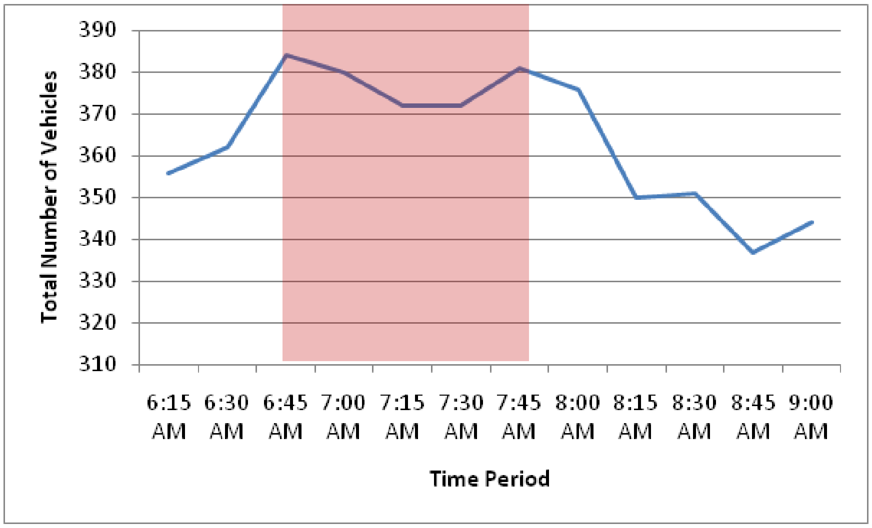



Figure 42: Location 6 with Peak Hour

4.4.2.8 Location 7 Data Results

Location 7 was the intersection of Goldenrod Road (SR 551) midway between Lake Underhill Road and Goldenrod Road crossing and Curry Ford Road and Goldenrod Road crossing. A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. A primary graph of the collected data is shown below. Figure 43: Location 7, Data Results

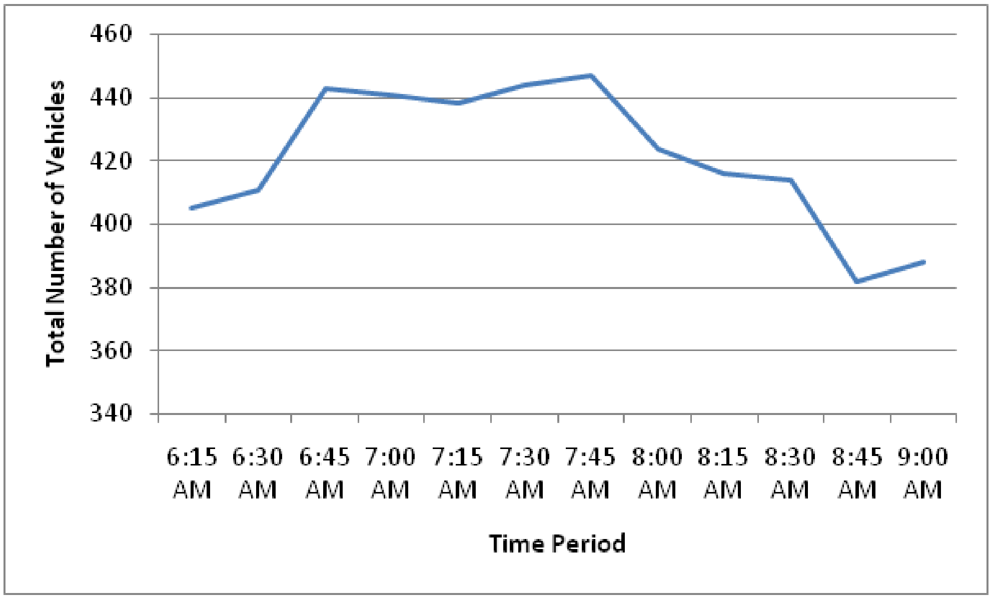



Figure 43: Location 7, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour of that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 44: Location 7 with Peak Hour highlights the peak hour in light red.

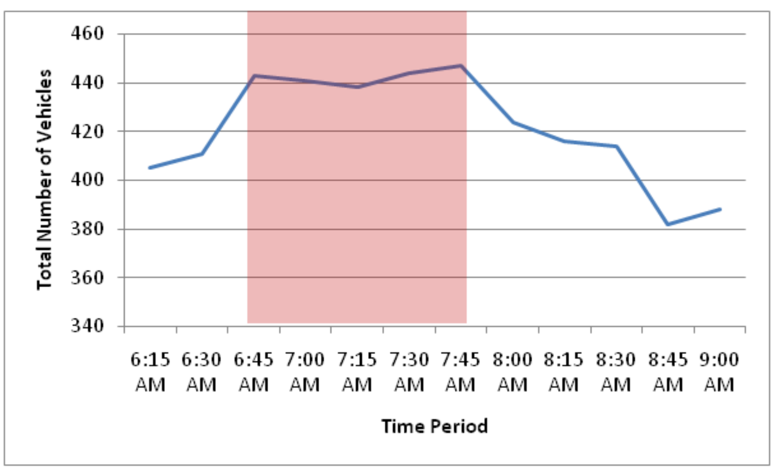



Figure 44: Location 7 with Peak Hour

4.4.2.9 Location 8 Data Results

Location 8 was the intersection of East Colonial Drive (HW 50) with north Econlockhatchee A total of three consecutive hours of data collection were collected at that point between the hours of

6:00am and 9:00am. A primary graph of the collected data is shown below. Figure 45: Location 8, Data Results.

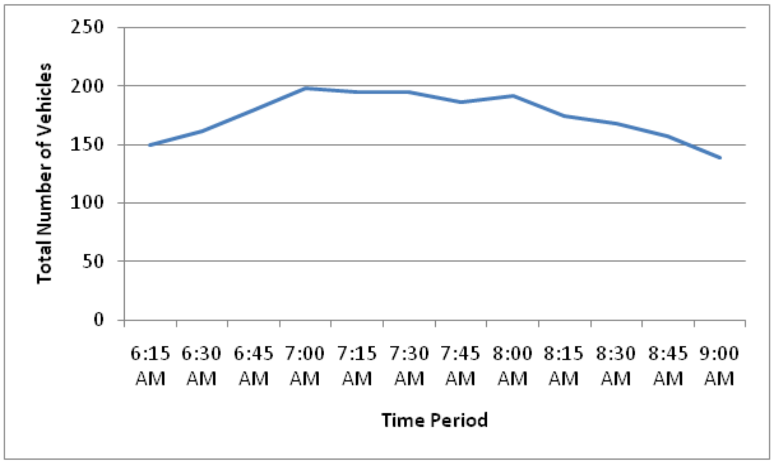



Figure 45: Location 8, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak hour of that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 45: Location 8, Data Results highlights the peak hour in light red.

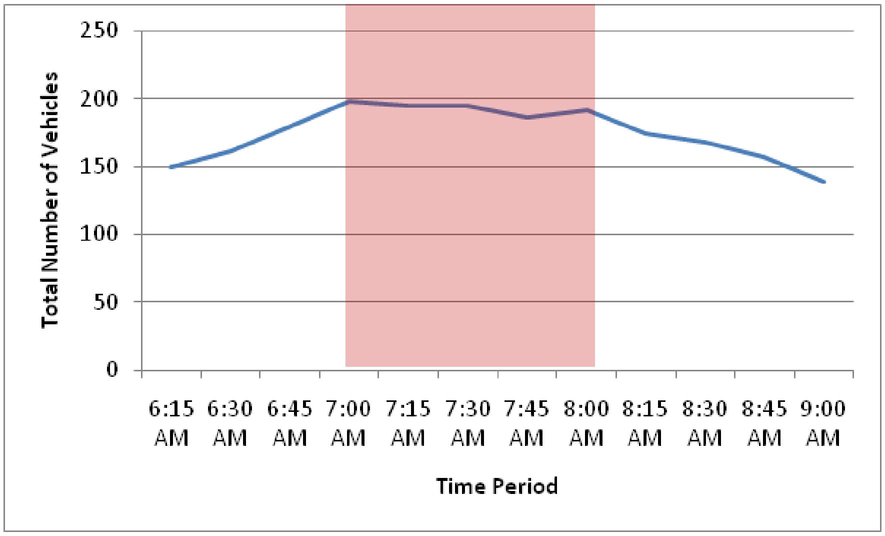



Figure 46: Location 8 with Peak Hour

4.4.2.10 Location 9 Data Results

Location 9 was the interchange of freeways 408/417 near exit 16. A total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am. A primary graph of the collected data is shown below. Figure 47: Location 9, Data Results.

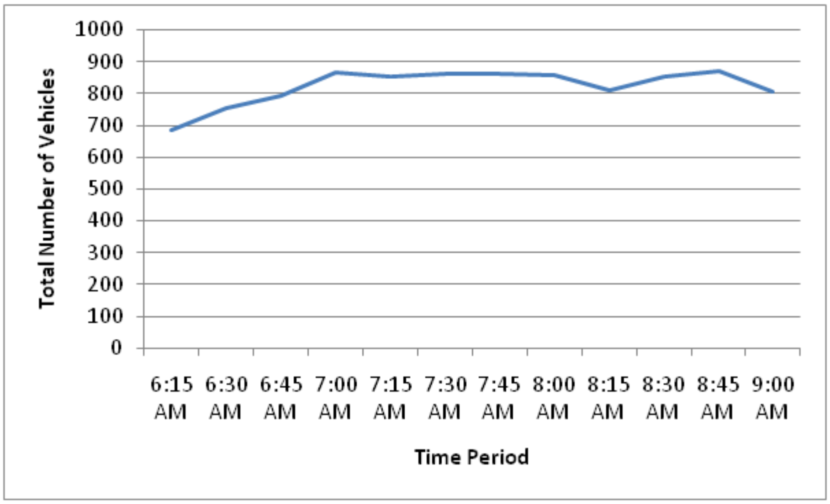



Figure 47: Location 9, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour for that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 48: Location 9 with Peak Hour highlights the peak hour in light red.

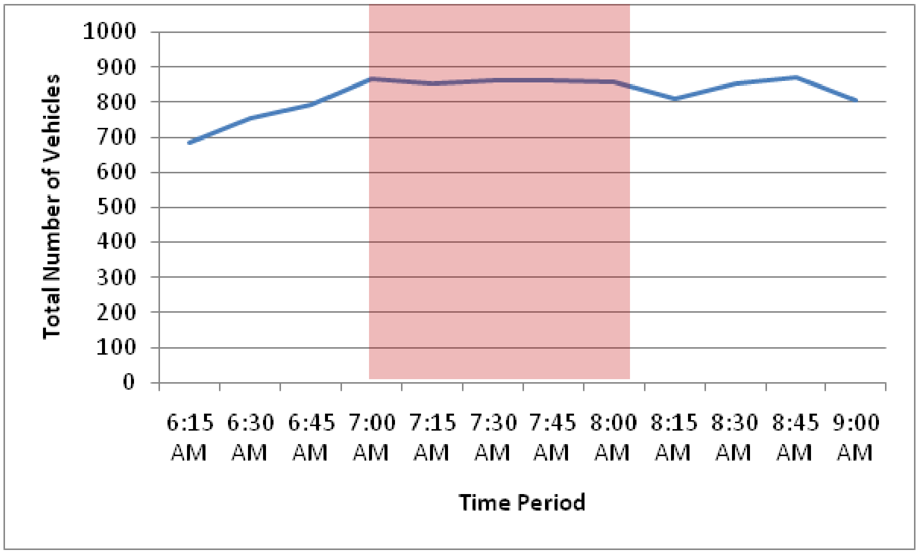



Figure 48: Location 9 with Peak Hour

4.4.2.11 Location 10 Data Results

Location 10 was the intersection East Colonial Drive (HW 50) and North Chickasaw Trail a total of three consecutive hours of data collection were collected at that point between the hours of 6:00am and 9:00am.A primary graph of the collected data is shown below. Figure 49: Location 10, Data Results

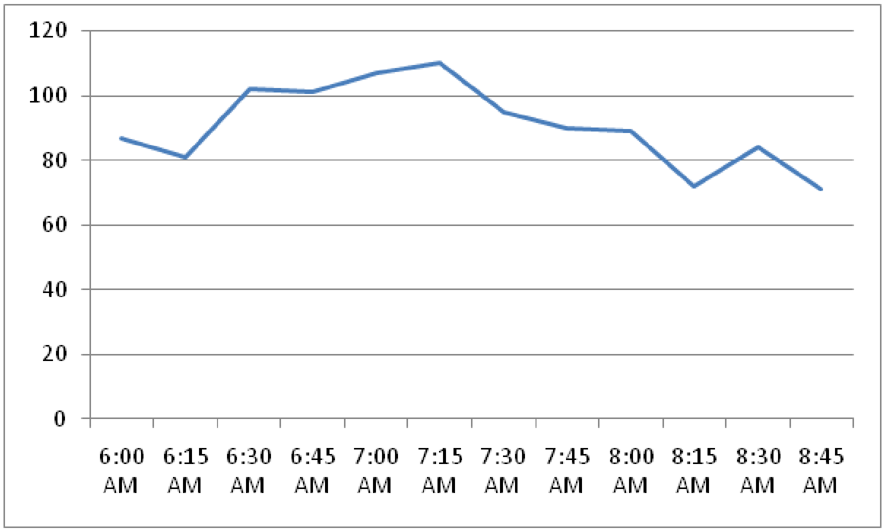



Figure 49: Location 10, Data Results

After the primary analysis for the data was performed, a detailed analysis was made to find the exact peak traffic hour for that location. The analysis showed that the time between 7:00am and 8:00am was the time where the highest number of vehicles passed through that point. Figure 50: Location 10 with Peak Hour in light red.

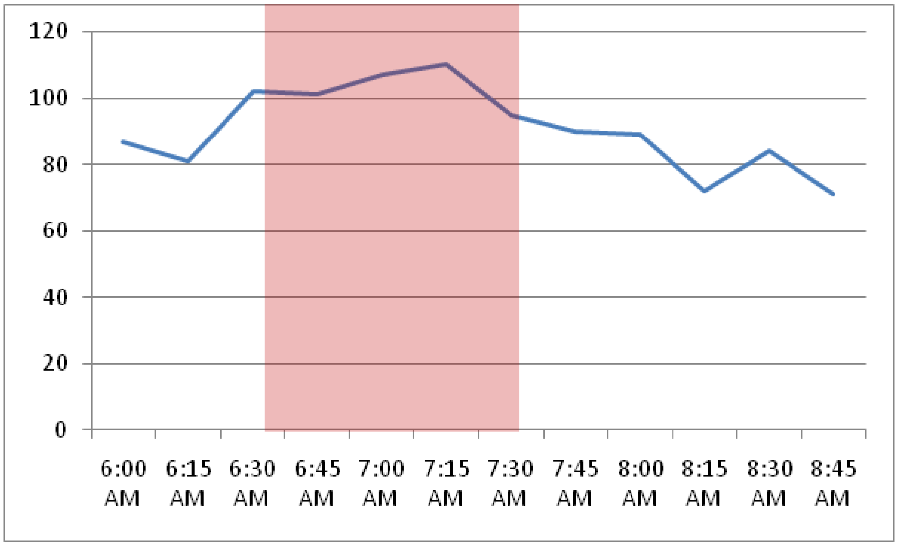



Figure 50: Location 10 with Peak Hour

### 4.4.3 Calculation of the actual time t(v)

It should be noted that when it comes to economic feasibility, usually a comparison is conducted between the cost of blocking the whole road for a shorter total duration versus the cost of partially blocking the road for a relatively longer duration. While the former allows faster completion of road construction tasks, the latter option requires less detour planning. In addition to these costs, the cost of delay due to construction should be considered in assessing the alternatives and selecting the best solution. Moreover, the social value of delay and how much a daily commuter is willing to pay to avoid going through traffic congestion must be precisely estimated in terms of time and money. Since the travel time per unit distance is an inverse function of the speed, delays are expected to noticeably increase as the speed goes down. Also with reduced speeds, density rises as more and more users enter the congested zone, reducing inter-vehicle spacing and causing the speed to fall to almost zero. It has been reported that the travel times tend to rise exponentially as a function of demand for the scarce road space, as illustrated in Figure 51: Marginal Cost Curve above the Standard BPR (Kockelman, 2004)

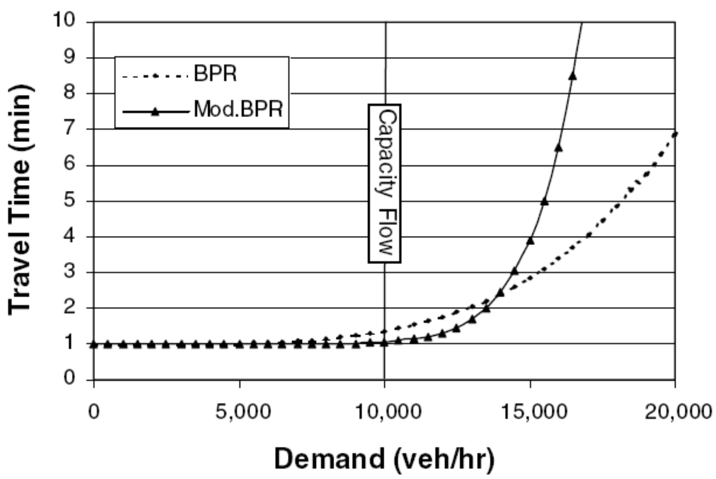



Figure 51: Marginal Cost Curve above the Standard BPR (Kockelman, 2004)

In this study a formula developed by the Bureau of Public Roads (BPR) is used to calculate the common travel time (FHWA, 1979), as shown in Equation 1.

$$t(V) = t_f\left(1 + 0.15\left(\frac{V}{C}\right)^4\right) \ldots \ldots (1)$$

Where:

**V** is the traffic volume,

**C** is the practical capacity, corresponding to approximately 80 percent of the true capacity,

**t (V)** is the actual travel time, as a function of demand volume V, and

**t*f*** is the free-flow travel time

#### 4.4.3.1 Traffic Volume

Table 31: Traffic Volume

| From | To | V |
|---|---|---|
| A | F | 1786 |
| F | E | 927 |
| E | D | 927 |
| D | C | 424 |
| E | B | 600 |
| A | B | 1075 |
| B | C | 1075 |
| C | J | 927 |
| A | I | 3506 |
| A | G | 1786 |
| G | H | 425 |
| H | I | 438 |
| I | J | 480 |
| K | J | 780 |
| L | H | 425 |
| G | M | 1786 |
| M | L | 1546 |
| L | K | 1546 |

### 4.4.4 Capacity

Table 32: Link Capacity

| From | To | C(pc/h) |
|---|---|---|
| A | F | 3800 |
| F | E | 3800 |
| E | D | 3800 |
| D | C | 1700 |
| E | B | 1700 |
| A | B | 1700 |
| B | C | 1700 |
| C | J | 1700 |
| A | I | 4500 |
| A | G | 3800 |
| G | H | 1700 |
| H | I | 1700 |
| I | J | 1700 |
| K | J | 1700 |
| L | H | 1700 |
| G | M | 3800 |
| M | L | 3800 |
| L | K | 3800 |

#### 4.4.4.1 Adjusted Capacity

The 40% deduction of the capacity of the road had been determined by the actual observation of multiple traffic lights within the network. After observing multiple traffic lights it found that the cycle average is green60 % of the time and red 40 % of the time, thus reducing the road capacity by 40%.

Table 33: Link Capacity with Reduction

| From | To | Capacity Reduction by 40% |
|---|---|---|
| A | F | 2280 |
| F | E | 2280 |
| E | D | 2280 |
| D | C | 1020 |
| E | B | 1020 |
| A | B | 1020 |
| B | C | 1020 |
| C | J | 1020 |
| A | I | 4500 |
| A | G | 2280 |
| G | H | 1020 |
| H | I | 1020 |
| I | J | 1020 |
| K | J | 1020 |
| L | H | 1020 |
| G | M | 2280 |
| M | L | 2280 |
| L | K | 2280 |

#### 4.4.4.2 Free-Flow Travel Time

Table 34: Free-Flow Travel Time

| From | To | tf(sec) |
|---|---|---|
| A | F | 153 |
| F | E | 138 |
| E | D | 71 |
| D | C | 203 |
| E | B | 248 |
| A | B | 85 |
| B | C | 140 |
| C | J | 89 |
| A | I | 122 |
| A | G | 194 |
| G | H | 48 |
| H | I | 51 |
| I | J | 165 |
| K | J | 103 |
| L | H | 106 |
| G | M | 90 |
| M | L | 43 |
| L | K | 228 |

Now since we have all three variables (the traffic volume, the practical capacity, and the free-flow travel time) we can find the actual travel time by applying equation 1

$$t(V) = t_f\left(1 + 0.15\left(\frac{V}{C}\right)^4\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Example calculation:

$$t(V) = 100\left(1 + 0.15\left(\frac{V100}{100C}\right)^4\right)$$

4.4.4.3 Actual Travel Time

Table 35: Actual Travel Time

| From | To | tf(sec) | V | C(pc/h) | Capacity Reduction by 40% | t(v) |
|---|---|---|---|---|---|---|
| A | F | 153 | 1786 | 3800 | 2280 | 162 |
| F | E | 138 | 927 | 3800 | 2280 | 139 |
| E | D | 71 | 927 | 3800 | 2280 | 71 |
| D | C | 203 | 424 | 1700 | 1020 | 204 |
| E | B | 248 | 600 | 1700 | 1020 | 252 |
| A | B | 85 | 1075 | 1700 | 1020 | 101 |
| B | C | 140 | 1075 | 1700 | 1020 | 166 |
| C | J | 89 | 927 | 1700 | 1020 | 98 |
| A | I | 122 | 3506 | 4500 | 4500 | 128 |
| A | G | 194 | 1786 | 3800 | 2280 | 205 |
| G | H | 48 | 425 | 1700 | 1020 | 48 |
| H | I | 51 | 438 | 1700 | 1020 | 51 |
| I | J | 165 | 480 | 1700 | 1020 | 167 |
| K | J | 103 | 780 | 1700 | 1020 | 108 |
| L | H | 106 | 425 | 1700 | 1020 | 106 |
| G | M | 90 | 1786 | 3800 | 2280 | 95 |
| M | L | 43 | 1546 | 3800 | 2280 | 44 |
| L | K | 228 | 1546 | 3800 | 2280 | 235 |

## 4.5 Shortest Path Formulation

Shortest path formulation or shortest path problem is a solution to find the path between two vertices.or nodes, in such a way to minimize the work done. An example of using shortest path formulation or shortest path problem is going from one point to another on a road map.

### 4.5.1 Mathematical Formulation of Shortest Path Method

To select the optimal solution, a modification to the shortest path formulation is proposed. This method is based on sending a single unit of flow from one node (e.g. node 1) to a destination node (e.g. node m) at the least possible cost (Bazaraa, 1990). In such a case the mathematical formulation of the problem could be described as follows:

$$Minimize \sum_{i=1}^{m}\sum_{j=1}^{m} c_{ij}x_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$Subject\ to \sum_{j=1}^{m} x_{ij} - \sum_{k=1}^{m} x_{ki} = \begin{cases} 1, & i = 1 \\ 0, & i \neq 1\ or\ m \\ -1, & i = m \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$x_{ij} = 0\ or\ 1 \quad (i, j = 1, 2, \ldots\ldots\ldots, m) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The summation is taken over the existing arcs of the network. The constant $x_{ij}$ (which is equal to 0 or 1) indicates whether the arc is in path or not.

Where the sums and the 0 – 1 requirement are taken over existing arcs in G. Also, the constants $x_{ij}$ = 0 or 1 indicates that each arc is either in path or not.

### 4.5.2 Modeling Critical Facilities:

Driving through a critical facility zone must be taken into consideration, especially if the detour is expected to create a traffic jam. Critical facilities include, but are not limited to, shelters, hospitals, and fire stations. Those facilities must be considered when selecting a new route for the detour. In many cases detours can disturb and jam the whole area or network, which may prevent emergency vehicles from reaching the critical facilities.

## 4.6 Results

As it was mentioned before, the objective of this chapter is to present linear formulation to aid in optimizing the impact of construction detour planning decisions when it comes to calculate the travel time during the existence of construction detours. Thus, many calculations were done with travel time and then finding the shortest path formulation.

Table 36: Calculating the Actual Travel Time

| From | To | tf(sec) | V | C(pc/h) | Capacity Reduction by 40% | t(v) |
|---|---|---|---|---|---|---|
| A | F | 153 | 1786 | 3800 | 2280 | 162 |
| F | E | 138 | 927 | 3800 | 2280 | 139 |
| E | D | 71 | 927 | 3800 | 2280 | 71 |
| D | C | 203 | 424 | 1700 | 1020 | 204 |
| E | B | 248 | 600 | 1700 | 1020 | 252 |
| A | B | 85 | 1075 | 1700 | 1020 | 101 |
| B | C | 140 | 1075 | 1700 | 1020 | 166 |
| C | J | 89 | 927 | 1700 | 1020 | 98 |
| A | I | 122 | 3506 | 4500 | 4500 | 128 |
| A | G | 194 | 1786 | 3800 | 2280 | 205 |
| G | H | 48 | 425 | 1700 | 1020 | 48 |
| H | I | 51 | 438 | 1700 | 1020 | 51 |
| I | J | 165 | 480 | 1700 | 1020 | 167 |
| K | J | 103 | 780 | 1700 | 1020 | 108 |
| L | H | 106 | 425 | 1700 | 1020 | 106 |
| G | M | 90 | 1786 | 3800 | 2280 | 95 |
| M | L | 43 | 1546 | 3800 | 2280 | 44 |
| L | K | 228 | 1546 | 3800 | 2280 | 235 |

Implementing the Actual travel time in the model as illustrated in Figure 52: Screen Shot of the Formulation When Run It Based on Shortest Time

| From/To | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | 101 | | | | 162 | 205 | | 129 | | | | |
| B | | | 166 | | | | | | | | | | |
| C | | | | | | | | | | 99 | | | |
| D | | | 204 | | | | | | | | | | |
| E | | 253 | | 72 | | | | | | | | | |
| F | | | | | 139 | | | | | | | | |
| G | | | | | | | | | | | | | 96 |
| H | | | | | | | | | 52 | | | | |
| I | | | | | | | | | | 167 | | | |
| J | | | | | | | | | | | | | |
| K | | | | | | | | | | 109 | | | |
| L | | | | | | | | 107 | | | 236 | | |
| M | | | | | | | | | | | | 45 | |

| Start | End |
|---|---|
| A | J |

Detour

| From | To |
|---|---|
| A | I |
| I | J |
| J | End |

Detour

Figure 52: Screen Shot of the Formulation When Run It Based on Shortest Time

As we can see the best route was selected to start at Point A, travel through point I and terminating at the final destination which is point J. Results will be further discussed in the following chapter. The figure below illustrates the generated route.

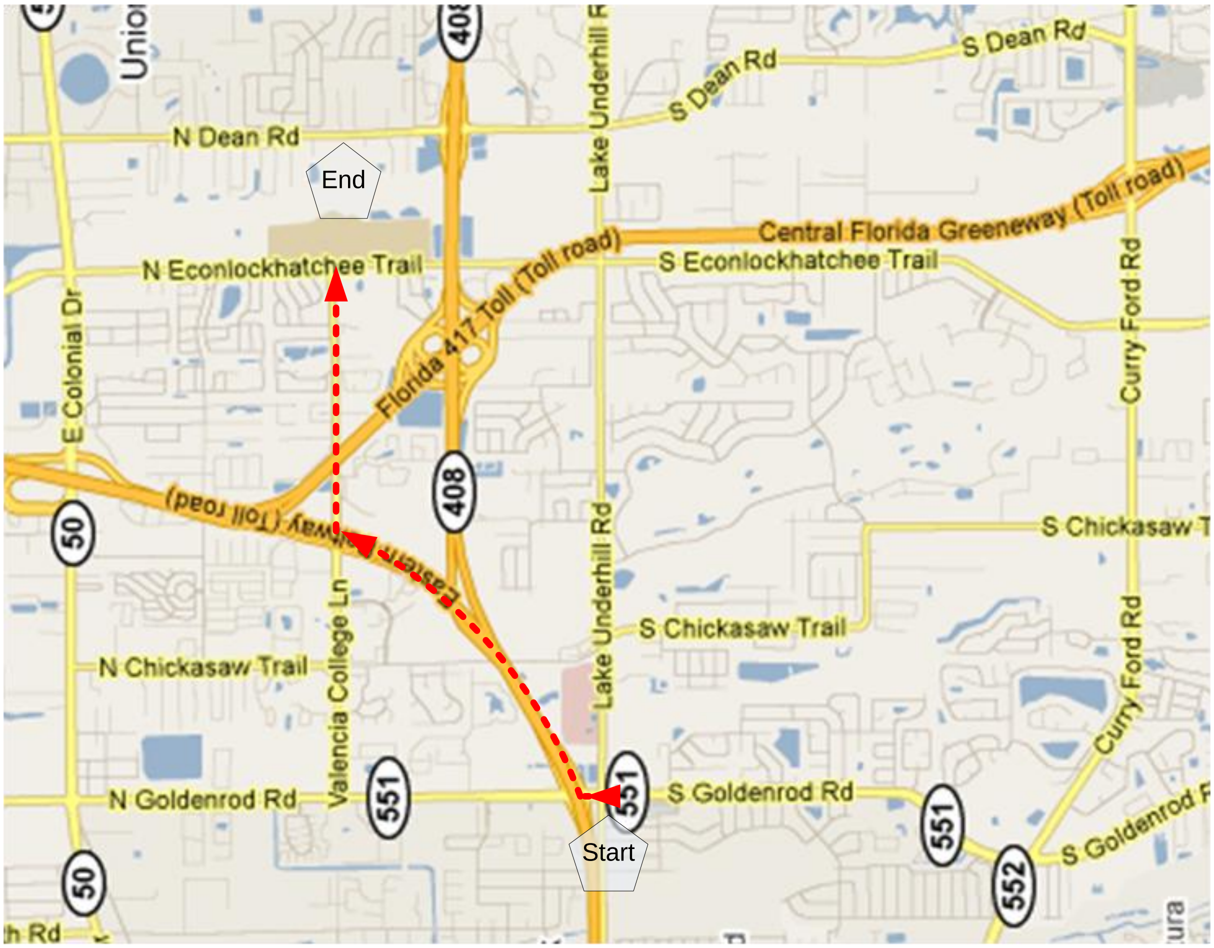


Figure 53: Generated Map Based on Shortest Time

# CHAPTER FIVE: MODELING THE IMPACT OF TRAVEL COST ON SELECTING SHORTEST ROUTE

## 5.1 Introduction

The objective of this chapter is to present a linear formulation to aid in optimizing the impact of construction detour planning decisions when it comes to calculate the travel cost during the existence of construction detours.

The main objective when it comes to determine the impact of travel cost when selecting shortest route is developing a linear model such as shortest path formulation to find a route that will take the least amount of time while focusing on the economical impact for the daily commuter, from start point to end point.

User cost of delay can be categorized as the cost of not only additional travel time but also any additional cost, with disregards if this cost is due to fuel consumption or any other expenses like vehicle usage or anything else. One of the first questions that the decision maker will be asked when designing a construction detour is, “What yields the lowest total cost for the daily commuter?” or, “What yields the maximum benefit over the project life for the daily commuter?” For such a reason, the construction detour planner must take into consideration the cost benefit of the detour, not only by focusing on the cost benefit for the authority who is designing the detour and paying for it, but mainly by focusing on the cost benefit for the daily commuter which is considered the main beneficiary of this detour.

### 5.1.1 Data Collection

Data was collected for modeling the impact of travel time when selecting the shortest route and being used for modeling the impact of travel cost when selecting shortest route. To see the detailed data collection, refer to chapter 4 section 4.4.

### 5.1.2 Data Analysis

Data analysis was preformed for modeling the impact of travel time when selecting the shortest route and being used for modeling the impact of travel cost when selecting shortest route. To see the detailed data analyses, refer to chapter 4 section 4.7.

## 5.2 Travel Cost-Based Optimization Model

After researching, no such program or clear guidelines were designed or found when it comes to assisting construction detour planners in generating a set of optimal construction site layout plans that minimize the travel cost. The only thing found was a small section in the *Plans Preparation Manual* chapter 10, *Transportation Management Plan*. For such a reason a model was created to help the construction detour planner was created in order to help aid when it comes to planning a construction detour while considering the shortest travel cost.

This model is based on shortest path formulation which is a technique that uses machine-learning and optimization techniques to develop a tool and guidelines that can help engineers make better detour plans based on lowest cost. This model could potentially offer a better utilization of the available capacity in the entire traffic network while considering low cost as a main factor.

### 5.2.1 Gas Costs

We all can feel the downturn in the economy nowadays as gas prices are continually rising. Perhaps the main reason for this is that OPEC hasn't increased oil producing capacity much since the early 80′ (Shipp, 2010) .

The figure below shows how the prices of gas have increased over the last ten years.

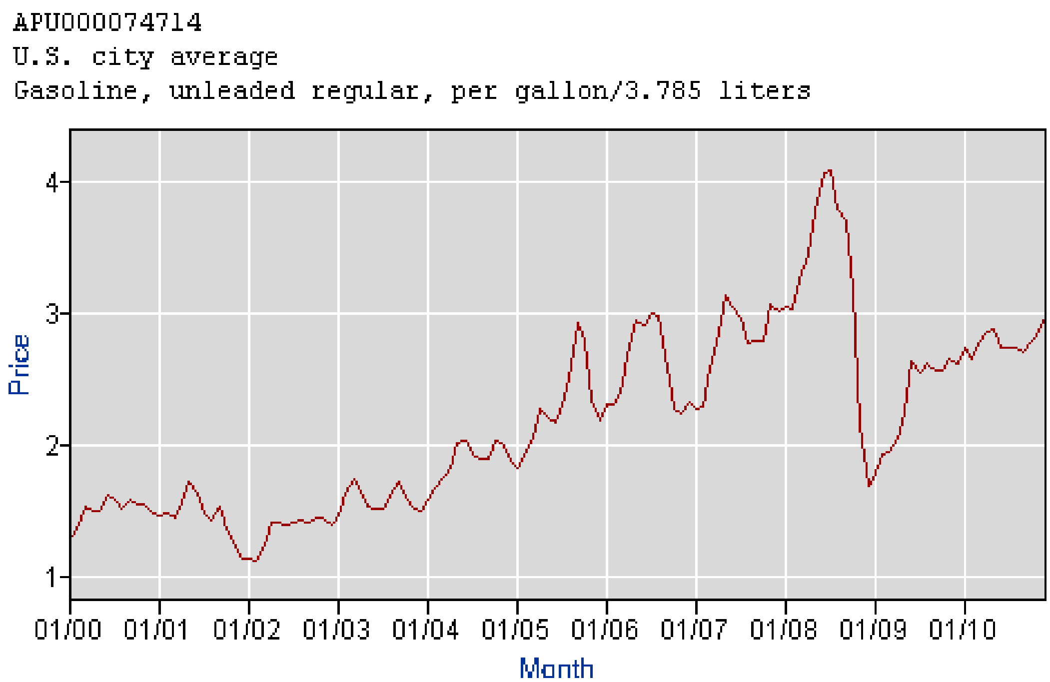



Figure 54: Gas prices from 2000 Until 2010 (Statistics, 2011)

Table 37: Gas Prices from 2000-2010 (Statistics, 2011)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 1.301 | 1.369 | 1.541 | 1.506 | 1.498 | 1.617 | 1.593 | 1.51 | 1.582 | 1.559 | 1.555 | 1.489 |
| 2001 | 1.472 | 1.484 | 1.447 | 1.564 | 1.729 | 1.64 | 1.482 | 1.427 | 1.531 | 1.362 | 1.263 | 1.131 |
| 2002 | 1.139 | 1.13 | 1.241 | 1.407 | 1.421 | 1.404 | 1.412 | 1.423 | 1.422 | 1.449 | 1.448 | 1.394 |
| 2003 | 1.473 | 1.641 | 1.748 | 1.659 | 1.542 | 1.514 | 1.524 | 1.628 | 1.728 | 1.603 | 1.535 | 1.494 |
| 2004 | 1.592 | 1.672 | 1.766 | 1.833 | 2.009 | 2.041 | 1.939 | 1.898 | 1.891 | 2.029 | 2.01 | 1.882 |
| 2005 | 1.823 | 1.918 | 2.065 | 2.283 | 2.216 | 2.176 | 2.316 | 2.506 | 2.927 | 2.785 | 2.343 | 2.186 |
| 2006 | 2.315 | 2.31 | 2.401 | 2.757 | 2.947 | 2.917 | 2.999 | 2.985 | 2.589 | 2.272 | 2.241 | 2.334 |
| 2007 | 2.274 | 2.285 | 2.592 | 2.86 | 3.13 | 3.052 | 2.961 | 2.782 | 2.789 | 2.793 | 3.069 | 3.02 |
| 2008 | 3.047 | 3.033 | 3.258 | 3.441 | 3.764 | 4.065 | 4.09 | 3.786 | 3.698 | 3.173 | 2.151 | 1.689 |
| 2009 | 1.787 | 1.928 | 1.949 | 2.056 | 2.265 | 2.631 | 2.543 | 2.627 | 2.574 | 2.561 | 2.66 | 2.621 |
| 2010 | 2.731 | 2.659 | 2.78 | 2.858 | 2.869 | 2.736 | 2.736 | 2.745 | 2.704 | 2.795 | 2.852 | 2.985 |

### 5.2.2 Link Cost

The process of finding the cost of each link was slightly more complicated than finding the travel time for each link. First of all, cost is always connected to time as much as time related to cost. For such a reason, more than one step were taken to find the exact cost per link. First, we find the cost per hour driving for each vehicle based on 2007 Urban Mobility report. The Average cost of time in 2005 was $14.60 per person hour(Schrank and Lomax, 2001). Based on the same report, which was issued by the Texas Transportation Institute, the vehicle occupancy was found to be 1.25 persons per vehicle. Since the cost per hour was found to be $14.60 based on 2005 gas prices, the average cost per time was adjusted to reflect 2011 gas prices which have risen dramatically. Adjustment illustrated in Table 38: Cost of Travel Dollar / Hour.

Table 38: Cost of Travel Dollar / Hour

| | |
|---|---|
| Average Gas Price in 2005 Dollar/Gallon | 2.29 |
| Current Gas Price Dollar /Gallon | 3.19 |
| Cost of Travel Time in 2005 Dollar / hour | 14.6 |
| Cost of Current Travel Time Dollar / hour | 20.3 |

Table 39: Cost of each link

| From | To | tf(sec) | V | C(pc/h) | Capacity Reduction by 40% | t(v) | COST per person | Cost |
|---|---|---|---|---|---|---|---|---|
| A | F | 153 | 1786 | 3800 | 2280 | 155 | 0.874 | 1.092 |
| F | E | 138 | 927 | 3800 | 2280 | 139 | 0.783 | 0.979 |
| E | D | 71 | 927 | 3800 | 2280 | 72 | 0.406 | 0.507 |
| D | C | 203 | 424 | 1700 | 1020 | 204 | 1.150 | ######## |
| E | B | 248 | 600 | 1700 | 1020 | 249 | 1.403 | 1.754 |
| A | B | 85 | 1075 | 1700 | 1020 | 88 | 0.496 | ######## |
| B | C | 140 | 1075 | 1700 | 1020 | 144 | 0.812 | 1.015 |
| C | J | 89 | 927 | 1700 | 1020 | 91 | 0.513 | 0.641 |
| A | I | 122 | 3506 | 4400 | 4700 | 130 | 0.733 | 1.666 |
| A | G | 194 | 1786 | 3800 | 2280 | 196 | 1.105 | 1.381 |
| G | H | 48 | 425 | 1700 | 1020 | 49 | 0.276 | 0.345 |
| H | I | 51 | 425 | 1700 | 1020 | 52 | 0.293 | 0.366 |
| I | J | 113 | 425 | 1700 | 1020 | 114 | 0.643 | 0.803 |
| K | J | 103 | 780 | 1700 | 1020 | 104 | 0.586 | 0.733 |
| L | H | 106 | 425 | 1700 | 1020 | 107 | 0.603 | 0.754 |
| G | M | 90 | 1786 | 3800 | 2280 | 91 | 0.513 | 0.641 |
| M | L | 43 | 1546 | 3800 | 2280 | 44 | 0.248 | 0.310 |
| L | K | 228 | 1546 | 3800 | 2280 | 229 | 1.291 | 1.613 |

## 5.3 Results when Modeling the Impact of Travel Cost

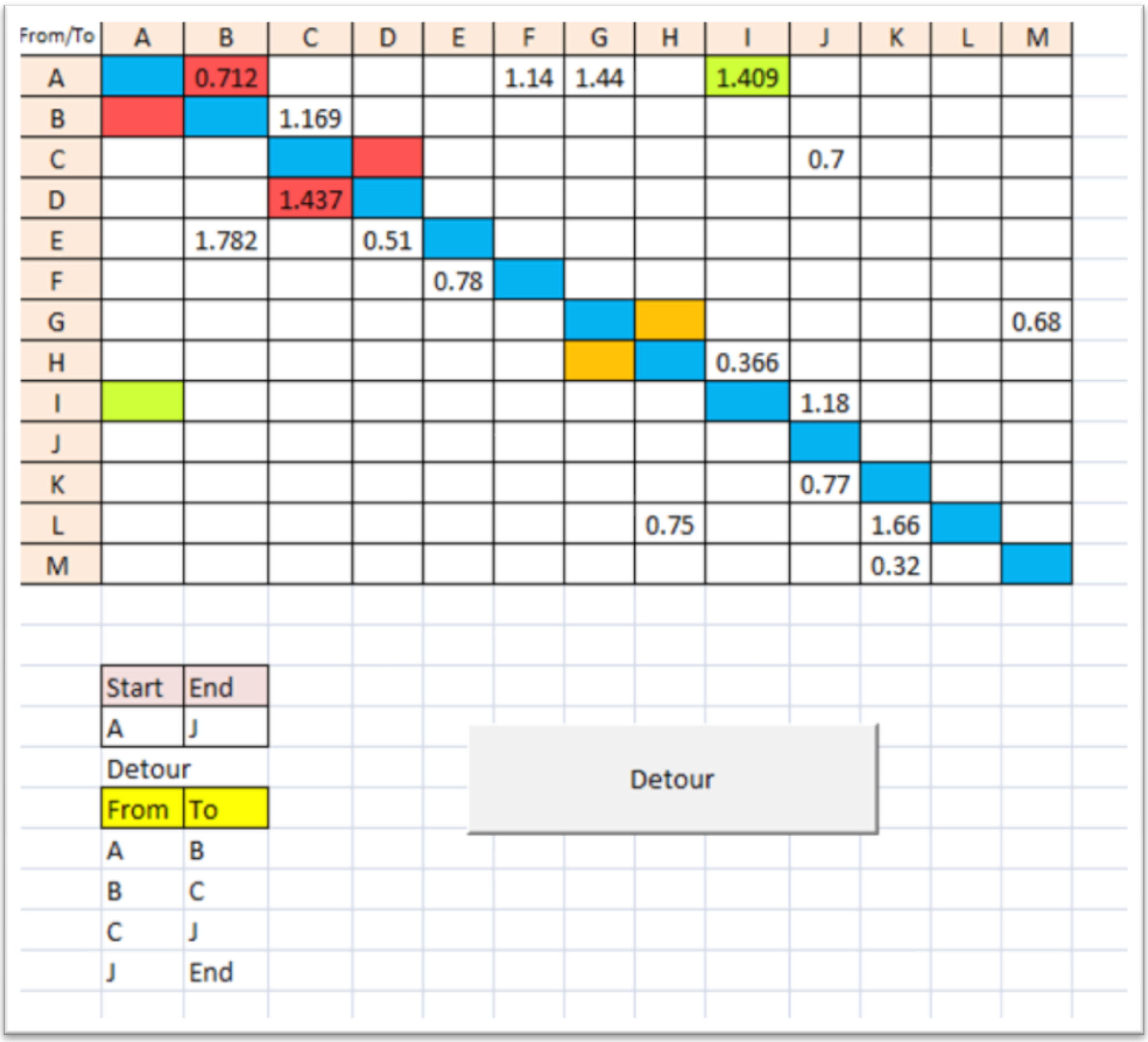
No one can deny how nice is it to reach his or her destination in the lowest time possible. Have we ever considered the cost of reaching our destination a couple minutes early? And what is the impact on someone’s life just for someone to save one or two minutes? Many people get aggravated when they have to take a long detour in order to avoid construction zones. In many cases the planner does not study the construction zone detour area in such a way where he or she can identify all possible scenarios. Many times, when a person is stuck in traffic due to whatever reason such as construction detours or morning rush hour, the driver might notice another driver try to do take illegal short cuts to save two or three minutes. Two or three minutes might not mean a lot of time for a regular person. However it can be a matter of life or death in the case of emergency vehicles. No one can put a price on a human life. For such a reason, when we modified this model to include the cost in dollar for each route, we put an infinite price for any link where an emergency vehicles hub does exist such as a fire station or emergency room at a hospital. This model will help the planner identify the route that will be considered the safest for the commuter as well as for the critical facilities around that location.

Critical facilities include, but are not limited to, shelters, hospitals, and fire stations. Those facilities must be considered when selecting a new route for the detour. In many cases detours can disturb and jam the whole area or network which may prevent emergency vehicles from reaching the critical facilities.

The figure below is showing how emergency vehicle could get stuck in traffic congestion.

Figure 55: Emergency Vehicle Stuck in Traffic (Demerjian, 2008)

Implementing the actual cost for each link in the model as illustrated in Figure 56: Screen Shot of the Formulation When Run It Based on Lowest Cost



| From/To | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | 0.712 | | | | 1.14 | 1.44 | | 1.409 | | | | |
| B | | | 1.169 | | | | | | | | | | |
| C | | | | | | | | | | 0.7 | | | |
| D | | | 1.437 | | | | | | | | | | |
| E | | 1.782 | | 0.51 | | | | | | | | | |
| F | | | | | 0.78 | | | | | | | | |
| G | | | | | | | | | | | | | 0.68 |
| H | | | | | | | | | 0.366 | | | | |
| I | | | | | | | | | | 1.18 | | | |
| J | | | | | | | | | | | | | |
| K | | | | | | | | | | 0.77 | | | |
| L | | | | | | | | 0.75 | | | 1.66 | | |
| M | | | | | | | | | | | 0.32 | | |

| Start | End |
|---|---|
| A | J |

Detour

| From | To |
|---|---|
| A | B |
| B | C |
| C | J |
| J | End |



Figure 56: Screen Shot of the Formulation When Run It Based on Lowest Cost

As we can see, the best route was selected as starting at point, proceeding through point I and terminating at the final destination which is point J. The figure below illustrates the Generated route based on the Lowest Cost.

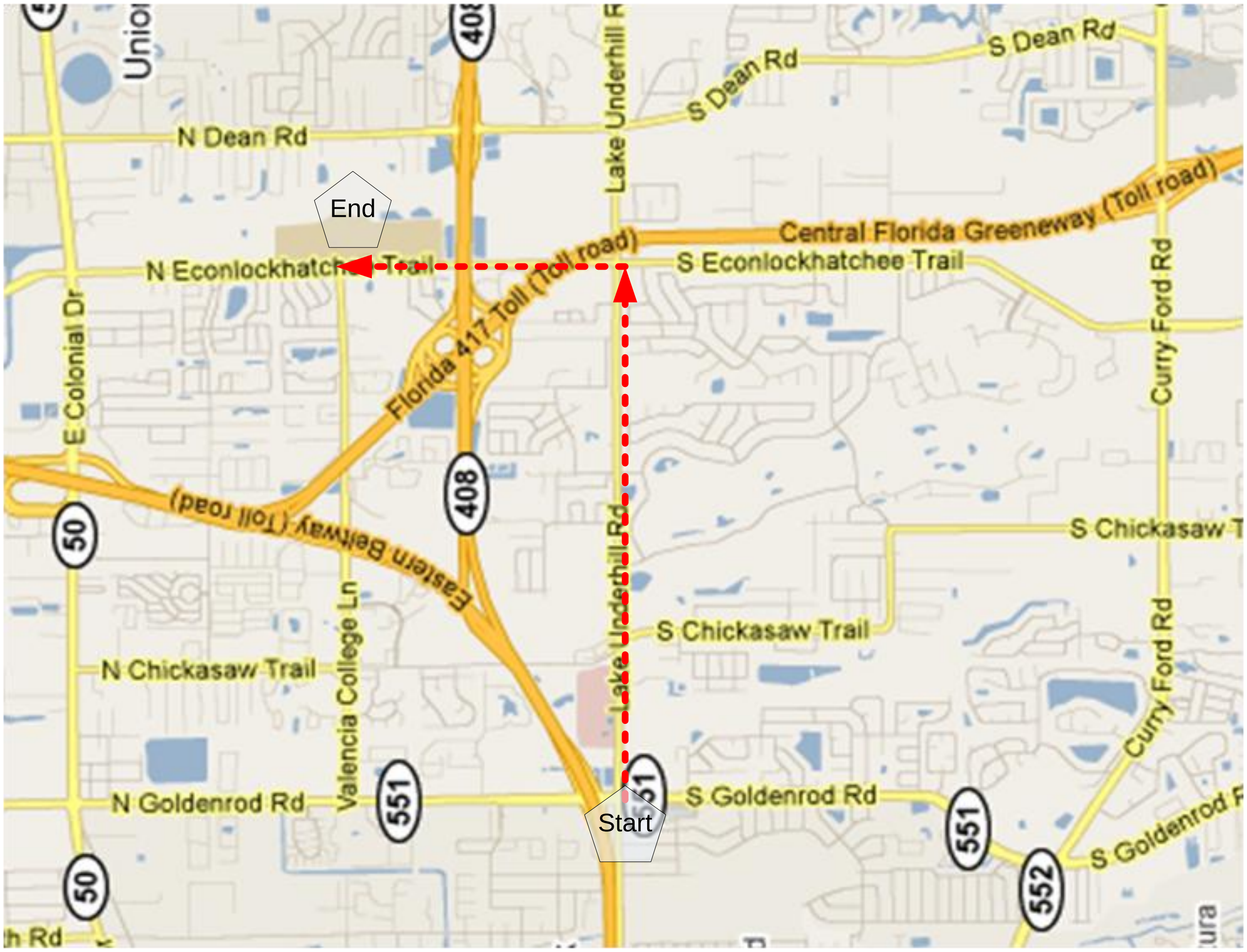



Figure 57: Generated Route Based on Lowest Cost

# CHAPTER SIX: RESEARCH FINDINGS

## 6.1 Overview

As mentioned in the previous chapters, the main objective of this research study is to formulate effective methodologies that can aid in optimizing the impact of construction detour planning decisions on both travel time and cost for the traveling public.

The research presented the decision variables that affect the detour planning and a framework for optimizing the planning. Two models have been developed to generate construction detours that minimize the travel time or cost for commuters. The ultimate goal of this research is to present construction planners with a robust tool for selecting and optimizing construction zone detours.

## 6.2 Time-Based Model

A time-based model has been developed in order to generate a route that takes the lowest amount of time. The model assumed that the critical constraint of planning the detour is time. As such, the total travel time of a route is suggested to be the overall optimization objective and criterion to compare among the possible alternative detour routes. Other key assumptions when building the time-based model was that traffic flows in only one direction. It was also assumed that the price of gas is $3.19 per gallon. The model treated the problem as a shortest path problem solved using liner programming to find the lowest time. The time-based model was capable of selecting the shortest travel time as shown in figure 59.

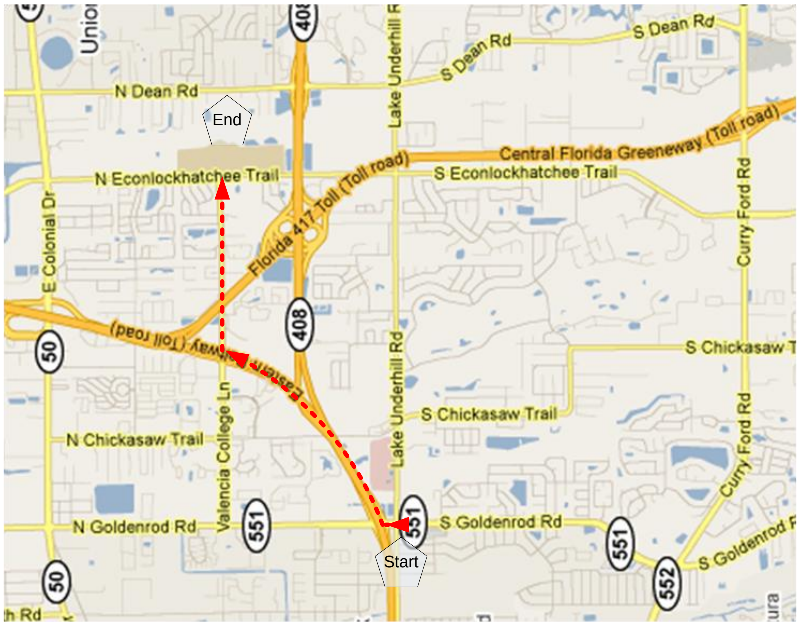



Figure 58: Generated Route using Time-Based Model

## 6.3 Cost-Based Model

A second cost-based model was developed to generate a route that takes into account the lowest amount of money. The cost-based model assumes that the critical objective of planning the detour is minimizing the overall detour cost. For such a reason, the overall cost of a route is suggested to be the overall optimization objective and decisive factor to compare among the possible alternative detour routes. A unique feature of the model is that it takes into consideration the effect on critical facilities such as hospitals, fire stations…etc. Other critical assumptions taken into consideration when building the cost-based model were that first, traffic flows in only one direction and second, the cost of driving on a critical facility link is considered very high. Third, it was assumed that the cost of gas is $3.19 per gallon. The final assumption was that each truck or bus is equal to 1.5 passenger vehicles. The model treated the problem as a shortest path problem solved using liner programming to find the lowest cost. With all other variables being constant, the total cost of a route is a concept that should help not only with saving the daily commuter time but also with reducing transportation costs, carbon fuel consumption, and greenhouse gases. As such, this should ultimately help to provide the most economic and sustainable detour alternative. The cost-based model was able to generate the lowest cost route, shown in figure 60.

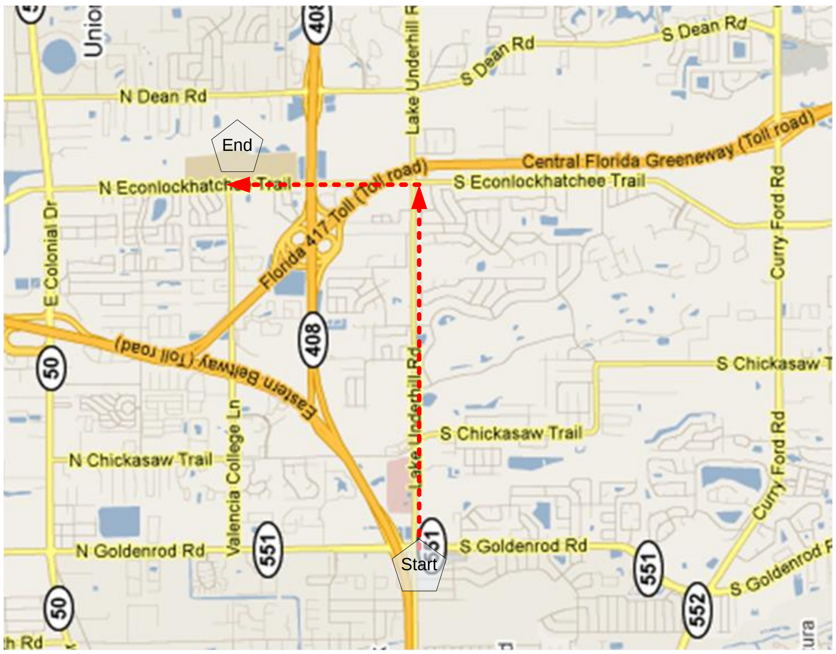



Figure 59: Generated Route using Cost-Based Model

## 6.4 Comparison between the Two Models

It should be noted that when it comes to economic feasibility, usually a comparison is conducted between the costs of blocking the whole road for a shorter total duration versus the cost of partially blocking the road for a relatively longer duration. While the former allows faster completion of road construction tasks, the latter option requires less detour planning. In addition to these costs, the cost of delay due to construction should be considered in assessing the alternatives and selecting the best solution. Moreover, the social value of delay and how much a daily commuter is willing to pay to avoid going through traffic congestion must be precisely estimated in terms of time and money. Since the travel time per unit distance is an inverse function of the speed, delays are expected to noticeably increase as the speed goes down. Also, with reduced speeds, density rises as more and more users enter the congested zone, reducing inter-vehicle spacing and causing the speed to fall to almost zero.

Analyzing the collected data to find the peak hour was a critical step to find the travel time and cost. This was important to provide the planner with the flexibility to vary the time of delay or the cost of the route according to the traffic demands during the busiest time of the day. The tables below illustrate travel time and cost for both of the generated routes.

Table 40: Time Comparison between Both Generated Routes

| Route A Toll | | | Route B Hospital | | |
|---|---|---|---|---|---|
| From | To | t(v) Seconds | From | To | t(v) Seconds |
| A | I | 130 | A | B | 88 |
| I | J | 114 | B | C | 144 |
| | | | C | J | 91 |
| | | 244* | | | 323 |

*Optimal Time-Based Route

Table 41: Cost Comparison between Both Generated Routes

| Route A Toll | | | Route B Hospital | | |
|---|---|---|---|---|---|
| From | To | Cost in $ | From | To | Cost |
| A | I | 1.666 | A | B | 0.62 |
| I | J | 0.803 | B | C | 1.015 |
| | | | C | J | 0.641 |
| | | 2.469 | | | 2.276* |

*Optimal Cost-Based Route

## 6.5 Summary and Conclusion

This research aimed to explore the process of planning construction detours and how to offer a better understanding of the factors associated with said planning. Construction zones are traffic way areas where construction, maintenance or utility work is identified by warning signs, signals and indicators. This includes those on transport devices that mark the beginning and end of construction zones. The main objectives of the research are to first identify all the decision variables that affect the planning of construction detours and secondly, to implement a model based on shortest path formulation to identify the optimal alternatives for construction detours. Two models were developed: one based on time while the other was based on cost. These models aimed to find the optimal detour around blocked construction zone areas and ease the challenges to construction planners as they are required to plan vehicle routes around construction zones. It is recommended that detour planners take into consideration these two main factors: time and cost. The optimal route choice would ideally benefit the community by keeping the detour throughway reliable, safe, optimal, and efficient. The optimization model found both solutions, the time–based model and cost-based model, valid. The planner has the final decision whether he/she would like to compromise time to save on cost or compromise cost to save on time.

The developed model should prove useful to construction planners and would help in identifying the optimal routes that reduce travel time and cost. Ultimately, this should also help in reducing carbon fuel consumption and greenhouse gases, resulting in the most economical and sustainable alternative.

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