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EVALUATING DESIGN-BUILD vs. TRADITIONAL CONTRACTING METHODS FOR STIP PROJECTS

An Assessment of Travel Impact & Delay Cost

Prepared For:

Utah Department of Transportation
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UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract

Highway construction impacts travel time and causes vehicular delays for road users. Innovative construction techniques like the design build, or fast track method can reduce the time of construction activity when compared to traditional build methods, thus resulting in reduced network delay. The faster the construction activity occurs, the lower the impact on users and the higher the savings in delay cost. This study assesses the travel and cost impacts due to traditional build and fast track techniques for the Utah Department of Transportation's five-year road improvement programs which are a part of the Statewide Transportation Improvement Plan.

The build scenarios were modeled from 2004 until 2010 using a macroscopic transportation planning simulation model called VISUM. A partial network algorithm was developed to run traffic assignments on reduced networks that represented the project areas. Five Statewide Transportation Improvement projects were identified and grouped into three analysis areas to analyze the impact comprehensively. The simulation results were quantified in terms of measures of effectiveness viz. vehicle miles of travel, vehicle hours of delay and vehicle hours of delay/vehicle miles of delay (second delay). Finally, the delay was converted into daily delay cost to assess the cost savings and suggest the best contracting technique for the projects.

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ABSTRACT

Highway construction impacts travel time and causes vehicular delays for road users. Innovative construction techniques like the design build, or fast track method can reduce the time of construction activity when compared to traditional build methods, thus resulting in reduced network delay. The faster the construction activity occurs, the lower the impact on users and the higher the savings in delay cost. This study assesses the travel and cost impacts due to traditional build and fast track techniques for the Utah Department of Transportation's five-year road improvement programs which are a part of the Statewide Transportation Improvement Plan.

The build scenarios were modeled from 2004 until 2010 using a macroscopic transportation planning simulation model called VISUM. A partial network algorithm was developed to run traffic assignments on reduced networks that represented the project areas. Five Statewide Transportation Improvement projects were identified and grouped into three analysis areas to analyze the impact comprehensively. The simulation results were quantified in terms of measures of effectiveness viz. vehicle miles of travel, vehicle hours of delay and vehicle hours of delay/vehicle miles of delay (second delay). Finally, the delay was converted into daily delay cost to assess the cost savings and suggest the best contracting technique for the projects.

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LIST OF ACRONYMS

FT	Fast-Track
NB	No-Build
NCHRP	National Cooperative Highway Research Program
OD	Origin-Destination
STIP	Statewide Transportation Improvement Program
TB	Traditional Build
TIP	Transportation Improvement Program
UDOT	Utah Department of Transportation
UTA	Utah Transit Authority
UTL	Utah Traffic Laboratory
WFRC	Wasatch Front Regional Council of Governments

EXECUTIVE SUMMARY

Highway improvement projects have a significant impact on road users in terms of increase in travel time due to the construction activity. Therefore, the construction period plays a significant role in the impact on road users. With the Traditional Build (TB) method, construction time is longer, while innovative design build methods, also called fast track (FT), can reduce the time of construction drastically. This study is an assessment of TB and FT construction methods to measure the travel impact for five Statewide Transportation Improvement Program (STIP) projects. These are part of the Utah Department of Transportation's (UDOT's) five-year road improvement program that incorporates many highway projects funded through federal, state and local agencies.

The macroscopic "transportation planning" model, VISUM, was used to simulate various time of day scenarios from 2004 through 2010. No-build (NB), TB and FT, scenarios were modeled in the network and traffic was assigned using travel demand matrices for all the years. A partial network algorithm was developed to run traffic assignments on the reduced networks that represented the five projects eventually grouped into three analysis regions. The simulation results were quantified in terms of measures of effectiveness (MOEs) viz. vehicle miles of travel (VMT), vehicle hours of delay (VHD) & Second Delay (VHD in sec/VMT). Then the delay was converted into "delay cost" to measure the impacts of NB, TB and FT on the individual projects.

The findings of the study indicate that the VMT shows an increasing trend for all the projects for the NB, TB and FT scenarios without a significant change. For the 700 East project, the daily increase in VMT is 10.8%; for the 7800 South project it is 11.3%, and for the I-215 project the increase in daily VMT is 11.2%. However, there is a significant variation in VHD for all the projects for the NB, TB and FT scenarios.

The 700 East project shows that the daily VHD is much lower for FT than for the TB and NB scenarios. Daily VHD increases by only 6.5% from 2004 to 2008, whereas, for the TB scenario, it increases by approximately 12.2%. For the 7800 South project it was observed that the PM peak VHD is not much different than the AM peak. This suggests that this roadway needs a capacity augmentation. The PM peak VHD is higher than the AM peak. This suggests that construction should not be done during the PM period.

The I-215 project shows that the AM peak VHD for all the scenarios is almost equal, with a marginal difference in the absolute VHD value between the TB and FT scenarios. The AM and PM peak VHD are within the same range for both time periods; the AM is within 320-440 and the PM is within 350-500. This is due to the fact that, since I-215 is an interstate, the travel demand is equal during the day and night. In terms of absolute value, the VHD for this project is 1/10 of the VHD for the other two projects. The average second delay for I-215 is the lowest among all the projects for all the scenarios. With the FT method, a lower second delay is observed for all the projects. For the 700 East project, the savings in second delay with FT compared to TB is 0.91; for 7800 South it is 0.7 and for I-215 it is 0.35. The FT method results in significant savings in delay cost for all the projects. For the 700 East project, the delay cost savings for FT is $7.2 million when compared to TB; for the 7800 South project it is $5.4 million and for I-215 it is $2 million.

From this study it can be seen that the FT method saves significantly in delay costs when compared to the TB method. The delay savings observed at 700 East is significant and it is highly recommended that this project be done using the FT method. Also, it is recommended that the construction be done in the off

peak periods and definitely not during the PM peak. The highest impact will be due to the 700 East and 7800 South projects, followed by the State St. and 10600 S and I-215 projects.

1. INTRODUCTION

This chapter discusses the background and scope of the project. The first section deals with the Statewide Transportation Improvement Projects (STIP) and the role played by the governmental agencies in regard to various aspects of these projects. The second section contains the scope, broad goals, and objectives of the study. The last section explains the organization and general structure of the report.

1.1 About the STIP Projects

The STIP is a compilation of a number of the Utah Department of Transportation's (UDOT's) five-year highway and transit projects. These projects are a compilation of many highway and transit projects that are financially supported by local, state and federal governments [1].

These programs are developed by the State departments of transportation, Metropolitan Planning Organization (MPO), federal and local governments. For the Salt Lake Valley, they are developed by UDOT, local governments, and the Wasatch Front Regional Council (WFRC), which is the MPO for the region. The WFRC is also responsible for developing Transportation Improvement Programs (TIPs) that form a part of the STIP projects developed by UDOT [2].

The horizon year for the current STIP is 2008. All the projects that have been identified within the document receive funding until the horizon year. For every project that is identified, the funding source depends on the type of project and its location. The federal funding sources include the Federal Transit Funds and Congestion Mitigation and Air Quality Program (CMAQ). Funding could also be provided by state, local, or county agencies.

This study assesses some of the STIP projects in the Salt Lake Valley. The projects that were selected also form a part of the WFRC's TIP.

1.2 Scope of the Study

This study analyzes the STIP projects for Fast-Track (FT) and Traditional Build (TB) contracting methods, to identify whether there would be benefits in terms of delay savings for these two methods of contacting. The scope of this study is limited to analyzing five selected STIP projects and to model various build scenarios using simulation tools. Considering the defined nature of the projects, the modeling is done from the year 2004 until 2008, the horizon year for the STIP project. The specific objectives underlying this task are:

- Define the project areas for all five identified STIP projects
- Model various build scenarios using a simulation model
- Define the measures of effectiveness (MOEs) to analyze the simulation results
- Simulate the scenarios for multiple periods of the day to understand travel behavior
- Estimate the travel and cost impacts of the projects
- Recommend the best contracting technique for each project

1.3 Organization of the Report

The report is divided into nine chapters, with subsections in each chapter. The first chapter offers an introduction to the project and a broad overview of the STIP projects. The literature review in the second chapter briefly discusses various studies that have been done in regard to the use of simulation tools for travel forecasting. This section also reviews published articles to demonstrate the travel impacts of construction activities for similar projects in other states. The third section of the report is the methodology that explains in detail the process adopted to meet the research goals and objectives.

The fourth section of the report deals with explaining the projection selections, the factors that were taken into consideration when selecting the five projects, and the general project characteristics. The fifth section of the report gives a detailed description of the modeling procedure. This includes an explanation of the techniques and tools used, the analysis procedure that was adopted, the long term and short term impacts of the projects that affected the model network, and an algorithm that was developed specifically for the use of the simulation tool.

The sixth section of the report describes the various MOEs and why they were selected. The seventh chapter discusses the results for the modeling of the projects. The final section of the report includes conclusions and recommendations for the study for all five project areas.

2. LITERATURE REVIEW

Travel demand modeling is one of the most effective ways to understand the long term impacts of transportation projects. However, one of the challenges is to model the travel impact in terms of cost parameters. There are many studies that demonstrate the use of travel demand modeling theory using simulation models, but very few of these studies address the issue of cost conversion of the travel impact. This chapter discusses some of the studies that highlight the use of travel demand modeling tools to achieve a certain set of objectives.

DeJohn et al [3] used the travel demand modeling tool Tranplan to assess the statewide impact of long range transportation projects. Various supply and demand strategies that formed a part of the transportation projects were incorporated into the model. The projections were done for the years 2000, 2010 and 2025. The projections considered travel demand management, transit rich, ITS/TSM and system capacity augmentation scenarios. The VHD and VMT were used as MOEs to assess system performance under these conditions. This literature highlighted the used of demand modeling tools for assessing various types of policy implications on a system. The research of Hwang et al [4] deals with the estimation of delay and congestion in terms of MOEs like VMT. Although no kind of cost issue is addressed in the study, it deals with parameters that are commonly used as measures in travel demand forecasting studies.

The research performed by Leurent Fabien [5] is one of the very few works that discusses the issue of cost vs. time in traffic assignment models. The author ascertains that most travel demand models convert delay into a cost factor to assess the cost-benefit. The author identifies cost vs. time as an economic phenomenon and then develops mathematical models to demonstrate the effect of travel time on cost.

Ross et al [8] documented a National Cooperative Highway Research Program (NCHRP) synthesis on the treatments for work zones. The author recommends using a straight dollar value and multiplying it by delay to get the travel time benefits for a project. This methodology was adopted for this study based on the scope of the project.

Forkenbrock and Weisbrod [11] published some guidelines in the form of an NCHRP report that deals with assessing the social and economic impacts of a transportation project. This guidebook addresses vehicle operating costs but does not suggest any method for user delay cost calculation. However, this book is useful in understanding the likely travel impact of transportation projects and the easiest way to assess them. The research is very comprehensive in explaining the different aspects of travel demand modeling and its impact on commuters.

The studies mentioned in this section deal with the dynamics of travel demand forecasting, but there are far fewer studies that deal with the conversion of delay to cost.

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3. METHODOLOGY

The methodology of this study was primarily divided into three stages: identifying the relevant projects, modeling various scenarios, and the final analysis. Figure 3.1 diagrams the various stages of the research process.

In the first stage of the study, a few of the relevant projects are selected from UDOT's STIP plan for 2004-2008, considering the overall scope of the project. The selection of the projects was based on the limitations of the model network, the recommendations made by UDOT and the project type. The project type is based on the overall estimated project cost as listed in the WFRC's TIP plan for 2004-08 and the impact area of the project.

The second stage of this study was to model various scenarios individually for the selected projects. The simulations were done using VISUM, a macroscopic "transportation planning" model. VISUM was calibrated for the Salt Lake Valley by a research team at the UTL for an earlier study. Since the network of the STIP projects is smaller than the available network in the model, a partial assignment algorithm was used to simulate the scenarios for the smaller regions. The results of the simulations are quantified in terms of certain MOEs for the No-Build (NB), TB and FT scenarios. The AM, PM, Mid-Day (MD) and Evening (EV), and Origin-Destination (OD) matrices are assigned on all three scenarios to quantify the impact for different times of day.

VISUM works according to the four step travel demand modeling procedure. Three of the four steps are already performed by the WFRC, so the matrices used in this model are taken from the WFRC's transportation planning models. The assignments using VISUM work according to an algorithm that was developed specifically to analyze smaller networks such as those in these projects. This algorithm is generic and can be applied to any other network transformation procedure in VISUM. The algorithm and the procedures are discussed in detail in the subsequent sections of this report.

The last stage of this study was to convert the MOEs in terms of delay cost to understand the implications of the projects. The simulation results are quantified both in terms of travel impact and delay cost. At the end of the project, savings in delay cost are identified and the best contracting method is recommended for all project types.

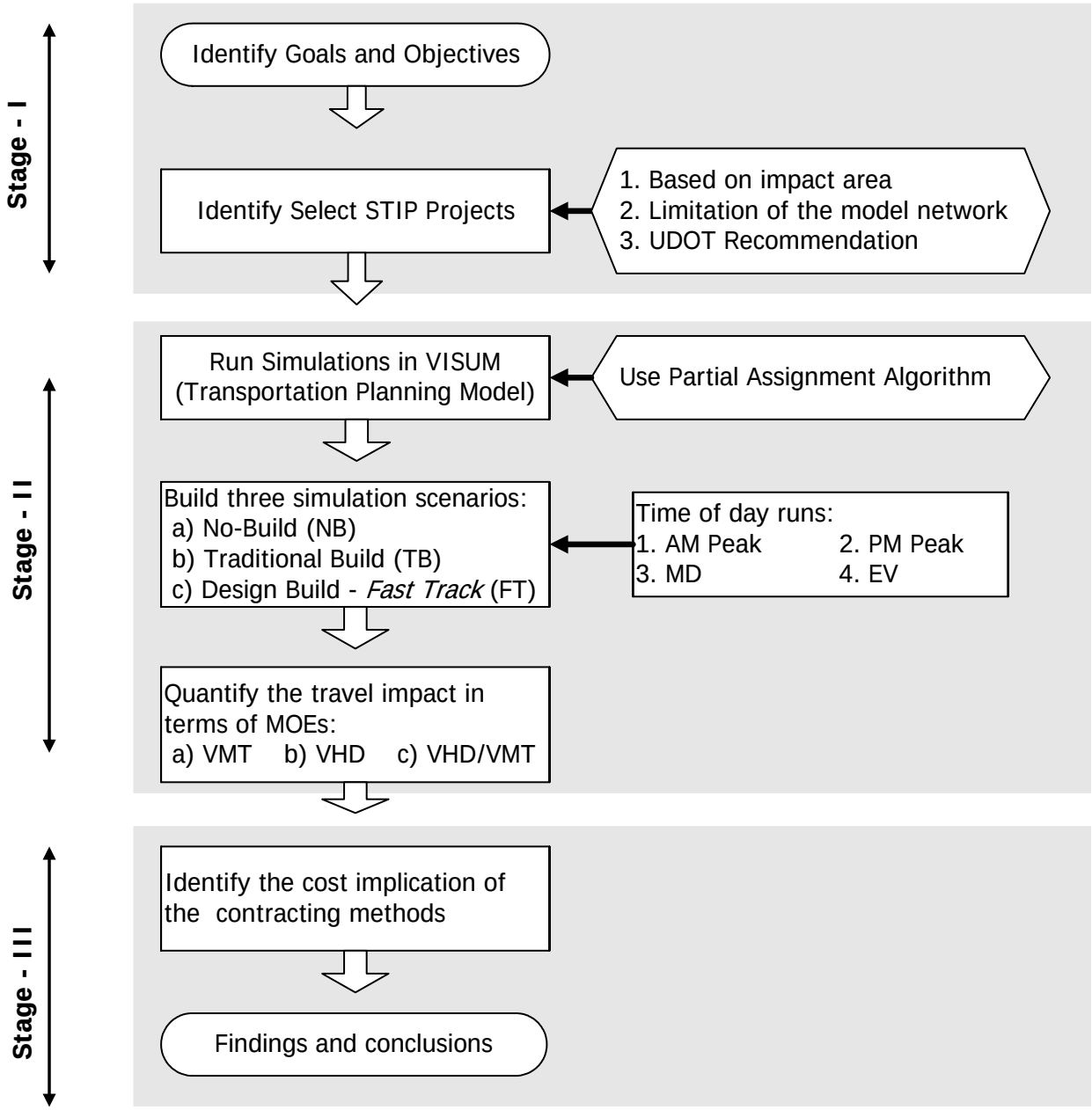

Figure 3.1 Research Methodology

4. PROJECT SELECTIONS

This chapter describes the projects that were selected for modeling and the network characteristics for each project. A total of five projects were considered for analysis based on the scope of the study. The selection was based on the total STIP estimated cost, UDOT recommendations, the limitations of the model network, and the impact area. Vicinity to major arterials was considered a potential impact on the network. The next sections discuss each project and its area characteristics.

4.1 Project # 1 – State Street & 10600 South

This project is located at the intersection of two major arterial roads: State Street and 10600 South. Any construction activity on State St. will likely have an impact on the street and its surrounding area. 10600 South feeds into I-15 South. The proposed construction activities documented in the WFRC's TIP 2004-2008 [1] plan are:

- Widen State St. by 14 feet at the east intersection
- Accommodate an additional left turn lane on 10600 South from State St.
- Widen a small portion on the west side of State St.

Figure 4.1 shows the project area and its vicinity. Table 4.1 gives a summary of the overall project characteristics as documented in the TIP plan.

Table 4.1 Project Characteristics (State St. & 10600 S)

Type of work:	Intersection improvement
Estimated project cost:	$ 3,224,270
Potential impact area:	State St., 10600 S and 700 E

Source: Transportation Improvement Program 2004-2008, WFRC

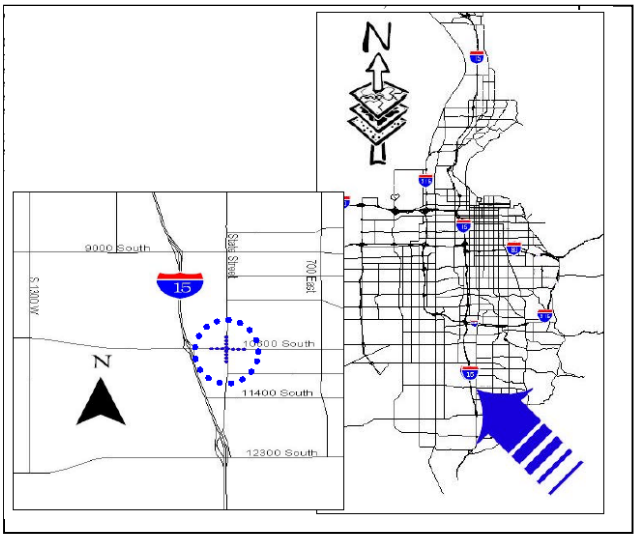

Figure 4.1 State Street & 10600 South Project Location (source: TIP)

4.2 Project #2 – 7800 S (between Redwood Rd. & Bangerter Hwy.)

This project is on a significant east-west corridor in the Salt Lake Valley and is between two of the most heavily used arterial roads: Redwood Rd. and Bangerter Hwy. The construction activity on 7800 S between these two arterials will have an impact not only on 7800 S, but also on these two arterials. This will likely impact the travel pattern in the vicinity of these two roads as well. The proposed construction activities documented in the WFRC's TIP 2004-2008, [1] plan are:

- Widen 7800 S from 2 to 4-5 lanes from 2700 W to 1850 W
- Widen from 2-4 lanes to 4-5 lanes and perform reconstruction from 2700 W to Bangerter Hwy.

The proposed construction activity is aimed to relieve traffic congestion on this heavily traveled route and to augment the capacity of the existing roadway. Figure 4.2 depicts the construction area and its impact area. Table 4.2 gives the overall characteristics that account for construction activity on both sections of the roadway.

Table 4.2 Project Characteristics (7800 S)

Type of work:	Lane widening
Estimated project cost:	$ 21,750,820
Potential impact area:	Redwood Rd., Bangerter Hwy, 7800 S

Source: Transportation Improvement Program 2004-2008, WFRC

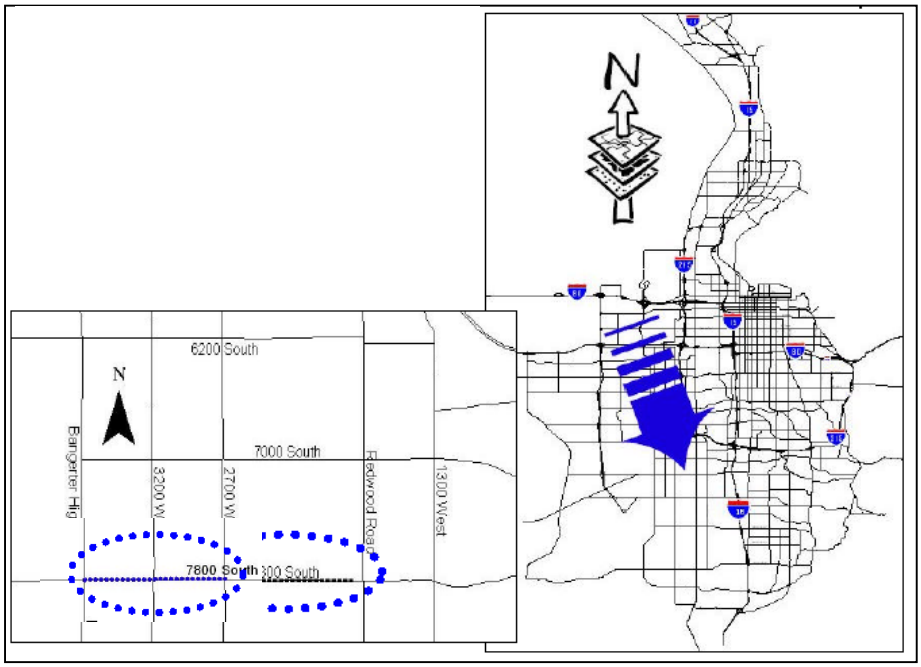

Figure 4.2 7800 S – 2700 W to 1850 W & 2700 W to Bangerter Hwy (source: TIP)

4.3 Project # 3 – 700 E (9400 S to 10600 S)

700 E is one of the most heavily traveled roadways in the Salt Lake Valley and any construction activity will have an impact on the road and its travel pattern. The impact area for this project is defined by State St. to the west, 10600 S to the south and 9000 S to the north. 700 E is classified as a "principal arterial" by UDOT's functional classification system. The project was identified in 1999 in the WFRC's TIP plan. Some of the proposed construction activities enumerated by the TIP 2004-2008 document [1] are:

- Widen 700 E to two lanes in each direction
- Improve the shoulder and the signalized junctions along the travel route

The proposed construction activity is aimed to relieve traffic congestion on this heavily traveled route and to augment the capacity of the existing roadway. Figure 4.3 depicts the construction area and its impact area. Table 4.3 contains the overall characteristics.

Table 4.3 Project Characteristics (700E)

Type of work:	Widening from 2 to 4-5 lanes & shoulders
Estimated project cost:	$19,873,000
Potential impact area:	700 E, State St., 10600 S & 9000 S

Source: Transportation Improvement Program 2004-2008, WFRC

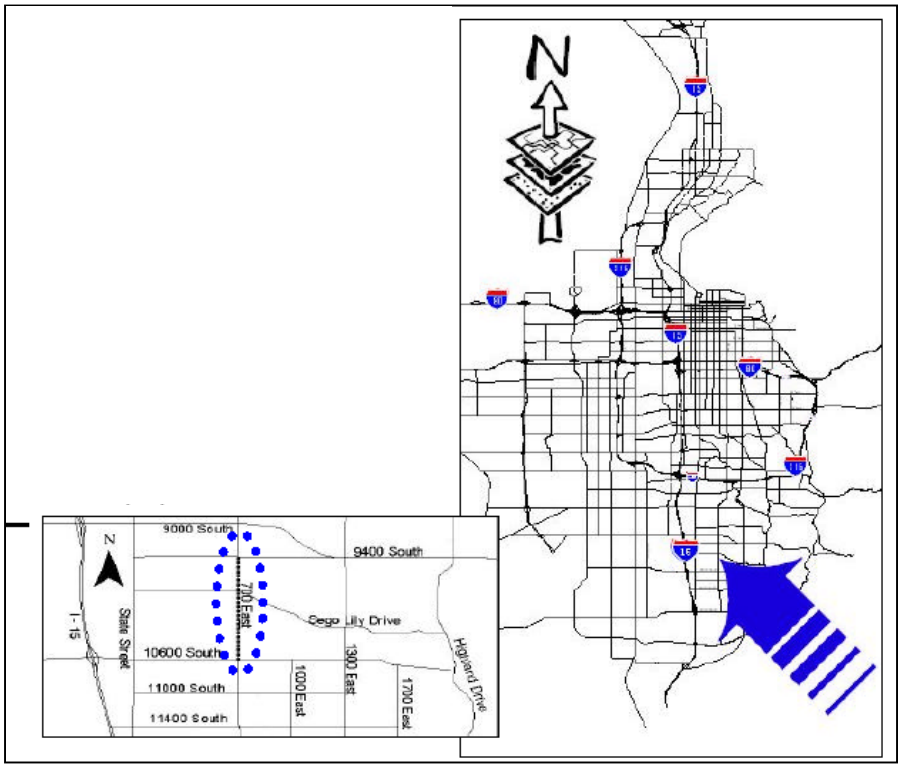

Figure 4.3 700 E – 9400 S to 10600 S (source: TIP)

4.4 Project # 4 – State Street TRAX Crossing

This project is one of the bridge replacement projects for the Utah Transit Authority's (UTA's) TRAX system. In addition, an intersection improvement project is proposed between 7800 S and 8600 S. Although some amount of traffic impact is anticipated, the bridge replacement will not have a direct impact on network performance since the bridge is a rail bridge and not a roadway facility. The intersection improvement will definitely render some impacts on State St. Since this is a significant travel mode, some traffic impact is anticipated. The proposed construction activities enumerated by the WFRC's TIP 2004-2008 document [2] are:

- Improve the intersection between 7800 S and 8600 S
- Replace the TRAX bridge

The bridge replacement will be a double tracking on the State St. Bridge to increase frequency and alleviate safety concerns. Figure 4.4 depicts the construction area and its impact area. Table 4.4 contains the overall characteristics.

Table 4.4 Project Characteristics (State Street TRAX Bridge & X-ing)

Type of work:	TRAX bridge replacement & intersection improvement
Estimated project cost:	$10,000,000
Potential impact area:	State Street roadway

Source: Transportation Improvement Program 2004-2008, WFRC

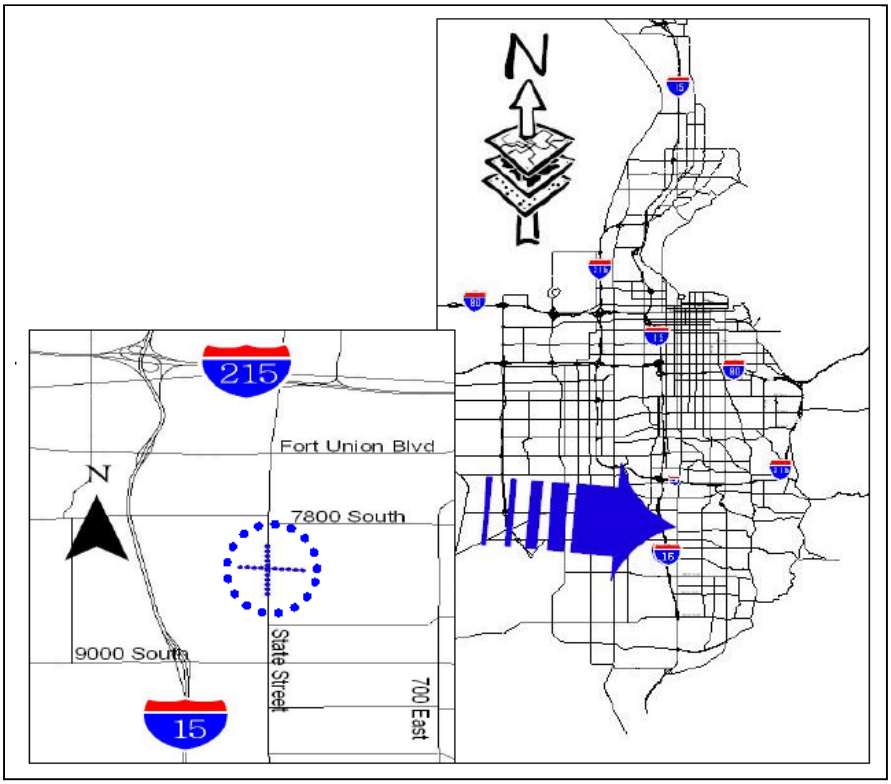

Figure 4.4 State Street TRAX Bridge & Intersection (source: TIP)

4.5 Project #5 – I-215 Bridge Replacement (on I-215 at 3900 South)

This project is one of the bridge replacement projects on I-215 and is one of the first projects done by UDOT that uses pre-fabricated construction technology. Although this technology is more expensive than traditional construction techniques, it saves a significant amount of construction time and delay costs associated with commuter delays. Since I-215 is a major roadway, it will be impacted by the construction activity. However, using a pre-fabrication technique may lead to savings in user delays; therefore, it was considered necessary to assess this project.

Since the activity involves bridge replacement and direct construction activity on the interstate, there will be a capacity reduction on the facility that may or may not impact the travel pattern in the region. Some of the project details are enumerated in Table 4.5.

Table 4.5 Project Characteristics (I-215 Pre-fabrication Bride Replacement on I-215 at 3900 South)

Type of work:	Bridge replacement
Estimated project cost:	$4,350,000 (Pre-fabrication cost estimation)
Potential impact area:	I-215

Source: Transportation Improvement Program 2004-2008, WFRC

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5. MODELING PROCEDURE

This chapter will discuss the modeling procedure for simulating the selected projects for all the scenarios and all the years under consideration. The chapter is divided into three sections. The first section discusses the overall modeling approach, the simulation scenarios considered and the rationale for grouping the projects into three project areas. The second section discusses the simulation tool, VISUM, and the last section explains the algorithm that was developed to run the simulations in VISUM for small networks.

5.1 Defining the Analysis Areas

The overall modeling approach was based on defining an analysis area to capture the impact, not only on the affected section, but within the region. Using this approach, five analysis areas representing all five projects were defined.

The project on 7800 S was kept as a single analysis area and the project on I-215 was again defined as a separate analysis area. Projects 1, 3, and 4 (State St. & 10600 S; 700E and State St. TRAX crossing) were grouped into one analysis area. They were also studied as separate projects within separate analysis areas. The following criteria were taken into consideration when defining the analysis areas:

- Proximity of the project area to major arterial roads within the immediate region
- Presence of a group of projects in the same region
- Project type and the severity of the construction project on the road user

Analysis area 2 is comprised only of the 7800 S project because this project is within two major arterials: Redwood Rd. and Bangerter Hwy. Since the construction activity on 7800 S would likely have an impact on these two arterials, it was defined as a separate area.

Analysis area 3 is comprised only of the I-215 project. It was considered important to model the network that was likely to be impacted by construction activity on the interstate, so this was kept as a separate analysis area.

5.1.1 Considering the Long Term & Short Term Impacts on the Project Area

After defining the analysis areas, the short and long term impacts of the projects were defined prior to assigning traffic using the simulation model. This was important because some of the projects with lane widening will have a permanent impact on the network since the lane capacity will change. Some of the other projects that involve intersection improvement or bridge replacement will affect the network capacity only temporarily and will not cause a permanent network change. Table 5.1 explains the impact for all the projects.

Table 5.1 Long & Short Term Impacts of the Projects

Project	Type	Impact
#(1) State St., 10600 South	Intersection improvement	Long term – network change
#(2) 7800 S	Lane widening	Long term – network change
#(3) 700 E	Lane widening	Long term – network change
#(4) State St., TRAX Bridge	TRAX Bridge	Short term – no change in network
#(5) I-215	Bridge replacement	Short term – no change in network

Defining these changes will lead to changes in the model network. The simulations will be different for each project depending on these short term and long term changes. For projects 1, 2 and 3, the network in the model and the capacity on the specific links needs to be changed after construction ends. This will impact travel since the capacity will increase at a future date. For projects 3 and 4, there is no change in the model network because there is reconstruction. Hence, the network remains the same for all the years.

5.1.2 Simulation Scenarios

Three simulation scenarios were identified to model the impact of all the analysis areas using the simulation tool, VISUM. The first scenario was NB. For NB, there would be no construction or capacity augmentation and the demand would be met by the existing capacity for all the model years. This does not take into account any of the projects and the future travel projections are based on the assignment of the matrices on the existing network.

For the TB scenario, the construction activities for all five projects defined within the three analysis areas would continue from 2004 until 2010. This scenario was modeled taking into account the long term impact of the construction activity. Therefore, the network would function at a reduced capacity throughout the construction period, from 2004 to 2008. So the simulations are run assuming a TB construction period from 2004 to 2008 and a FT construction period from 2004 to 2005.

The third scenario was the FT scenario. For FT, the construction time for all the projects is short and the benefits in terms of capacity augmentation on the project network are achieved sooner. It was assumed that the FT method would take one year, from 2004 to 2005. The traffic assignment for the years 2006 to 2010 was done on the improved network that resulted from the construction activity.

The difference in TB and FT is that, with TB, the benefits obtained as a result of the improvement of the road capacities will come into effect after a longer period of time; whereas, the benefits for FT will come into play after one year when construction ends. So the TB scenario will get the same benefits as FT after the year 2010 when construction has ended.

5.2 Incorporating Work Zone Capacity

Notwithstanding the short or long term impacts, the capacity of the roadway is affected during the construction period. Therefore, to model the construction sections, work zone capacity standards were incorporated into the model on the affected links. For the freeway sections on I-215, a work zone capacity of 1600 phpl (source: HCM) was used to model the network. For the other projects, the existing capacity of the roadway was reduced by approximately 13% to model the construction period scenarios. For other urban roads, the capacity values suggested by the NCHRP's synthesis 208 on "Work Zone Capacity" were used. The values are shown in Table 5.2.

Table 5.2 Construction Capacity Values

	Basic Capacity (vph)	Work Zone Capacity (vph)
Multi lane highway		
3 lanes in each direction	5,700	4,220
2 lanes in each direction	3,800	2,880
1 lane in each direction	--	1,570
Urban Intersection		
3-lane approach	1,900	1,650
2-lane approach	1,350	1,100
1-lane approach	800	500

Source: NCHRP Synthesis 208

These capacity values were incorporated into each network for various scenarios (TB, FT, and NB) for the simulation years 2004 through 2010. It should be noted that the reduced capacity values were applied only for the construction sections and for the period during which construction activity took place.

5.3 Using VISUM, the "Transportation Planning Model"

VISUM was used to simulate the impact of all the projects for all the scenarios. VISUM is widely used for transportation planning and travel demand modeling. The core of the model is the four step travel demand forecasting procedure. The model performs travel forecasting analysis and can be manipulated by the user for specific uses.

Calibration of this model was not necessary for this study since it was done for a previous research study at the UTL. The previously calibrated version was used for various traffic assignments for the project areas. However, an algorithm was developed that was used for traffic assignments for smaller project regions.

The network characteristics for the entire transportation network in the Salt Lake Valley are defined in terms of links and nodes in the model. The WFRC has divided the region into 600x600 Trip Assigned Zones (TAZs) and the model uses the same divisions. The links and the nodes form a part of the 600 zones within the region. All the nodes in the network are defined by the turning relations that govern the direction of traffic. These relations can be exported into micro-simulation models like VISSIM to perform a more detailed analysis if needed. Like all other travel demand modeling tools, VISUM also uses time based assignment procedures. The traffic assignments for this study were done using the "equilibrium traffic" assignment procedure.

5.4 Developing a Partial Assignment Algorithm

The simulation model available had a network for the entire Salt Lake Valley. Since the analysis areas have a smaller network, it was necessary to reduce the network and assign traffic on the reduced network. A partial assignment algorithm was developed in accordance with the underlying principles of the model and was used for partial network assignment. Figure 5.1 is a conceptual representation of the underlying principle.

The first step of the algorithm is to input the base network (for the entire Salt Lake region) and assign the base OD matrix. The simulation runs are done for all the times of the day: AM peak, PM peak, MD and EV periods. Once the traffic has been assigned, the analysis area network is activated and the partial network generation operation command is used. This also prompts the model to re-read the OD matrix and reduces the total assigned trips to the ones only in the region. This creates a new OD matrix with trips that are comprised only of intra-zonal and inter-zonal trips. The trips that do not pass through the smaller network are eliminated. The new, smaller network that is generated is defined with default internal node numbers and the external zones. This operation is done for all the scenarios and for all periods of the day in all three analysis areas.

At this point it is also necessary to check the assigned traffic on the reduced network links with the base assigned network traffic to make sure that the assignment has been run correctly. If any discrepancy is found, the second stage of the algorithm must be repeated. If the assignment is correct, the final version is saved and the required data is exported from the partially assigned network for further analysis. Figure 5.2 shows all the steps of the algorithm.

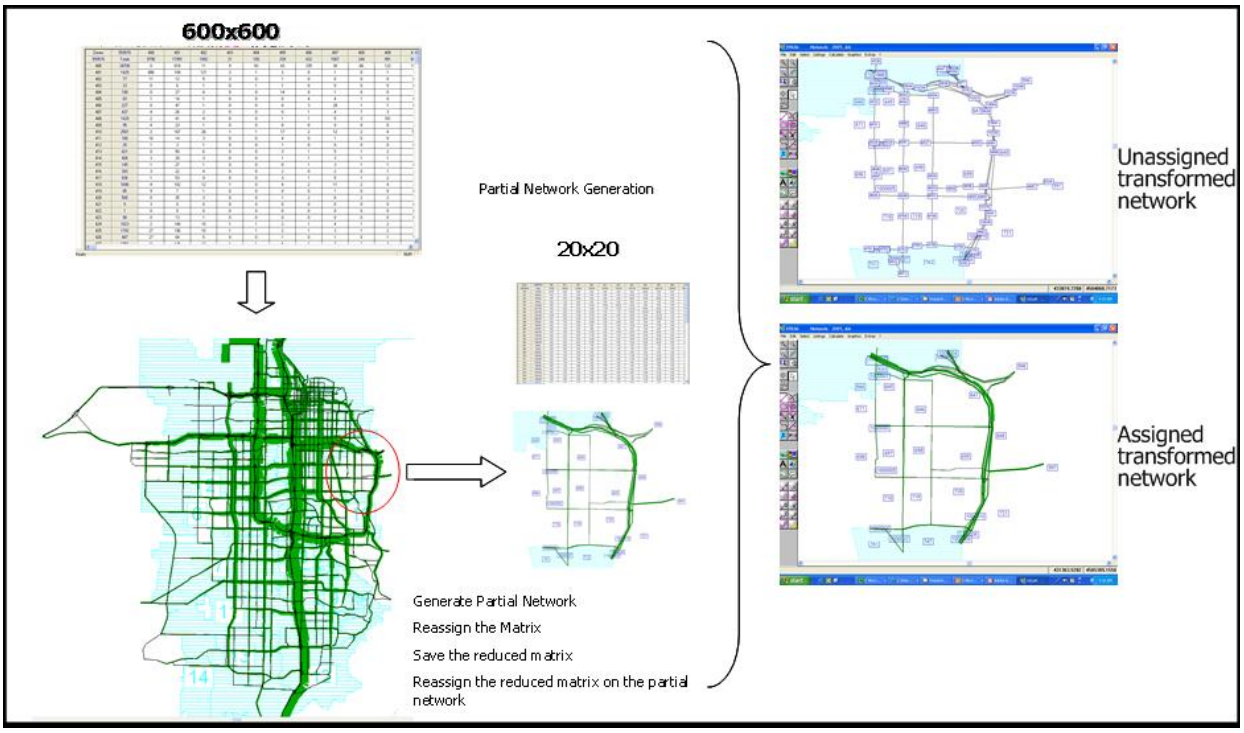

Figure 5.1 Conceptual Representation of the Partial Assignment

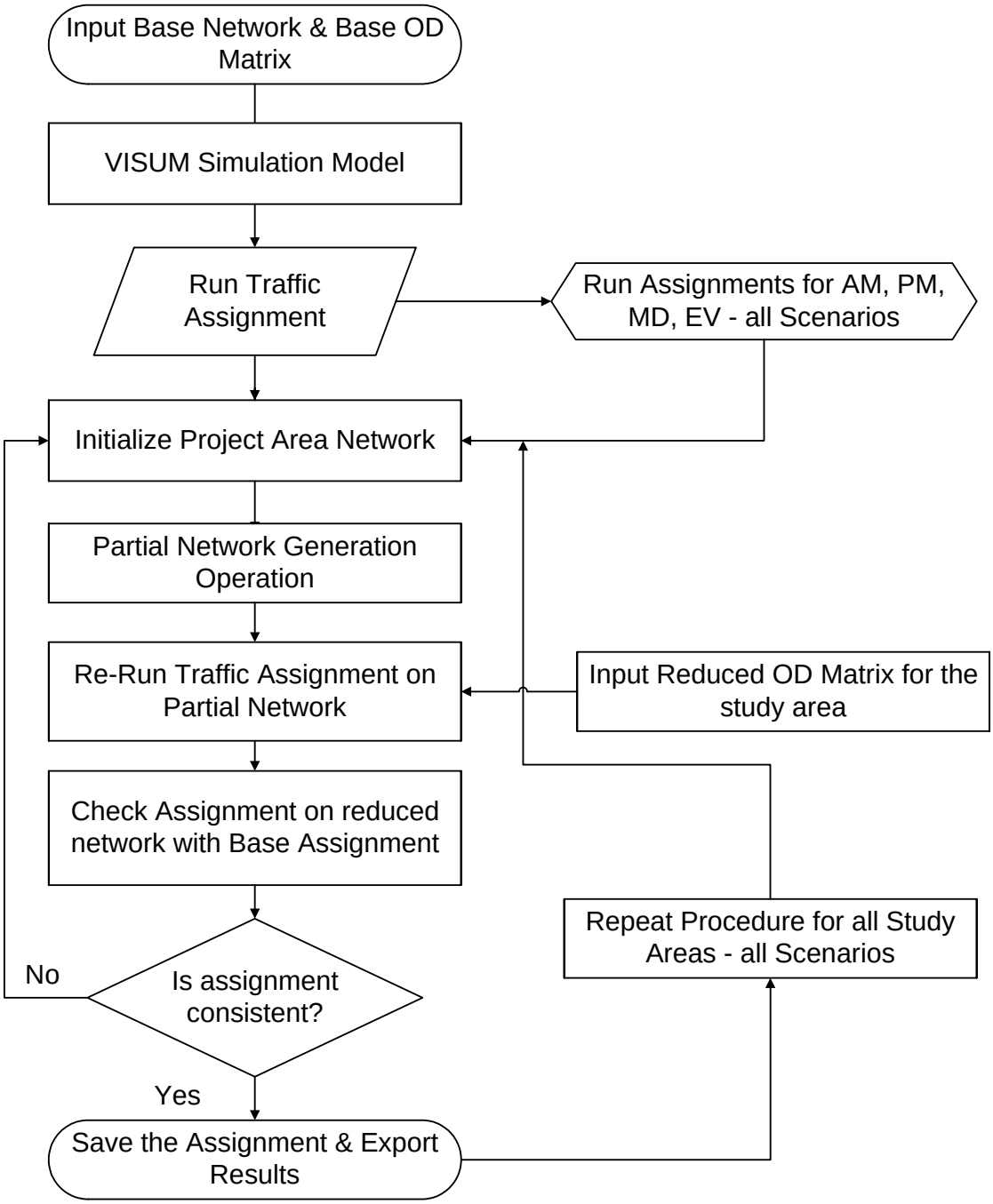

Figure 5.2 Partial Assignment Algorithm

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6. MEASURES OF EFFECTIVENESS

This chapter will discuss the MOEs that were identified to analyze the impact of the projects and the methods to compute the traffic assignments. The MOEs were selected based on the underlying objective of analyzing the long term travel impact, the user delays due to the construction activity and the type of simulation model used.

6.1 Vehicle Miles of Travel

A VMT is defined as the product of the sum of the total miles of travel on a roadway and the total number of vehicles at a given point in time. It can be expressed as a yearly value or a daily value depending on the travel assignment. For this study, yearly travel demand matrices were assigned. VISUM is based on a network definition with links. The VMT computation can be expressed mathematically as:

Where:

t= simulation time
i= link number (from 1 to n)
vol_t = volume on link "i" at simulation time "t"

In this study, the VMT values are computed for all times of days, for all the simulation years (from 2004 until 2010), and for all three analysis areas. VMT is a measure of the total travel miles on a roadway facility that reflects the travel demand for a region. A higher VMT value suggests that the travel demand is higher for the region and suggests a travel pattern that has a higher number of vehicles traveling within the region.

6.2 Vehicle Hours of Delay

Delay on a network is the time taken in hours for a vehicle to travel at the congested speed minus the time taken in hours to travel at the ideal speed [3]. The total VHD for a system is the product of this factor and the total number of vehicles traveling within the system at a given simulation time, "t." In other words, the total delay is the product of the total vehicle hours traveled within the system multiplied by the total number of vehicles. Mathematically it can be expresses as:

Where:

t= simulation time
i= link number (from 1 to n)
t_c = current travel time after simulation on link "i" at simulation time "t"
t_f = free flow travel time on link "i" at simulation time "t"

In this study, the VHD values are computed for all times of day, for all the simulation years (from 2004 until 2010), and for all three analysis areas. The current travel time, $t_{c,}$ is the current time of travel with the congested speed and the time, $t_{f,}$ is the time of travel at free flow speed. VHD is a very efficient way of measuring the total system delay within a system and can also be expressed as the user delay value.

6.3 Second Delay (VHD in sec/VMT)

This MOE is defined as the ratio of the VHD expressed in seconds with the total VMT for a region. Second delay helps to measure the total delay within the system per VMT. A higher VHD or VMT value within a system does not necessarily suggest that the system is performing sub optimally, hence this MOE helps to resolve this discrepancy. Mathematically it can be expressed as:

Where:

VMT_t = vehicle miles of travel at simulation "t"

VHD_t = vehicle hours of delay at simulation "t"

Second delay can be computed to understand the system behavior for the whole system or for individual links within the system. It is an effective way to comprehend the effect on delay within a network. For this study this MOE is used for all the analysis areas and all three scenarios.

7. RESULTS

This chapter analyzes the simulation results for the different build scenarios. The results are quantified in terms of the MOEs mentioned in chapter six and travel impact is assessed. The cost implication, which is expressed in terms of user delay cost, is also discussed in this chapter.

7.1 Travel Impact in Terms of VMT & VHD

This section will discuss the VMT and the VHD values for all the analysis areas for all five projects for the AM peak, PM peak and daily periods. The results are first explained for the daily values and then are broken down into two sets of graphs representing the AM and PM peak periods separately. The VMT values are discussed first, followed by the VHD values.

7.1.1 Project #1 (State Street and 10600 S Intersection)

Figure 7.1 shows an increasing trend in daily VMT over the years for all the build scenarios. The VMT in 2010 shows an increase of 10.3% from 2004; the increase is gradual over the years. In terms of absolute number, the VMT increases from approximately 1280000 in 2004 to 1450000 in 2010. Comparing the daily graph with the AM and PM peak periods suggests that the travel demand during the off peak hours is significantly less than the peak hours.

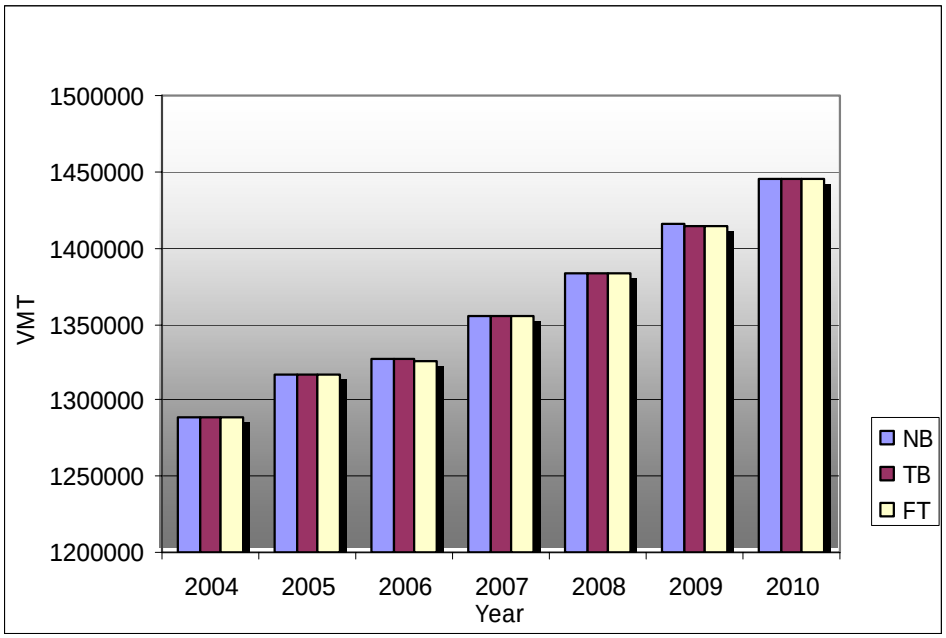


Figure 7.1 Project #1-Vehicle Miles of Travel (Daily)

Figures 7.2 and 7.3 show that the PM peak VMT is higher than the AM peak VMT. The growth is approximately 10.3% over the years for both periods. The increase in VMT is gradual from 2005 to 2006 but is much sharper from the years 2007 to 2010. In terms of absolute number, during the AM peak period VMT varies from approximately 215000 to 240000 and the PM peak VMT varies from 350000 to 390000 over the period.

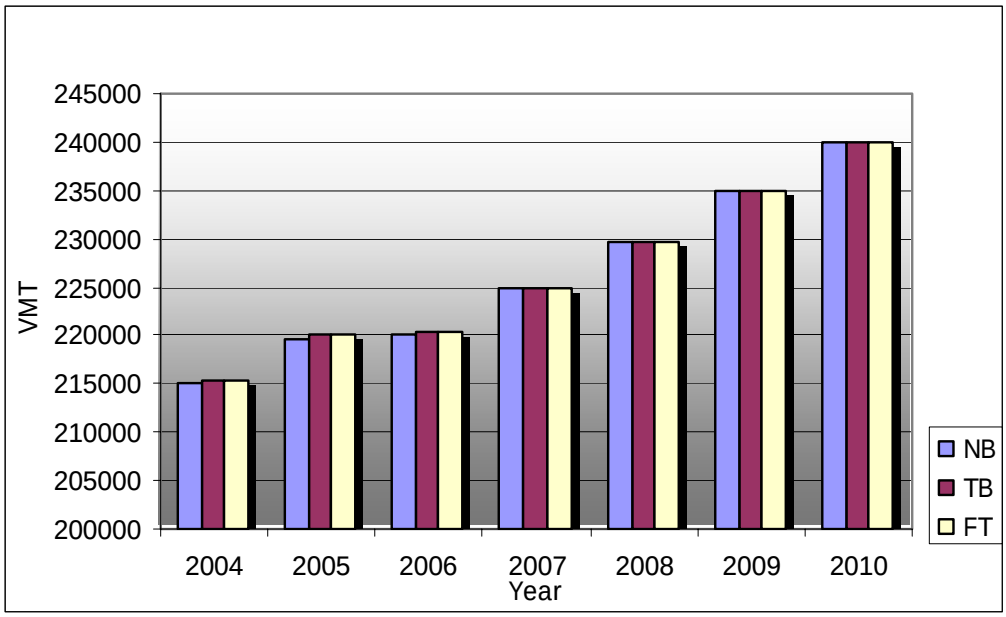


Figure 7.2 Project #1-Vehicle Miles of Travel in the AM Peak Period

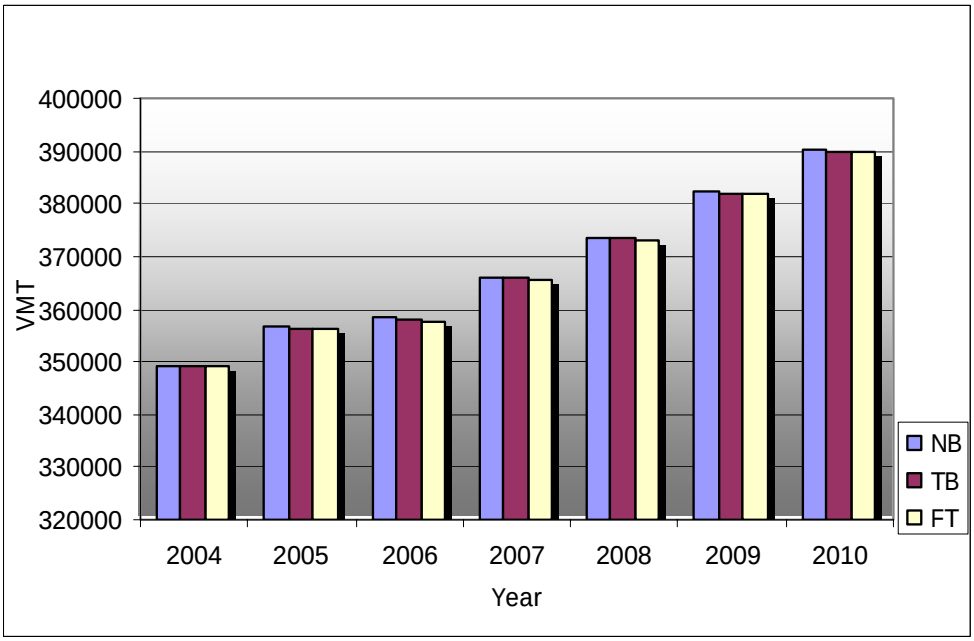


Figure 7.3 Project #1-Vehicle Miles of Travel in the PM Peak Period

Figures 7.4 and 7.5 show the VHD for the AM and PM peak periods for the project. The PM peak VHD is almost two times the AM peak VHD and is more constant than the AM peak. In both the scenarios the FT method has a significant savings over NB and TB.

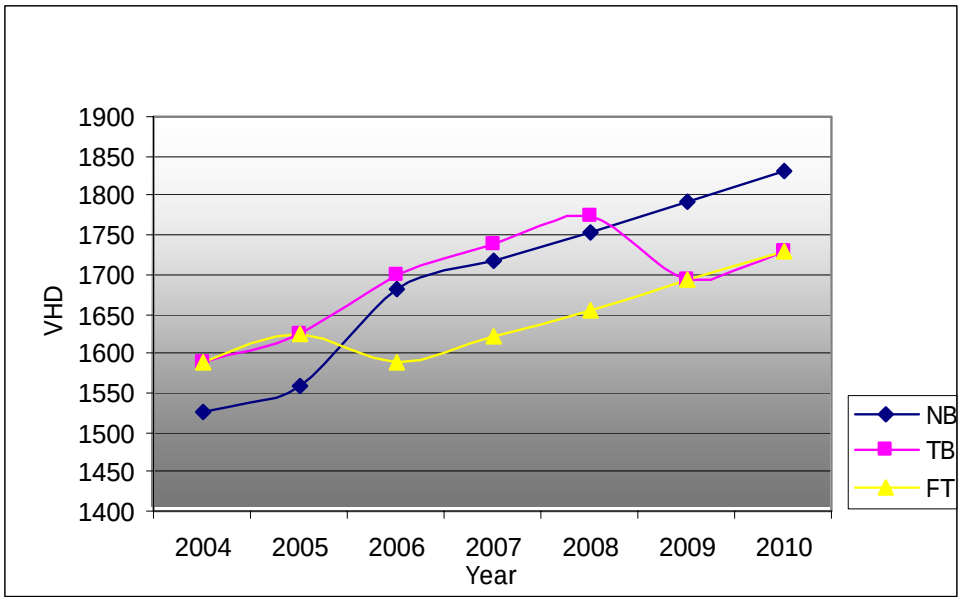


Figure 7.4 Project #1-Vehicle Hours of Delay in the AM Peak Period

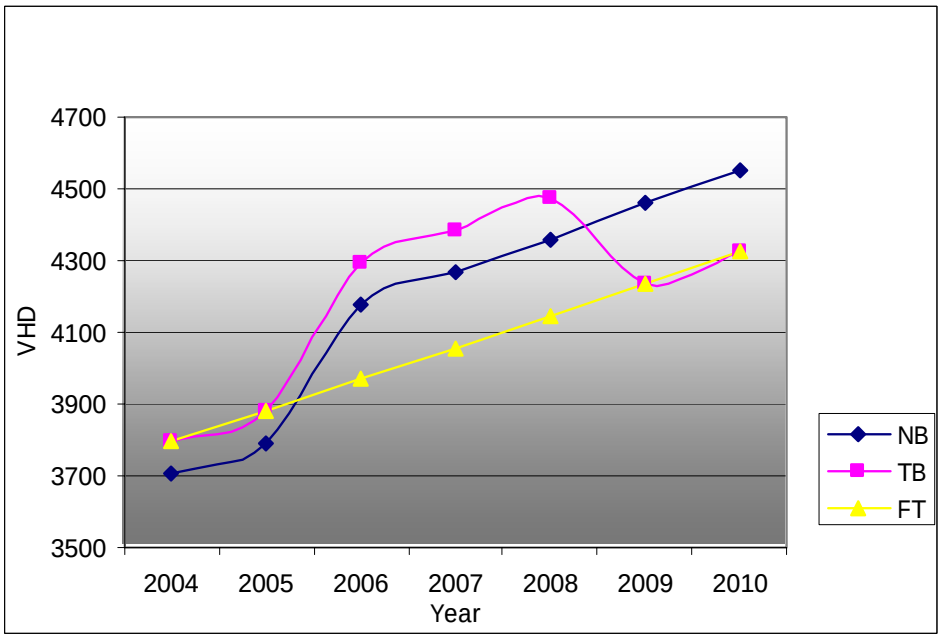


Figure 7.5 Project #1-Vehicle Hours of Delay in the PM Peak Period

Figure 7.6 shows the daily VHD for all the simulation scenarios for all the years. The FT daily VHD is much more intense than for TB or NB. The travel time benefits that are obtained by the TB scenario after 2008 are obtained by the FT scenario after 2005. The variation in VHD for the FT scenario is much more gradual than the variation in VHD for the NB and TB scenarios.

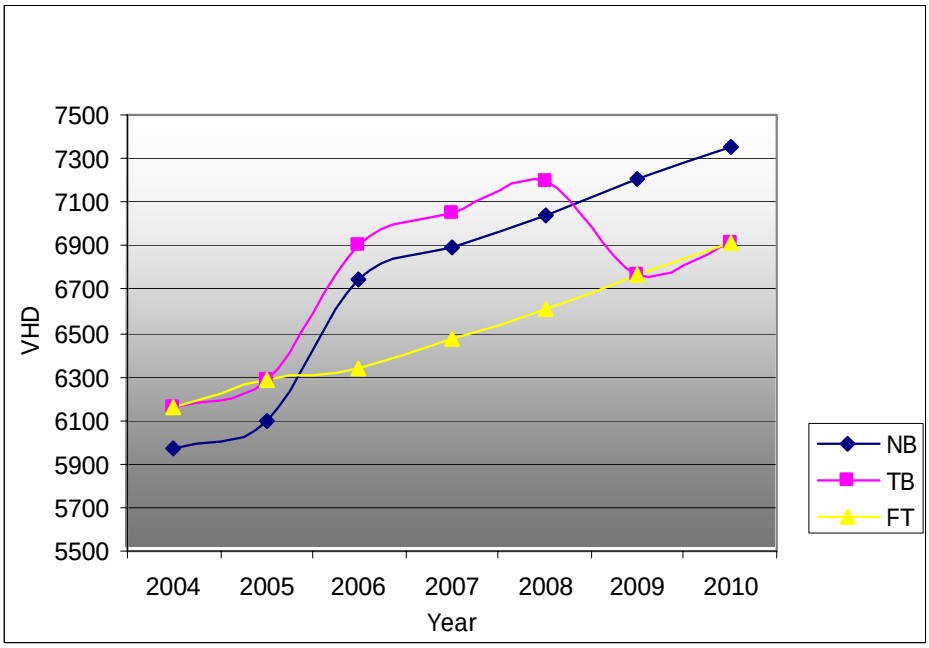


Figure 7.6 Project #1-Vehicle Hours of Delay (Daily)

The VMT and VHD trends for the three build scenarios lead to some important observations. It should be noted that the PM peak period has higher VMT and VHD, so construction should be avoided during the PM peak periods. Also, the construction scenarios do not have an impact on VMT as it increases. Hence, it can be said the travel pattern will remain the same for the region. This indicates that 10600 S is a major arterial and it is unlikely that commuters will change their travel behavior on this route.

7.1.2 Project #2 (7800 S Redwood Rd./Bangerter)

Figures 7.7 and 7.8 show the AM and PM peak VMT for the build scenarios during all the simulation periods. The PM peak period has a higher VMT than the AM peak period and there is an increasing trend over the years. There is a marginal increase in VMT for the FT scenario in the AM peak over NB and TB. There is an increase of 10.7% in the AM peak VMT and a 12.6% increase in the PM peak VMT over the years.

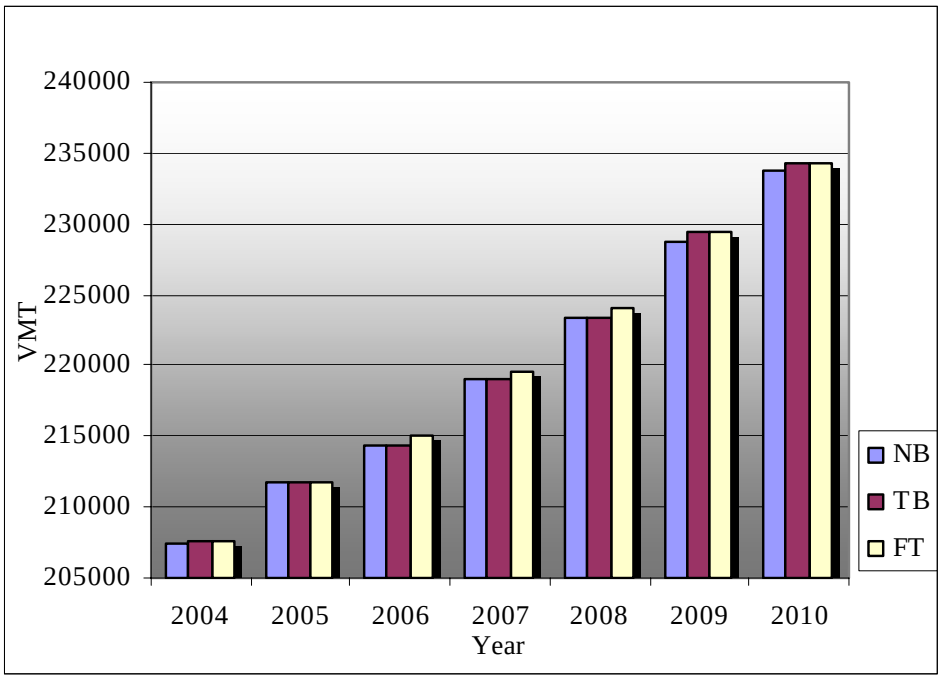


Figure 7.7 Project #2-Vehicle Miles of Travel in the AM Peak Period

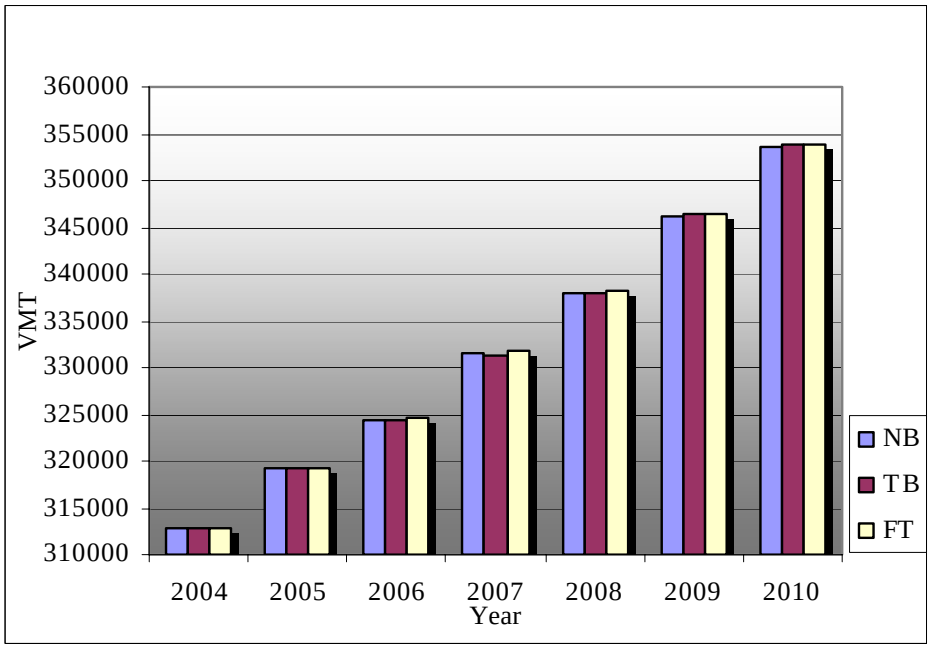


Figure 7.8 Project #2-Vehicle Miles of Travel in the PM Peak Period

Figure 7.9 shows the daily variation of VMT over the years for all three scenarios. The VMT increases over the years by 11.5%. This increase is almost constant for all the scenarios. The peak period variation also shows that the PM peak has a higher VMT than the AM peak.

There is a marginal difference in the absolute value of VMT for all the build scenarios. At a couple of points the FT scenario shows a higher VMT than the other two scenarios. This shows that the travel demand increases marginally with improvements in the road network for the FT scenario.

The off-peak VMT is much lower when compared to the AM or PM peak. Hence, the absolute difference in VMT is much lower.

An increasing VMT for all the scenarios suggests that the travel pattern for the region will not be drastically affected by construction activities. This suggests that 7800 S is a critical arterial that will keep inducing travel demand regardless of the network improvements. However, there may be significant differences in the VHD values that will impact user delays.

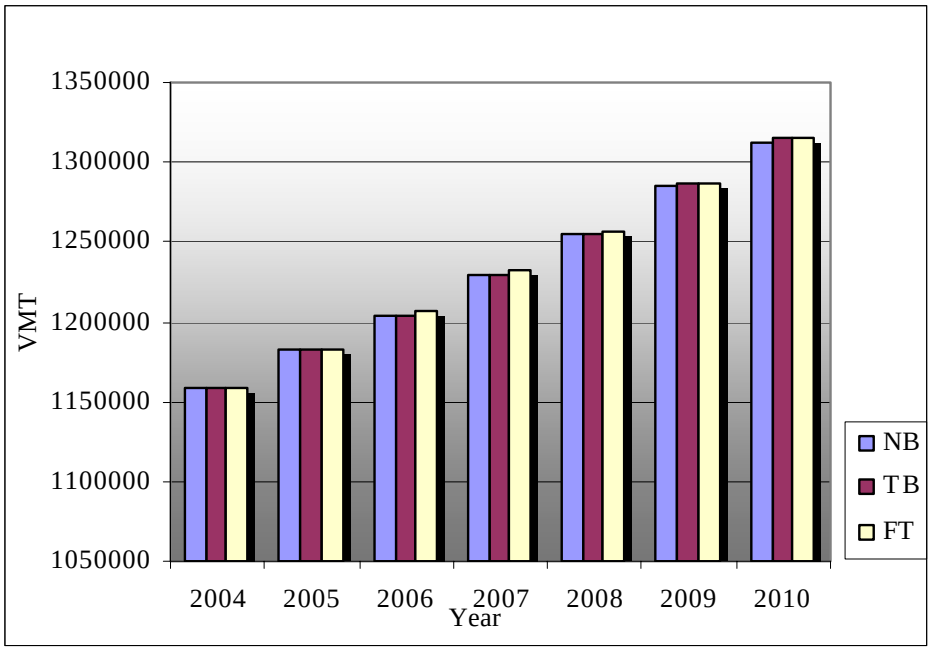


Figure 7.9 Project #2-Vehicle Miles of Travel (Daily)

Figures 7.10 and 7.11 show the VHD values for the AM and PM peak periods. The PM peak VHD is more than double that of the AM peak. Also, the variation in the NB and TB VHD for the AM peak is higher than the variation in the PM peak VHD. However, the FT VHD is significantly less than for the NB and TB scenarios. The slope for FT in the AM and PM peaks is similar; hence, the percentage increase in VHD is the same for both scenarios. There is a 14.5% increase in the AM peak VHD over the years for the FT build scenario. For the PM peak there is a 18.6% increase. There are significant savings in delay for the FT scenario over NB and TB.

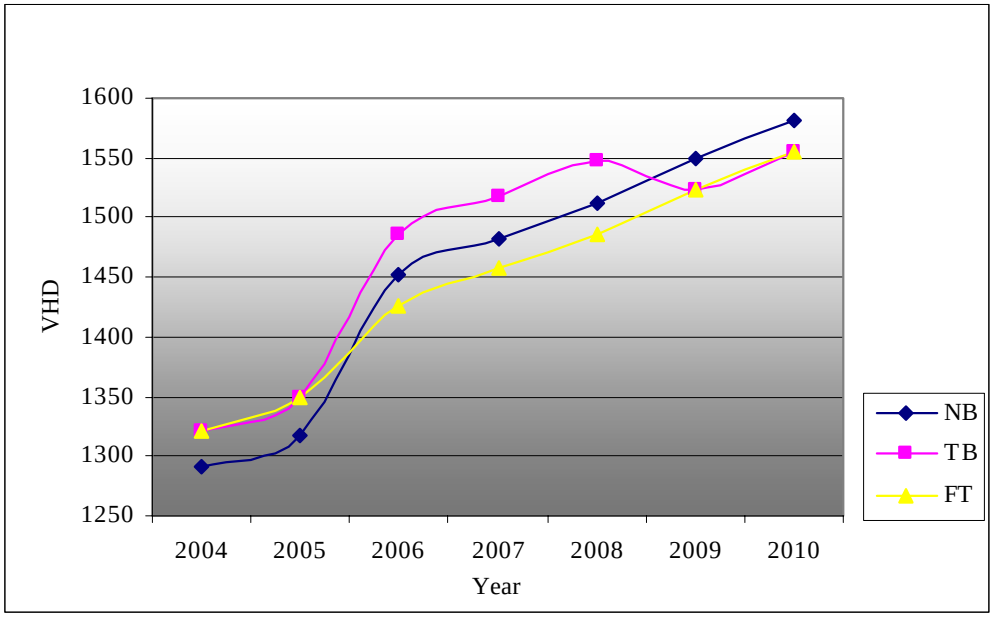


Figure 7.10 Project #2-Vehicle Hours of Delay in the AM Peak Period

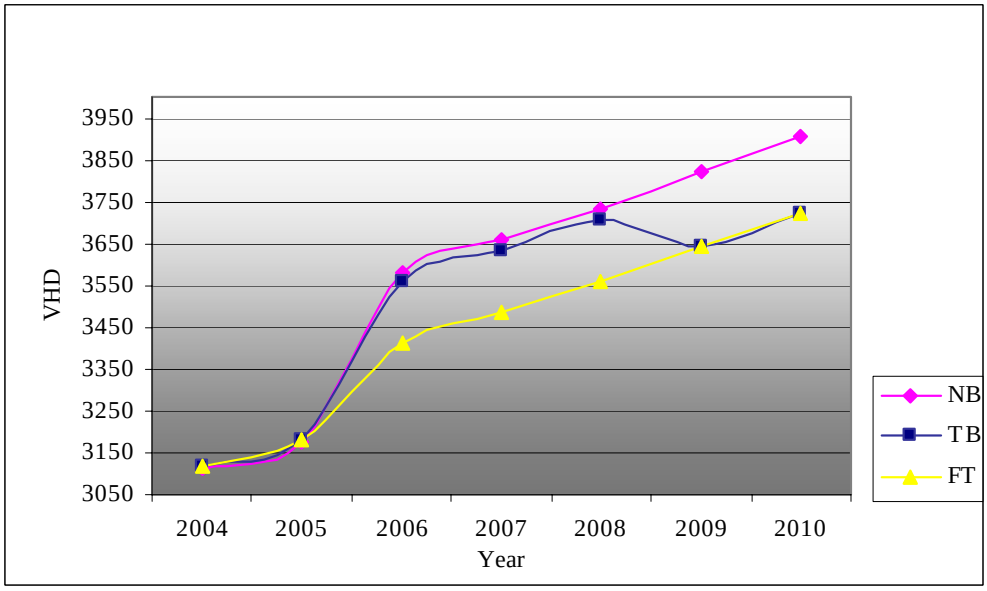


Figure 7.11 Project #2-Vehicle Hours of Delay in the PM Peak Period

The daily VHD values shown in Figure 7.12 indicate that the NB and TB scenarios will have the same VHD on the network over time. This tells us that this section of the roadway demands capacity augmentation over the years to keep up with the increasing travel demand. The absolute increase in VHD for the FT scenario is very gradual but there is a significant saving in user delay over NB and TB.

It can also be seen that the FT and TB scenarios initially have a higher VHD than the NB scenario, but later the rise in NB and TB is much sharper than FT.

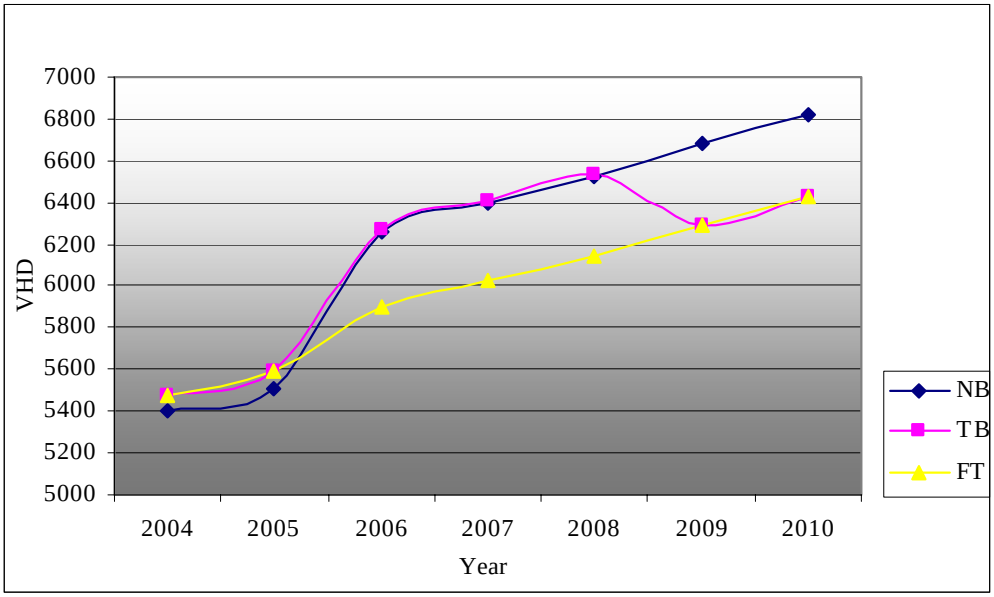


Figure 7.12 Project #2-Daily Vehicle Hours of Delay

Given all the scenarios, it is evident that the FT method will have savings in delay that are much higher than the other two scenarios. Also, the PM peak is more critical than the AM peak. It is recommended that the construction be done after the PM peak.

7.1.3 Project #3 (700 E)

Two sets of analysis will be discussed for this project. One will assume that there is no link closure and the other (called Scn-II) will assume that a section of 700 E will be closed during the construction period. It can be seen from the analysis that the VHD values for the link closure scenario are much higher than when there is no link closure on the network. The VHD graphs for the AM, PM and daily scenarios also have the plot for the Scn-II that assumes the link closure.

Figure 7.13 shows that the daily VMT shows an increasing trend over the years for all the build scenarios. The VMT in 2010 shows an increase of 11.6% from 2004 and the increase is gradual over the years. This means that the travel pattern is not drastically affected by the construction activity over the years for all three build scenarios. In terms of absolute number, the VMT increases from approximately 1950000 in 2004 to 2150000 in 2010. If we compare the daily graph with the AM and PM peak periods, it suggests that the travel demand during the off peak hours is significantly less than the peak hours.

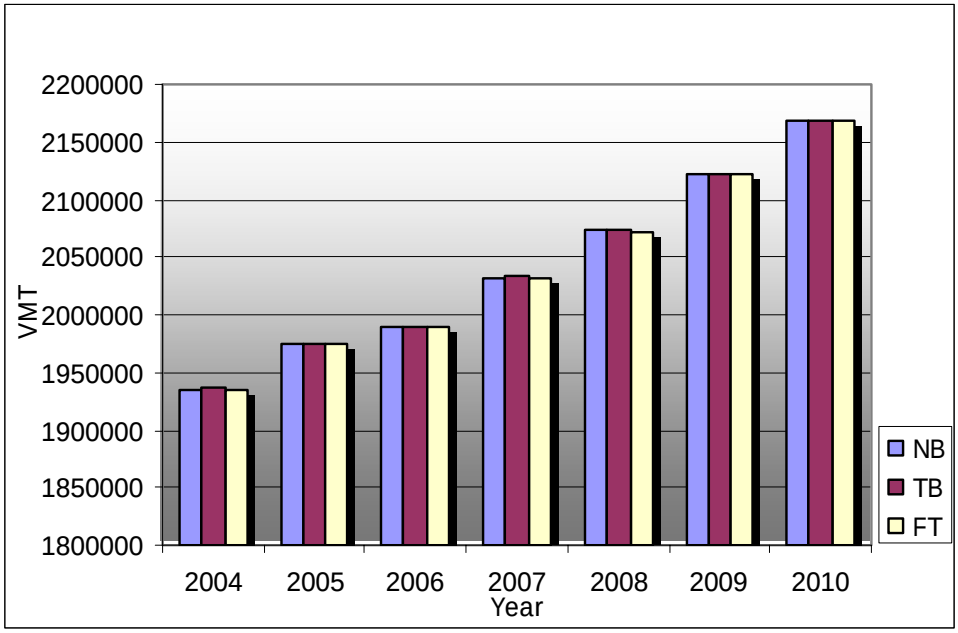


Figure 7.13 Project #3-Vehicle Miles of Travel (Daily)

Figures 7.14 and 7.15 show that the PM peak has almost two times the VMT of the AM peak. For both the periods the growth is approximately 10.8% over the years. 700 E is a major arterial and is unlikely to have a change in travel pattern over the years. Also, it is concluded that the PM peak period will have a higher impact than the AM peak period. The increase in VMT is gradual from 2005 to 2006 but is much sharper from 2007 to 2010. In terms of absolute number, during the AM peak period VMT varies from approximately 320000 to 360000 and the PM peak VMT varies from 520000 to 585000 over a period of seven years.

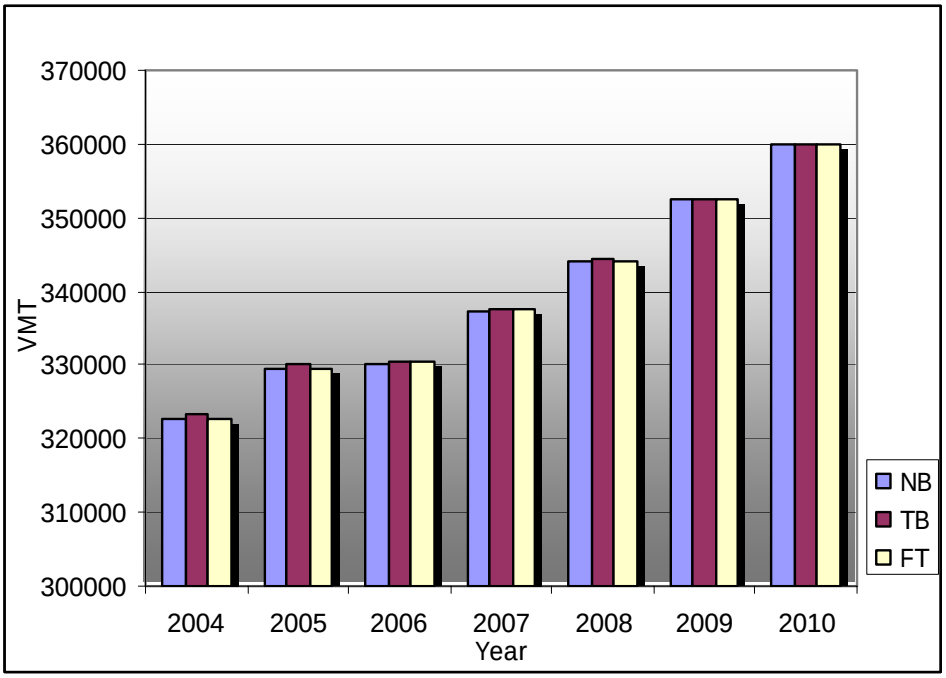


Figure 7.14 Project #2-Vehicle Miles of Travel in the AM Peak Period

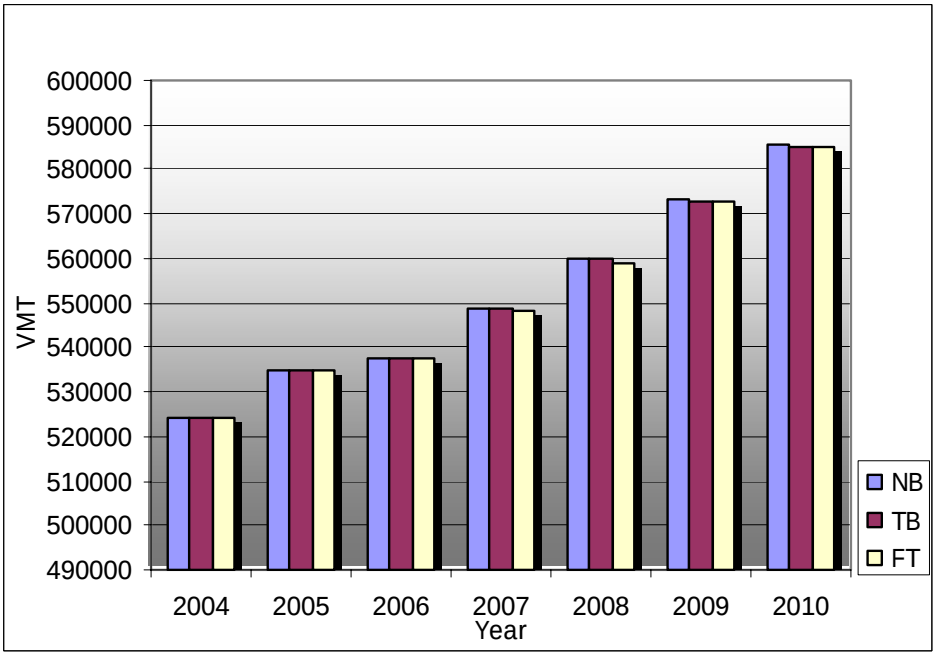


Figure 7.15 Project #3-Vehicle Miles of Travel in the PM Peak Period

Figures 7.16 and 7.17 show the VHD values for the AM, PM and daily periods for all three build scenarios from the years 2004 to 2010. The link closure scenario will have a significant impact on the VHD values for the FT scenario and the impact is higher than the TB scenario. The VHD values for the PM peak period are higher the AM peak period. There will be marginal savings in delay cost if the link is closed over the regular FT scenario.

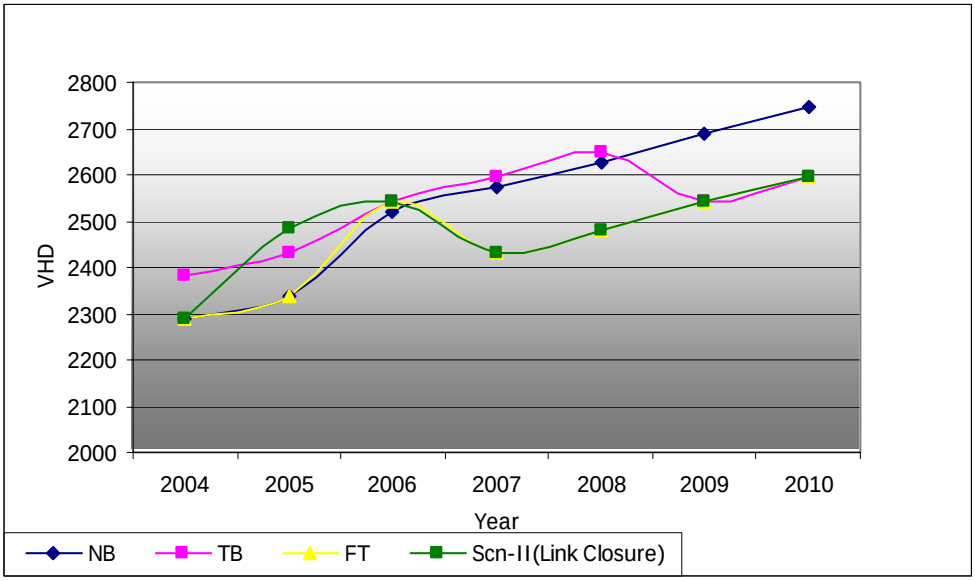


Figure 7.16 Project #3-Vehicle Hours of Delay in the AM Peak Period

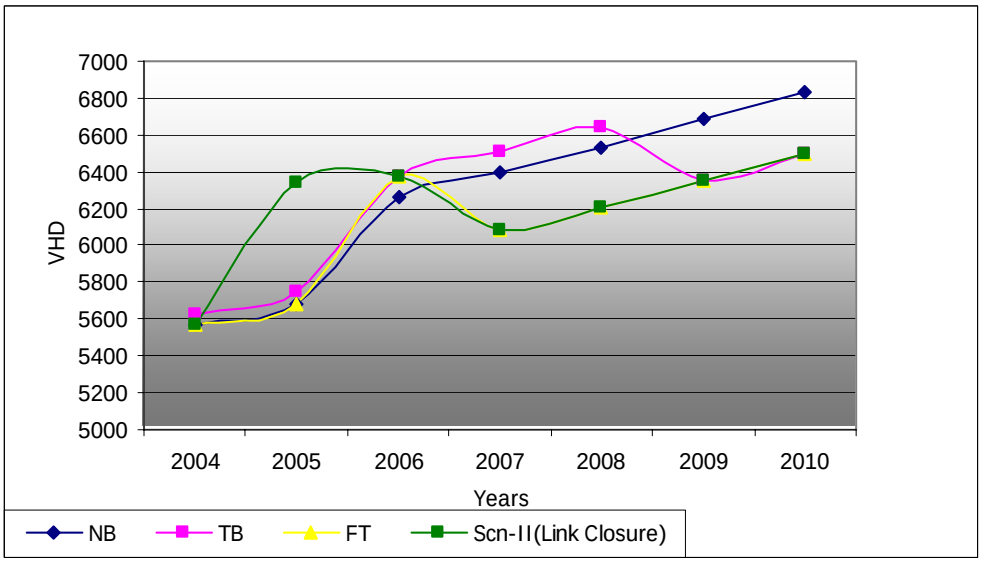


Figure 7.17 Project #3-Vehicle Hours of Delay in the PM Peak Period

Figure 7.18 shows the daily VHD for all the build scenarios for all the simulation years including the scenario for the link closure. The FT scenario has a significant saving in VHD over the NB and TB scenarios if the link is not closed. The travel time benefits that are obtained by the TB scenario after 2008 are obtained by the FT scenario after 2005. The variation in VHD for the FT scenario is much more gradual than the variation in VHD for the NB and TB scenarios.

The VMT and VHD trends for the three build scenarios lead to some important observations. It should be noted that the PM peak period has higher VMT and VHD, so construction should be avoided during the PM peak periods. Also, it is seen that the construction scenarios do not have an impact on the VMT as it continues to increase. Hence, it can be said the travel pattern will remain the same for the region. This indicates that 700 E is a major arterial and it is unlikely that commuters will change their travel behavior.

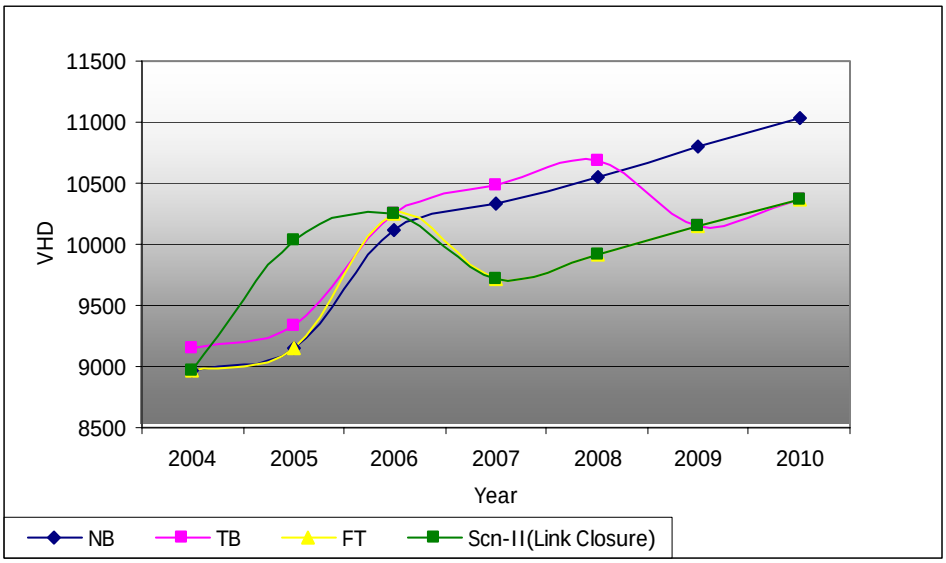


Figure 7.18 Project #3 - Daily Vehicle Hours of Delay

Given all the facts it is evident that the delay savings are higher with the FT method and the benefits can be achieved in a shorter amount of time. However, the option of closing the link will have a totally different implication. If the FT method with the link closure is adopted, the VHD benefits obtained from 2007 to 2009 over the TB will be nullified by the VHD incurred from 2005 to 2006. As shown in Figure 7.18, the FT has a high benefit in terms of VHD over TB if there is no link closure. Since 700 E is a major arterial, it is highly recommended that the link not be closed at any point.

7.1.4 Project #4 (State St. and TRAX Crossing)

Like project #3, the analysis of this project has also been done where the VHD for a second scenario has been computed. The Scn-II (link closure) incorporates the scenario where it is assumed that the link will be closed. The AM, PM and daily VHD graphs also show this scenario.

Figures 7.19 and 7.20 show that the VMT for the AM and PM peak periods are almost the same for all the build scenarios although there is an absolute increase over the years. The VMT increased by approximately 11.1% over the years for both the peak periods.

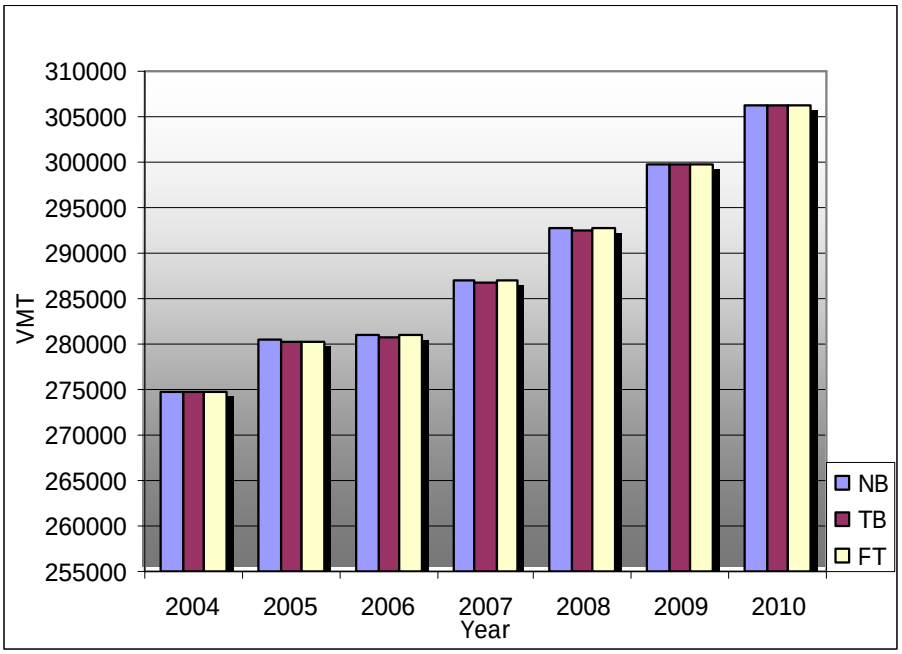


Figure 7.19 Project #4-Vehicle Miles of Travel in the AM Peak Period

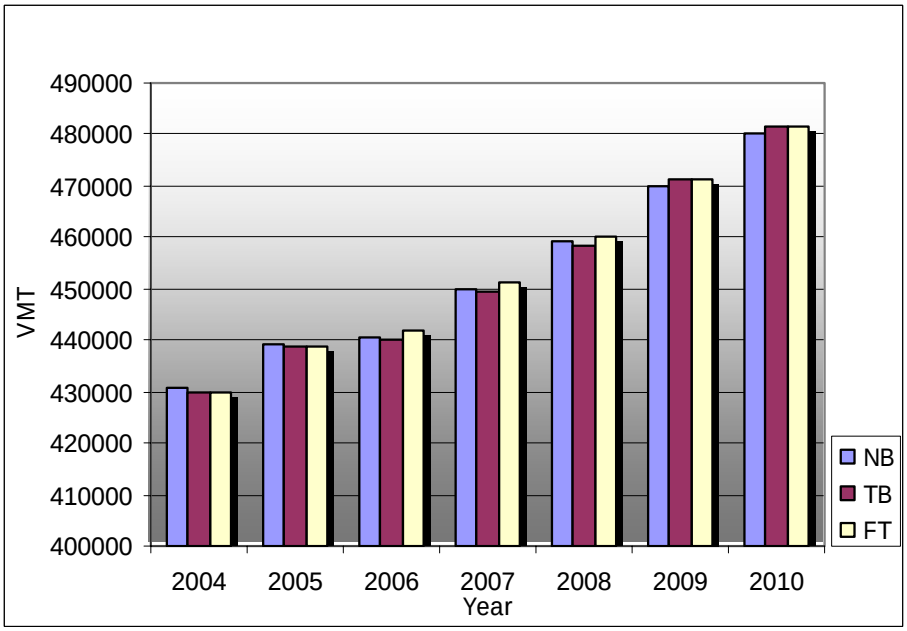


Figure 7.20 Project #4-Vehicle Miles of Travel in the PM Peak Period

Figure 7.21 shows the daily VMT for all the project scenarios for all the time periods. The daily VMT shows an increasing trend over the years and there is an increase of 10.9% from 2004 until 2010. The NB scenario has a marginally higher VMT until 2008 and thereafter all the scenarios have almost the same VMT.

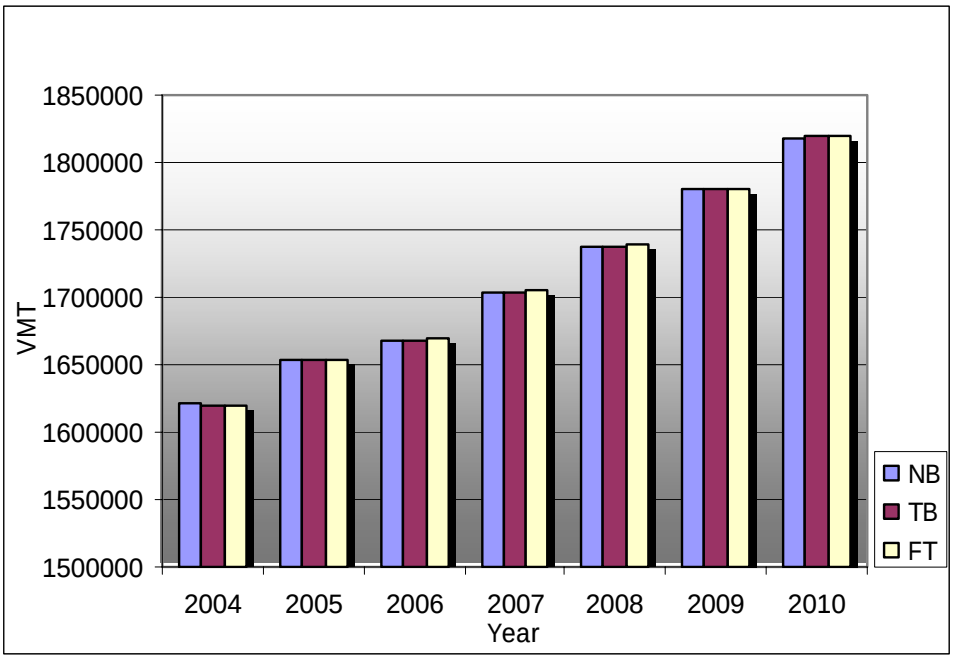


Figure 7.21 Project #4- Vehicle Miles of Travel (Daily)

In terms of absolute numbers, the daily VMT in 2004 is 1625000; for 2008 it is 1750000 and for 2010 it is 1825000.

Figures 7.22 and 7.23 show the VHD for the AM and PM peak periods for this project area. The link closure scenario graph shows that the VHD is much higher than all the scenarios if the link is closed. However, if the link is not closed there is not a significant change in VHD for the AM and the PM peak periods. There is a sharp increase in VHD from 2004 until 2006 and then the increase becomes more gradual. It is interesting to note that the VHD for this project remains unchanged for the TB and FT scenarios unless the link is closed, in which case the VHD increases. This suggests that the project will have a minimal impact regardless of the type of construction. Also, absolute VHD is lower than the numbers obtained for the other projects.

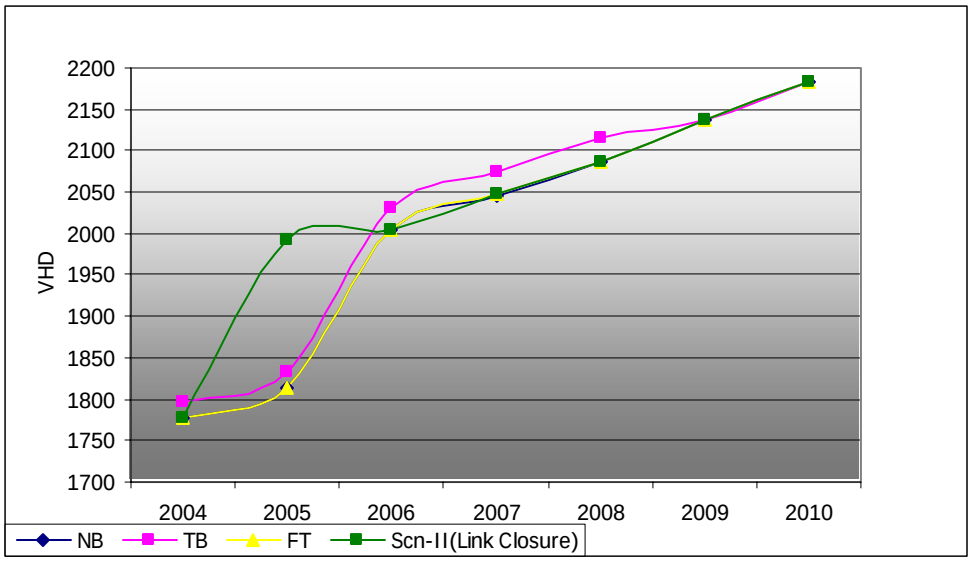


Figure 7.22 Project #4-Vehicle Hours of Delay in the AM Peak Period

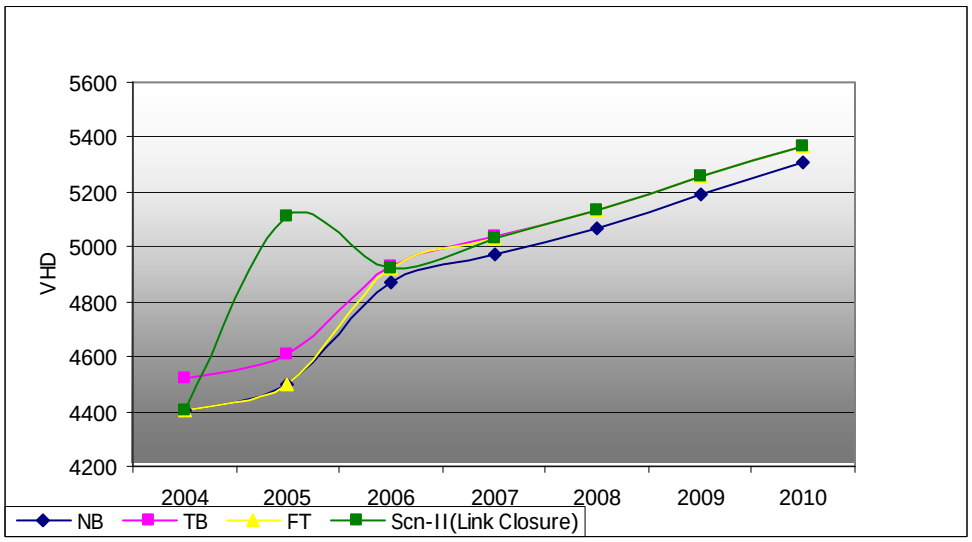


Figure 7.23 Project #4-Vehicle Miles of Travel in the PM Peak Period

The daily VHD values suggest that the delay is higher for the FT (link closure) scenario than for TB or NB. Other than this, there is not a significant difference in VHD; therefore, any construction method can be used. However, the link closure will definitely cause a sharp increase in VHD values, as shown in Figure 7.24.

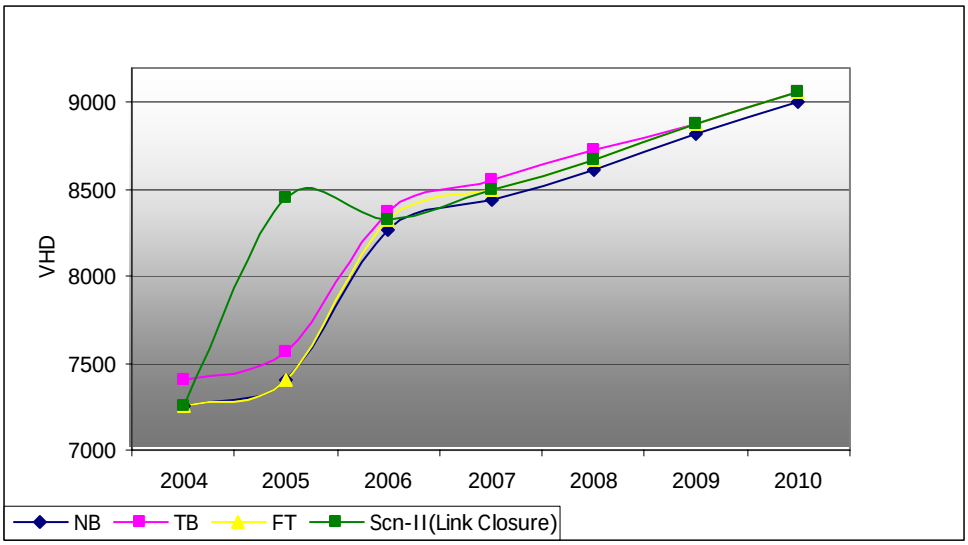


Figure 7.24 Project #4-Daily Vehicle Hours of Delay

Given all the scenarios, it can be said that the project impact is much lower compared to the other three projects. The VHD values are not significantly affected by the different build scenarios and substantial benefits in terms of user delays are not obtained with the FT scenario. For this project, using TB or FT will not make much of a difference in terms of user delays.

Project #5 (State St. and TRAX Crossing)

Figures 7.25 and 7.26 show that the VMT for the AM and PM peak periods are almost the same for all the build scenarios and there is an increase in VMT over the years. The VMT increased by approximately 12.1% over the years for both peak periods. Unlike all the other projects, there was not a significant difference in the VMT for the AM and PM peak periods. This can be attributed to the fact that the project is on an interstate and the travel patterns during the AM and PM periods are not likely to change significantly.

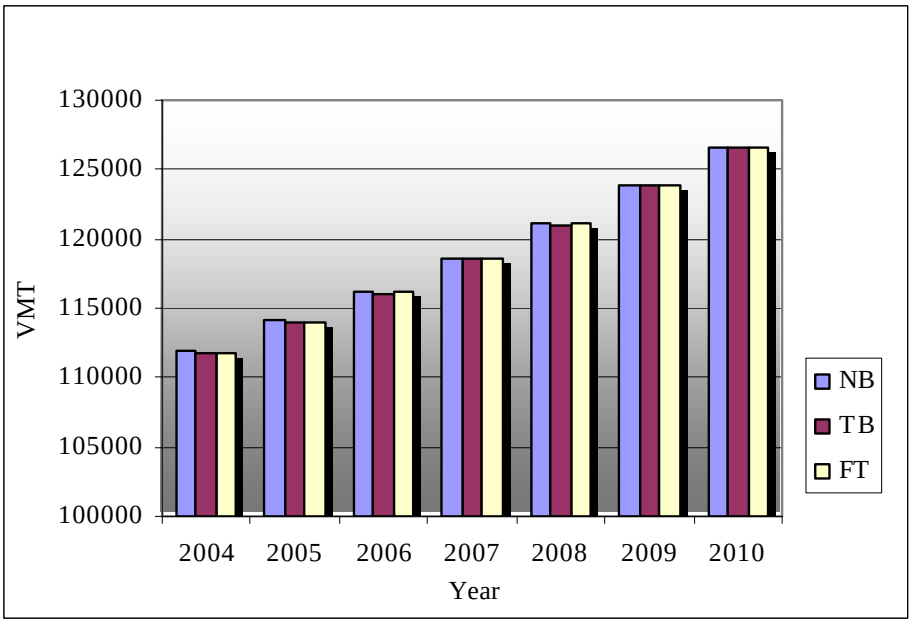


Figure 7.25 Project #5-Vehicle Miles of Travel in the AM Peak Period

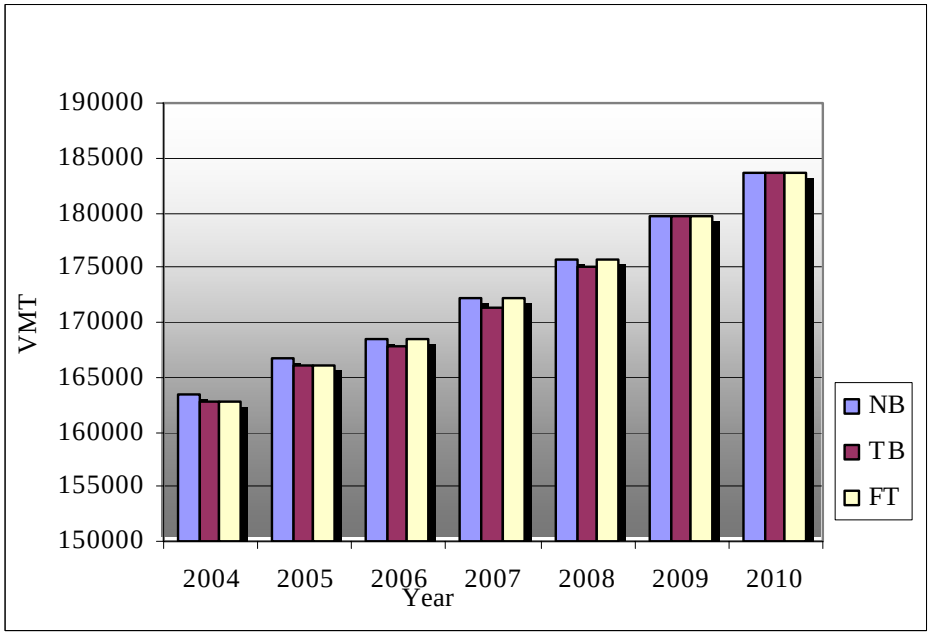


Figure 7.26 Project #5-Vehicle Miles of Travel in the PM Peak Period

Figure 7.27 shows the daily VMT for all the project scenarios for all the time periods. It can be seen that the daily VMT shows an increasing trend over the years and there is an increase of 11.2% from 2004 until 2010. The NB scenario has a marginally higher VMT until 2008. After 2008 all the scenarios have almost the same VMT.

In terms of absolute numbers, the daily VMT in 2004 is 630000; for 2008 it is 680000 and for 2010 it is 710000.

After comparing the AM and PM peak VMT with the daily values it can be concluded that there is a significant VMT during the off peak periods as well. This suggests that the interstate is used extensively during the off peak periods.

A stronger conclusion can be reached when the VHD is taken into account and compared with the VMT.

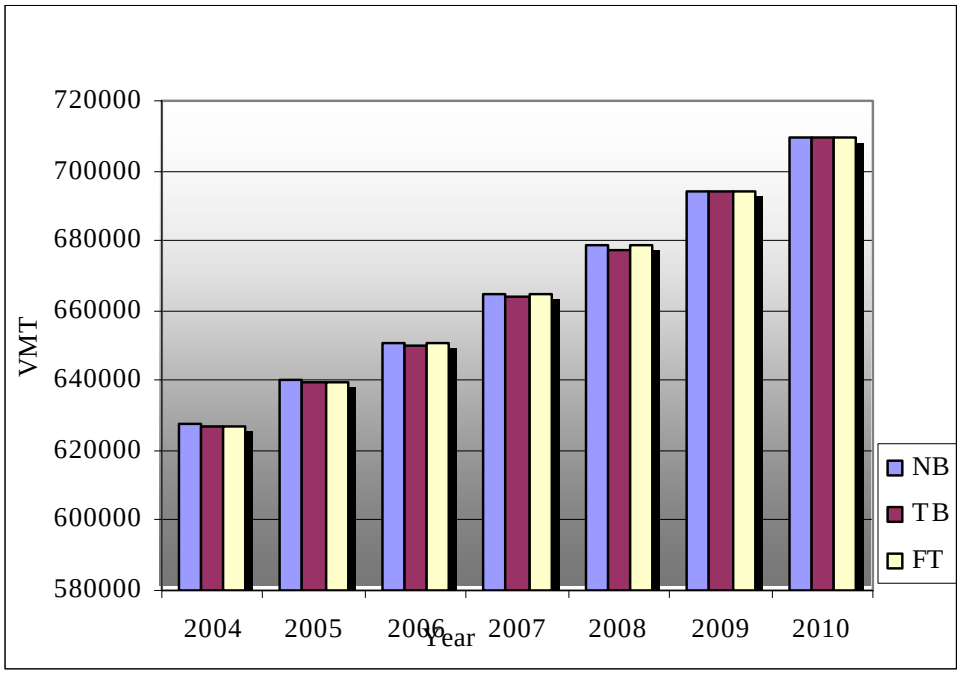


Figure 7.27 Project #5-Vehicle Miles of Travel (Daily)

Figures 7.28 and 7.29 show the VHD for the AM and PM peak periods for this project area. The absolute VHD is much lower when compared to the VHD for the previous projects. There is not much of a difference in the range of VHD for the peak periods. This suggests that the interstate is used by a similar amount of traffic for both peak periods. However, there is no change in the VHD values during the AM peak for all three build scenarios. There is a sharp increase in VHD from 2004 until 2006 and then the increase is more gradual. There is an increase of 27.7% in the AM peak VHD for FT and a marginal increase of approximately 2% for the PM peak FT method. The VHD for NB during the PM peak is almost the same from 2006 until 2010.

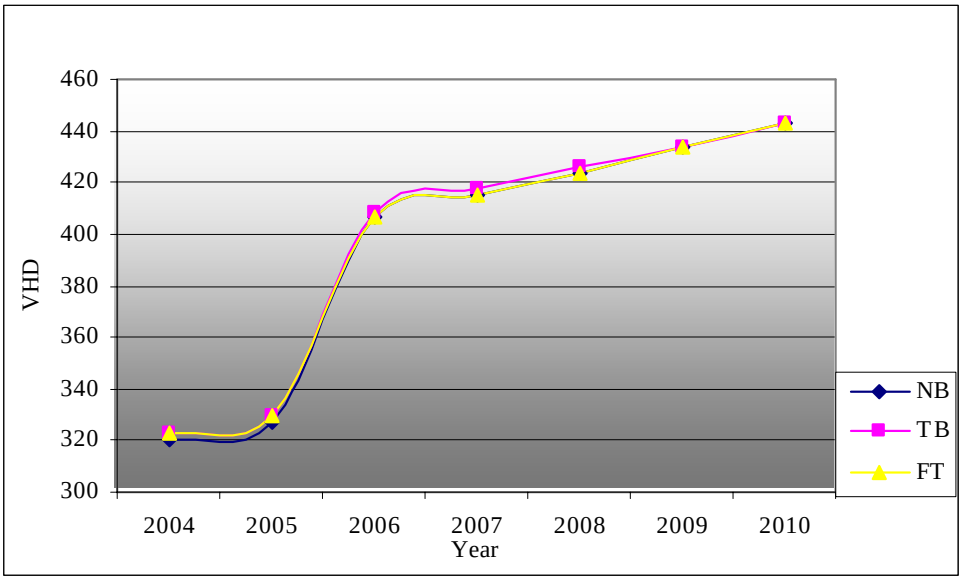


Figure 7.28 Project #5-Vehicle Hours of Delay in the AM Peak Period

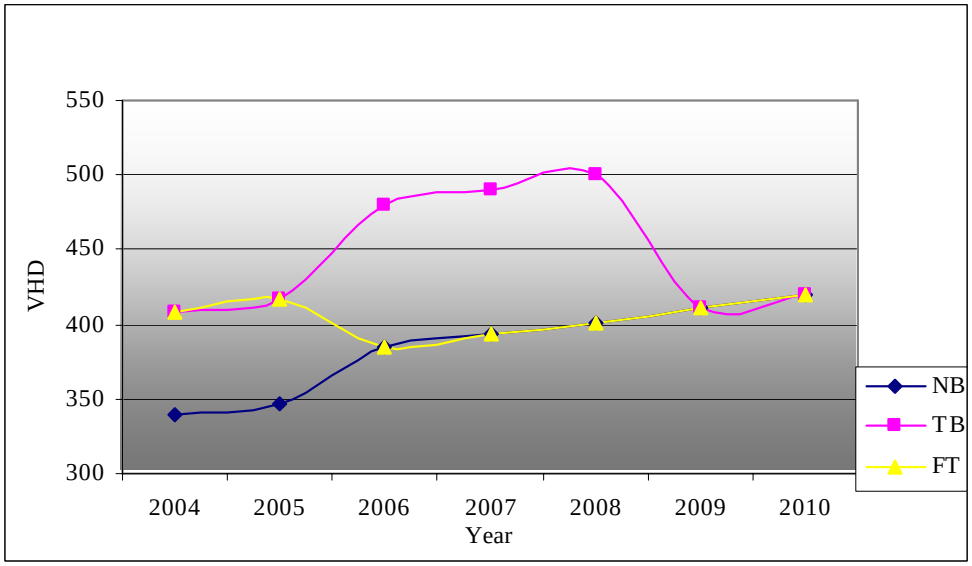


Figure 7.29 Project #5-Vehicle Miles of Travel in the PM Peak Period

The daily VHD values suggest that the delay is higher for FT and TB than for NB from 2004 until 2006. After 2006 the FT and NB scenarios have similar delay values, but the TB scenario has a significantly higher delay.

With the FT method the increase in VHD is 16.2% from 2004 until 2008. In terms of absolute value, however, the VHD for this project is significantly lower than for the other two projects.

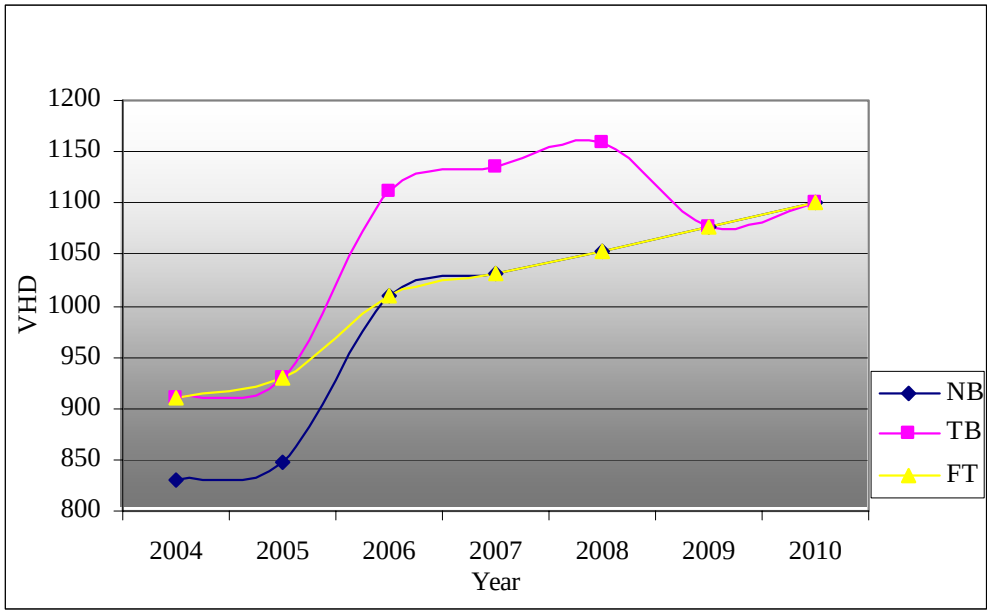


Figure 7.30 Project #5-Daily Vehicle Hours of Delay

Given all the scenarios, it is evident that the FT method will have significant savings in delay and the savings are much higher than the other two scenarios. Nevertheless, this project will have a significantly lower impact than the other two projects in terms of absolute VHD numbers. Since there is not much difference in the AM and PM peak VMT and VHD values, it is recommended that the construction be carried out during the nighttime.

7.2 Second Delay (VHD in sec/VMT)

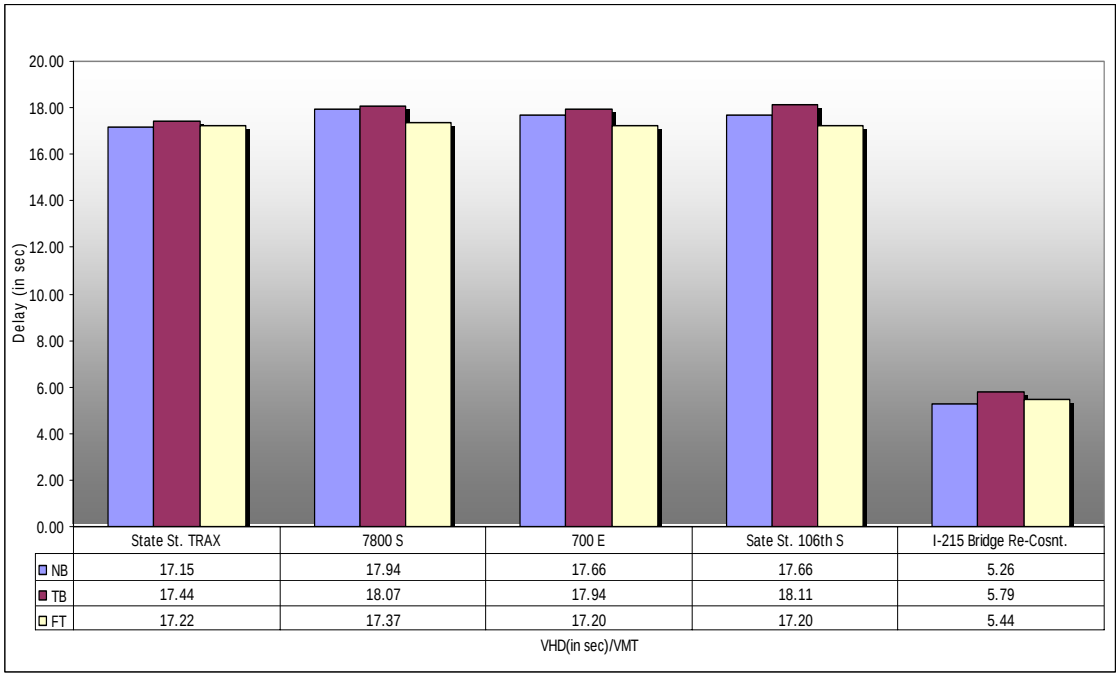
Second delay is a very good measure of network performance regardless of the total VMT on the network. This MOE is used to directly measure the impact of the project for all three build scenarios in this study. Table 7.1 shows the second delay for all the analysis areas comprising all of the projects for 2004 and 2008. The years were chosen with consideration of the horizon year of the STIP projects and the start time.

Table 7.1 Second Delay for All Projects

Project #1	**State St. TRAX Crossing**		
	NB	TB	FT
2004	16.12	16.47	16.13
2008	17.84	18.09	17.95
Average	*17.15*	*17.44*	*17.22*
Project #2	**7800 S**		
	NB	TB	FT
2004	16.77	17.02	17.02
2008	18.72	18.76	17.60
Average	*17.94*	*18.07*	*17.37*
Project #3	**700 E**		
	NB	TB	FT
2004	16.68	17.01	17.19
2008	18.32	18.56	17.21
Average	*17.66*	*17.94*	*17.20*
Project #4	**State St. 10600 S**		
	NB	TB	FT
2004	16.68	17.19	17.19
2008	18.32	18.73	17.21
Average	*17.66*	*18.11*	*17.20*
Project #5	**I-215 Bridge Reconstruction**		
	NB	TB	FT
2004	4.76	5.23	5.23
2008	5.59	6.16	5.59
Average	*5.26*	*5.79*	*5.44*

It can be observed from Table 7.1 that the lowest second delay is observed for the I-215 project for all the build scenarios. For the 700 E project there is an increase of 1.64 seconds for TB from 2004 to 2008, but for FT it is 0.2 seconds. FT also has the lowest average second delay over TB and NB. This shows that with the TB construction method there will be a higher impact on the network for a longer period of time than for the FT method.

For the 7800 S project there is an increase of 1.74 seconds with TB from 2004 to 2008, but for FT it is 0.58 seconds. Again, FT will have a lower impact on the network than the TB method for a longer period of time.



	State St. TRAX	7800 S	700 E	Sate St. 106th S	I-215 Bridge Re-Cosnt.
NB	17.15	17.94	17.66	17.66	5.26
TB	17.44	18.07	17.94	18.11	5.79
FT	17.22	17.37	17.20	17.20	5.44

Figure 7.31 Average Second Delay (VHD in sec/VMT)

Figure 7.31 shows that the second delay for the I-215 project is the lowest, followed by the 7800 S, State St TRAX, 700 E and 10600 S projects. Also, the FT method has the lowest value when compared to the NB and TB methods for all three project areas.

From this it can be concluded that, when the three projects are compared, the FT method will have significant savings in user delays. It can also be concluded that the I-215 project will have a lower impact than the other two. This can be attributed to the fact that it is an interstate and the severity of the project is much lower. The second delay for 700 E is higher since it is a major arterial. The same is true for 7800 S since it is in proximity to two major arterials: Redwood Rd. and Bangerter Hwy.

7.3 Cost Implications (Delay Cost Due to Construction VHD)

It is difficult to convert travel impact into monetary values. The research on conversion of delay into cost terms is also very sparse. However, one method to convert vehicular delay due to construction into monetary terms is to multiply the VHD by a dollar value that represents delay per hour. For this study, a methodology proposed by the NCHRP's report 358 entitled "Recommended Practices for Use of Traffic Barrier and Control Treatments for Restricted Work Zones" was used to convert the delay in terms of user cost. The proposed estimate of the value of time of $13 per vehicle hour of delay is used and is multiplied by the daily VHD for each analysis area to obtain the dollar value. This cost is the "delay cost" due to construction delay. Figures 7.32, 7.33, 7.34, 7.35 and 7.36 represent the estimated delay cost for each of the projects.

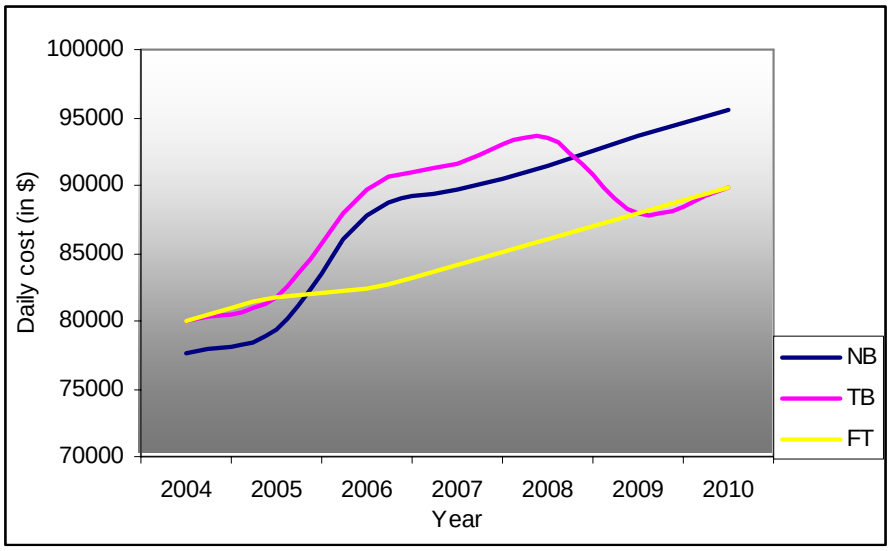


Figure 7.32 Delay Cost Estimate for Project #1– State St. 10600 S

Figure 7.32 shows that there are significant savings in delay cost for the FT method over the TB method. It should also be noted that the benefits obtained by the TB method catch up with the FT method only after construction ends in 2008. It is recommended that the FT method be adopted for the State St. 10600 S project. There is a steep rise in delay cost for the NB and TB scenarios but the FT scenario has a gradual slope.

Figure 7.33 shows that the NB and TB scenarios for the 7800 S project have a similar daily delay cost from 2006 until 2008. Later, the TB scenario reaps the benefits and the cost becomes equivalent to FT. But, the FT scenario has a much lower daily delay cost than both the scenarios and the delay cost benefits are much higher. The benefit in daily delay cost for FT when compared to NB and TB is approximately $10,000. There is a gradual increase in the cost for FT from 2006 until 2010.

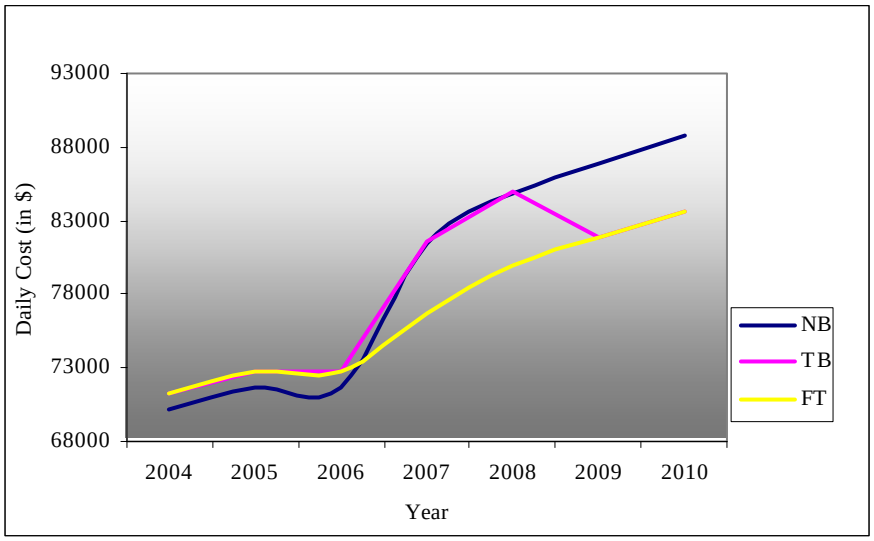


Figure 7.32 Delay Cost estimate for Project #2– 7800 S Redwood/Bangerter

Figure 7.33 gives the daily delay cost estimate for the 700 E project. It can be seen that the daily delay benefit of FT vs. TB is approximately $8000. The delay cost benefit obtained from this project is less than the 7800 project.

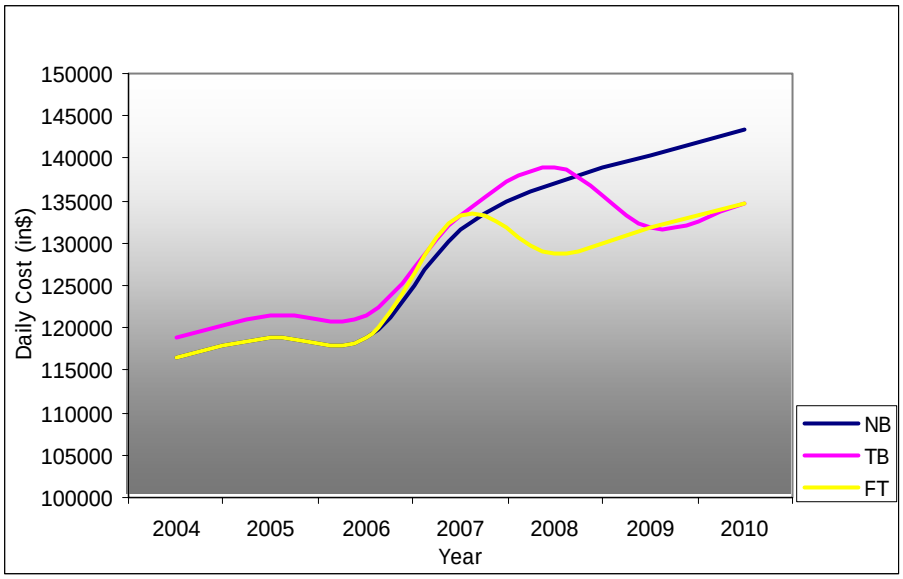


Figure 7.33 Delay Cost Estimate for Project #3– 700 E

Figure 7.34 is the delay cost calculation for the State St. TRAX project. It can be observed that minimal delay cost benefits are obtained when either the TB or FT method is used. This is due to the fact that the impact area for this project is very small and the magnanimity of the project is lower in terms of user delays.

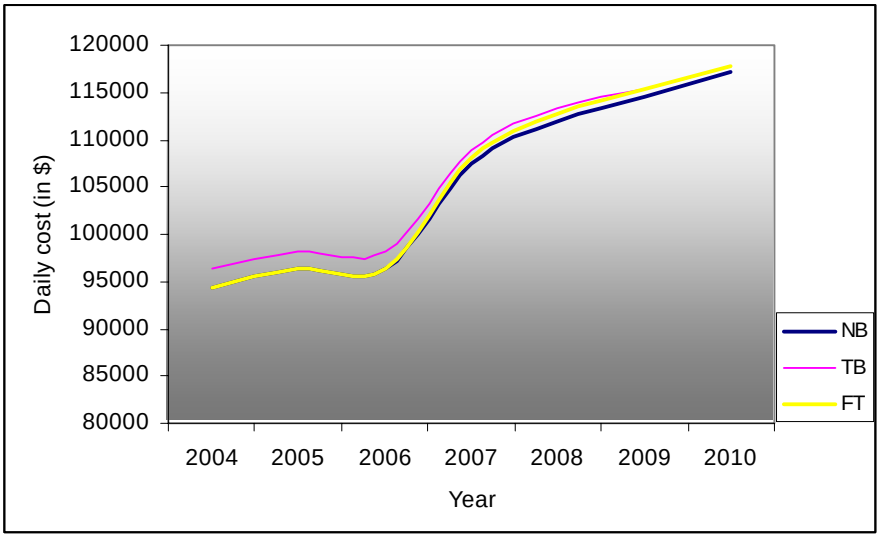


Figure 7.34 Delay Cost Estimate for Project #4– State St. TRAX

Figure 7.35 gives the daily delay cost estimate for the I-215 bridge reconstruction project. It can be seen that the daily delay benefit of FT vs. TB is approximately $1000. However, it is interesting to observe that there is no difference in FT and NB after 2006. Compared to the other four projects, the daily delay cost benefits are much lower for I-215. This is due to the fact that the VHD for this project is also significantly lower than the other projects.

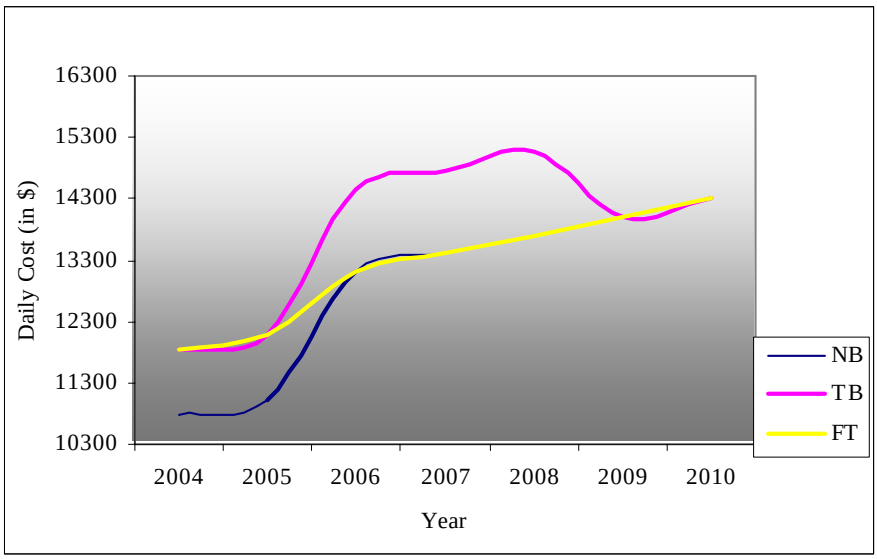


Figure 7.35 Delay Cost Estimate for Project #5– I-215 Bridge Reconstruction

Table 7.2 compares the estimated cost of the projects and the savings in delay cost during the period of construction. It can be seen that the highest benefits are obtained for the 700 E project, followed by the 7800 S and I-215 projects. The State St. TRAX project has marginal savings over the other four projects.

If the FT method is used for the 700 E project, there will be a savings of $7.2 million in terms of delay; $5.4 million for 7800 S and $2 million for I-215. From these results, it is highly recommended that the 700 E project be done with the FT method. Also, since 700 E is a major arterial, the FT method should be used to reduce the delay on the network due to construction.

Table 7.2 Savings for FT Compared to TB for the Project Duration

	Project Cost	Delay Cost Saving
7800 S (Redwood/Bangerter)	$21.3 Million	$5.4 Million
I-215 Bridge Reconstruction	$4.35 Million	$2 Million
700 E	$20 Million	$7.2 Million

The delay cost amounts to 1/3 of the total project cost for the 700 E project and ¼ of the total project cost for the 7800 S project. Although comparing the delay cost with the estimated project cost might not be a very accurate method of comparison, it does give a ballpark figure that would help to decide which method of construction should be used.

8. CONCLUSIONS

The FT method has higher benefits in terms of reduced delay and delay cost than the TB method. However, the extent of this benefit depends on many factors. Therefore, there are varying levels of travel time and delay cost savings for the projects analyzed in this study. For road construction projects that are a part of long range plans like the STIP, it is necessary to model the impact for a network. The use of a "transportation planning model" like VISUM for this study proved to be beneficial in forecasting travel demand for future years.

For this study, the impact of construction varied depending on the type of project, the extent of the project, the existing and future travel demand, and the type of construction method used. The PM peak period for all the projects was observed to be critical. Construction during the PM peak is not recommended. Also, in terms of travel and cost impacts, project #5 (I-215) had the lowest impact over the other four projects.

Some significant conclusions that can be drawn about the 700 E project (# 3) are:

- The VHD is the highest for this project.
- The PM peak period is critical since the VHD and VMT are higher and will have a significant impact on construction.
- The average second delay is lowest for FT but is higher than the other projects.
- There is a savings of $7.2 million in delay cost for FT over TB.

Some significant conclusions about the 7800 S – Redwood/Bangerter Project (# 2) are:

- The VHD for NB and TB are almost equal after 2005. This shows that capacity augmentation is needed in the long run due to increasing travel demand.
- There is a savings in delay cost with the FT method.
- Due to higher VHD and VMT values during the PM peak, construction is not desirable during this period.
- There are fewer trip changes for the TB and NB scenarios because, in spite of construction, the VHD values are almost equal.
- There is a savings of $5.4 million for FT over TB.

Some significant conclusions about the I-215 project (#5) are:

- The VHD is the lowest in absolute number compared to the other projects.
- The AM and PM peak VHD is almost the same in terms of absolute number.
- The seconds of delay are the lowest compared to the other projects.
- It has the least impact anticipated due to the construction activity, but off peak construction is desirable.
- There is a savings of $2 million if FT is used over TB.

Some significant conclusions about the State St. 10600 S (#1) are:

- The VHD is the lowest in absolute number compared to the other projects.

9. RECOMMENDATIONS

The following recommendations were made after analyzing all of the projects:

- The FT method is recommended for all three projects since the savings in delay cost due to construction is much higher than the TB method.
- Construction should be avoided during the PM peak period as it will cause higher network delays.
- Construction should be done between the late evening and dawn to minimize the impact due to delay.
- The State St. TRAX project does not have a significant impact in terms of the construction method used
- The option of link closure for the State St. and TRAX project and 700 E should not be considered as there would be no delay savings for 700 E and there would be a negative delay for State St.
- The I-215 project will have the least impact on delay. However, construction is recommended only during the off peak hours.
- The savings in delay cost is the highest for the 700 E and 7800 S project. Therefore, the FT method should definitely be considered.

REFERENCES

1. Statewide Transportation Improvement Program 2004-208, *Utah Department of Transportation*, 2004
2. Transportation Improvement Program 2004-2008, *Wasatch Front Regional Council*, December 2003.
3. DeJohn, A., Miller, R., Winslow, K., Grenier, J. and Cano, D. Model Based Long-Range Transportation Planning Tool for New Jersey. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1817,* TRB, National Research Council, Washington, D.C., pp. 93-101, 2002.
4. Hwang H., Greene, D., Chin, S. and Gibson, A. Real-Time Indicators of Vehicle Kilometers of Travel and Congestion. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1719,* TRB, National Research Council, Washington, D.C., pp. 209-214, 2000.
5. Leurent F. Cost Versus Time Equilibrium over a Network. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1443,* TRB, National Research Council, Washington, D.C., pp. 84-91, 1994.
6. Graham, J. and Migletz,, J., Development and Implementation of Traffic Control Plan for Highway Work Zones, *National Cooperative Highway Research Program, Synthesis 208,* 1994.
7. Shahawy, M. Prefabricated Bridge Elements and Systems to Limit Traffic Disruption During Construction, *National Cooperative Highway Research Program, Synthesis 324,* 2003
8. Ross, H.E. et al, Recommended Practices for Use of Traffic Barrier and Control Treatments for Restricted Work Zones, *National Cooperative Highway Research Program, Report 358,* 1994.
9. Toledo, T. et al. Calibration and Validation of Microscopic Traffic Simulation Tools. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1831,* TRB, National Research Council, Washington, D.C., pp. 65-75, 2003.
10. Forkenbrock, D. and Weisbrdo, G. Guidebook for Assessing the Social and Economic Effects of Transportation Projects. *National Cooperative Highway Research Program, Report 456,* 2001.
11. Martin, P., Stevanovic, A. and Disegni, R. User Impacts of the I-15 Design-Build Reconstruction, *Utah Traffic Lab*, Report UTL-1001-50, July 2003.

APPENDIX

VMT Project No. 1 - at State St. and 10600 S					VHD Project No. 1 - at State St. and 10600 S				
		NB	TB	FT			NB	TB	FT
2004	AM	214973.65	215393.18	215393.18	2004	AM	1524.592	1589.757	1589.757
	PM	349090.99	348963.89	348963.89		PM	3708.363	3796.939	3796.939
	MD	435061.14	435206.28	435206.28		MD	737.9233	766.775	766.775
	EV	289790.3	289790.96	289790.96		EV	0.993191	2.937328	2.937328
	DAILY	1288916.1	1289354.3	1289354.3		DAILY	5971.872	6156.409	6156.409
2005	AM	219584.93	220013.46	220013.46	2005	AM	1557.296	1623.858	1623.858
	PM	356579.16	356449.33	356449.33		PM	3787.91	3878.386	3878.386
	MD	444393.4	444541.65	444541.65		MD	753.7521	783.2227	783.2227
	EV	296006.44	296007.11	296007.11		EV	1.014495	3.000335	3.000335
	DAILY	1316563.9	1317011.6	1317011.6		DAILY	6099.972	6288.467	6288.467
2006	AM	220167	220258.24	220243.32	2006	AM	1680.467	1700.509	1587.393
	PM	358233.36	358080.63	357763.62		PM	4178.474	4293.094	3971.952
	MD	449062.58	449205.59	448948.18		MD	889.4157	904.0944	780.4532
	EV	299122.41	299122.41	299122.41		EV	1.027457	3.011482	1.027457
	DAILY	1326585.3	1326666.9	1326077.5		DAILY	6749.385	6900.709	6340.825
2007	AM	224889.68	224982.88	224967.64	2007	AM	1716.514	1736.986	1621.443
	PM	365917.63	365761.62	365437.81		PM	4268.104	4385.183	4057.152
	MD	458695.18	458841.26	458578.32		MD	908.4941	923.4877	797.1943
	EV	305538.72	305538.72	305538.72		EV	1.049497	3.07608	1.049497
	DAILY	1355041.2	1355124.5	1354522.5		DAILY	6894.162	7048.732	6476.839
2008	AM	229612.37	229707.52	229691.96	2008	AM	1752.561	1773.463	1655.494
	PM	373601.9	373442.61	373112		PM	4357.735	4477.271	4142.352
	MD	468327.78	468476.92	468208.47		MD	927.5725	942.8809	813.9354
	EV	311955.03	311955.03	311955.03		EV	1.071536	3.140677	1.071536
	DAILY	1383497.1	1383582.1	1382967.5		DAILY	7038.94	7196.756	6612.852
2009	AM	234918.19	234999.62	234999.62	2009	AM	1793.059	1693.748	1693.748
	PM	382234.99	381733.78	381733.78		PM	4458.432	4238.072	4238.072
	MD	479149.77	479027.7	479027.7		MD	949.0066	832.7436	832.7436
	EV	319163.61	319163.61	319163.61		EV	1.096297	1.096297	1.096297
	DAILY	1415466.6	1414924.7	1414924.7		DAILY	7201.593	6765.66	6765.66
2010	AM	239957.29	240040.47	240040.47	2010	AM	1831.521	1730.08	1730.08
	PM	390434.11	389922.14	389922.14		PM	4554.067	4328.981	4328.981
	MD	489427.75	489303.07	489303.07		MD	969.3632	850.6063	850.6063
	EV	326009.82	326009.82	326009.82		EV	1.119813	1.119813	1.119813
	DAILY	1445829	1445275.5	1445275.5		DAILY	7356.071	6910.787	6910.787

VMT Project No. 2 - at 7800 Redwood and Bangerter					VHD Project No. 2 at 7800 Redwood and Bangerter				
		NB	TB	FT			NB	TB	FT
2004	AM	207451.6	207572.2	207572.2	2004	AM	1290.783	1321.805	1321.805
	PM	312791.1	312825.6	312825.6		PM	3115.012	3119.63	3119.63
	MD	401846.9	401601.4	401601.4		MD	993.6862	1038.376	1038.376
	EV	236957.4	236957.4	236957.4		EV	0.551951	0.898878	0.898878
	DAILY	1159047	1158957	1158957		DAILY	5400.03	5480.71	5480.71
2005	AM	211685.3	211808.4	211808.4	2005	AM	1317.125	1348.781	1348.781
	PM	319174.6	319209.8	319209.8		PM	3178.584	3183.296	3183.296
	MD	410047.9	409797.3	409797.3		MD	1013.966	1059.568	1059.568
	EV	241793.3	241793.3	241793.3		EV	0.563215	0.917222	0.917222
	DAILY	1182701	1182609	1182609		DAILY	5510.24	5592.56	5592.56
2006	AM	214420.2	214406.3	215025	2006	AM	1451.427	1485.181	1426.736
	PM	324459.4	324349.5	324729.4		PM	3582.343	3558.05	3414.019
	MD	420506.9	420476.2	421975.5		MD	1227.727	1230.282	1057.222
	EV	244651.9	244651.9	244651.9		EV	0.904694	0.926243	0.926243
	DAILY	1204038	1203884	1206382		DAILY	6262.4	6274.44	5898.9
2007	AM	219019.6	219005.4	219637.3	2007	AM	1482.56	1517.038	1457.341
	PM	331419.2	331307	331695		PM	3659.186	3634.372	3487.251
	MD	429527	429495.6	431027		MD	1254.063	1256.672	1079.899
	EV	249899.8	249899.8	249899.8		EV	0.9241	0.946111	0.946111
	DAILY	1229866	1229708	1232259		DAILY	6396.73	6409.03	6025.44
2008	AM	223400	223385.5	224030.1	2008	AM	1512.211	1547.379	1486.487
	PM	338047.6	337933.1	338328.9		PM	3732.37	3707.059	3556.996
	MD	438117.5	438085.5	439647.6		MD	1279.144	1281.805	1101.497
	EV	254897.8	254897.8	254897.8		EV	0.942582	0.965033	0.965033
	DAILY	1254463	1254302	1256904		DAILY	6524.67	6537.21	6145.95
2009	AM	228786.3	229431.6	229431.6	2009	AM	1548.672	1522.328	1522.328
	PM	346198.1	346486.3	346486.3		PM	3822.36	3642.758	3642.758
	MD	448680.9	450247.8	450247.8		MD	1309.985	1128.055	1128.055
	EV	261043.6	261043.6	261043.6		EV	0.965308	0.988301	0.988301
	DAILY	1284709	1287209	1287209		DAILY	6681.98	6294.13	6294.13
2010	AM	233693.9	234353	234353	2010	AM	1581.892	1554.982	1554.982
	PM	353624.3	353918.6	353918.6		PM	3904.351	3720.897	3720.897
	MD	458305.3	459905.8	459905.8		MD	1338.085	1152.253	1152.253
	EV	266643.1	266643.1	266643.1		EV	0.986015	1.009501	1.009501
	DAILY	1312267	1314821	1314821		DAILY	6825.31	6429.14	6429.14

VMT Project No. 3 - at 700 E					VHD Project No. 3 - at 700 E				
		NB	TB	FT			NB	TB	FT
2004	AM	322773.7	323422.4	322773.7	2004	AM	2289.11	2380.563	2289.11
	PM	524145.2	524102.6	524145.2		PM	5567.949	5630.589	5567.949
	MD	653225.6	653612.4	653225.6		MD	1107.96	1138.256	1107.96
	EV	435107.7	435108.7	435107.7		EV	1.491233	1.491233	1.491233
	DAILY	1935252	1936246	1935252		DAILY	8966.51	9150.899	8966.51
2005	AM	329360.9	330022.8	329360.9	2005	AM	2335.827	2429.146	2335.827
	PM	534842	534798.6	534842		PM	5681.58	5745.499	5681.58
	MD	666556.8	666951.4	666556.8		MD	1130.572	1161.486	1130.572
	EV	443987.5	443988.5	443987.5		EV	1.521667	1.521667	1.521667
	DAILY	1974747	1975761	1974747		DAILY	9149.5	9337.652	9149.5
2006	AM	330234	330399.4	330399.4	2006	AM	2520.575	2542	2542
	PM	537323.2	537294.1	537294.1		PM	6267.398	6373.972	6373.972
	MD	673560.2	673818.9	673818.9		MD	1334.057	1340.304	1340.304
	EV	448661.2	448661.2	448661.2		EV	1.541109	1.541109	1.541109
	DAILY	1989779	1990173	1990173		DAILY	10123.57	10257.82	10257.82
2007	AM	337317.7	337486.6	337434.6	2007	AM	2574.643	2596.528	2432.043
	PM	548849	548819.3	548129.3		PM	6401.836	6510.697	6085.423
	MD	688008.4	688272.6	687833.1		MD	1362.673	1369.054	1195.732
	EV	458285.2	458285.2	458285.2		EV	1.574167	1.574167	1.574167
	DAILY	2032460	2032864	2031682		DAILY	10340.73	10477.85	9714.773
2008	AM	344064	344236.4	344183.3	2008	AM	2626.135	2648.458	2480.684
	PM	559826	559795.6	559091.9		PM	6529.873	6640.911	6207.132
	MD	701768.5	702038	701589.8		MD	1389.927	1396.435	1219.646
	EV	467450.9	467450.9	467450.9		EV	1.60565	1.60565	1.60565
	DAILY	2073109	2073521	2072316		DAILY	10547.54	10687.41	9909.068
2009	AM	352359.7	352481.8	352481.8	2009	AM	2689.454	2540.496	2540.496
	PM	573323.9	572572.1	572572.1		PM	6687.314	6356.791	6356.791
	MD	718688.8	718505.7	718505.7		MD	1423.439	1249.053	1249.053
	EV	478721.5	478721.5	478721.5		EV	1.644364	1.644364	1.644364
	DAILY	2123094	2122281	2122281		DAILY	10801.85	10147.98	10147.98
2010	AM	359918	360042.7	360042.7	2010	AM	2747.144	2594.991	2594.991
	PM	585622	584854	584854		PM	6830.76	6493.148	6493.148
	MD	734105	733918	733918		MD	1453.972	1275.846	1275.846
	EV	488990.3	488990.3	488990.3		EV	1.679636	1.679636	1.679636
	DAILY	2168635	2167805	2167805		DAILY	11033.56	10365.66	10365.66

VMT Project No. 4 - at State St. TRAX Crossing					VHD Project No. 4 - at State St. TRAX Crossing				
		NB	TB	FT			NB	TB	FT
2004	AM	274783.1	274721.2	274721.2	2004	AM	1777.031	1795.866	1777.031
	PM	430636.1	429990.2	429990.2		PM	4407.764	4518.043	4407.764
	MD	559435.6	559090.5	559090.5		MD	1072.871	1093.457	1072.871
	EV	356012.7	356012.7	356012.7		EV	1.095694	1.095694	1.095694
	DAILY	1620867	1619815	1619815		DAILY	7258.762	7408.462	7258.762
2005	AM	280390.9	280327.7	280327.7	2005	AM	1813.297	1832.516	1813.297
	PM	439424.6	438765.5	438765.5		PM	4497.718	4610.248	4497.718
	MD	570852.7	570500.5	570500.5		MD	1094.767	1115.773	1094.767
	EV	363278.3	363278.3	363278.3		EV	1.118056	1.118056	1.118056
	DAILY	1653946	1652872	1652872		DAILY	7406.9	7559.655	7406.9
2006	AM	280980.3	280848.8	280987.6	2006	AM	2003.368	2031.002	2003.724
	PM	440630.6	440005.6	441814.6		PM	4867.272	4929.357	4924.354
	MD	579162	579198	579162		MD	1392.132	1413.364	1390.08
	EV	366977.2	366977.2	366977.2		EV	1.145974	1.145974	1.145974
	DAILY	1667750	1667030	1668941		DAILY	8263.918	8374.869	8319.305
2007	AM	287007.5	286873.1	287014.9	2007	AM	2046.341	2074.568	2046.705
	PM	450082.3	449444	451291.7		PM	4971.677	5035.094	5029.984
	MD	591585.3	591622.1	591585.3		MD	1421.994	1443.681	1419.898
	EV	374849.1	374849.1	374849.1		EV	1.170556	1.170556	1.170556
	DAILY	1703524	1702788	1704741		DAILY	8441.183	8554.514	8497.758
2008	AM	292747.6	292610.6	292755.2	2008	AM	2087.268	2116.06	2087.639
	PM	459083.9	458432.8	460317.5		PM	5071.111	5135.796	5130.584
	MD	603417	603454.5	603417		MD	1450.434	1472.554	1448.296
	EV	382346	382346	382346		EV	1.193967	1.193967	1.193967
	DAILY	1737595	1736844	1738836		DAILY	8610.006	8725.604	8667.713
2009	AM	299806	299813.8	299813.8	2009	AM	2137.594	2137.974	2137.974
	PM	470152.9	471416.2	471416.2		PM	5193.38	5254.287	5254.287
	MD	617966	617966	617966		MD	1485.405	1483.216	1483.216
	EV	391564.8	391564.8	391564.8		EV	1.222754	1.222754	1.222754
	DAILY	1779490	1780761	1780761		DAILY	8817.602	8876.699	8876.699
2010	AM	306237	306244.9	306244.9	2010	AM	2183.446	2183.835	2183.835
	PM	480237.9	481528.3	481528.3		PM	5304.78	5366.994	5366.994
	MD	631221.6	631221.6	631221.6		MD	1517.268	1515.031	1515.031
	EV	399964	399964	399964		EV	1.248983	1.248983	1.248983
	DAILY	1817661	1818959	1818959		DAILY	9006.743	9067.109	9067.109

VMT Project No. 5 - at I-215 'Lego Bridge'					VHD Project No. 5 - at I-215 'Lego Bridge'				
		NB	TB	FT			NB	TB	FT
2004	AM	111853.8	111772.9	111772.9	2004	AM	320.7235	323.029	323.029
	PM	163314	162756.3	162756.3		PM	339.6476	408.1011	408.1011
	MD	216507.6	216358.9	216358.9		MD	168.6869	178.4498	178.4498
	EV	135960.6	135898	135898		EV	0.895611	0.895611	0.895611
	DAILY	627636	626786	626786		DAILY	829.954	910.476	910.476
2005	AM	114136.6	114054	114054	2005	AM	327.2689	329.6214	329.6214
	PM	166647	166077.9	166077.9		PM	346.5792	416.4297	416.4297
	MD	220926.1	220774.3	220774.3		MD	172.1294	182.0917	182.0917
	EV	138735.3	138671.4	138671.4		EV	0.913889	0.913889	0.913889
	DAILY	640445	639578	639578		DAILY	846.891	929.057	929.057
2006	AM	116123.4	116030.5	116123.4	2006	AM	406.2532	408.6618	406.2532
	PM	168484.4	167795.5	168484.4		PM	384.7587	479.8729	384.7587
	MD	225590.5	225394.5	225590.5		MD	217.908	222.3002	217.908
	EV	140587.1	140522.7	140587.1		EV	0.936305	0.936305	0.936305
	DAILY	650785	649743	650785		DAILY	1009.86	1111.77	1009.86
2007	AM	118614.3	118519.4	118614.3	2007	AM	414.9675	417.4278	414.9675
	PM	172098.5	171394.8	172098.5		PM	393.0119	490.1664	393.0119
	MD	230429.6	230229.3	230429.6		MD	222.5822	227.0686	222.5822
	EV	143602.8	143537	143602.8		EV	0.956389	0.956389	0.956389
	DAILY	664745	663680	664745		DAILY	1031.52	1135.62	1031.52
2008	AM	121105.2	121008.3	121105.2	2008	AM	423.6818	426.1938	423.6818
	PM	175712.6	174994	175712.6		PM	401.2652	500.4599	401.2652
	MD	235268.6	235064.1	235268.6		MD	227.2564	231.8371	227.2564
	EV	146618.4	146551.3	146618.4		EV	0.976473	0.976473	0.976473
	DAILY	678705	677618	678705		DAILY	1053.18	1159.47	1053.18
2009	AM	123903.7	123903.7	123903.7	2009	AM	433.4721	433.4721	433.4721
	PM	179772.9	179772.9	179772.9		PM	410.5375	410.5375	410.5375
	MD	240705.1	240705.1	240705.1		MD	232.5078	232.5078	232.5078
	EV	150006.4	150006.4	150006.4		EV	0.999037	0.999037	0.999037
	Daily	694388	694388	694388		Daily	1077.52	1077.52	1077.52
2010	AM	126561.5	126561.5	126561.5	2010	AM	442.7703	442.7703	442.7703
	PM	183629.1	183629.1	183629.1		PM	419.3437	419.3437	419.3437
	MD	245868.3	245868.3	245868.3		MD	237.4952	237.4952	237.4952
	EV	153224.2	153224.2	153224.2		EV	1.020467	1.020467	1.020467
	DAILY	709283	709283	709283		DAILY	1100.63	1100.63	1100.63