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The Feasibility of Closing Vehicle Crossings along St. Charles Avenue: A Study of Transit Safety and Performance

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A Thesis

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List of Abbreviations

DPW	City of New Orleans Department of Public Works
HCM	Highway Capacity Manual
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GIS	Geographic Information Systems
LOS	Level of Service
LRT	Light Rail Transit
ROW	Right-of-way
RPC	New Orleans Regional Planning Commission
RTA	New Orleans Regional Transit Authority
TAZ	Traffic Analysis Zone
TDM	Travel Demand Model

Abstract

The St. Charles streetcar is an important transit line in the city of New Orleans, with about 65,000 people living within a ½ mile walking distance from it. However, the line experiences a very high streetcar/automobile crash rate due in large part to the large number of grade vehicle crossings over the tracks that lack signalization. Through traffic modeling, the closure of many of these vehicle crossings and the diversion of automotive traffic to the remaining, signalized crossings is analyzed to determine traffic impacts on street network. The result is a modest increase in traffic, about 7-8%, at the remaining signalized intersections.

Keywords: Streetcar, St. Charles Avenue, Vehicle Crossings, TransCAD, traffic modeling, crashes, safety.

Chapter 1: Introduction

Overview

Light rail transit (LRT) is an important mode of urban transportation. LRT systems are characterized by external guidance, rail technology, right-of-way (ROW) separation and electric propulsion. Because of the broad nature of these characteristics, LRT encompasses many forms of rail transportation. Everything from regional service commuter systems to local streetcars can be considered LRT. The Saint Charles Streetcar line in New Orleans is one such example of LRT.

The St. Charles Street Car line runs 6.6 miles from Carondelet Street and Canal Street in the Central Business District at the edge of the French Quarter to the intersection of Carrollton and Claiborne Avenue in Uptown New Orleans. The streetcar itself operates in two different ROW schemes. Approximately 5.5 miles of the line, from the intersection of Carrollton Avenue and Claiborne Avenue to Lee Circle, operates in a dedicated right-of-way (ROW). For this portion the streetcar is positioned in the median of St. Charles and Carrollton Avenues. In the downtown portion of the St. Charles line, from Lee Circle to Canal Street, the streetcar operates in a shared ROW. Here the streetcar operates on tracks built into the roadway and shares a lane with automotive traffic.

Figure 1: St. Charles Streetcar in shared and dedicated right-of-way. ***(Source: Vivek Shah, 2012)***

Approximately 65,000 people live within one-half mile of the streetcar line (US Census Bureau, 2010). Considering the total population of the city is about 384,000, this represents 17% of the population and makes the St. Charles line an important part of the city's public transit system.

Time performance and safety are major concerns with the line (Marks & Breun, 2012). Both issues are affected by the significant number of vehicle crossings over the tracks (Marks & Breun, 2012). There are currently about six to seven crashes per month between streetcars and turning vehicles (Marks &

Breun, 2012). This accounts for about 5% of all the light rail/automotive crashes in the entire nation (Marks & Breun, 2012). Not only do the crashes themselves cause delays, the fact that there are 101 at-grade vehicle crossings along the line means that there are a 101 potential places for a crash between streetcar and automotive traffic[1]. Each crossing is a point of potential streetcar delay, whether from a crash or traffic. This thesis will examine the feasibility of closing many vehicle crossings and the effect it may have on streetcar operations, traffic flow and the safety of both.

Study Area

The focus of this thesis is the portion of the St. Charles streetcar line that operates in a dedicated ROW along the median of St. Charles and Carrollton Avenues. However, when the research for this thesis began, the New Orleans Regional Transit Authority (RTA) was performing maintenance work on the Carrollton Avenue portion of the streetcar line. Therefore, Carrollton Avenue is excluded and this thesis will focus on the portion of the St. Charles streetcar line that operates in the median of St. Charles Avenue from Fern Street to Lee Circle (see Figure 2).

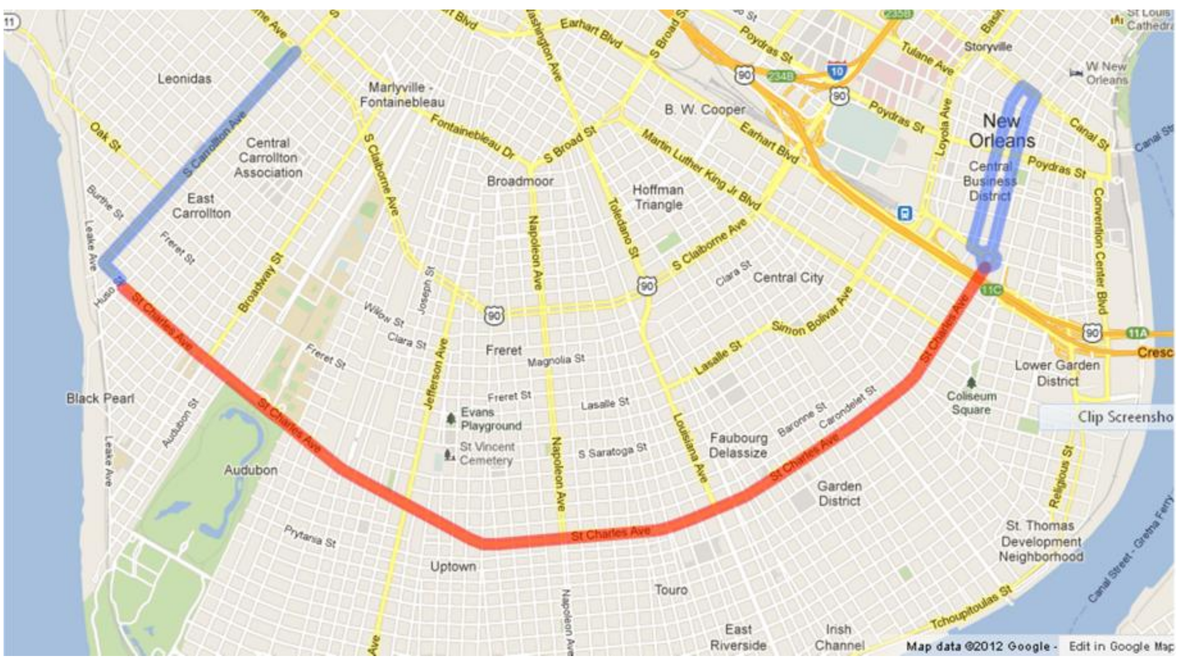

Figure 2: St. Charles streetcar line, study area in red.

Research Questions

[1] Crossing number derived from a simple count of crossings on a map.

The research goals of this thesis are two-fold. The first goal is to determine best practices regarding at-grade crossings by looking at current research and existing urban examples. This will be addressed in the literature review. The second goal is to determine the feasibility of closing many of the 101 vehicle crossings along St. Charles Avenue and represents the original research and analysis of this thesis.

Question 1: Based on current research and real-world examples, what are the best for at-grade vehicle crossings of light rail lines?

Light rail systems are in use all over the world and have been for decades, so New Orleans is certainly not the only city to deal with the issue of at-grade vehicle crossings. Much research has been done regarding this issue and many cities have dealt with it in a variety of ways.

Question 1a: How do other cities treat at-grade vehicle crossings of LRT tracks?

Dozens of cities within the United States and around the world operate LRT lines within their urban cores that operate at grade. These lines inevitably interact with vehicular traffic at grade crossings. What common and effective practices can be gleaned from other cities and current research?

Question 1b: What effects do these practices have on vehicular traffic and transit service?

With every action there are trade-offs. Actions taken to improve the performance of one mode sometimes come at the expense of another mode. The trade-off of concern here is the between traffic flow and transit performance and safety.

Question 1c: Outside of the treatment of at-grade vehicle crossings, what other changes improve service and safety on for LRT and how could these changes be applied to the St. Charles streetcar line?

The design of vehicle crossings is not the only method available to improve the safety and performance of transit systems. What other methods are regularly employed that could be adopted here in New Orleans?

Question 2: What is the feasibility of closing vehicle crossings and diverting all turning traffic along St. Charles Avenue to the existing signalized intersections?

Through the literature review, we see that allowing automobile crossings only at signalized intersections is the common practice with grade crossings of LRT lines. There are currently 12 signalized intersections within the study area. Can these 12 crossings handle turning traffic along St. Charles Avenue?

Question 2a: What level of service can be expected at the signalized intersections?

If traffic is to be diverted to only the signalized intersections, it is important to know how well that traffic will flow or whether the additional traffic will cause serious delays at certain signalized intersections.

Question 2b: What improvements in streetcar safety can be expected?

Fewer vehicle crossings mean fewer points of interaction between the streetcar and automobiles. This certainly means a lower potential for crashes. What reduction in crashes can be expected from the closure of vehicle crossings?

Overview of Methodology

Vehicle Crossing Closure Simulation

The New Orleans Regional Planning Commission (RPC) runs a regional traffic model to predict traffic flow through the five parishes within its jurisdiction. Because of its regional scope, the model does not include small local streets – which make up the majority of vehicle crossings on St. Charles Avenue, only major roadways and collectors. With some minor tweaking, the model can be made to reflect the study area with vehicle crossings only at existing signalized intersections. The model will be run to determine approximate traffic volumes at these intersections and along St. Charles Avenue. **Research questions: 2**

Level of Service at Intersections

If vehicles are to be diverted to existing signalized intersections, then it should be determined whether the intersections can handle the increase traffic. Using traffic volume and movement data from the crossing closure simulation, the level of service will be calculated for each intersection and be used to determine the feasibility of the vehicle crossing scheme. **Research question: 2a**

Observations of Traffic during Track Maintenance

When performing maintenance on the streetcar tracks on Carrollton Avenue, many of the vehicle crossings were closed, forcing diversions in automotive traffic. Even though the streetcar was not running at this time, the fact that many of the crossings were closed does provide a real-world test of the effect of such closures on automotive traffic. During the course of this construction, the researcher observed traffic flow throughout this area to see how it was affected by the limited number of crossings. **Research questions: 2, 2a**

Streetcar/Vehicle Crashes

Every time a streetcar collides with a vehicle at a crossing the RTA compiles a crash report. Each report contains the date, day of week, time and location of the crash. The data currently exists as an excel table that simply lists the crashes in order of occurrence. This data will be analyzed spatially using Geographic Information Systems (GIS) software and temporally using statistical methods. This analysis will only be applied to study area. Crashes that occurred outside of the study area will be ignored because they are beyond the scope of this thesis. **Research questions: 2b**

Position of Stakeholders

St. Charles Avenue is managed by a number of different agencies, each tasked with operating a different part of the corridor. The operation of the streetcar line and the related infrastructure – tracks, overhead wires and stops – is managed by the RTA; The roadways, vehicle crossings and traffic signals are managed by Department of Public Works; The Regional Planning Commission has a stake because St. Charles Avenue is considered a major arterial roadway that is part of the regions congestion management system, as mandated by federal legislation. There is also the local transit advocacy group, Transport for NOLA, which has an interest in the streetcar line. The interviews conducted with representatives of these different agencies and organizations provide context to the research and inform conclusions and recommendations. **Research questions: 2, 2a, 2b**

Chapter 2: Literature Review

Introduction

The purpose of this chapter is to answer, through a review of existing research and current, urban examples the following question: What are the best practices in regards to at-grade vehicle crossings of light rail lines (Research Question 1)? The goal of this chapter is to also address other practices employed by cities that improve light rail safety and performance.

Best Practices in Light Rail At-Grade Crossings

In recent years there has been a resurgence in LRT construction around the world. Much of this construction is in the United States as US cities have historically lagged behind their European counterparts when it comes to public transit investment (Hass-Klau & Crampton, 2002). The type of light rail built has varied from streetcars operating in shared ROWs with traffic to high quality LRT lines that operate in separated ROWs with grade separation at speeds up to 50 miles per hour (Hass-Klau & Crampton, 2002). This increase in planning and construction of LRT has also led to an increase in research on various aspects of LRT, safety at grade crossings being one of them.

Current Research and Design Standards

The Federal Highway Administration's *Manual of Uniform Traffic Control Devices* states:

Figure 3: Streetcar crossing warning sign on St. Charles Ave ***(Source: Vivek Shah, 2012)***

"Because grade crossings are a potential source for crashes and congestion, agencies should conduct engineering studies to determine the cost and benefits of eliminating these crossings." (Federal Highway Administration, 2009, p. 749)

The manual goes on to say that any at-grade crossing that cannot be justified should be eliminated. This sentiment is echoed in a number of other studies. In their study *Median Light Rail Crossings: Accident Causation and Countermeasures,* Coifman and Bertini note that the two best ways to prevent accidents are to remind drivers that there are special risks in the given situation and physically prevent drivers from taking those risks (Coifman & Bertini, 1997). The simple message being: the easiest way to reduce LRT/vehicle crashes is to reduce the number of possible conflict points.

At points where grade crossings of LRT tracks must exist, they should be limited only to crossings and intersections with some sort of signalization (Meshkati, Rahimi, Torabzadeh, Grote, & Parental, 2007). Active warning devices such as traffic lights and railroad arms are always preferred to passive warning devices like stop, yield or warning signs, raised crossings and pavement markings (Korve, Farran, Mansel, Levinson, Chira-Chavala, & Ragland, 1996). This is because they force to driver to acknowledge the existence of a rail crossing and the dangers therein instead of depending on the driver to be cognizant of their surroundings (Coifman & Bertini, 1997; Vuchic, 2007). Cross traffic at non-signalized intersections should not be permitted because this increases the possibility for delay and for crashes (Vuchic, 2007). At signalized intersections, vehicle movements in which drivers cross LRT tracks should be limited only to dedicated signal phases to prevent the delay of transit vehicles and crashes between automobiles and LRT (Vuchic, 2007).

This sentiment is echoed in almost all of the literature. The Los Angeles Metropolitan Transit Authority (LAMTA), for example, does not allow grade crossings of their LRT lines without signalization (Metropolitian Transportation Authority, 2003). This is not simply a preference but a matter of policy on the part of the LAMTA. The Federal Transit Administration (FTA) and the Federal Railroad Administration (FRA) each cite unregulated crossings as areas with the highest rate of crashes with vehicles and recommends against their use ((FRA, 2009; FTA, 2009).

Examples of Best Practices

The St. Charles streetcar is certainly not the only example of median running LRT in the world and certainly not in the United States. Numerous cities have successful LRT systems that operate in a similar fashion to the St. Charles streetcar line. This section is an overview of grade crossing design features common to urban LRT systems throughout the world. All in all the examples, LRT vehicles operate in roadway median or alongside traffic in a dedicated ROW and experience operating speeds of about 20 mph.

Boston, MA

Like New Orleans, Boston is a historic city with most of its neighborhoods built before the advent of cars when walking and horses were the main mode of urban transportation. This history makes the street grid in Boston very similar to that in New Orleans. Short blocks and limited sight lines are common throughout Boston proper and many of the older suburban neighborhoods (Korve, Farran, Mansel, Levinson, Chira-Chavala, & Ragland, 1996).

Figure 4: Pleasant St. Station, Green Line, Boston (triposo.com)

The Massachusetts Bay Transportation Authority is operator of public transit in the greater Boston, Massachusetts area. Part of their system is the Green Line, a light rail line that begins in downtown Boston and ends, with four branches in suburban neighborhoods to the west of the city. Of the four branches of the Green Line, three spend considerable portions of their route in the median of a major roadway. The median running portions of the Green Line account for 37% of the line's operations (Massachusetts Bay Transportation Authority, 2009).

Vehicle crossings along the median running portions of the Green Line are limited. There is one crossing approximately every 740 feet on two of the branches and every 1050 feet for another branch, and all of these crossings have transit-only and left-turn signals to direct traffic and prevent collisions (Korve, Farran, Mansel, Levinson, Chira-Chavala, & Ragland, 1996). This limits vehicle crossings along median running portions of the Green Line to once every three to four blocks[2].

Los Angeles, CA

The Los Angeles County Metropolitan Transportation Authority (LACMTA) operates the 22 mile Metro Blue Line between downtown Los Angeles and downtown Long Beach (Korve, Farran, Mansel, Levinson, Chira-Chavala, & Ragland, 1996). The Blue Line operates in a variety of ROW configurations. About 1-mile of the line operates in a subway tunnel in downtown Los Angeles, 15-miles where the line operates on an existing freight railroad track and 6-miles where the line operates within the median or along the side of major roadways (Ogden, et al., 2001). It is this 6 mile stretch that is important to this thesis.

Along these 6 miles of operation, the Blue Line traverses the Los Angeles and Long Beach street networks at-grade, creating numerous at-grade crossings. During this 6 mile stretch there are 72 crossings, or about one every one-sixth of a mile (Korve, Farran, Mansel, Levinson, Chira-Chavala, & Ragland, 1996). This places a crossing every 880 feet, similar to the spacing found in Boston along the Green Line. Each of these crossings is regulated with active signalization through traffic lights (Ogden, et al., 2001). Places where the crossing roadway has speeds of 40 mph or greater, railway arms are used to physically prevent drivers from crossing the tracks when a train is approaching (Korve, Farran, Mansel, Levinson, Chira-Chavala, & Ragland, 1996).

Figure 5: LACMTA Expo Line operating in median (Are You Ready to Expo?!, 2012)

More recently, the LACMTA has considered the construction of a new LRT line: the Exposition Line. This line is planned to operate completely within the median of Exposition Blvd and

[2] Crossing spacing derived from map-based measurement of Green Line.

connect Los Angeles to Culver City (Meshkati, Rahimi, Torabzadeh, Grote, & Parental, 2007). Based on crash data from the Blue Line and other LRT lines in Los Angeles, design induced human error was found to be the primary cause of vehicle crashes (Meshkati, Rahimi, Torabzadeh, Grote, & Parental, 2007). Intersections with high crash rates were ones in where traffic control measures did not fully convey to drivers the dangers presented by the LRT line (Meshkati, Rahimi, Torabzadeh, Grote, & Parental, 2007). At these crossings, control measures regarding the train were limited to passive control measures such as warning signs instead of active control measures like traffic signals.

Baltimore, MD

The Maryland Mass Transit Administration operates the Baltimore Central Light Rail Line (BCLR) which extends 30 miles from downtown Baltimore to Hunt Valley, PA and the Baltimore-Washington International Airport. The LRT operates mostly on existing rail lines except for in downtown Baltimore where the LRT operates on Howard Street (Ogden, et al., 2001). On Howard Street the BCLR runs in "semi-exclusive" ROW where the line is separated from vehicular traffic by 6 inch high curbs on either side of the tracks, except at intersections (Pecheux & Saporta, 2009).


Figure 6: Baltimore Central Light Rail on Howard St.

There are 17 intersections along Howard Street that are all regulated with active signalization and separate signals for the BCLR and auto traffic (Ogden, et al., 2001). Travel across the BCLR tracks is only allowed during dedicated signal phases (Korve, Farran, Mansel, Levinson, Chira-Chavala, & Ragland, 1996; Ogden, et al., 2001). Despite this, some intersections still had high crash rates where drivers would turn left across the tracks in violation of the left-turn signal indication (Pecheux & Saporta, 2009). The solution was to change left-turn signals from a leading left to a lagging left. This allowed BCLR vehicles to pass through the intersection a head of left turning vehicles instead of behind.

International Examples

Cities throughout the world, particularly in Europe, have been operating LRT systems for decades. Many of the cities not only operate LRT lines in similar configurations as the St. Charles streetcar, but also operate streetcar vehicles almost identical to those that run on St. Charles. In the cities of Hannover, Germany, Zurich, Switzerland and Strasbourg, France similar practices can be found.

All these cities operate LRT systems, mostly with streetcars, operating in dedicated or shared ROWs (Hass-Klau & Crampton, 2002). In Hannover, 80 percent of the network is separated from traffic, operating either along the side or in the median of major corridors (Hass-Klau & Crampton, 2002). Vehicles are only able to cross the streetcar lines at specified intersections that employ active signalization.

As in New Orleans, trams outside the city center in Strasbourg have their own ROW (see Figure 7). Intersections are all signalized and significant pavement markings are present to clearly indicate to drivers and pedestrians the location of the tracks (Hass-Klau & Crampton, 2002).

Figure 7: Tram in median, Strasbourg, France (Photo2ville, 2008)

Zurich, Switzerland operates about 70% of its tram network in its own ROW. Most of this dedicated ROW is simply pavement markings on the street to indicate which part of the roadway is for the tram and which is for automobiles (Hass-Klau & Crampton, 2002). Despite the dedicated ROW, the in street operation creates potential for vehicle/tram interactions, particularly at intersections. To mitigate this, all trams in Zurich have priority at all traffic lights (Vuchic, 2007; Hass-Klau & Crampton, 2002). This prioritization scheme includes separate signals for trams and vehicles and further indicates to drivers the dangers presented by the tram (Vuchic, 2007).

Other Practices to Improve LRT Safety and Performance

The previous sections looked at current research regarding grade crossings of light rail lines and how a various cities dealt with them. But what other changes can be made to improve safety and service of the St. Charles streetcar line? This section seeks to answer that question with a review a relevant literature and urban examples.

Signals and Signs

Based on a review of related literature, it is recommended that all at-grade vehicle crossings of light rail tracks be at intersections with active signalization. In most cases, this means full traffic signals with left turn lanes and separate signals for light rail vehicles. However, this is not required in New Orleans. Active signalization encompasses a wide range of signal types, all of which regularly change to inform roadway users of changing conditions in traffic movement (Vuchic, 2007). Grade crossings can continue at many minor streets along St. Charles Avenue, but may not require a full traffic signal in all directions. Instead, blank-out signs that alert drivers of approaching streetcars and prevent movement across the tracks may be sufficient (see Figure 8) (Federal Highway Administration, 2009). The RTA is already considering the use of such signs at various crossings, particularly in high crash areas (Marks & Breun, 2012).

Figure 8: No Left Turn Blank-out Sign (Tassimco Tech)

Transit Signal Prioritization

As seen in numerous cities – Boston, Los Angeles, Zurich, et al - prioritization of transit vehicles at intersections is a common practice. Transit Signal Prioritization (TSP) of rail vehicles at intersections is important because they are locations of the most frequent delays (Vuchic, 2007, p. 369; Hass-Klau & Crampton, 2002). Furthermore, if the LRT vehicle is in the median of roadway, the parallel travel lanes actually see an improvement in traffic movement due to the longer green lights that accommodate the LRT (Chandler & Hoel, 2004).

Near side vs. Far side stopping

Currently on St. Charles Avenue the streetcar stops on the near side of every intersection, meaning it stops before passing through the intersection. This stop placement actually slows down transit service because it adds stop dwell time to the list of factors that may prevent the train from passing through the intersection (Wang, Hallenbeck, Zheng, & Zhang, 2007).

But stop location is more important when transit is given signal prioritization. Dwell time at transit stops depends primarily on the speed of boarding and alighting (Currie, Delbose, & Reynolds, 2011). Naturally the stop dwell time varies from stop to stop and time of day. With near-side stops, this variability in dwell time makes it very difficult to predict TSP and can actually negate much of the benefit gained from TSP (Wang, Hallenbeck, Zheng, & Zhang, 2007). Far-side stopping, however, allows the transit vehicles to pass through the intersection first, before stopping, eliminating the variability of stop dwell time in TSP schemes.

Electronic Fare Cards & Ticketing Kiosks

Ticketing is the largest determinant of dwell time with streetcars and a potential source of delay (Currie, Delbose, & Reynolds, 2011). In New Orleans, ticketing on the street is a major source of delay and the RTA is currently considering a number of options on how to address it (Marks & Breun, 2012). Unlike other forms of rail transit, streetcars do not usually utilize transit stations at stops. Separated station areas makes ticketing prior to boarding easier because access to the station can be limited to those that have purchased a transit ticket. Instead streetcar stops are usually shelters or sidewalk corners similar to those used for bus transit (Vuchic, 2007). This means that ticketing occurs on the vehicle itself instead of before.

In their study of light rail systems throughout the world Hass-Klau and Crampton found that almost city researched employed some type of electronic fare collection to speed the boarding process (Hass-Klau & Crampton, 2002). Ticketing kiosks were also available at busy stops to allow passengers to purchase their transit ticket before boarding. This sped up the boarding process to the point that ticketing related delays were infrequent (Hass-Klau & Crampton, 2002). Some cities even incentivize the use of electronic fare cards by charging lower fares for those who use the cards. Those who use cash pay a higher fare because they slow down the boarding process (Vuchic, 2007; Hass-Klau & Crampton, 2002).

Chapter 3: Methodology

Introduction

This section explains the methodology used to answer the second research question: What is the feasibility of closing vehicle crossings and diverting all turning traffic along St. Charles Avenue to the existing signalized intersections? Furthermore, what effect on vehicular traffic and transit safety can be expected?

Streetcar/Vehicle Crash Analysis

Every time a streetcar collided with a vehicle at a crossing the RTA compiled crash report. Each report contains the date, day of week, time and location of the crash. The data exists as an excel table that simply lists the crashes in order of occurrence. This data was analyzed spatially using GIS software and temporally using statistical methods. The analysis was only applied to study area. Crashes that occurred outside of the study area were ignored because they were beyond the scope of this thesis.

The purpose of this analysis was to better understand safety along the St. Charles Streetcar line. This analysis provided context for potential road closures and provided context for recommendations.

Spatial Analysis

The crash data from the RTA exists in an Excel spreadsheet[3]. This form does not lend itself well to spatial analysis so before any spatial analysis was completed the information was geocoded using ArcGIS. The resulting map was analyzed for clusters of crashes to locate potential hotspots. For the clusters that were found, further on-site analysis was conducted to determine what factors may be contributing to the high number of crashes.

The on-site analysis of crash hotspots looked at a number of factors to determine potential causes for the high rate of crashes.

- *Intersection design and physical characteristics.* What traffic control devices are employed at the intersection? Does this street connect major roadways?

- *Observed traffic flow.* Is this a high traffic or low traffic crossing? Why?

- *Surrounding land uses.* Is the area primarily residential or commercial? Are there nearby land uses affecting traffic flow?

[3] The RTA may have this data in other forms, but this was the manner in which it was released for the purpose of this thesis.

Temporal Analysis

Using the date and time information provided by the RTA, an analysis of temporal trends was completed to determine which days and times had the highest number of crashes and whether or not it is significant. Temporal analysis was also applied to hotspots identified through spatial analysis to determine if crashes in an area were more or less likely at a given time of day or day of week.

Vehicle Crossing Closure Simulation

In the literature review, it was determined that the two primary methods for improving safety at at-grade crossings were to limit the number of crossings and to regulate the allowed crossings with active signalization. The primary variable to be manipulated in this simulation is the number of vehicle crossings along the St. Charles streetcar. For this purpose, it will be assumed that only the intersections along St. Charles Avenue that currently have a traffic signal will allow the crossing of the St. Charles streetcar line by automotive traffic. This includes left turns and U-turns.

The effect of closures of vehicle crossings on traffic movements was modeled using TransCAD. The RPC currently uses TransCAD for its regional traffic models. Because of their regional scope, the RPC traffic model does not include minor streets and roadways, only major and minor arterials and collectors (Roesel, 2012). This means that vehicle crossings along St. Charles Avenue for all those minor streets are not part of the model, but major streets are, hence limiting turning movements. It also means that a majority of the New Orleans street grid is not in the model. The model does not over-estimate the total number of trips to and from each TAZ, but the lack of the complete street grid means that those trips are assigned to an artificially low number of available streets. The result is that traffic counts on the available streets is higher than it would be in real life because the numerous parallel streets that do exist are not available.

Each neighborhood in the region is encoded as a Traffic Analysis Zone (TAZ) within the model. Population and land use characteristics of the neighborhood are coded into a single point, called a centroid. This centroid is connected to the modeled streets via a centroid connector. Using demographic information coded into each centroid the simulation determines how many trips are made to (attracted) and from (generated) each TAZ on the encoded street network. Trips tend to follow the shortest path in the model so a minor collector may actually have more trips assigned to it than a major arterial if the minor collector is the shorter path between two TAZs.

The RPC model also divides trips based on mode choice. Trips to and from a given TAZ are divided up by mode – car and transit – based on the demographic information encoded into the model. Automotive and transit trips are modeled throughout the region. Furthermore, the model does not count trips taken within a particular TAZ, only those taken between different TAZs. The trips within a TAZ are shorter and are more likely to be done by walking or biking. By not counting these short trips, the RPC model does not count pedestrians and cyclists. This is, however, not a problem because the model is designed to be regional in scope and walking and cycling are not modes geared towards short, local trips, not trips across a region.

The model was therefore edited for use in this thesis. The edited model will hence forth be referred to as the "thesis model." Not every street with a signalized intersection on St. Charles Avenue is included in the RPC model. The few missing streets were added to the thesis model. Furthermore, a there were a few minor collector streets included in the model that do not have signalized intersections with St. Charles Avenue. These streets were removed to limit crossings to the signalized intersections.

Table 1: RPC Traffic Model Time Periods

Time Period Name	Hours
AM Peak	6AM to 9AM
Mid-Day	9AM to 4PM
PM Peak	4PM to 7PM
Night Time	7PM to 6AM

The final model output consists of two parts: roadway traffic counts for specific time periods and turning movements at each intersection. The roadway traffic counts are divided into four time periods, pre-determined by the RPC and used in their regular traffic modeling (see Table 1).

In the RPC model, St. Charles Avenue is coded as a pair of parallel one-way streets with the streetcar running between them. This configuration does not affect route selection within the model, but it does create additional intersections because each cross street has an intersection with each of the parallel one-way streets that make up St. Charles Avenue. Therefore, there are two intersection outputs for each actual intersection along St. Charles Avenue. LOS calculations were done by combining paired intersection counts.

Level of Service Calculations

Intersection traffic counts derived from the thesis model will be counts for PM Peak hours, a three hour time period. These traffic counts will have to be converted into hourly counts for the LOS calculations. To achieve this adjustment, the PM Peak counts will simply be divided by three. The LOS calculations will be done using the methodology and worksheets found in the 2000 Highway Capacity Manual (HCM). An output of "Control Delay per Vehicle" will be generated for each intersection in units of seconds of delay per vehicle (Transportation Research Board, 2000, pp. 16-2). Using Table 2, the LOS will be determined. The New Orleans Department of Public Works (DPW) considers a LOS grade of D or better to be acceptable for an intersection (Yrle & Haywood, 2012).

Table 2: Level of Service Criteria for Signalized

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	10-20
C	20-35
D	35-55
E	55-80
F	> 80

Source: Highway Capacity Manual, 2000: P. 16-2

In the RPC model, St. Charles Avenue is coded as a pair of parallel one-way streets with the streetcar running between them. This configuration does not affect route selection within the model, but it does create additional intersections because each cross street has an intersection with each of the parallel one-way streets that make up St. Charles Avenue. Therefore, there are two intersection outputs for each actual intersection along St. Charles Avenue. The turning volume counts used for the LOS calculations were derived by combining paired intersection counts to determine actual turning volumes.

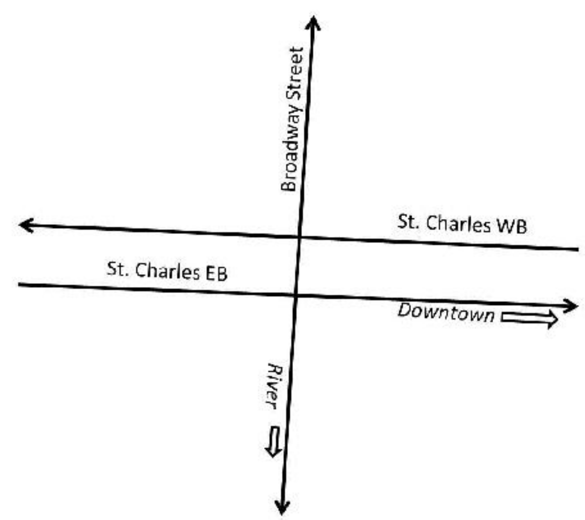

Figure 9: Sample Intersection in Thesis Model

Observations of Traffic Conditions during Track Repairs

When research for this thesis was started the RTA was in the process of replacing track ties along the Carrollton Avenue portion of the St. Charles streetcar line. This was the first phase of a larger project to replace all the track ties along the St. Charles streetcar line (Marks & Breun, 2012). During the first phase of the repair project, many of the at-grade vehicle crossings were closed, forcing drivers to make turns at only select intersections. This is in effect a real world experiment of what this thesis seeks to analyze: the effect of road closures on automotive traffic.

For this step, in person observations of vehicular traffic will be made to determine if the construction induced road closures cause any noticeable change in traffic congestion when compared to pre-construction traffic patterns experienced by the researcher as a consistent user of Carrollton Avenue as a pedestrian, cyclist, driver and transit user. These observations are not scientific in nature and not intended to be. They are intended to provide context for potential changes to vehicle crossings along the St. Charles streetcar line.

Position of Stakeholders

St. Charles Avenue is managed by a number of different agencies, each tasked with operating a different part of the corridor. The operation of the streetcar line and the related infrastructure – tracks, overhead wires and stops – is managed by the RTA; the roadways, vehicle crossings and traffic signals are managed by Department of Public Works; The Regional Planning Commission has a stake because St. Charles Avenue is considered a major arterial roadway that is part of the regions congestion management system, as mandated by federal legislation.

Interviews were conducted with key representatives from each agency to provide context for research topic and to help guide the policy recommendations. Furthermore, the director of the local transit advocacy group, Transport for NOLA, was interviewed to gain an outsider's perspective on issues related to the study area.

Chapter 4: Results & Analysis

Introduction

The results of the methodology from Chapter 3 are presented and analyzed here in Chapter 4. Presentation of the data done through maps and tables and the raw data can be found in full in the appendix. Using first-hand knowledge, on-site observations, stakeholder positions and current literature, the interpretation of these results add meaning and context to the data.

Streetcar/Vehicle Crashes Analysis

In 2011, the St. Charles streetcar was involved in 90 crashes with vehicles on the tracks. Of these crashes, 22 occurred between Lee Circle and Canal Street where the streetcar operates in a shared ROW with traffic, 5 occurred on Carrollton Avenue and one at the Carrollton Garage. These crashes, while significant when regarding safety and delay along the streetcar line, are outside the study area and will therefore be ignored in this analysis. The remaining 62 crashes are analyzed based on location and time to find any patterns and determine any hotspots that may exist. All full map and list of all streetcar/vehicle crashes in 2011 can be found in the appendix.

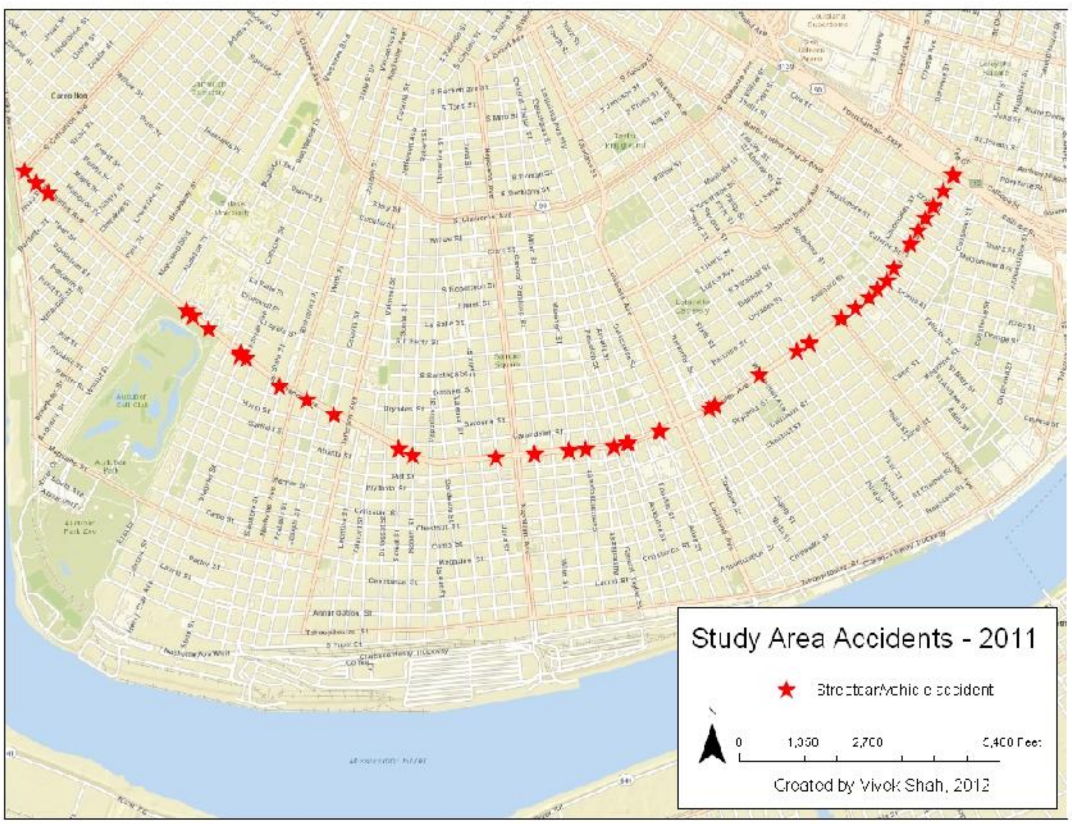

Figure 10: Study Area Crash Map

Spatial Analysis

The streetcar/vehicle crashes along St. Charles Avenue were analyzed spatially, moving from larger to smaller spatial units. The first step was to identify high crash areas and try to understand why crashes were occurring there based land use, roadway conditions and observations of traffic habits. Second, each section is looked at in more detail and high crash crossings are pulled out. The analysis of the crossings looks at many of the same criteria as the larger sections, but with a smaller scope. Land use, roadway conditions, observed traffic patterns and other characteristics are noted.

Table 3: Streetcar crashes by section of St. Charles Avenue

Area	Crashes
Calliope to Jackson	19
Jackson to Louisiana	8
Louisiana to Napoleon	12
Napoleon to Jefferson	4
Jefferson to State	3
State to Broadway	11
Broadway to Fern	5
Total:	62

High Crash Areas

To analyze the spatial distribution of crashes along the St. Charles streetcar line, the study area was first divided into seven sections based on land use and roadway characteristics to identify areas with higher crash rates. After dividing the crashes by section, we find three areas that stand out: Calliope to Jackson, Louisiana to Napoleon and State to Broadway (see Table 3).

Calliope Street to Jackson Avenue

This section of St. Charles Avenue is a major commercial area in the city of New Orleans. Commercial development in this section ranges from suburban style strip mall design to older, historic buildings that are close to the street. St. Charles Avenue has two lanes of traffic in each direction in this section. Based on traffic counts conducted by the RPC this section is the highest traffic area of St. Charles Avenue (NORPC, 2008). Crashes here seem to be the result of high traffic volumes. The dense commercial nature of the land use and the proximity to the Pontchartrain Expressway, which runs above Calliope Street, indicate the potential for a high traffic area. This high level of traffic also means a high number of turning movements over the streetcar tracks. Currently, drivers on St. Charles Avenue are not allowed to make left turns at any signalized intersection except Calliope Street. Instead they must make left turns and U-turns at a number of non-signalized crossings.

Left turns are not permitted at every crossing, but the only indication of this fact is a few “No Left Turn” signs. There is no physical prevention of left turns or active signalization. As a result, crashes have occurred at every signalized intersection in this section: Jackson Avenue, Felicity Street, Martin Luther King Jr. Boulevard and Erato Street.

Jackson Avenue to Louisiana Avenue

As we move towards Uptown New Orleans on St. Charles Avenue from Jackson Avenue towards Louisiana Avenue, the land use becomes more residential although numerous commercial uses can still be found. Like the previous section, this section of St. Charles Avenue has two travel lanes in each direction. There is only one signalized intersection in this section, Washington Avenue. All other crossings are lack signalization. The fact that this section is more residential in character means that most of the day, people are traveling through this section instead of to and from it. This seems to minimize the number of vehicles that cross the streetcar tracks and thus explains the lower crash rate.

Louisiana Avenue to Napoleon Avenue

At the intersection of St. Charles Avenue and Louisiana Avenue there is a concentration of commercial development, extending about one block away from the intersection in each direction. The land use turns to residential as you move down St. Charles Avenue towards Napoleon Avenue. At the intersection of Napoleon Avenue and St. Charles Avenue there is another concentration of commercial development that radiates about one block out from the intersection. This section St. Charles Avenue has only one lane of traffic in each direction.

The main land use feature in this section is Touro Hospital, which is near the intersection of Louisiana Avenue and St. Charles Avenue. The hospital and the surrounding medical buildings create more traffic in the area that just residential land use would. But the hospital is not directly on St. Charles, but is instead a block away Prytania Street. It is also a block away from Louisiana Avenue. This means neither St. Charles Avenue nor Louisiana Avenue, the major roadways in the area, offer direct access to the hospital complex. Instead, people driving to the hospital must turn onto a smaller street to reach their destination. This increases the volume of turning movements at vehicle crossings over the streetcar tracks and therefore increases the potential for an crash.

Napoleon Avenue to Jefferson Avenue

This portion of St. Charles Avenue has only one travel lane in each direction and the surrounding land use is of a lower density than the previous sections. Aside from a few schools, the surrounding land use is almost entirely single family residential. This means the traffic demands for this stretch of St. Charles Avenue are relatively light except for morning rush and evening rush hour when people are going to or coming from work. Therefore there have been very few crashes in this stretch.

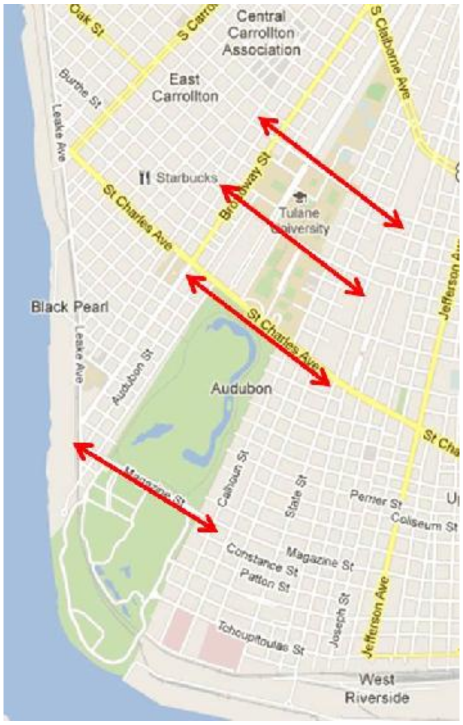

Figure 11: Four streets available to cross the universities and the park.

Jefferson Avenue to State Street

Like the section between Napoleon Avenue and Jefferson Avenue, this section is primarily single family residential housing with a few schools. St. Charles Avenue has only one travel lane in each direction and there are no signalized crossings in this section. The low intensity land use surrounding this section leads to lower traffic volumes along St. Charles Avenue and fewer turning movement across the streetcar tracks, resulting in fewer crashes.

State Street to Broadway Street

Between State Street and Broadway Streets are two universities, Tulane and Loyola, and Audubon Park. The rest of the section is primarily residential. Audubon Park and Tulane University, in particular, break up the dense street grid of the area and greatly reduce the number of roads that can be taken traveling east and west. Where there would normally be 15 parallel streets that can be used, there are instead four: Magazine Street, Freret Street, Willow Street and St. Charles Avenue (see Figure 11). The effect on traffic flow is the funneling of thru-traffic to the four available roadways. This greatly increases traffic along this section of St. Charles Avenue.

Tulane and Loyola Universities also have a number of vehicle entrances on St. Charles Avenue. Drivers entering and exiting the campuses often turn left over the streetcar tracks to do so. This increased level of traffic coupled with the increased a concentration of turning movements, increases the potential for streetcar/vehicle interaction and therefore, crashes.

High Crash Intersections

There are a few specific intersections along St. Charles Avenue with a high number of crashes. Henry Clay Avenue, Delachaise Street, Calliope St and the Audubon Park Entrance each have a significantly high number of crashes (see Table 4). Beyond those four crossings, there were 10 different intersections with two crashes each and 26 with only one crash each.

Table 4: Streets with the most streetcar/vehicle crashes

Cross Street	# of crashes in 2011
Henry Clay Avenue	5
Audubon Park Entrance	4
Calliope Street	4
Delachaise Street	3

Henry Clay Avenue and Audubon Park Entrance

Henry Clay Avenue and the Audubon Park Entrance are both located between State Street and Broadway Street, where Audubon Park, Tulane and Loyola Universities funnel traffic to St. Charles Avenue by preventing travel on parallel streets. Together they account for 9 of the 11 crashes that occurred in this section.

Henry Clay Avenue runs parallel to Audubon Park and is considered a minor collector street by the RPC. It serves as an important connection between St. Charles Avenue and Magazine Street. Henry Clay Avenue intersects with St. Charles Avenue in a T section meaning all traffic that crosses the streetcar tracks is turning left. This means that drivers turning left from either direction of St. Charles Avenue at Henry Clay Avenue are turning when the streetcar is potentially in their blind spot. It is difficult to tell which traffic movements create the most potential for crashes. However, standing at the stop line on Henry Clay Avenue, one can see the streetcar tracks and about one block in either direction on St. Charles Avenue making it unlikely that a driver turning left from Henry Clay Avenue onto St. Charles Avenue is going to turn in front of an approaching streetcar.

The Audubon Park Entrance is not a street or vehicle entrance to Audubon Park, but the name used for the streetcar vehicle crossing in front of the main entrance to the park and Tulane University. This crossing is used entirely as a turn-around for drivers traveling in both directions on St. Charles. No entrance into Audubon Park or Tulane can be accessed. Based on observations of traffic patterns, the crossing seems to be used mostly by people traveling to and from Tulane and Loyola Universities. The crossing seems to be used by people making U-turns before entering or after leaving either university and by people seemingly circling while looking for street side parking on St. Charles Avenue.

Delachaise Street

Delachaise Street is parallel to Louisiana Avenue and one block uptown from the intersection with St. Charles Avenue. There are no permitted left turns at the intersection of St. Charles Avenue and Louisiana Avenue so drivers on St. Charles Avenue who do want to make a left onto Louisiana Avenue must instead drive through the intersection, make a U-turn, come back to the intersection and make a right. This is commonly referred to as a New Orleans Left. For people driving west on St. Charles who want to turn left onto Louisiana Avenue, Delachaise Street is the first opportunity to make a U-turn, resulting in a number of turning movements across the streetcar tracks on St. Charles Avenue.

Secondly, Delachaise Street also leads to the main entrance of Touro Hospital, making it an important connection from St. Charles Avenue. The hospital is a major traffic generator and the use of Delachaise Street to access is surely increases turning volume on that crossing.

Calliope Street

Calliope Street is a unique case. It is the only signalized intersection within the study area that permits left turns. Its location under the Pontchartrain Expressway means it is a street with numerous on and off ramps to the expressway and the Crescent City Connection Bridge and therefore experiences heavy traffic because people use it to get on and off the expressway. However, this permitted left requires the driver to cross over the streetcar tracks as they pass under the expressway. This constant mixing of streetcar and automotive traffic in the left turn lane is the reason there are so many crashes at the intersection (Marks & Breun, 2012).

In years previous to 2011, Calliope Street was the location of far more crashes because while the intersection had a dedicated left turn signal, there was no additional signalization to inform drivers of an approaching streetcar. As a result, drivers would commonly try to make a left even after the left turn signal has gone (Marks & Breun, 2012). To solve this problem, the RTA installed a streetcar signal to indicate to drivers when a streetcar would be passing through and to indicate to the streetcar operator when they should go through the intersection. Even though Calliope Street had the second most crashes of any intersection in 2011, it has experienced a significant decrease since the installation of a separate streetcar signal which serves as evidence of the effectiveness of active signalization for controlling automotive traffic (Marks & Breun, 2012).

Temporal Analysis

The RTA has in each crash record the time of the crash and the day of the week. This analysis is intended to help understand the temporal patterns of streetcar/vehicle crashes by breaking down the crashes by time of day and day of week.

Table 5: Streetcar Crashes by Time Period

Time Period	Crash Total
AM Peak (6am-9am)	8
Midday (9am-4pm)	31
PM Peak (4pm-7pm)	13
Night Time (7pm-6am)	10
Total	62

The RPC travel demand model separates trips based on the time of day. AM Peak, Midday, PM Peak and Night Time are the four categories used. The streetcar crashes from 2011 were categorized in the same way (see Table 5). Based on this breakdown, we can see that half of all crashes happened during the midday hours. Slightly more crashes occurred during PM Peak hours than in the AM or night time hours, but not enough to be significant.

Exactly half of all crashes happened during midday, between 9AM and 4PM. AM and PM peak times have higher traffic volumes, and hence more turning movements across the tracks, but they each have significantly fewer crashes.

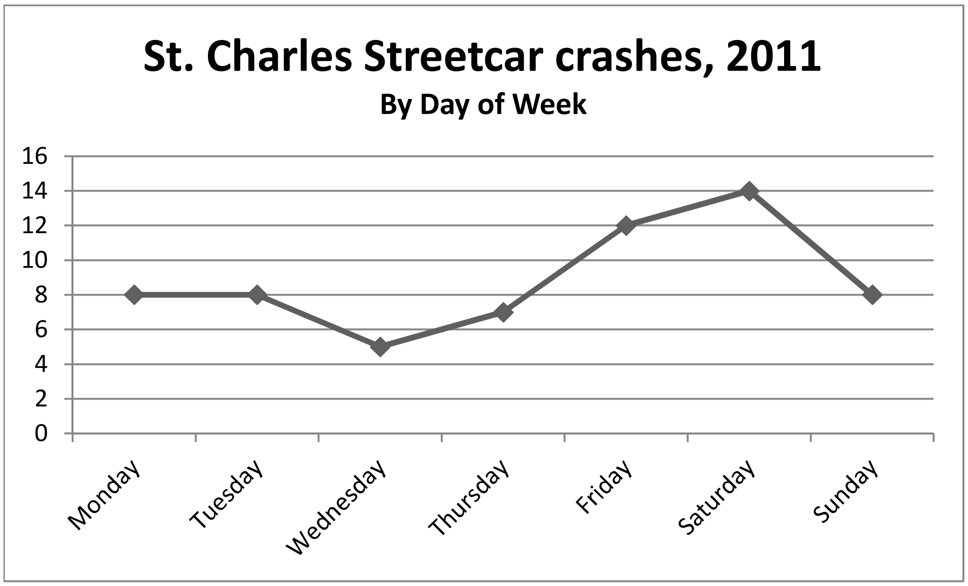

Figure 12: Streetcar Crashes by Day of Week - 2011

In terms of days of the week, more crashes occurred on Friday and Saturday, with 12 and 14 respectively, than any other day of the week (see Figure 12).

Table 6: Friday & Saturday Crashes by Time Period

Friday Crash Breakdown	
AM Peak (6am-9am)	1
Midday (9am-4pm)	8
PM Peak (4pm-7pm)	2
Night Time (7pm-6am)	1
Total	12

Saturday Crash Breakdown	
AM Peak (6am-9am)	1
Midday (9am-4pm)	5
PM Peak (4pm-7pm)	4
Night Time (7pm-6am)	4
Total	14

On Friday, a clear majority the crashes occurred during midday (see Table 6). On Saturday, however, no time period stands out with more crashes. Instead, the crashes are fairly evenly distributed between Midday, PM Peak and Night Time. But since it is Saturday, time periods designed to account for travel to and from work do not explain encompass non-work day travel.

Vehicle Closure Simulation & Level of Service Calculations

After running the thesis model, traffic counts for each intersection were recorded. PM Peak volumes were used because they represented the highest hourly traffic flow. Because St. Charles Avenue is coded in the model as a pair of parallel, one-way streets with the streetcar in the middle, each cross street has two intersections with St. Charles Avenue

Table 7: Level of Service for Signalized Intersections along St. Charles Ave

Intersection Cross Street	Avg Delay(s/veh)	Level of Service
Broadway Street	114	F
State Street	964	F
Nashville Avenue	751	F
Jefferson Avenue	299	F
Napoleon Avenue	202	F
Louisiana Avenue	279	F
Washington Avenue	325	F
Jackson Avenue	200	F
Felicity Street	111	F
MLK Blvd/Melpomene Street	103	F
Erato Street	169	F
Calliope Street	64	E

The resulting traffic counts and turning movement counts were used to calculate the LOS for each intersection. As can be seen in Table 7, every intersection along St. Charles Avenue received a LOS grade of E or F, with some intersections like Nashville Avenue and State Street experiencing very high delays.

At first, this result was viewed as a failure of the simulated closure scheme. Because the RPC model does not include a vast majority of the New Orleans street grid, trips that may actually occur on local streets are instead diverted to a few major roadways. The lack of street grid results in very large traffic counts at intersections, probably much larger than what can be reasonably expected. The traffic counts from the unedited RPC model are actually very similar to those in the thesis model, indicating that a LOS calculation of intersections in the original model would yield similar results and all the intersections would receive a failing grade.

Therefore, it is actually more useful to compare the thesis model results to the RPC model to see what percent increase in traffic can be expected. For most of the intersections, St. Charles Avenue actually saw a reduction in PM Peak traffic volume (see Table 8). Felicity Street and Erato Street, which were not in the RPC model, actually reduced the traffic burden on MLK Blvd/Melpomene Street.

Table 8: PM Peak (4-7pm) Hourly Average Traffic Counts for St. Charles Ave east and west bound approaches.

Intersection Cross Street	RPC Model - St. Charles		Thesis Model - St. Charles		% Change	
	EB	WB	EB	WB	EB	WB
Broadway Street	425	533	475	770	11.92%	44.28%
State Street	-	-	684	1010	-	-
Nashville Avenue	493	596	987	726	100.07%	21.87%
Jefferson Avenue	606	557	683	586	12.64%	5.14%
Napoleon Avenue	638	785	536	840	-15.99%	7.00%
Louisiana Avenue	700	1028	653	1102	-6.66%	7.19%
Washington Avenue	894	1072	850	1169	-4.88%	9.01%
Jackson Avenue	880	1364	858	1484	-2.54%	8.79%
Felicity Street	-	-	859	1347	-	-
MLK Blvd/Melpomene	772	1642	740	1342	-4.14%	-18.27%
Erato Street	-	-	729	1696	-	-
Calliope Street	793	1178	818	1203	3.07%	2.15%

The addition of State Street is an interesting situation. In the RPC model, State Street does not exist, but in its approximate location is a centroid connector that goes from St. Charles Avenue, to a TAZ centroid, to Magazine Street. The connectors do not go north of St. Charles Avenue. In the thesis model, these centroid connectors were recoded as State Street and extended north past St. Charles Avenue to Freret Street and Willow Street. This turned State Street into a direct connection between two TAZ centroids. In the RPC model, traffic was moving from a TAZ centroid to Nashville Avenue via Willow and Freret Street. From there it was going straight south on Nashville to St. Charles Avenue, Magazine Street and Tchoupitoulas Street. With the addition of State Street, much of that traffic was instead going down State Street, turning left onto St. Charles Avenue and then turning right onto Nashville Avenue because this was now the route of shortest distance for many trips. The result is a significant spike in traffic at the Nashville Avenue intersection, particularly for the east bound portion of St. Charles Avenue.

Observations of Traffic Flow during Track Repairs

The first phase of the RTA's track-tie replacement project started in the spring of 2012 on the Carrollton Avenue portion of the streetcar line. During this phase of repairs, construction crews were closing crossings as they worked on them. For a week, from April 15th to April 20th, all but three crossings between Oak Street and Claiborne Avenue were closed, with the only open crossings being Willow Street, Hickory Street and Sycamore Street (see Figure 13).

Vehicles used the crossings accordingly and traffic never appeared to become a problem. Observations of traffic flow were made every morning between 8 and 9am and every evening between 5:30 and 6:30pm during the week of April 15th to record the effect of the closures on peak hour traffic. At no point during the week did traffic appear to back up. All intersections remained clear and traffic seemed to move smoothly through the three open crossings. It is important to note that the streetcars were not running on the tracks during this time, so drivers did not have to worry about approaching trains when turning across the tracks.

Figure 13: Open & Closed Crossings during Phase 1 Track-Tie Project

Conclusion

The St. Charles streetcar line has a very high streetcar/automobile crash rate. Even though there are a few areas and intersections that can be considered hot stops, the crashes are fairly well distributed along the corridor (see Figure 10). Every crossing along the streetcar line is a place with the potential for a crash and almost all the crossings in the study area were the site of a streetcar/automobile crash in 2011.

Despite the clear safety issue presented by all the crossings, they still serve an important function regarding traffic flow throughout the St. Charles Avenue corridor (Yrle & Haywood, 2012). The traffic model run for this thesis showed that closing all crossings within the study area except those with traffic signals, creates only a 7-8% increase in traffic at each signalized intersection. Based on these modeling results, the closure of many of the vehicle crossings along St. Charles Avenue is possible and that it would not adversely affect traffic flow in the corridor.

Beyond the model results, the closure of vehicle crossings on Carrollton Avenue had little visible effect on traffic flow during the construction period. Based on these observations, it can be concluded that the permanent closure of the crossings is not likely to negatively impact traffic flow through and around the Carrollton Avenue corridor. These observations provide reason to believe that the closure of numerous vehicle crossings along the rest of the St. Charles streetcar line could also be done without upsetting traffic flow. At the very least, portions of the line that have traffic patterns similar to the observed section of Carrollton Avenue could see numerous crossings closed.

The methodology described in Chapter 3 of this thesis sought to answer research question number two: What is the feasibility of closing vehicle crossings and diverting all turning traffic along St. Charles Avenue to the existing signalized intersections? Based on the results of that methodology, it can be determined that the closure of vehicle crossings is a feasible endeavor, at least from a traffic management perspective. Furthermore, the observed traffic flow along Carrollton Avenue during the track-tie replacement project provide a real-world test of whether it is feasible to close vehicle crossings along St. Charles streetcar line.

Chapter 5: Conclusion & Policy Implications

Current State of St. Charles Streetcar Line

The St. Charles streetcar line connects numerous neighborhoods in New Orleans. It starts Uptown on Carrollton Avenue and continues along St. Charles Avenue through the Central Business District and to Canal Street and the edge of the French Quarter. In total, about 65,000 people live within a ½ mile walking distance, making it a very important transit line (US Census Bureau, 2010). The St. Charles streetcar is usually billed as line mostly for tourists, but a majority of its riders are actually locals, not out-of-towners ((Marks & Breun, 2012). Between Claiborne Avenue and Lee Circle the streetcar line operates in a dedicated ROW in the median of Carrollton and St. Charles Avenues.

Despite this dedicated ROW, the St. Charles streetcar has a very high crash rate with personal vehicles. This is due to the large number of unregulated crossings along the tracks. Every block along the line there is an opportunity for drivers to cross over the streetcar tracks, thus increasing the risk of crashes. In 2011, there were 90 streetcar/vehicle collisions, 62 of which occurred in the thesis study area where the streetcar operates in a dedicated ROW.

Not only do the numerous vehicle crossings pose a serious safety risk to streetcar users and drivers alike, it is a significant source of delay for the streetcar line. Every block is a place where a vehicle standing on the tracks may force a streetcar to stop and wait instead of being able to continue down the line. The frequency of vehicle crossings can actually be considered to negate much of the benefit of operating in a dedicated ROW, separated from traffic.

Closure of Vehicle Crossings

Based on existing literature and urban examples, it is best practice to allow the crossing of light rail tracks by turning traffic only at intersections with some form of active signalization. This has been considered a best practice for so long, however, that no other American city had to deal with the problem of vehicle crossings without active signalization like New Orleans does. Each city that was researched built their crossings with active signalization in the beginning, hence never had the need reassess crossing safety issues.

The only intersection that meets the best practice criterion along the St. Charles line is Calliope Street. It is the only street in which turning traffic is provided a separate signal to indicate when it is safe to turn and cross over the tracks. All other signalized intersections in the study area do not allow left turns, so drivers instead travel past the traffic light and make a U-turn at the next available cross street, one without any sort of active signalization.

Through the crossing closure simulation and the LOS calculations, it was determined that a redirection of all turning traffic to existing signalized intersections and the addition of left turn signals at those intersections would result in approximately a 7-8% increase in traffic at the signalized intersections within the study area during peak hours. Some intersections, like MLK Blvd, would experience a significant reduction in automotive traffic because of the diversion of traffic to Felicity Street and Erato Street, two streets parallel to MLK Blvd that would allow left turns.

But improvements in streetcar safety and performance can be had without forcing all turning movements to current signalized intersections. In Boston, the MBTA allows a vehicle crossing over the tracks of the Green Line approximately every 1000 feet. In New Orleans, that would be every three to four blocks. This crossing scheme, if applied to New Orleans would result in the closure of 66-75% of current vehicle crossings. The remaining crossing can then be improved with some form of active signalization (see Figure 8) that informs drivers of an approaching streetcar so they don't continue over the tracks. The number of crossings would be reduced, and with it the number of potential crash points, but there would be more places to cross that simply at major intersections so traffic impacts would likely be minimal.

Further improvements can be made by employing tactics used in other cities. TSP can reduce streetcar dwell time at traffic signals by giving the streetcar priority. It can also improve traffic flow on St. Charles Avenue because drivers would benefit from the longer green lights given to the streetcar. Far-side stopping at signalized intersections can greatly improve the benefits from TSP by allowing the streetcar to pass through the intersection before stopping instead of stopping on the near-side of the intersection and missing a green light due to boarding passengers. Electronic fare cards and ticket kiosks can speed the boarding process and improve streetcar performance by reducing dwell time at stops due to the boarding process. For New Orleans residents, the electronic card would make sense and the ticket kiosks would allow tourists to board quickly instead of fumbling for change while the streetcar waits.

Policy Implications

In order to adequately address safety issues with the St. Charles streetcar line and the vehicle crossings therein, an important policy shift must take place. Currently, the primary focus of the Department of Public Works (DPW) is automotive traffic (Yrle & Haywood, 2012). Therefore the improvement of safety along the St. Charles streetcar line is certainly important, but the department seems reluctant to consider any measure that impedes automotive travel. In order to address safety issues at vehicle crossings, the impeding of automotive traffic must be seriously considered. It is because drivers are not impeded when crossing the streetcar tracks that crashes occur frequently.

Beyond the operational aspects of the St. Charles streetcar and the corridor as a whole, historic preservation is an issue to be dealt with. The entirety of St. Charles Avenue is a National Historic Landmark, designated as such in 1974, to be preserved in its 1922 state (RTA, 2012). Being on the historic registry means that any changes to the avenue must not alter the character of the corridor. On these grounds, the historic preservation community in New Orleans has at times opposed measures to improve the safety and service of the streetcar line (Marks & Breun, 2012). It is therefore reasonable to think that the same community would oppose a change to St. Charles Avenue as drastic as the closure of vehicle crossings. However, the safety issues surround vehicle crossings are not something that can be just ignored. What does it mean to preserve the historic character of an area and how will the city balance that goal with the goals of safety and transit service and accessibility?

Future Research

The results of this thesis provide a look into the potential for the closing of vehicle crossings along St. Charles Avenue to improve the safety and performance of the St. Charles streetcar. This is in no way a definitive study and more research would be needed to enact some of the recommendations properly. The following future research should be conducted to better understand the St. Charles Avenue corridor.

Comprehensive Traffic Study and Micro-simulation

The traffic model used for this thesis was based on the RPC's regional travel demand model. The RPC model is a macro simulation designed to model travel patterns for the entire Greater New Orleans region. To better understand the effects of closing vehicle crossings along St. Charles Avenue, a micro-simulation would have to be conducted. A micro-simulation would better model traffic patterns at select intersections and crossings by applying a narrower focus to the corridor and taking into account all modes of travel. A micro-simulation would also take into account trips done within TAZs and not just ones between them.

However, in order to conduct a proper micro-simulation, detailed traffic data must be available. Data regarding traffic hourly traffic volumes and turning movements at each intersection would be needed. Since this data does not currently exist a comprehensive traffic study would need to be conducted to so that the micro-simulation can be as robust as possible. Such a traffic study would have to collect hourly traffic counts throughout the corridor as well as turning movements at each intersection. Such information would have to be collected for all modes of transportation: pedestrians, cyclists, transit, automobiles and freight.

Real World Experimentation with the Closing of Vehicle Crossings

Beyond simulations and models, a real-world experiment can also be conducted. Mimicking the closure of vehicle crossings that occurred as part of the track-tie replacement project, the city can close a number of crossings with barricades to see the effect on vehicular traffic and streetcar safety and performance. Such an experiment can be employed on just a specific stretch, between Jefferson and Napoleon Avenues for example, or for the entire corridor. If traffic congestion increases beyond acceptable levels in any section, the barricades can simply be removed to allow turning movements again. Such an experiment can also be used to determine which crossings should be left open. The placement of open crossings is very important and should be optimized to best correlate to neighborhood travel patterns.

Conclusion

This thesis discusses the option of closing vehicle crossing to improve the safety and performance of the St. Charles streetcar line. The data gathered indicates that many vehicle crossings along the St. Charles streetcar line are not necessary and can in fact be closed. The streetcar line has been a major source of crashes for many years and new options must be considered to address the problem. There is no guarantee that the closure of many crossings and installation of signals at the remaining crossings will increase safety or improve performance for the streetcar line. Enough crossings must remain open to maintain good traffic flow and appropriate signals must be used at these crossings to ensure driver recognition of and compliance with the new system.

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Appendix

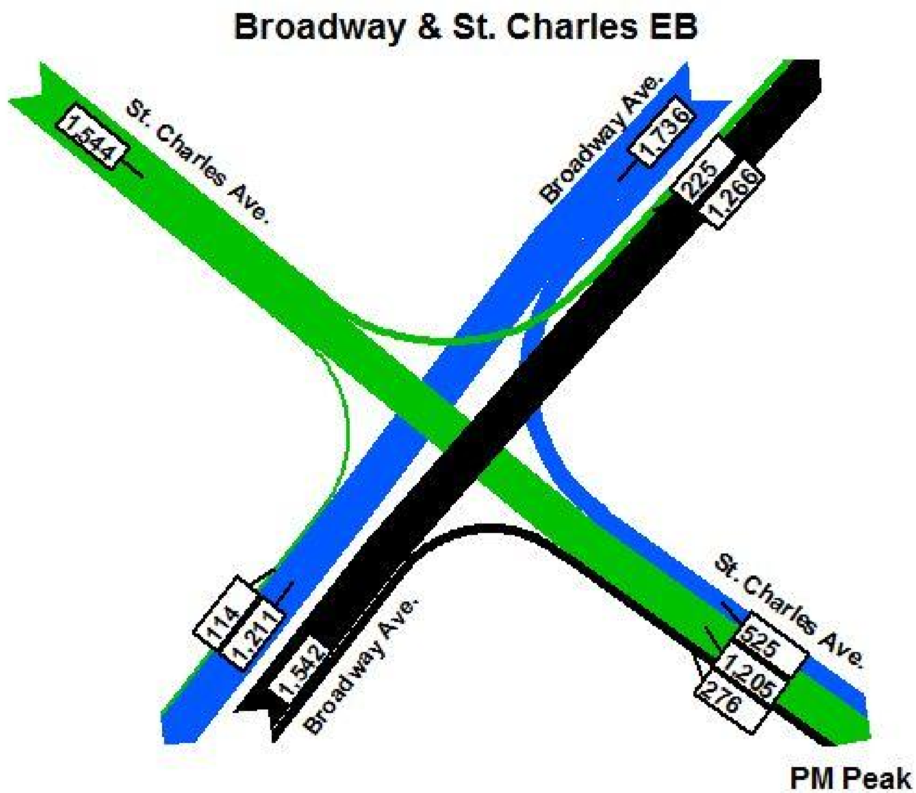
Streetcar/Vehicle Crash Data - 2011

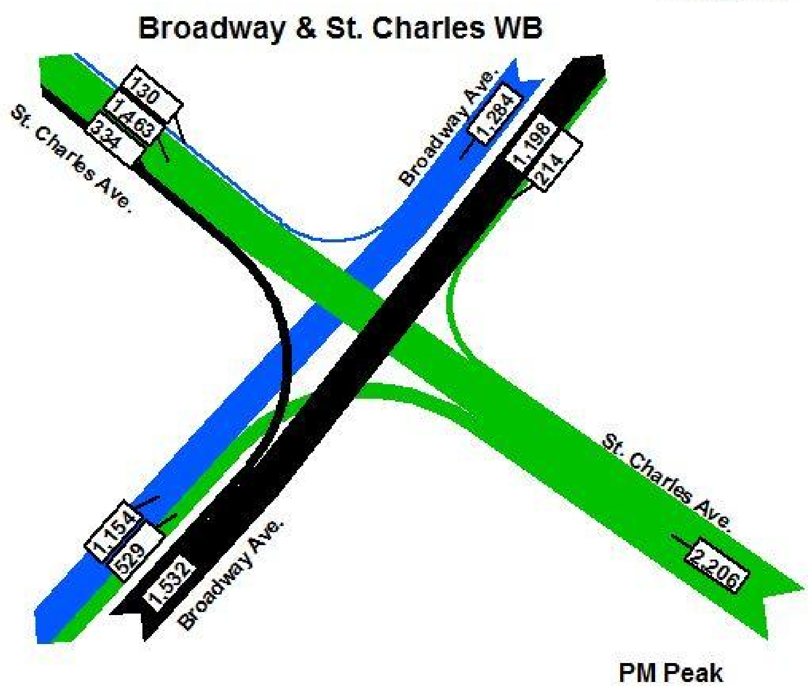
Date	Day	Time	Location
1/4/2011	Tues	7:25	ST CHARLES & SHORT
1/11/2011	Tues	8:47	ST CHARLES & ELENORE
1/21/2011	FRI	8:34	CARROLLTON & ST CHARLES
1/22/2011	SAT	12:24	ST CHARLES & HENRY CLAY
1/26/2011	WED	20:22	ST CHARLES & JOSEPHINE
1/28/2011	FRI	13:15	ST CHARLES & CALLIAPE
2/1/2011	TUES	19:43	ST CHARLES & JACKSON
2/8/2011	TUES	10:13	ST CHARLES & MELPOMENE
2/12/2011	SAT	16:59	ST CHARLES & FERN
2/17/2011	THUR	23:40	S CARROLLTON & HAMPSON
3/3/2011	THURS	8:27	ST CHARLES & HARMONY
3/14/2011	MON	19:36	ST CHARLES & EXPOSITION
3/16/2011	WED	11:05	ST CHARLES & ARABELLA
3/20/2011	SUN	10:43	ST CHARLES & FIRST
4/1/2011	FRI	0:00	CARROLLTON & BURTHE
4/3/2011	SUN	14:40	ST CHARLES & FELICITY
4/8/2011	FRI	12:40	ST CHARLES & AUDUBON
4/9/2011	SAT	18:08	ST CHARLES & WASHINGTON
4/16/2011	SAT	16:41	ST CHARLES & CONSTANTINOPLE
4/25/2011	MON	13:59	ST CHARLES & CALLIOPE
4/27/2011	MON	8:40	ST CHARLES & AUDUBON
5/7/2011	SAT	0:05	ST CHARLES & DELACHAISE
5/14/2011	SAT	15:39	ST CHARLES & CALLIOPE
5/15/2011	SUN	11:47	ST CHARLES & HENRY CLAY
5/16/2011	MON	14:00	ST CHARLES & CLIO
5/16/2011	MON	17:31	ST CHARLES & ERATO
5/22/2011	SUN	7:18	CARROLLTON & BURTHE
5/27/2011	FRI	12:19	ST CHARRLES & ST MARY
5/28/2011	SAT	12:25	ST CHARLES & HENRY CLAY
6/2/2011	THURS	14:32	ST CHARLES & SONIAT
6/7/2011	TUES	13:54	ST CHARLES & ERATO
6/24/2011	FRI	16:15	ST. CHARLES & TERPSICHORE
6/24/2011	FRI	21:25	ST.CHARLES & JACKSON
6/25/2011	SAT	12:50	ST. CHARLES & OCTAVIA
7/12/2011	TUES	15:04	ST CHARLES & SECOND STREET
7/16/2011	SAT	18:45	ST CHARLES & EXPEDITION

7/23/2011	SUN	23:30	ST CHARLES & SHORT
7/26/2011	TUES	16:31	ST CHARLES & PLUM
7/30/2011	SAT	0:53	ST CHARLES & GEN PERSHING
7/30/2011	SAT	17:30	ST CHARLES & FERN
8/2/2011	TUES	17:10	ST CHARLES & TERPSICHORE
8/12/2011	FRI	12:20	ST CHARLES & PENISTON
8/17/2011	WED	14:08	ST CHARLES & SECOND
8/27/2011	SAT	20:26	ST CHARLES & GEN PERSHING
8/29/2011	MON	15:27	ST CHARLES & ANTONINE
9/1/2011	THURS	12:31	ST CHARLES & DELACHAISE
9/1/2011	THURS	13:10	ST CHARLES & SONIAT
9/2/2011	FRI	12:23	ST CHARLES & EIGHT
10/5/2011	WED	17:10	ST CHARLES & HENRY CLAY
10/27/2011	THURS	16:18	ST CHARLES & EIGHT
10/28/2011	FRI	16:15	ST CHARLES & FIRST
10/29/2011	SAT	14:50	ST CHARLES & ST ANDREW
10/30/2011	SUN	14:25	ST CHARLES & THALIA
11/3/2011	THUR	11:19	ST CHARLES & AUDUBON
11/11/2011	FRI	11:25	ST CHARLES & ROBERT
11/13/2011	SUN	19:40	AT CHARLES & JENA
11/17/2011	THUR	10:29	ST CARLES & FELICITY
11/18/2011	FRI	13:50	ST CHARLES & HENRY CLAY
11/20/2011	SUN	17:40	ST CHARLES & PALMER
12/2/2011	FRI	14:00	ST CHARLES & MORENGO
12/8/2011	MON	19:30	ST CHARLES & MARENGO
12/10/2011	SAT	21:30	ST CHARLES & AMELIA
12/13/2011	TUES	19:22	ST CHARLES & PENISTON
12/15/2011	MON	7:40	ST CHARLES & CALLIOPE
12/17/2011	SAT	8:51	ST CHARLES & AUDUBON
12/25/2011	SUN	13:30	ST CHARLES & POLYMNIA

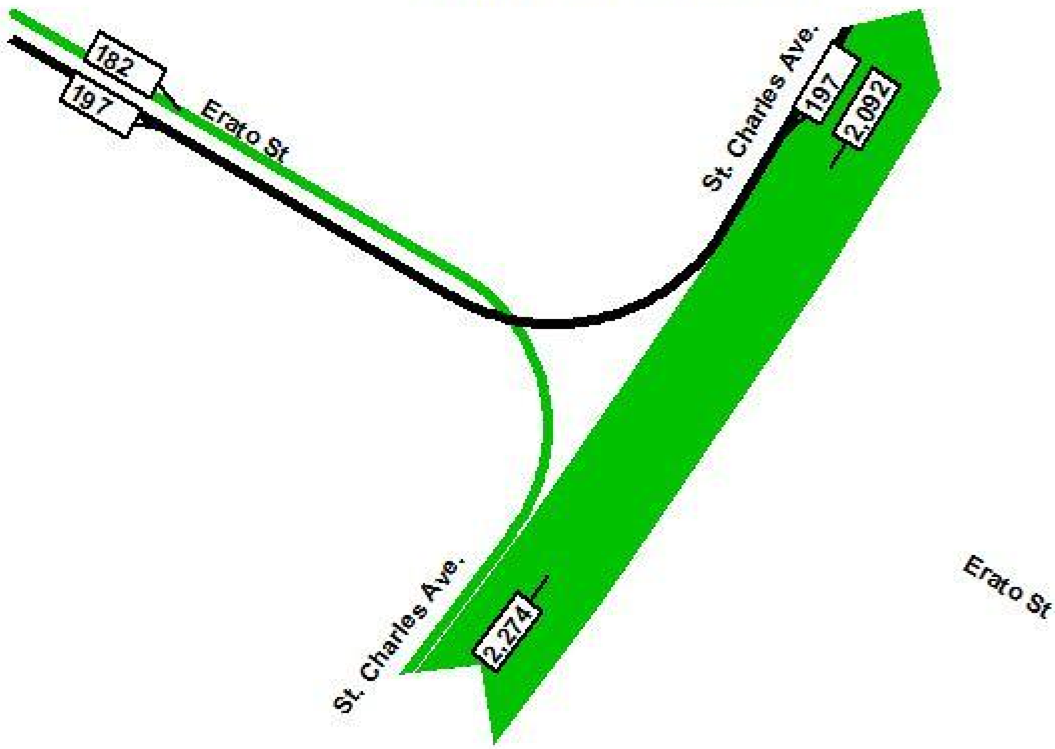
TransCAD Model Intersection Turning Movements

Vehicle counts for each intersection are based on the PM Peak, a three hour time period spanning form 4PM to 7PM. For the level of service calculations, all turning volumes for each approach and direction were divided by three to determine the average hourly traffic flow during the PM Peak.



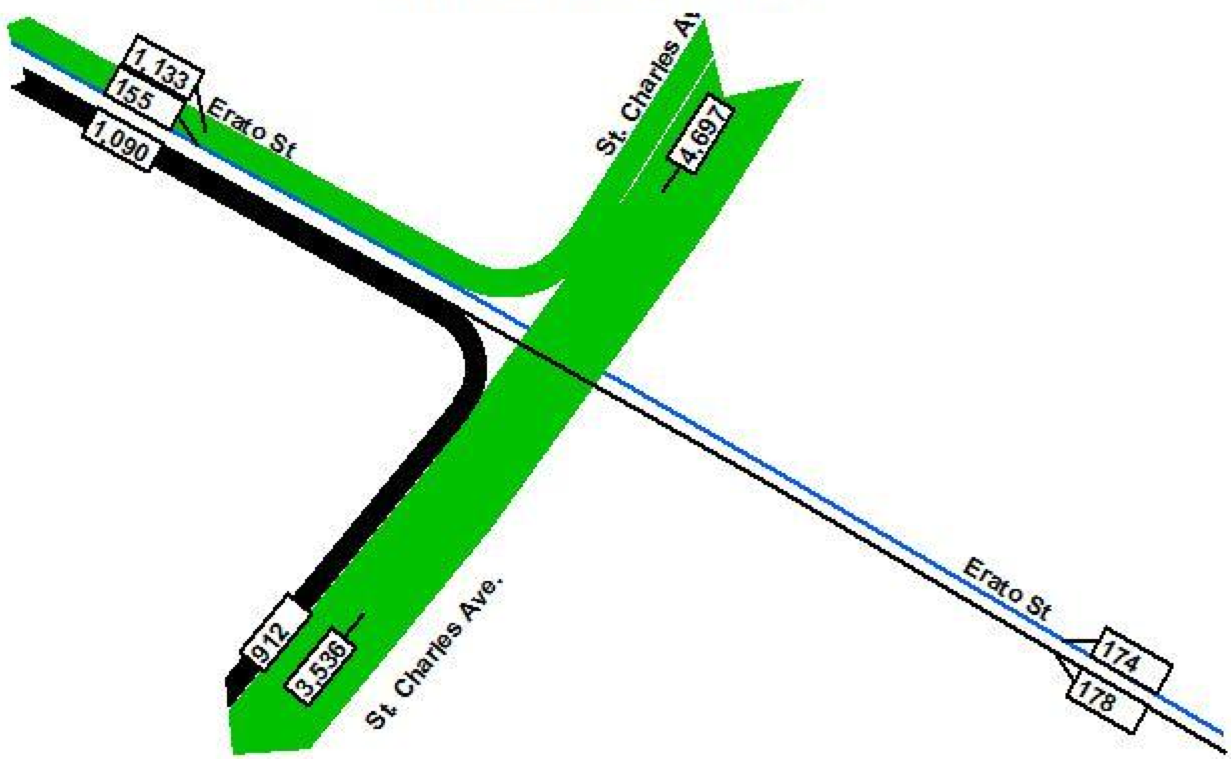


Erato & St. Charles EB



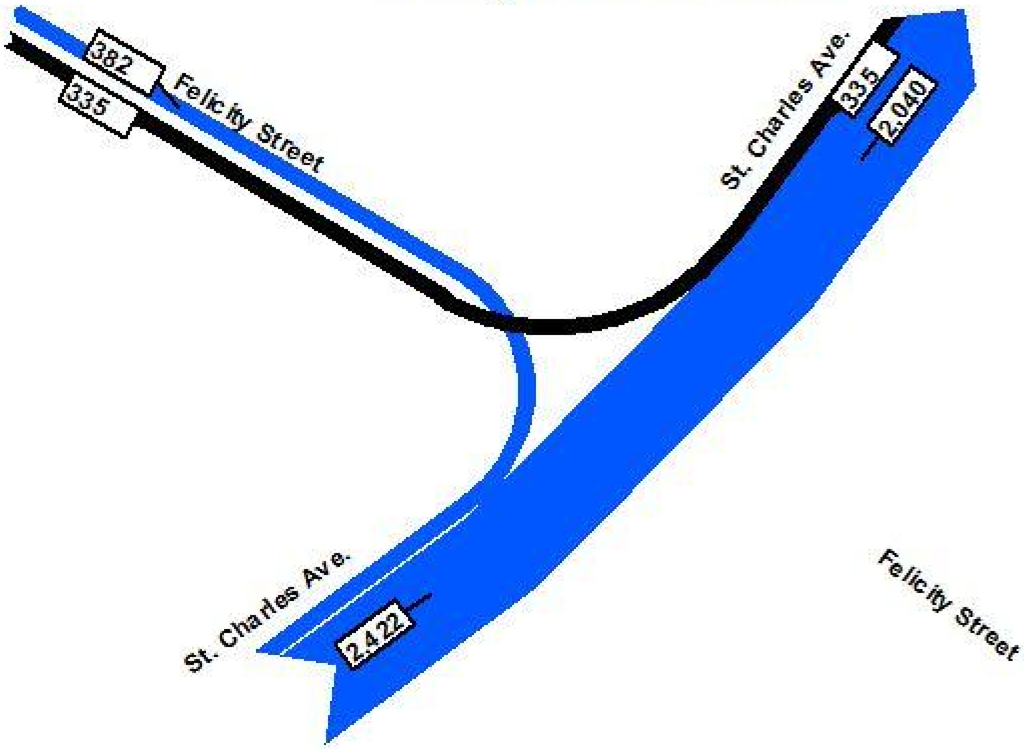
PM Peak

Erato & St. Charles WB



PM Peak

Felicity & St. Charles EB



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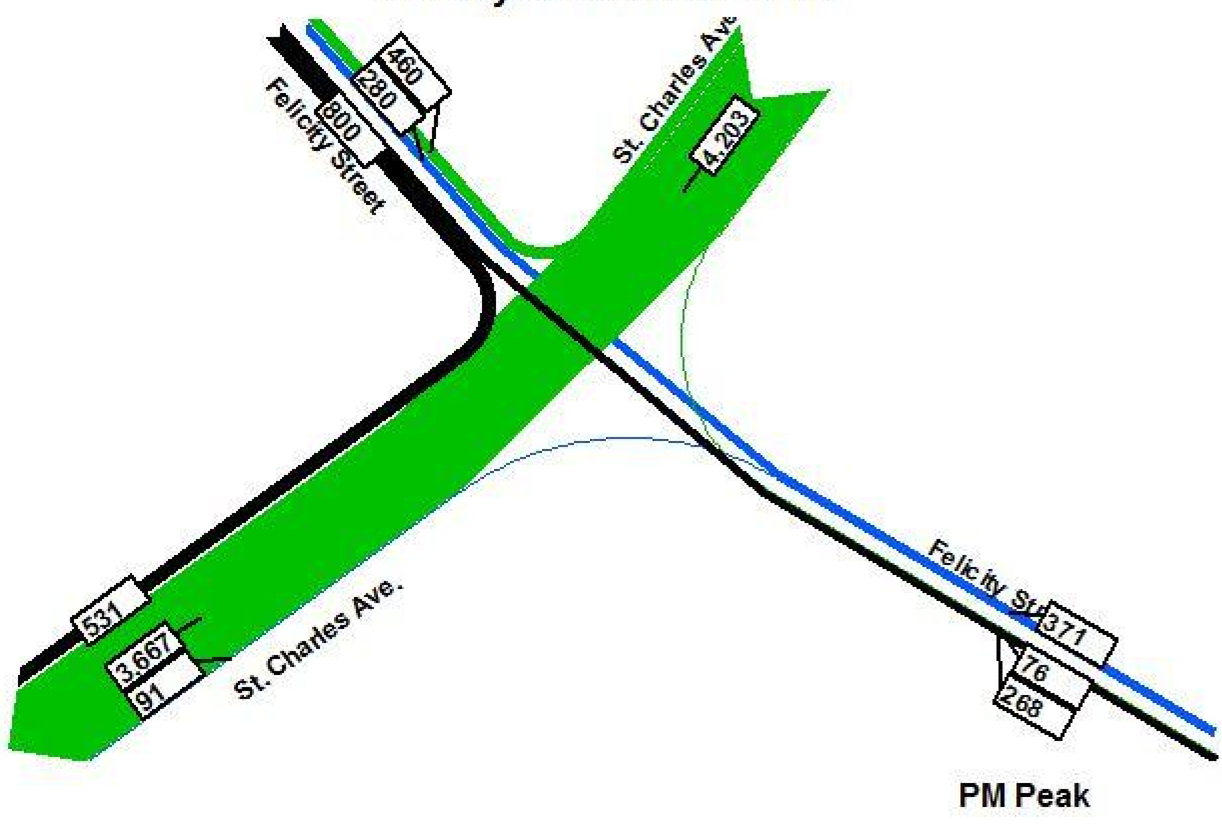
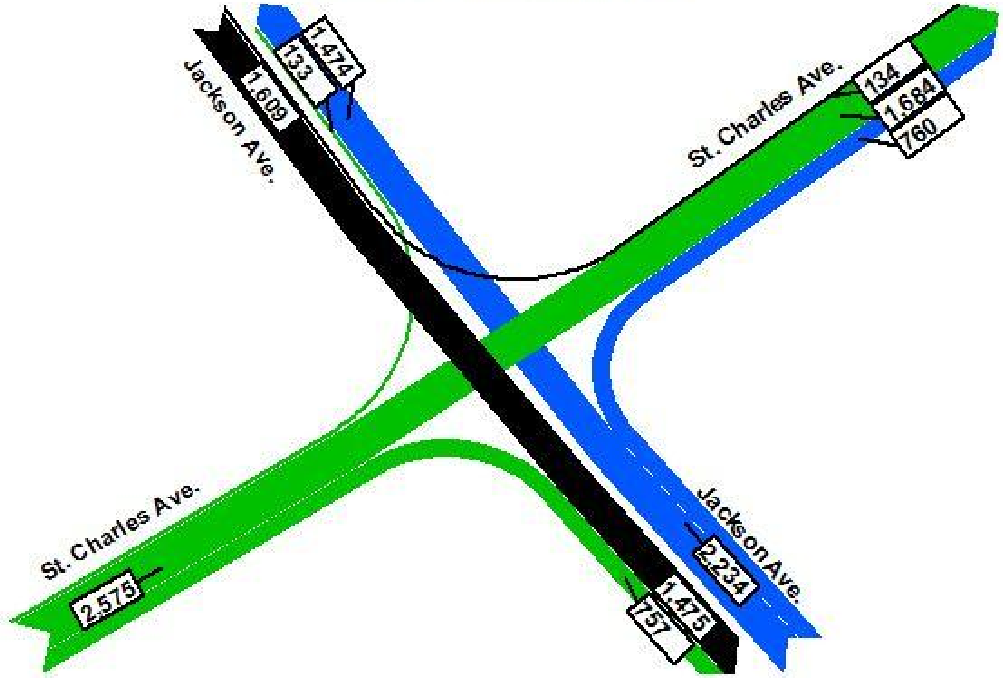


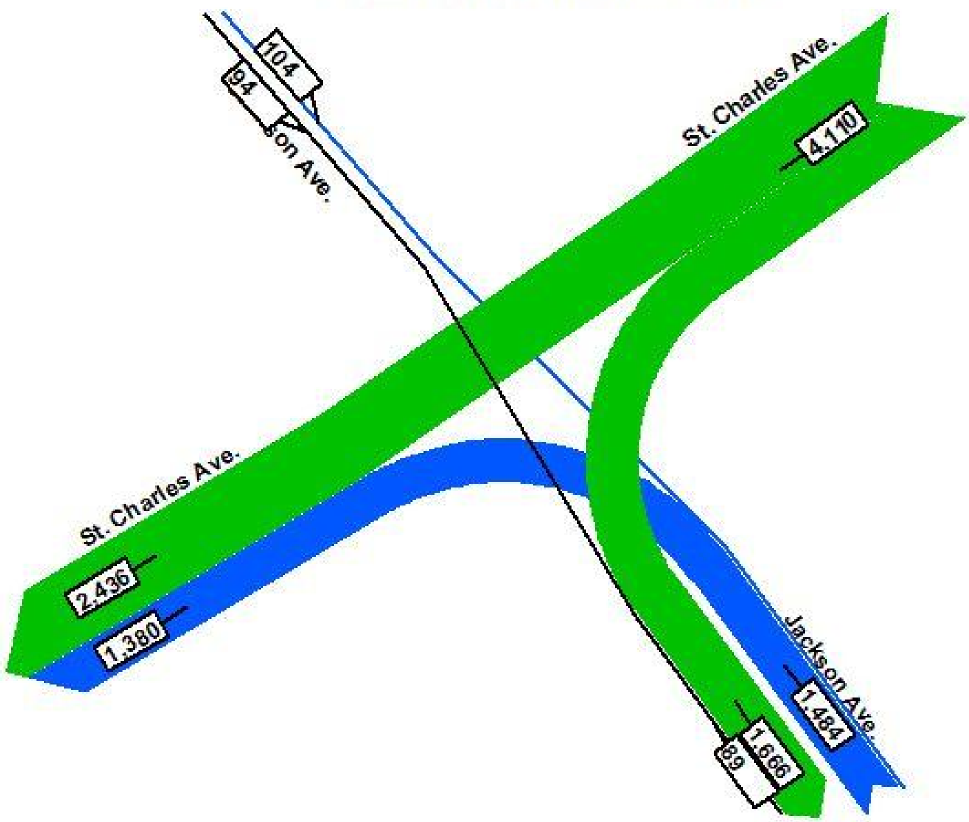
PM Peak

Jackson & St. Charles EB



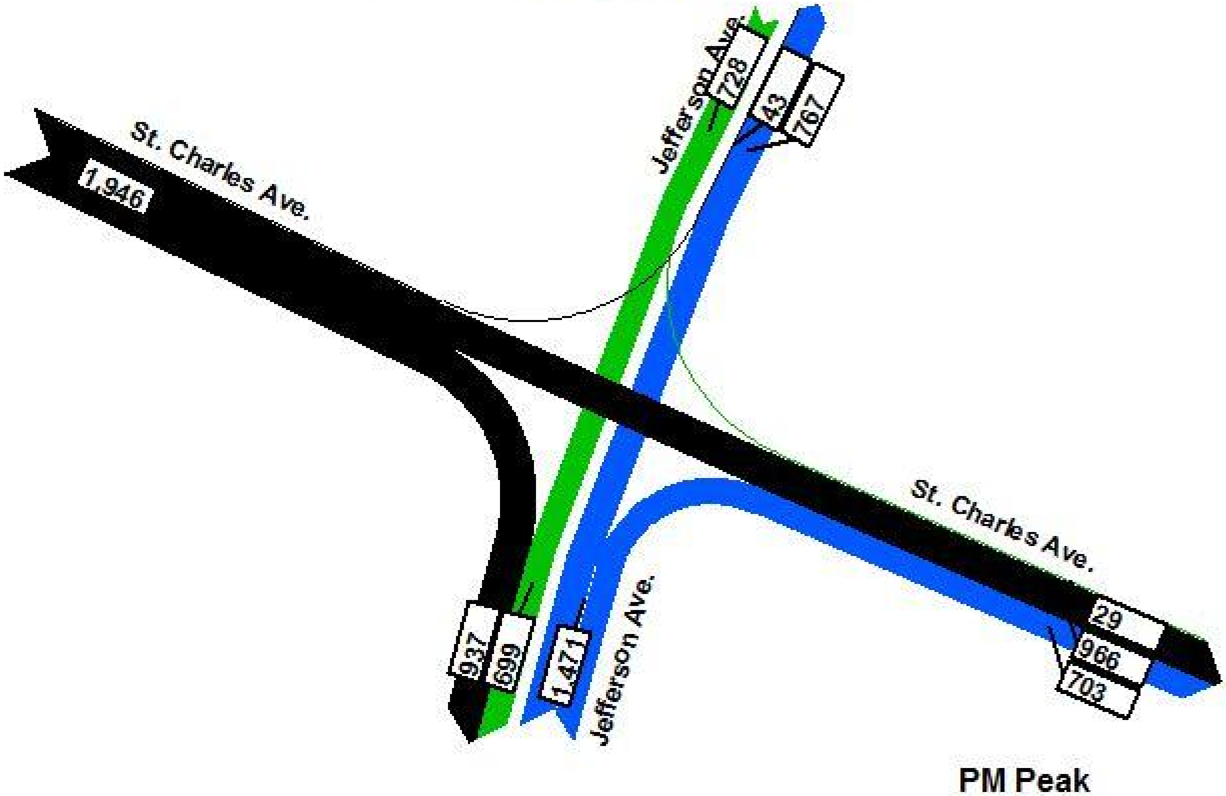
PM Peak

Jackson & St. Charles WB



PM Peak

Jefferson & St. Charles EB



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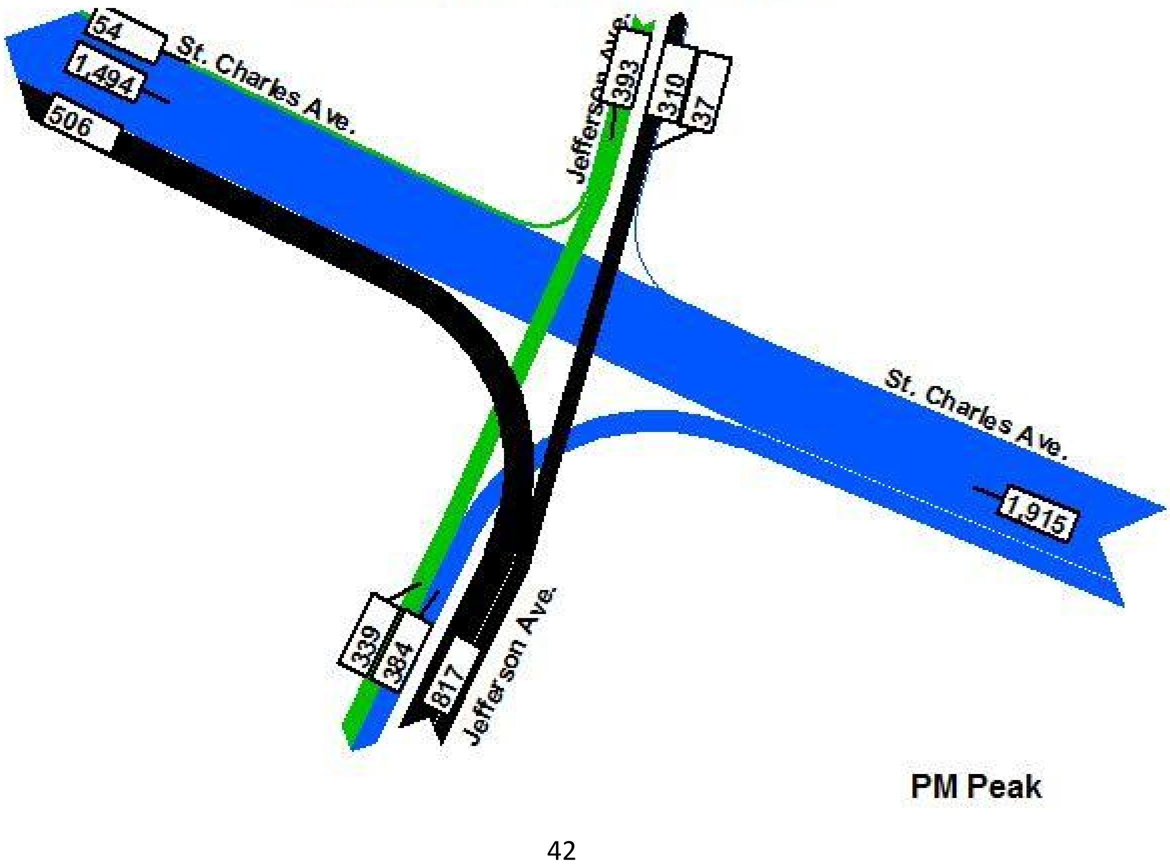
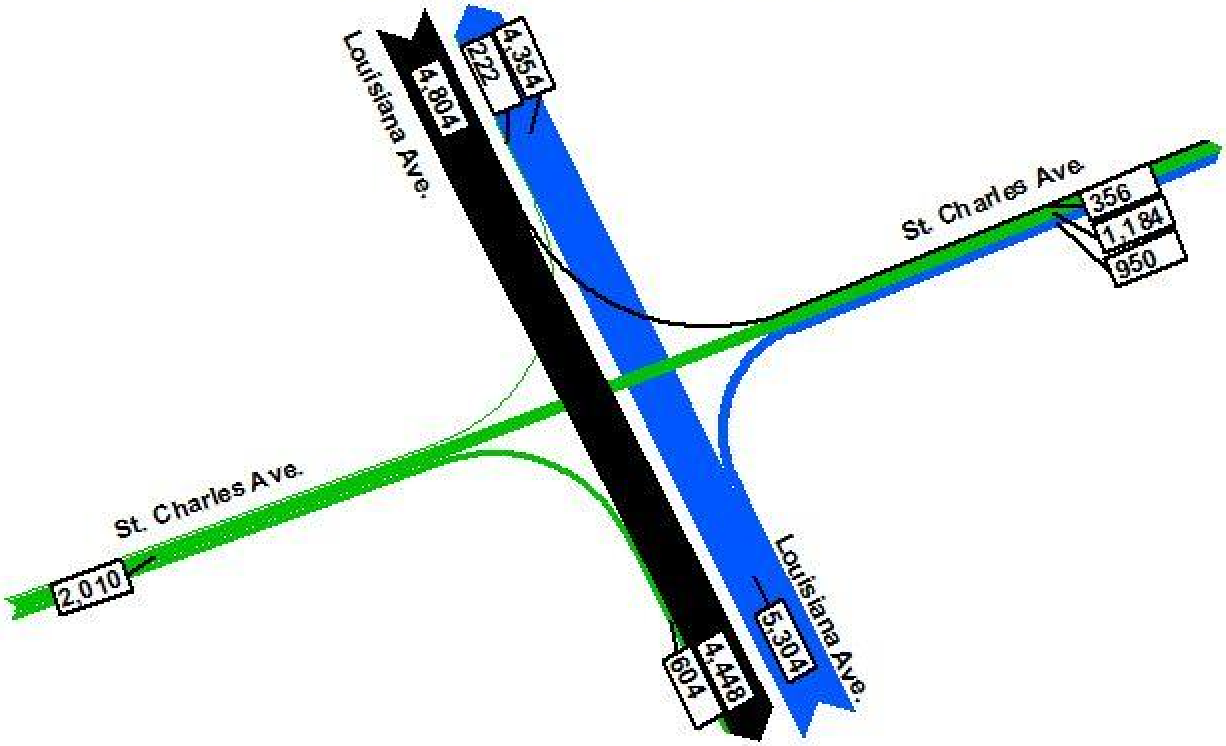
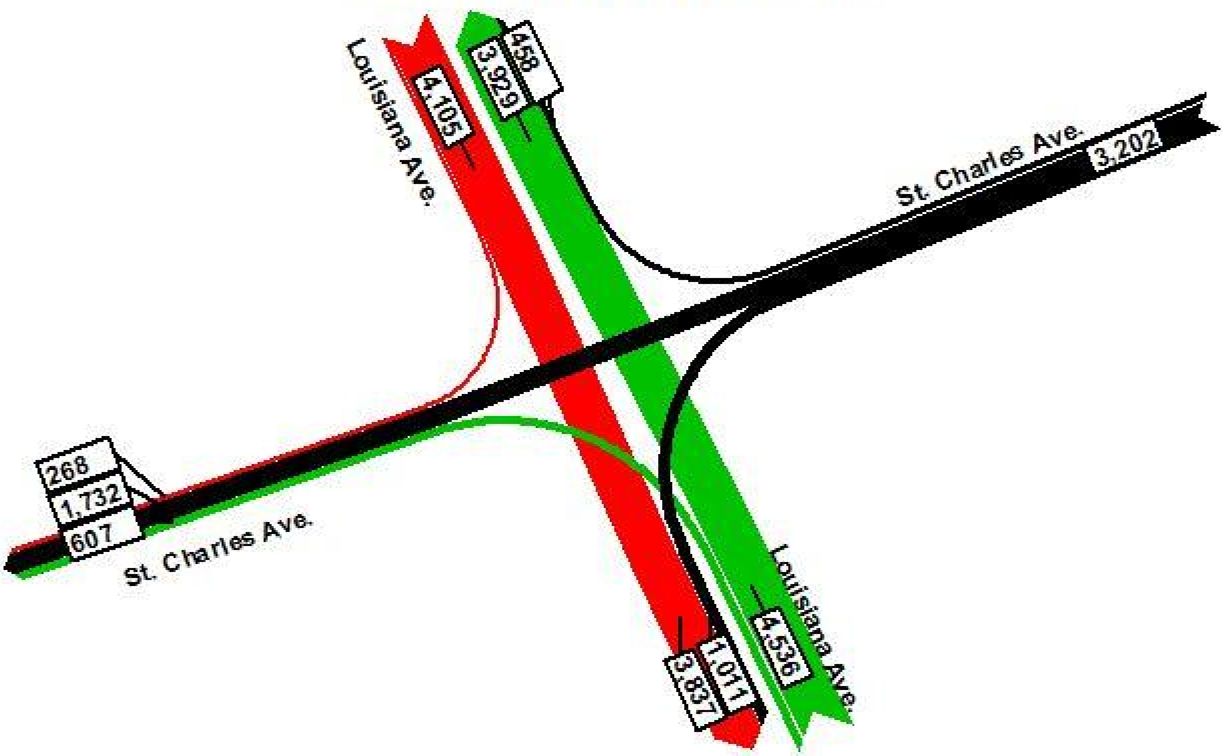


Louisiana & St. Charles EB



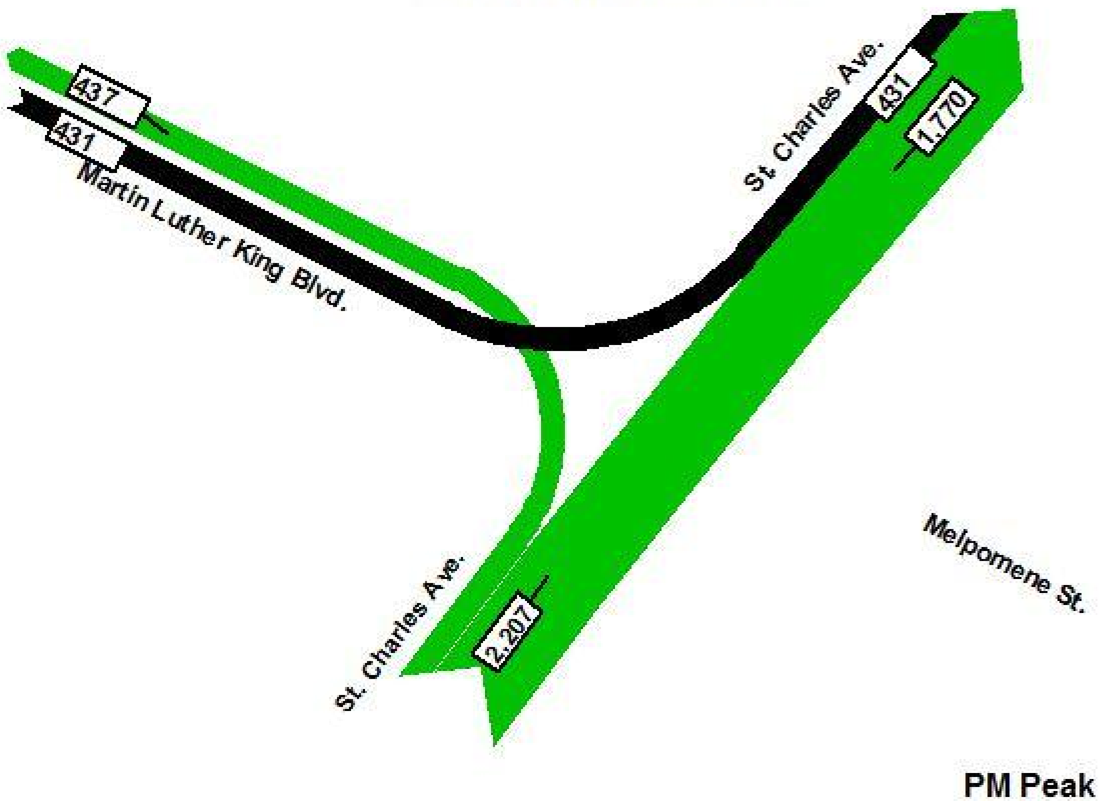
PM Peak

Louisiana & St. Charles WB

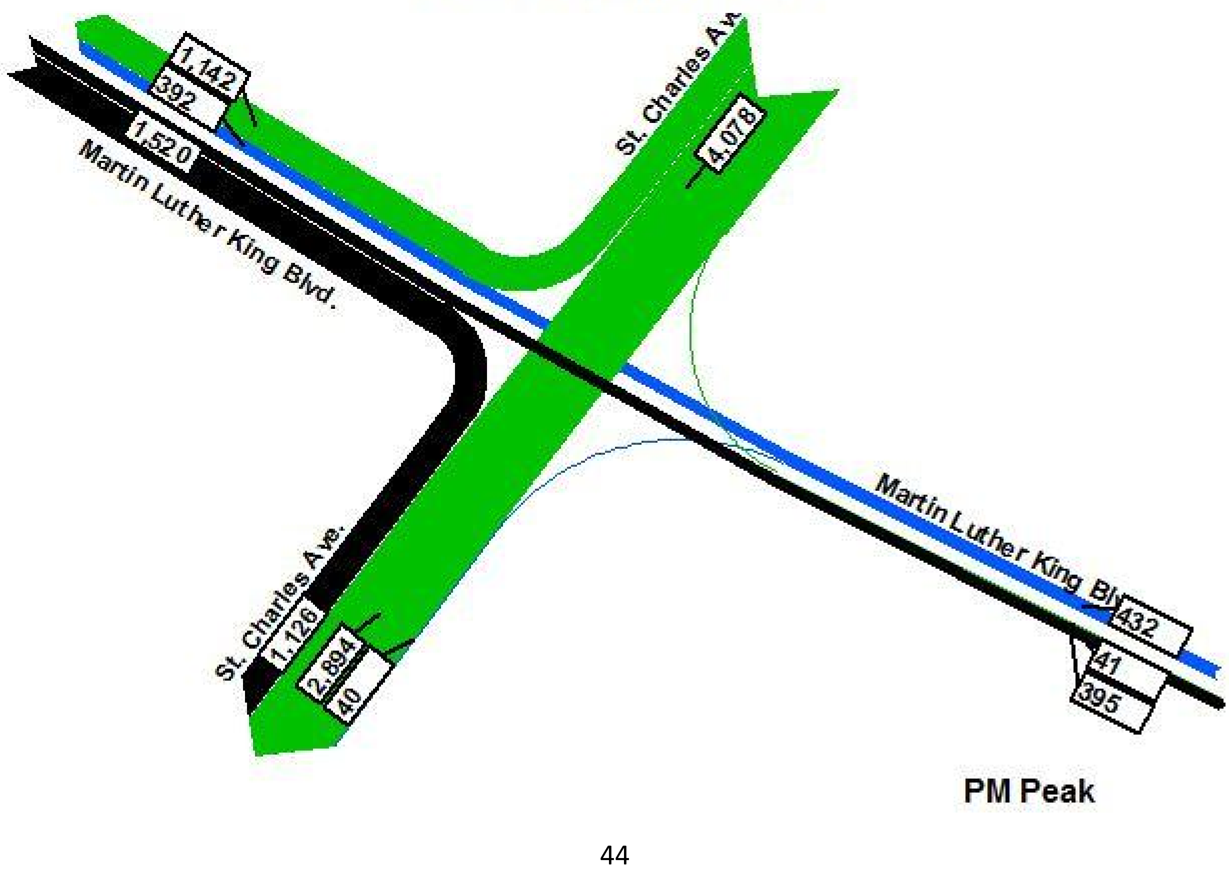


PM Peak

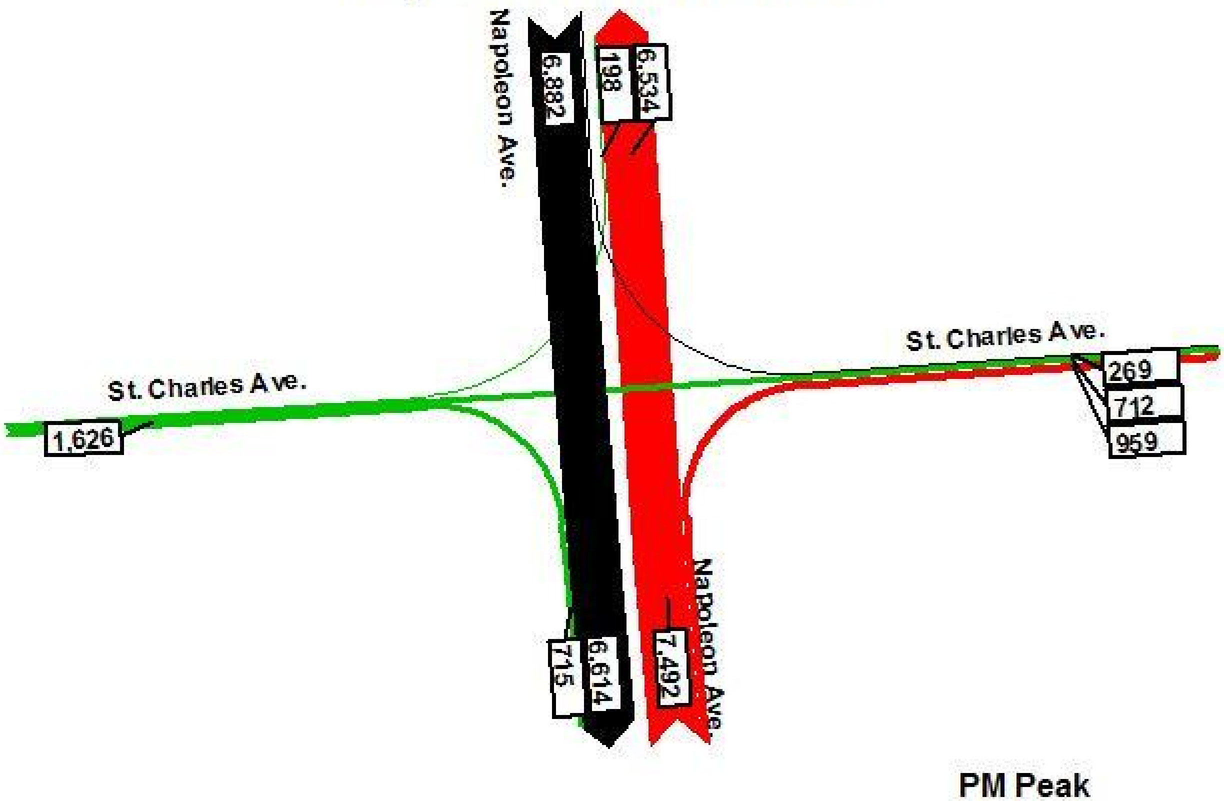
MLK & St. Charles EB



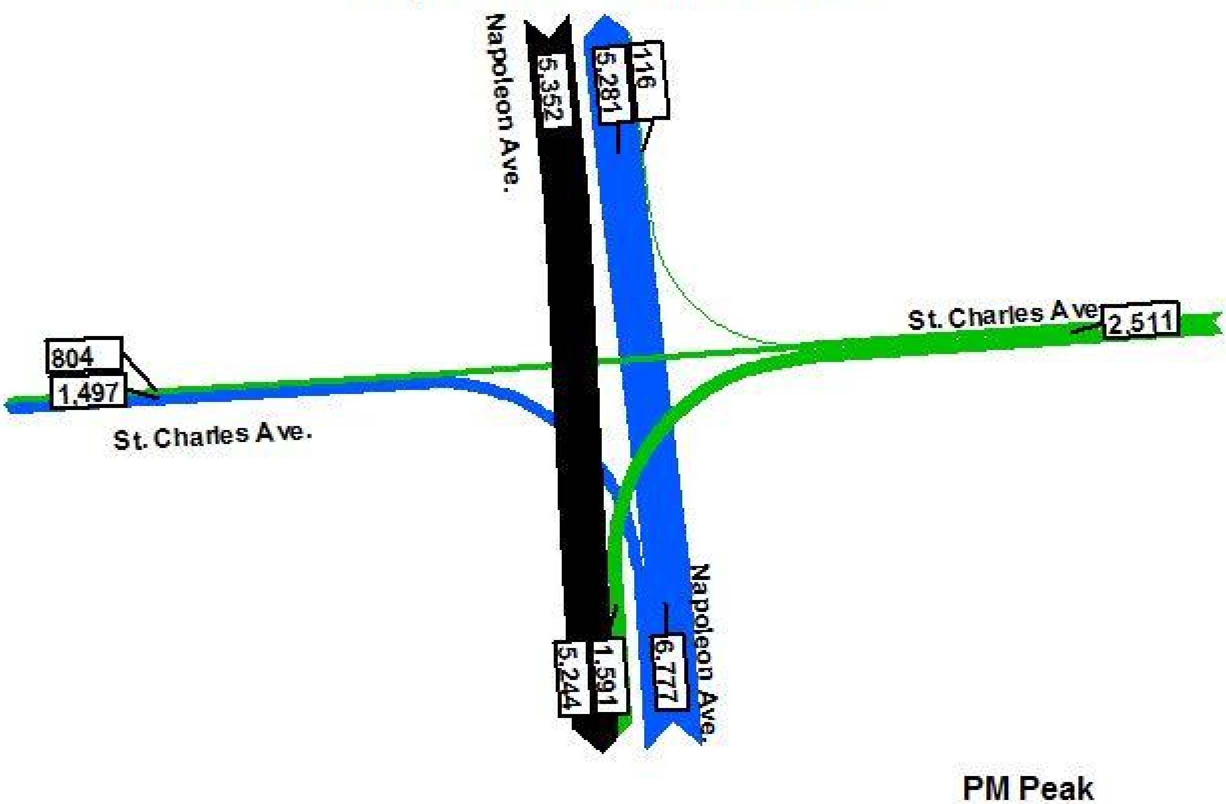
MLK & St. Charles WB



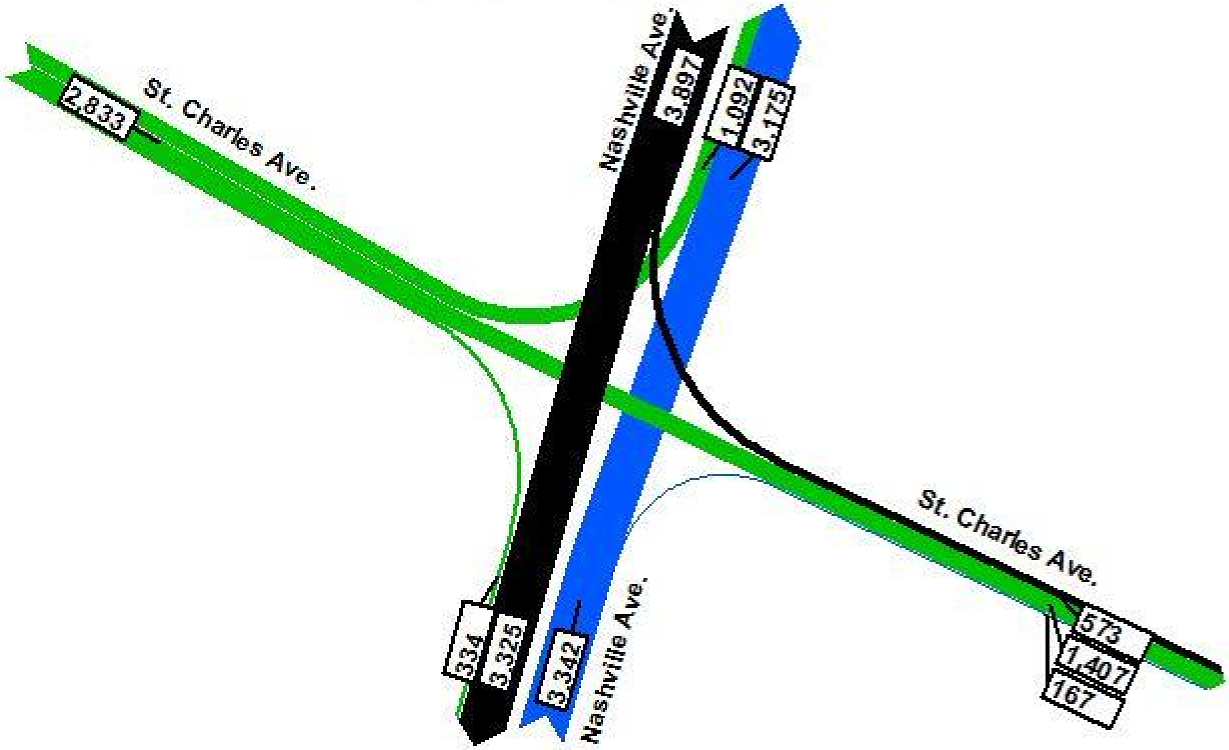
Napoleon & St. Charles EB



Napoleon & St. Charles WB

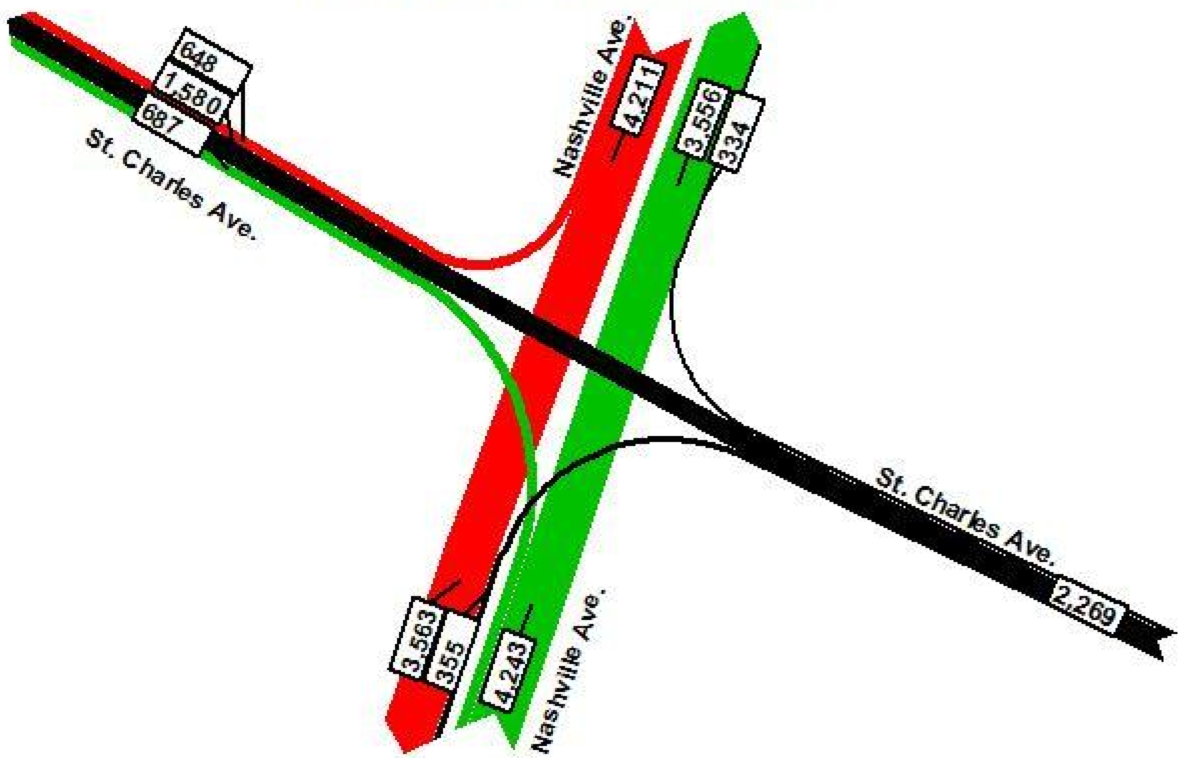


Nashville & St. Charles EB



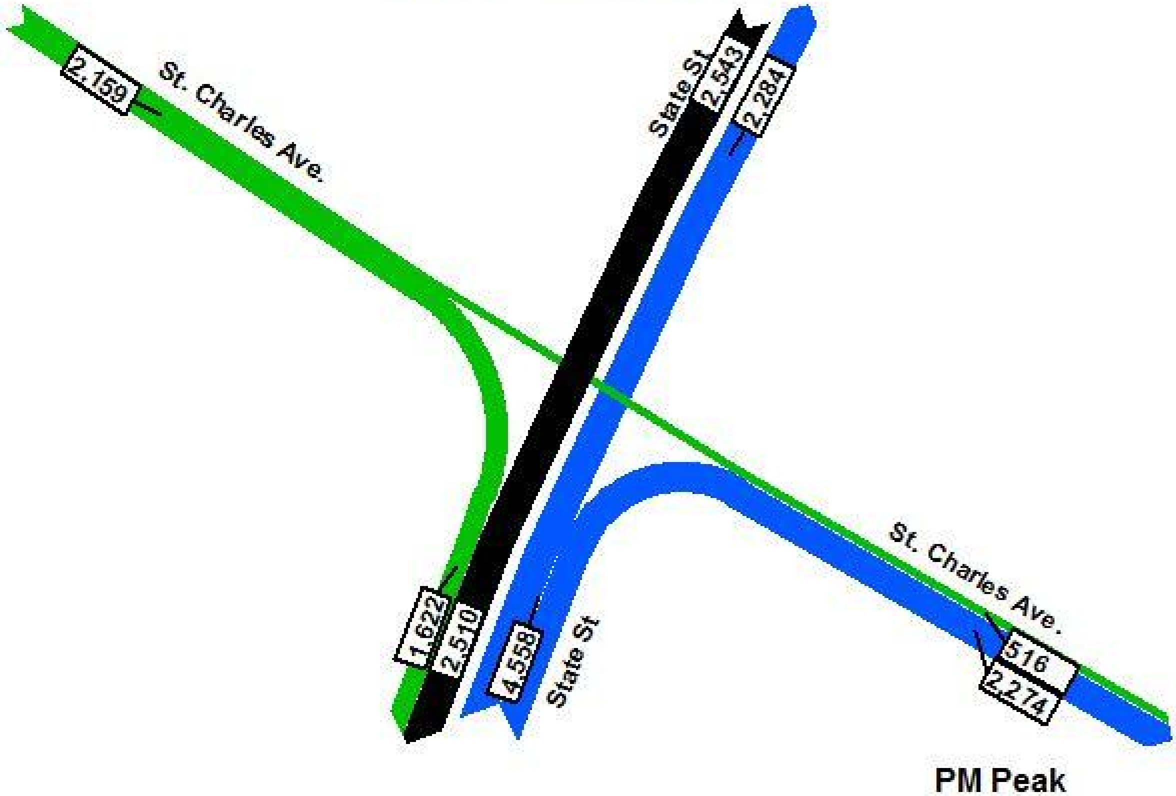
PM Peak

Nashville & St. Charles WB

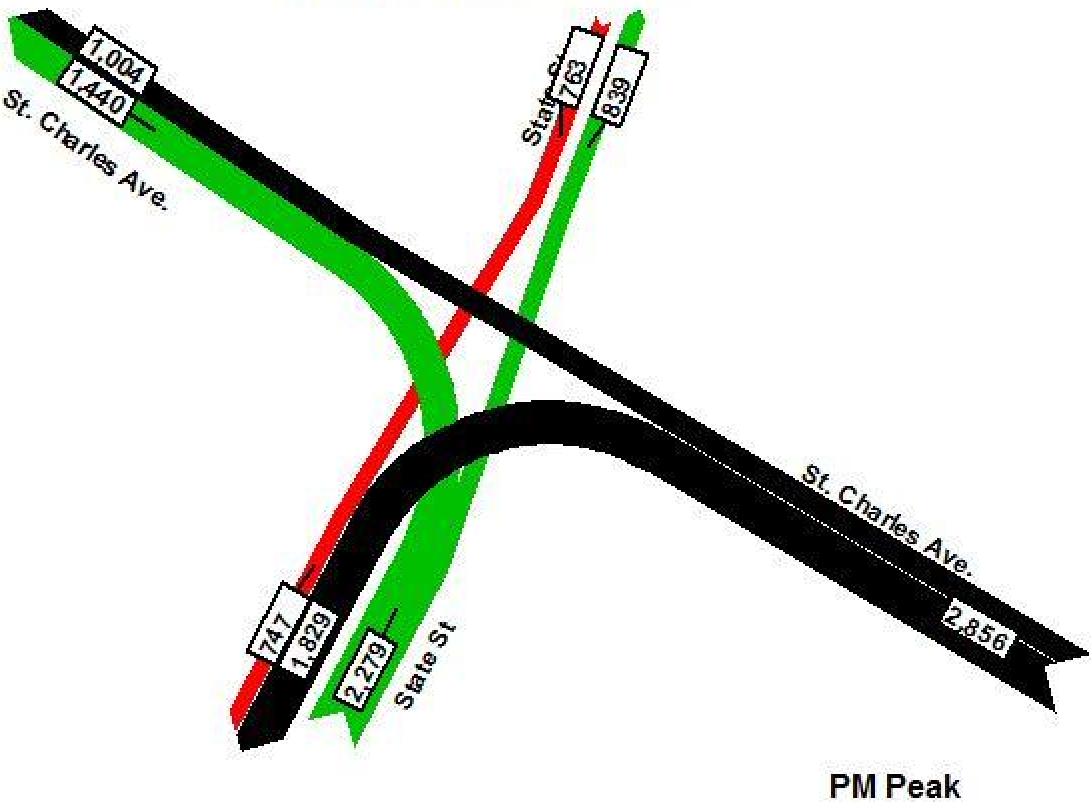


PM Peak

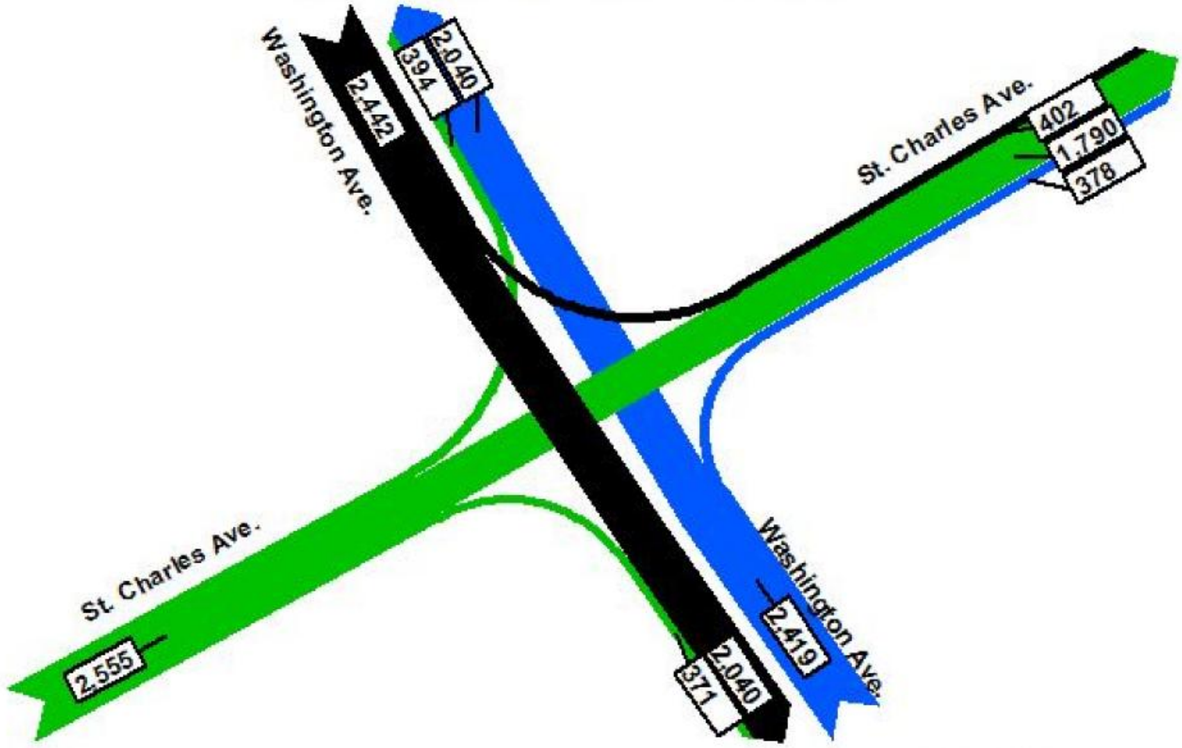
State & St. Charles EB



State & St. Charles WB

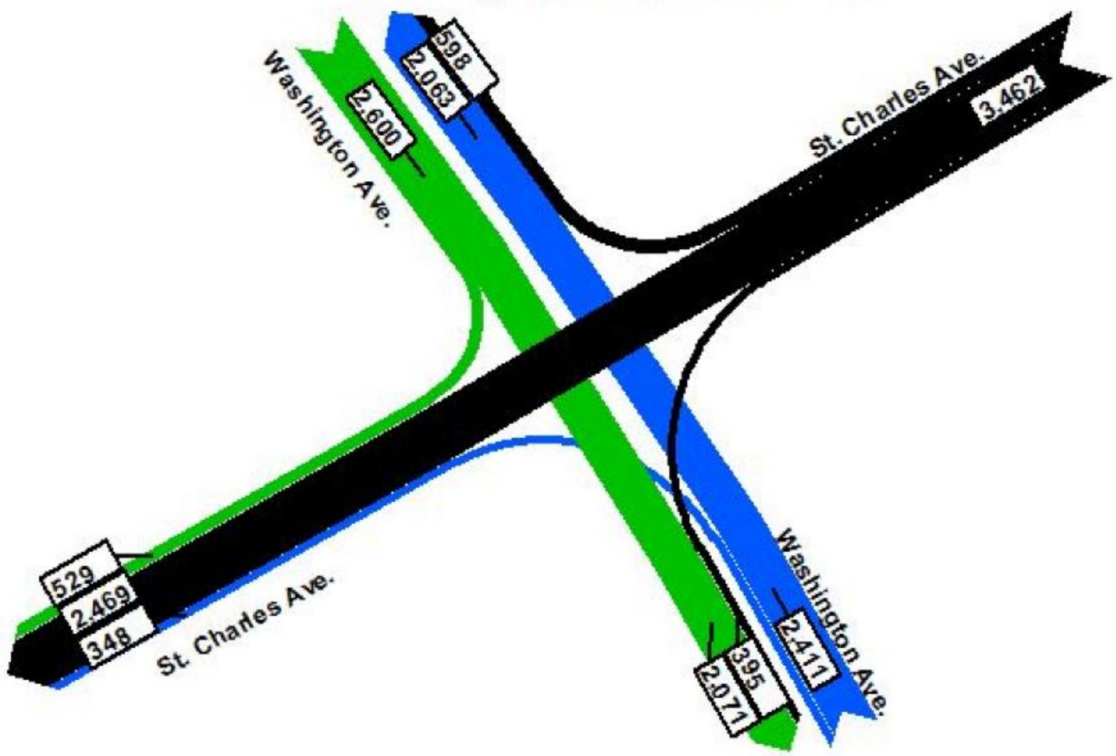


Washington & St. Charles EB



PM Peak

Washington & St. Charles WB



PM Peak

Level of Service Calculations

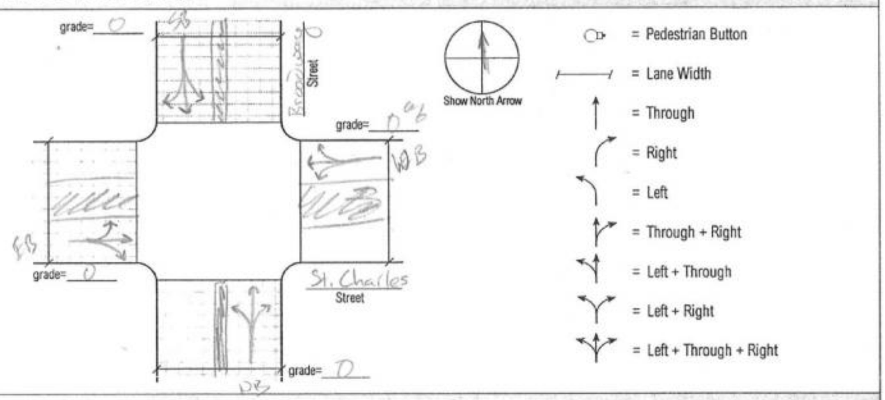
Highway Capacity Manual 2000

Broadway + St. Charles

INPUT WORKSHEET

General Information		Site Information	
Analyst		Intersection	
Agency or Company		Area Type	☐ CBD ☐ Other
Date Performed		Jurisdiction	
Analysis Time Period		Analysis Year	

Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	56	301	26	132	366	48	83	317	69	131	303	32
% heavy vehicles, % HV	3	3	3	3	3	3	3	3	3	3	3	3
Peak-hour factor, PHF		1.0			1.0			1.0			1.0	
Pretimed (P) or actuated (A)		P			P			P			P	
Start-up lost time, l_1 (s)		0			0			0			0	
Extension of effective green time, e (s)		0			0			0			0	
Arrival type, AT		3			3			3			3	
Approach pedestrian volume,[2] v_{ped} (p/h)		40			40			40			40	
Approach bicycle volume,[2] v_{bic} (bicycles/h)		25			25			25			25	
Parking (Y or N)		N			N			N			N	
Parking maneuvers, N_m (maneuvers/h)		0			0			0			0	
Bus stopping, N_B (buses/h)					0			1			.0	
Min. timing for pedestrians,[3] G_p (s)		10			10			10			10	

Signal Phasing Plan

	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM				Street car signal				
Timing	G = 16 Y = 4	G = 16 Y = 4	G = 16 Y = 4	G = 2 Y = 0	G = Y =	G = Y =	G = Y =	G = Y =
Protected turns			Permitted turns / Pedestrian			Cycle length, C = 62 s		

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

Chapter 16 - Signalized Intersections

Broadway + St. Charles.

Broadway

SUPPLEMENTAL WORKSHEET FOR PERMITTED LEFT TURNS OPPOSED BY SINGLE-LANE APPROACH

General Information

Project Description Broadway + St. Charles

Input

	EB	WB	NB	SB
Cycle length, C (s)		62		
Total actual green time for LT lane group,[1] G (s)			16	16
Effective permitted green time for LT lane group,[1] g (s)			16	16
Opposing effective green time, g_o (s)			16	16
Number of lanes in LT lane group,[2] N			1	1
Adjusted LT flow rate, v_{LT} (veh/h)			83	131
Proportion of LT volume in LT lane group, P_{LT}			0.18	0.28
Proportion of LT volume in opposing flow, P_{LTo}			0.28	0.18
Adjusted flow rate for opposing approach, v_o (veh/h)			131	83
Lost time for LT lane group, t_L			1	1

Computation

	EB	WB	NB	SB
LT volume per cycle, $LTC = v_{LT}C/3600$			1.429	2.256
Opposing flow per lane, per cycle, $v_{olc} = v_oC/3600$ (veh/C/ln)			2.256	1.429
Opposing platoon ratio, R_{po} (refer to Exhibit 16-11)			1.0	1.0
$g_f = G[e^{-0.860(LTC^{0.629})}] - t_L$ $\quad g_f \le g$ (except exclusive left-turn lanes)[3]			4.455	2.81
Opposing queue ratio, $qr_o = \max[1 - R_{po}(g_o/C), 0]$			0.742	0.742
$g_q = 4.943v_{olc}^{0.762}qr_o^{1.061} - t_L$ $\quad g_q \le g$			6.695	4.73
$g_u = g - g_q$ if $g_q \ge g_f$, or $g_u = g - g_f$ if $g_q < g_f$			9.305	11.27
$n = \max[(g_q - g_f)/2, 0]$			1.12	0.96
$P_{THo} = 1 - P_{LTo}$			0.72	0.82
E_{L1} (refer to Exhibit C16-3)			2.1	2.1
$E_{L2} = \max[(1 - P_{THo}^{\ n})/P_{LTo}, 1.0]$			1.1	0.961
$f_{min} = 2(1 + P_{LT})/g$			0.1475	0.16
$g_{diff} = \max[g_q - g_f, 0]$ (except when left-turn volume is 0)[4]			2.24	1.92
$f_{LT} = f_m = [g_f/g] + \left[\frac{g_u/g}{1 + P_{LT}(E_{L1} - 1)}\right] + \left[\frac{g_{diff}/g}{1 + P_{LT}(E_{L2} - 1)}\right]$ $(f_{min} \le f_m \le 1.00)$			0.9014	0.8783

Notes

1. Refer to Exhibits C16-4, C16-5, C16-6, C16-7, and C16-8 for case-specific parameters and adjustment factors.
2. For exclusive left-turn lanes, N is equal to the number of exclusive left-turn lanes. For shared left-turn lanes, N is equal to the sum of the shared left-turn, through, and shared right-turn (if one exists) lanes in that approach.
3. For exclusive left-turn lanes, $g_f = 0$, and skip the next step. Lost time, t_L, may not be applicable for protected-permitted case.
4. If the opposing left-turn volume is 0, then $g_{diff} = 0$.

Broadway

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Broadway + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	56	301	26	132	366	48	83	317	69	131	303	32
Peak-hour factor, PHF	1.0											
Adjusted flow rate, v_p = V/PHF (veh/h)	56	301	26	132	366	48	83	317	69	131	303	32
Lane group												
Adjusted flow rate in lane group, v (veh/h)		383			546			469			466	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.14	-	0.07	0.24	-	0.09	0.18	-	0.15	0.28	-	0.07
Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)												
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		1			1			1			1	
Lane width adjustment factor, f_w		1.0			1.0			1.0			1.0	
Heavy-vehicle adjustment factor, f_{HV}		0.94			0.94			0.94			0.94	
Grade adjustment factor, f_g		1.0			1.0			1.0			1.0	
Parking adjustment factor, f_p		1.0			1.0			1.0			1.0	
Bus blockage adjustment factor, f_{bb}		1.0			1.0			0.996			1.0	
Area type adjustment factor, f_a		1.0			1.0			1.0			1.0	
Lane utilization adjustment factor, f_{LU}		1.0			1.0			1.0			1.0	
Left-turn adjustment factor, f_{LT}		0.993			0.988			0.904			0.883	
Right-turn adjustment factor, f_{RT}		0.989			0.987			0.978			0.989	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		1747			1734			1561			1545	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

Broadway

CAPACITY AND LOS WORKSHEET

General Information

Project Description Broadway + St. Charles

Capacity Analysis

Phase number	1	2	3	3								
Phase type												
Lane group												
Adjusted flow rate, v (veh/h)	383	546	469	466								
Saturation flow rate, s (veh/h)	1797	1734	1561	1545								
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	4	4								
Effective green time, g (s), $g = G + Y - t_L$	16	16	16	16								
Green ratio, g/C	0.258	0.258	0.258	0.258								
Lane group capacity,[1] c = s(g/C), (veh/h)	450	447	402	399								
v/c ratio, X	0.85	1.22	1.17	1.17								
Flow ratio, v/s	0.219	0.315	0.3	0.302								
Critical lane group/phase (√)	✓	✓	✓									
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)	0.836											
Total lost time per cycle, L (s)	12											
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$	1.037											

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	383	546	469	466
Lane group capacity,[2] c (veh/h)	450	447	402	399
v/c ratio,[2] X = v/c	0.85	1.22	1.17	1.17
Total green ratio,[2] g/C	0.258	0.258	0.258	0.258
Uniform delay, $d_1 = \frac{0.50\,C\,[1 - (g/C)]^2}{1 - [\min(1, X)g/C]}$ (s/veh)	20.09	24.93	24.47	24.97
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	17.9	114.789	107.42	107.42
Initial queue delay, d_3 (s/veh) (Appendix F)	0	0	0	0
Uniform delay, d_1 (s/veh) (Appendix F)	–	–	–	–
Progression adjustment factor, PF	1.0	1.0	1.0	1.0
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	37.99	139.719	131.89	131.89
LOS by lane group (Exhibit 16-2)	D	F	F	F
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	37.99	139.719	131.89	131.89
LOS by approach (Exhibit 16-2)	D	F	F	F
Approach flow rate, v_A (veh/h)	383	546	469	466
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	114.89	Intersection LOS (Exhibit 16-2)		F

Notes

1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

State

INPUT WORKSHEET

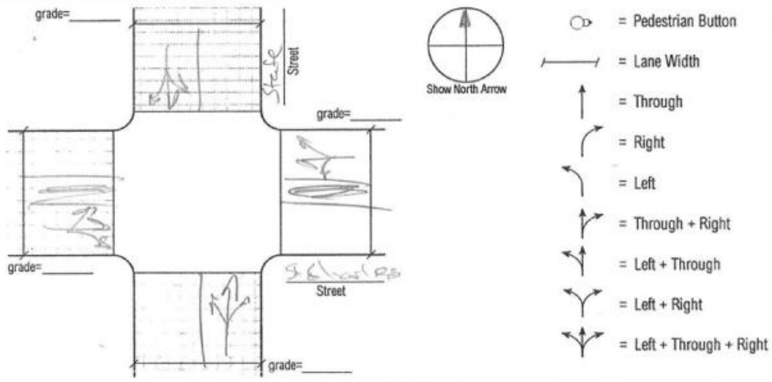
General Information

Analyst ______
Agency or Company ______
Date Performed ______
Analysis Time Period ______

Site Information

Intersection: State St, Charles
Area Type: ☐ CBD ☐ Other
Jurisdiction ______
Analysis Year ______

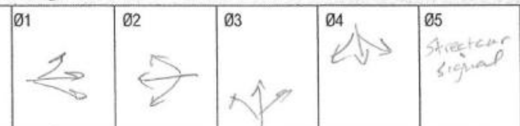
Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	0	172	540	609	334	0	480	279	758	0	249	0
% heavy vehicles, % HV		1			1			0			0	
Peak-hour factor, PHF	1.0	→										
Pretimed (P) or actuated (A)		P			P			P			P	
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)		2			2			2			2	
Arrival type, AT												
Approach pedestrian volume,[2] v_{ped} (p/h)	40			40			40			40		
Approach bicycle volume,[2] v_{bic} (bicycles/h)	25			25			25			25		
Parking (Y or N)	N			N			N			N		
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)	10			10			10			10		

Signal Phasing Plan



	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM					Streetcar signal			
Timing	G = 16 Y = 4	G = 16 Y = 4	G = 16 Y = 4	G = 16 Y = 4	G = 2 Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 82 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

State

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description State + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	0	172	540	609	334	0	480	279	758	0	249	0
Peak-hour factor, PHF	1.0 →											→
Adjusted flow rate, v_p = V/PHF (veh/h)	0	172	540	609	334	0	480	279	758	0	249	0
Lane group												
Adjusted flow rate in lane group, v (veh/h)		712			943			1517			249	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0	-	0.758	0.646	-	0	0.316	-	0.499	0	-	0

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		1			1			1			1	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.98			0.98			–			–	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		–			0.962			0.98			–	
Right-turn adjustment factor, f_{RT}		0.89			–			0.925			–	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		1684			1834			1715			1892	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

State

CAPACITY AND LOS WORKSHEET

General Information

Project Description: State + St. Charles

Capacity Analysis

Phase number	1	2	3	4								
Phase type	P	P	P	P								
Lane group												
Adjusted flow rate, v (veh/h)	712	943	1517	249								
Saturation flow rate, s (veh/h)	1684	1834	1715	1892								
Lost time, t_L (s), $t_L = l_1 + Y - e$	2	2	2	2								
Effective green time, g (s), $g = G + Y - t_L$	18	18	18	18								
Green ratio, g/C	0.22	0.22	0.22	0.22								
Lane group capacity,[1] c = s(g/C), (veh/h)	370	403	377.3	416.24								
v/c ratio, X	1.92	2.34	4.02	0.6								
Flow ratio, v/s												
Critical lane group/phase (√)	✓		✓	✓								
Sum of flow ratios for critical lane groups, Y_c; $Y_c = \Sigma$ (critical lane groups, v/s)												
Total lost time per cycle, L (s)												
Critical flow rate to capacity ratio, X_c; $X_c = (Y_c)(C)/(C - L)$												

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	712	943	1517	249
Lane group capacity,[2] c (veh/h)	370	403	377	416
v/c ratio,[2] X = v/c	1.92	2.34	4.02	0.6
Total green ratio,[2] g/C	0.22	0.22	0.22	0.22
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1, X)g/C]}$ (s/veh)	13.52	51.32	215.4	28.69
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2; $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	423.91	610.65	1369.8	6.252
Initial queue delay, d_3 (s/veh) (Appendix F)				
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.833	0.833	0.833	0.833
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)				
LOS by lane group (Exhibit 16-2)				
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	459.8	653.4	1548.4	30.15
LOS by approach (Exhibit 16-2)	F	F	F	C
Approach flow rate, v_A (veh/h)	712	943	1517	249
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	964.1	Intersection LOS (Exhibit 16-2)		F

Notes

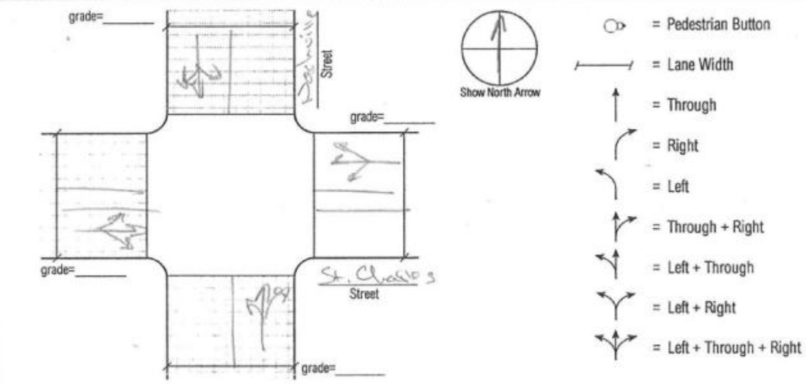
1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

Nashville

INPUT WORKSHEET

General Information		**Site Information**	
Analyst		Intersection	
Agency or Company		Area Type	☐ CBD ☐ Other
Date Performed		Jurisdiction	
Analysis Time Period		Analysis Year	

Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	364	469	111	118	526	111	229	1058	55	83	1100	216
% heavy vehicles, % HV		1			1			0			0	
Peak-hour factor, PHF		1.0										
Pretimed (P) or actuated (A)		P			P			P			P	
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)		2			2			2			8	
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)		40			40			40			40	
Approach bicycle volume,[2] v_{bic} (bicycles/h)		25			25			25			25	
Parking (Y or N)		N			N			N			N	
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)		10			10			10			10	

Signal Phasing Plan

	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM					street car signal			
Timing	G = 16 Y = 2	G = 16 Y = 2	G = 16 Y = 2	G = 16 Y = 2	G = 2 Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 74 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

Nashville

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Nashville + St. Charles.

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	364	469	111	118	526	111	229	1058	55	83	1100	216
Peak-hour factor, PHF	1.0	→										
Adjusted flow rate, v_p = V/PHF (veh/h)	364	469	111	118	526	111	229	1058	55	83	1100	216
Lane group												
Adjusted flow rate in lane group, v (veh/h)		944			755			1342			1399	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.39	-	0.12	0.16	-	0.07	0.17	-	0.041	0.06	-	0.15

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB LT	EB TH	EB RT	WB LT	WB TH	WB RT	NB LT	NB TH	NB RT	SB LT	SB TH	SB RT
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		1			1			1			1	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.98			0.98			–			–	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.981			0.997			0.992			0.997	
Right-turn adjustment factor, f_{RT}		0.982			0.989			0.994			0.978	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		1786			1830			1866			1845	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

Nashville

CAPACITY AND LOS WORKSHEET

General information

Project Description ______________________________

Capacity Analysis

Phase number	1	2	3	4								
Phase type	P	P	P	P								
Lane group												
Adjusted flow rate, v (veh/h)	944	755	1342	1399								
Saturation flow rate, s (veh/h)	1786	1830	1866	1845								
Lost time, t_L (s), $t_L = l_1 + Y - e$	2	2	2	2								
Effective green time, g (s), $g = G + Y - t_L$	18	18	18	18								
Green ratio, g/C	0.25	0.25	0.25	0.25								
Lane group capacity,[1] $c = s(g/C)$, (veh/h)	446.5	457.5	466	461								
v/c ratio, X	2.112	1.652	2.88	3.035								
Flow ratio, v/s												
Critical lane group/phase (√)	✓	✓	✓	✓								
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)												
Total lost time per cycle, L (s)												
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$												

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	944	755	1342	1395
Lane group capacity,[2] c (veh/h)	447	458	466	461
v/c ratio,[2] X = v/c	2.112	1.652	2.88	3.035
Total green ratio,[2] g/C	0.25	0.25	0.25	0.25
Uniform delay, $d_1 = \frac{0.50\,C\,[1 - (g/C)]^2}{1 - [\min(1, X)g/C]}$ (s/veh)	42.9	34.5	72.32	83.94
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	507	302	851.8	921.6
Initial queue delay, d_3 (s/veh) (Appendix F)				
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.714	0.714	0.714	0.714
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)				
LOS by lane group (Exhibit 16-2)				
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	537.6	326.6	902.6	981
LOS by approach (Exhibit 16-2)	F	F	F	F
Approach flow rate, v_A (veh/h)	944	755	1342	1395
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	751	Intersection LOS (Exhibit 16-2)		F

Notes

1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

Jefferson + St. Charles

INPUT WORKSHEET

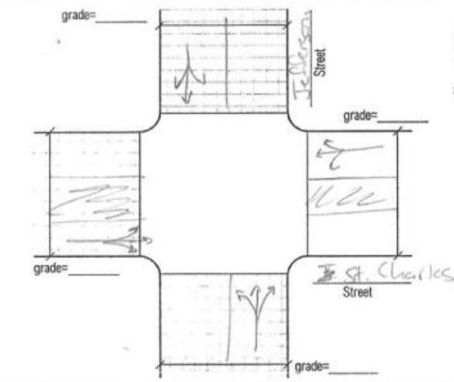
General Information

Analyst	
Agency or Company	
Date Performed	
Analysis Time Period	

Site Information

Intersection	
Area Type	☐ CBD ☐ Other
Jurisdiction	
Analysis Year	

Intersection Geometry

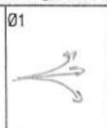
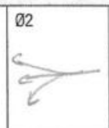


= Pedestrian Button
= Lane Width
= Through
= Right
= Left
= Through + Right
= Left + Through
= Left + Right
= Left + Through + Right

Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	14	322	312	128	498	13	168	103	234	10	113	18
% heavy vehicles, % HV	0 →											
Peak-hour factor, PHF	1.0 →											
Pretimed (P) or actuated (A)	P →											
Start-up lost time, l_1 (s)	1.0 →											
Extension of effective green time, e (s)	1.0 →											
Arrival type, AT	3 →											
Approach pedestrian volume,[2] v_{ped} (p/h)	40			40			40			40		
Approach bicycle volume,[2] v_{bic} (bicycles/h)	25			25			25			25		
Parking (Y or N)	N			N			N			N		
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)	10			10			10			10		

Signal Phasing Plan

	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM				Street car signal				
Timing	G = 16 Y = 4	G = 16 Y = 4	G = 16 Y = 4	G = 2 Y = 0	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns | Permitted turns / Pedestrian | Cycle length, C = 62 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

Jefferson

SUPPLEMENTAL WORKSHEET FOR PERMITTED LEFT TURNS OPPOSED BY SINGLE-LANE APPROACH

General Information

Project Description Jefferson + St. Charles

Input

	EB	WB	NB	SB
Cycle length, C (s)		62		
Total actual green time for LT lane group,[1] G (s)			16	16
Effective permitted green time for LT lane group,[1] g (s)			16	16
Opposing effective green time, g_o (s)			16	16
Number of lanes in LT lane group,[2] N			1	1
Adjusted LT flow rate, v_{LT} (veh/h)			168	10
Proportion of LT volume in LT lane group, P_{LT}			0.2	0.07
Proportion of LT volume in opposing flow, P_{LTo}			0.07	0.2
Adjusted flow rate for opposing approach, v_o (veh/h)			10	168
Lost time for LT lane group, t_L			1	1
Computation				
LT volume per cycle, $LTC = v_{LT}C/3600$			2.89	0.172
Opposing flow per lane, per cycle, $v_{olc} = v_oC/3600$ (veh/C/ln)			0.172	2.89
Opposing platoon ratio, R_{po} (refer to Exhibit 16-11)			1.0	1.0
$g_f = G[e^{-0.860(LTC^{0.629})}] - t_L$ $g_f \le g$ (except exclusive left-turn lanes)[3]			15	15
Opposing queue ratio, $qr_o = max[1 - R_{po}(g_o/C), 0]$			0.742	0.742
$g_q = 4.943v_{olc}^{0.762}qr_o^{1.061} - t_L$ $g_q \le g$			-0.056	7.1
$g_u = g - g_q$ if $g_q \ge g_f$, or $g_u = g - g_f$ if $g_q < g_f$			1	1
$n = max[(g_q - g_f)/2, 0]$			7.528	3.95
$P_{THo} = 1 - P_{LTo}$			0.93	0.8
E_{L1} (refer to Exhibit C16-3)			1.4	1.7
$E_{L2} = max[(1 - P_{THo}{}^n)/P_{LTo}, 1.0]$			6.013	2.929
$f_{min} = 2(1 + P_{LT})/g$			0.4	0.134
$g_{diff} = max[g_q - g_f, 0]$ (except when left-turn volume is 0)[4]			-15.056	-7.9
$f_{LT} = f_m = [g_f/g] + \left[\frac{g_u/g}{1 + P_{LT}(E_{L1} - 1)}\right] + \left[\frac{g_{diff}/g}{1 + P_{LT}(E_{L2} - 1)}\right]$ $(f_{min} \le f_m \le 1.00)$			0.5255	0.558

Notes

1. Refer to Exhibits C16-4, C16-5, C16-6, C16-7, and C16-8 for case-specific parameters and adjustment factors.
2. For exclusive left-turn lanes, N is equal to the number of exclusive left-turn lanes. For shared left-turn lanes, N is equal to the sum of the shared left-turn, through, and shared right-turn (if one exists) laoes in that approach.
3. For exclusive left-turn lanes, $g_f = 0$, and skip the next step. Lost time, t_L, may not be applicable for protected-permitted case.
4. If the opposing left-turn volume is 0, then $g_{diff} = 0$.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Jefferson + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	14	322	312	128	498	13	166	103	234	10	113	18
Peak-hour factor, PHF	1.0	→										→
Adjusted flow rate, v_p = V/PHF (veh/h)	14	322	312	128	498	13	168	103	234	10	113	18
Lane group												
Adjusted flow rate in lane group, v (veh/h)		648			639			505			141	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.02	-	0.48	0.2	-	0.02	0.33	-	0.46	0.07	-	0.13

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB			WB			NB			SB		
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		1			1			1			1	
Lane width adjustment factor, f_w		1			1			1			1	
Heavy-vehicle adjustment factor, f_{HV}		1.0			1.0			1.0			1.0	
Grade adjustment factor, f_g		1.0			1.0			1.0			1.0	
Parking adjustment factor, f_p		1.0			1.0			1			1	
Bus blockage adjustment factor, f_{bb}		1			1			1			1	
Area type adjustment factor, f_a		1			1			1			1	
Lane utilization adjustment factor, f_{LU}		1			1			1			1	
Left-turn adjustment factor, f_{LT}		0.999			0.990			0.5255			0.558	
Right-turn adjustment factor, f_{RT}		0.986			0.997			0.931			0.9885	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.999	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		1754			1867			925			1043	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General information

Project Description: Jefferson + St. Charles

Capacity Analysis

Phase number	1	2	3	3
Phase type	P	P	P	P
Lane group				
Adjusted flow rate, v (veh/h)	648	639	505	141
Saturation flow rate, s (veh/h)	1754	1867	925	1043
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	4	4
Effective green time, g (s), $g = G + Y - t_L$	16	16	16	16
Green ratio, g/C	0.258	0.256	0.258	0.256
Lane group capacity,[1] c = s(g/C), (veh/h)	453	483	239	269
v/c ratio, X	1.43	1.32	2.11	0.52
Flow ratio, v/s	0.37	0.34	0.55	0.14
Critical lane group/phase (√)	✓	✓	✓	
Sum of flow ratios for critical lane groups, Y_c; $Y_c = \Sigma$ (critical lane groups, v/s)	1.26			
Total lost time per cycle, L (s)	12			
Critical flow rate to capacity ratio, X_c; $X_c = (Y_c)(C)/(C - L)$	1.5624			

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	648	639	505	141
Lane group capacity,[2] c (veh/h)	453	483	239	269
v/c ratio,[2] X = v/c	1.43	1.32	2.11	0.52
Total green ratio,[2] g/C	0.258	0.258	0.255	0.258
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1,X)g/C]}$ (s/veh)	28.76	26.41	38.43	8.2
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2; $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	205	158	513	7
Initial queue delay, d_3 (s/veh) (Appendix F)	0	0	0	0
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.833	0.833	0.833	0.833
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	229	179	545	13.8
LOS by lane group (Exhibit 16-2)	F	F	F	B
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	229	179	545	13.8
LOS by approach (Exhibit 16-2)	F	F	F	B
Approach flow rate, v_A (veh/h)	648	639	505	141
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	299	Intersection LOS (Exhibit 16-2)		F

Notes

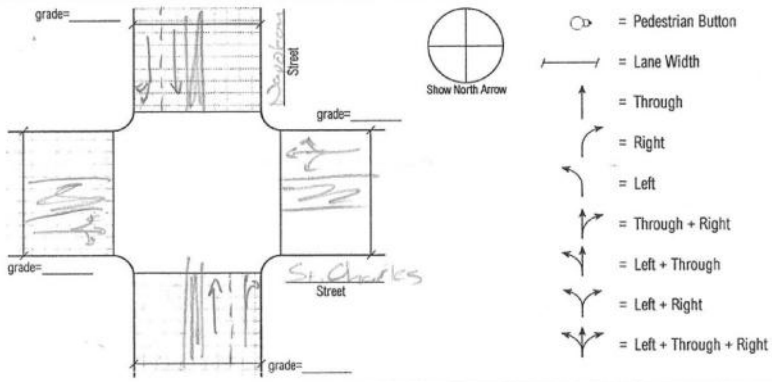
1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

Napoleon

INPUT WORKSHEET

General Information		**Site Information**	
Analyst		Intersection	Napoleon + St. Charles
Agency or Company		Area Type	☐ CBD ☐ Other
Date Performed		Jurisdiction	
Analysis Time Period		Analysis Year	

Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	66	237	237	570	868	30	0	2178	319	0	1798	0
% heavy vehicles, % HV	3											
Peak-hour factor, PHF	1.0											
Pretimed (P) or actuated (A)	P											
Start-up lost time, l_1 (s)		0			0			0	0		0	0
Extension of effective green time, e (s)		0										
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)	40			40			40			40		
Approach bicycle volume,[2] v_{bic} (bicycles/h)	25			25			25			25		
Parking (Y or N)	N			N			N			N		
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)	10			10			10			10		

Signal Phasing Plan

	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM				Street car signal				
Timing	G = 16 Y = 4	G = 16 Y = 4	G = 30 Y = 3	G = 2 Y = 0	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 75 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Napoleon + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	66	237	237	530	268	30	0	2178	319	0	1748	0
Peak-hour factor, PHF	1.0	→										→
Adjusted flow rate, v_p = V/PHF (veh/h)	66	237	237	570	268	30	0	2178	319	0	1748	0
Lane group												
Adjusted flow rate in lane group, v (veh/h)		540			828			2497			1748	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.12	-	0.44	0.64	-	0.04	0	-	0.13	0	-	0

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB LT	EB TH	EB RT	WB LT	WB TH	WB RT	NB LT	NB TH	NB RT	SB LT	SB TH	SB RT
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		1			1			2			2	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.94			0.94			0.94			0.94	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.994			0.969			0			0	
Right-turn adjustment factor, f_{RT}		0.934			0.994			0.9805			0	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.995			0.995			0.995			0.995	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		1651			1723			3488			3558	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General information

Project Description: Napoleon + St. Charles

Capacity Analysis

Phase number	1	2	3	3
Phase type	P	P	P	P
Lane group				
Adjusted flow rate, v (veh/h)	540	828	2497	1748
Saturation flow rate, s (veh/h)	1651	1723	3488	3558
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	3	3
Effective green time, g (s), $g = G + Y - t_L$	20	20	30	30
Green ratio, g/C	0.27	0.27	0.4	0.4
Lane group capacity,[1] $c = s(g/C)$, (veh/h)	445	465	1395	1423
v/c ratio, X	1.21	1.78	1.79	1.23
Flow ratio, v/s	0.33	0.45	0.72	0.49
Critical lane group/phase (√)	✓	✓	✓	
Sum of flow ratios for critical lane groups, Y_c; $Y_c = \Sigma$ (critical lane groups, v/s)	1.53			
Total lost time per cycle, L (s)	12			
Critical flow rate to capacity ratio, X_c; $X_c = (Y_c)(C)/(C - L)$	1.87			

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	540	828	2497	1748
Lane group capacity,[2] c (veh/h)	445	465	1395	1423
v/c ratio,[2] $X = v/c$	1.21	1.78	1.79	1.23
Total green ratio,[2] g/C	0.27	0.27	0.4	0.4
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1, X)g/C]}$ (s/veh)	29.7	38.5	47.6	26.6
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2; $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8kIX}{cT}}]$ (s/veh)	112.5	358.9	357.8	108
Initial queue delay, d_3 (s/veh) (Appendix F)	0	0	0	0
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.714	0.714	0.555	0.555
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	134	386	384	123
LOS by lane group (Exhibit 16-2)	F	F	F	F
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	134	386	384	123
LOS by approach (Exhibit 16-2)	F	F	F	F
Approach flow rate, v_A (veh/h)	540	828	2497	1748
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	279	Intersection LOS (Exhibit 16-2)		F

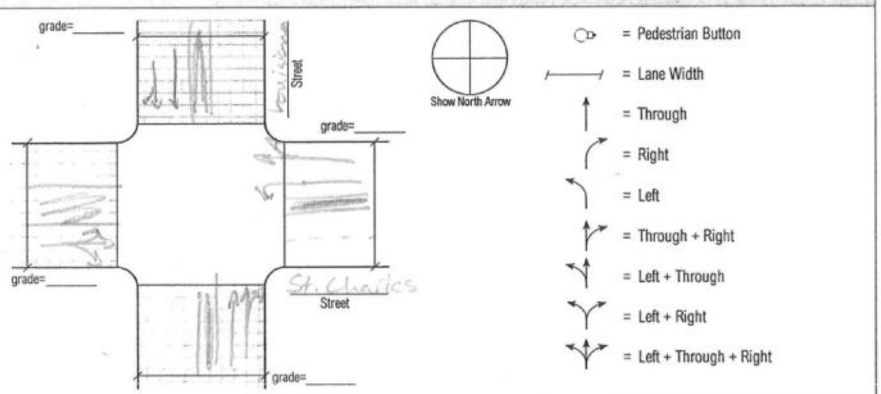
Notes

1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min. I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

INPUT WORKSHEET

General Information		Site Information	
Analyst		Intersection	Louisiana + St. Charles
Agency or Company		Area Type	☐ CBD ☐ Other
Date Performed		Jurisdiction	
Analysis Time Period		Analysis Year	

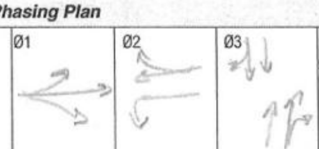
Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	74	395	201	337	577	150	0	1309	316	0	1279	89
% heavy vehicles, % HV	3											
Peak-hour factor, PHF	1.0											
Pretimed (P) or actuated (A)	P											
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)	40			40			40			40		
Approach bicycle volume,[2] v_{bic} (bicycles/h)	25			25			25			25		
Parking (Y or N)	N			N			N			N		
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)	10			10			10			10		

Signal Phasing Plan



	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM								
Timing	G = 20 Y = 4	G = 20 Y = 4	G = 30 Y = 3	G = 2 Y = 0	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 75 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Louisiana

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	74	395	201	337	577	150	0	1309	316	0	1279	89
Peak-hour factor, PHF	1.0											
Adjusted flow rate, v_p = V/PHF (veh/h)	74	395	201	337	577	150	0	1309	316	0	1279	89
Lane group												
Adjusted flow rate in lane group, v (veh/h)		670		337	727			1625			1368	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.11	-	0.3	1.00	-	0.21	0	-	0.24	0	-	0.07
Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)												
Base saturation flow, s_o (pc/h/ln)		1900		1900	1900			1900			1900	
Number of lanes, N		1		1	1			2			2	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.94		0.94	0.94			0.94			0.94	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.994		0.95								
Right-turn adjustment factor, f_{RT}		0.955			0.969			0.964			0.95	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997		0.997	0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999		0.999	0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		1689		1689	1723			3430			3554	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General Information

Project Description Louisiana

Capacity Analysis

Phase number	1	2	2	3	3							
Phase type	P	P	P	P	P							
Lane group												
Adjusted flow rate, v (veh/h)	670	727	337	1625	1368							
Saturation flow rate, s (veh/h)	1689	1723	1685	3430	3554							
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	4	3	3							
Effective green time, g (s), $g = G + Y - t_L$	20	20	20	30	30							
Green ratio, g/C	0.27	0.27	0.27	0.4	0.4							
Lane group capacity,[1] c = s(g/C), (veh/h)	456	465	456	1372	1421							
v/c ratio, X	1.47	1.56	0.74	1.18	0.96							
Flow ratio, v/s	0.4	0.42	0.2	0.47	0.38							
Critical lane group/phase (√)	✓	✓		✓								
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)	1.29											
Total lost time per cycle, L (s)	11											
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$	1.512											

Lane Group Capacity, Control Delay, and LOS Determination

	EB		WB	NB	SB
Lane group					
Adjusted flow rate,[2] v (veh/h)	670	337	727	1625	1368
Lane group capacity,[2] c (veh/h)	456	456	465	1372	1421
v/c ratio,[2] X = v/c	1.47	0.74	1.56	1.18	0.96
Total green ratio,[2] g/C	0.27	0.27	0.27	0.4	0.4
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1, X)g/C]}$ (s/veh)	33	25	34.4	25.6	21.92
Incremental delay calibration,[3] k					
Incremental delay,[4] d_2 $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	223.4	16.35	262.4	88.65	16.2
Initial queue delay, d_3 (s/veh) (Appendix F)					
Uniform delay, d_1 (s/veh) (Appendix F)					
Progression adjustment factor, PF	0.714	0.714	0.714	0.555	0.555
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	247	34.2	287	102.	28.
LOS by lane group (Exhibit 16-2)	F	C	F	F	C
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	247	206		102	28
LOS by approach (Exhibit 16-2)	F	F		F	C
Approach flow rate, v_A (veh/h)	670	1064		1625	1368
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	124.55	Intersection LOS (Exhibit 16-2)			F

Notes

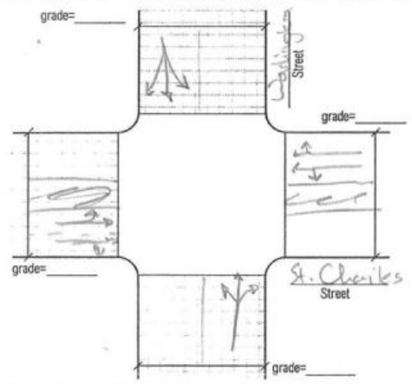
1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

Washington

INPUT WORKSHEET

General Information		**Site Information**	
Analyst		Intersection	Washington + St. Charles
Agency or Company		Area Type	☐ CBD ☐ Other
Date Performed		Jurisdiction	
Analysis Time Period		Analysis Year	

Intersection Geometry



= Pedestrian Button
= Lane Width
= Through
= Right
= Left
= Through + Right
= Left + Through
= Left + Right
= Left + Through + Right

Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	131	596	124	131	823	199	58	650	128	66	610	176
% heavy vehicles, % HV		2			2			1			1	
Peak-hour factor, PHF	1											→
Pretimed (P) or actuated (A)	P											→
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)		0			0			0			0	
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)		40			40			40			40	
Approach bicycle volume,[2] v_{bic} (bicycles/h)		25			25			25			25	
Parking (Y or N)		N			N			N			N	
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)		10			10			10			10	

Signal Phasing Plan

	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM				streetcar signal				
Timing	G = 20 Y = 4	G = 20 Y = 4	G = 10 Y = 4	G = 2 Y = 0	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns | Permitted turns / Pedestrian | Cycle length, C = 70 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Washington + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	131	596	124	131	823	199	58	650	128	66	610	176
Peak-hour factor, PHF	1.0	→										
Adjusted flow rate, v_p = V/PHF (veh/h)	131	596	124	131	823	199	58	650	128	66	610	176
Lane group												
Adjusted flow rate in lane group, v (veh/h)		851			1153			836			852	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.15	-	0.15	0.11	-	0.17	0.07	-	0.15	0.08	-	0.21

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		2			2			1			1	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.96			0.96			0.98			0.98	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.99			0.99			0.9			0.9	
Right-turn adjustment factor, f_{RT}		0.98			0.97			0.98			0.97	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.998			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		3525			3489			1636			1619	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General information

Project Description Washington + St. Charles

Capacity Analysis

Phase number	1	2	3	3								
Phase type	P	P	P	P								
Lane group	[illegible]	[illegible]	[illegible]	[illegible]								
Adjusted flow rate, v (veh/h)	851	1153	836	852								
Saturation flow rate, s (veh/h)	3525	3489	1636	1619								
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	11	4	4								
Effective green time, g (s), $g = G + Y - t_L$	20	20	16	16								
Green ratio, g/C	0.29	0.29	0.23	0.23								
Lane group capacity,[1] c = s(g/C), (veh/h)	1022	1011	376	372								
v/c ratio, X	0.83	1.14	2.22	2.29								
Flow ratio, v/s	0.24	0.33	0.51	0.53								
Critical lane group/phase (√)	✓	✓		✓								
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)	1.1											
Total lost time per cycle, L (s)	12											
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$	1.328											

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group	[illegible]	[illegible]	[illegible]	[illegible]
Adjusted flow rate,[2] v (veh/h)	851	1153	836	852
Lane group capacity,[2] c (veh/h)	1022	1011	376	372
v/c ratio,[2] X = v/c	0.83	1.14	2.22	2.29
Total green ratio,[2] g/C	0.29	0.29	0.23	0.23
Uniform delay, $d_1 = \frac{0.50\,C\,[1 - (g/C)]^2}{1 - [\min(1, X)g/C]}$ (s/veh)	23.237	26.358	42.403	43.845
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	7.8	135.6	557.5	560.4
Initial queue delay, d_3 (s/veh) (Appendix F)				
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.714	0.714	0.833	0.833
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	24.4	154.4	592.8	596.9
LOS by lane group (Exhibit 16-2)	C	F	F	F
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	24.4	154.4	592.8	596.9
LOS by approach (Exhibit 16-2)	C	F	F	F
Approach flow rate, v_A (veh/h)	851	1153	836	852
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	325.8	Intersection LOS (Exhibit 16-2)		F

Notes

1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

Jackson + St. Charles

INPUT WORKSHEET

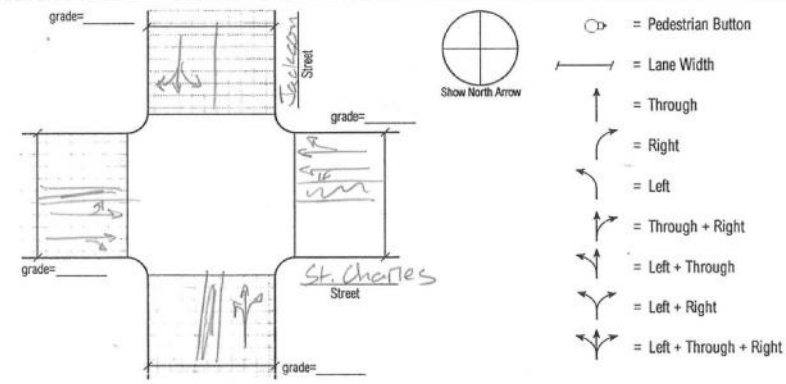
General Information

Analyst	
Agency or Company	
Date Performed	
Analysis Time Period	

Site Information

Intersection	
Area Type	☐ CBD ☐ Other
Jurisdiction	
Analysis Year	

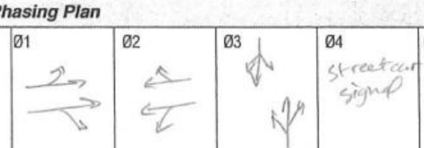
Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	44	561	252	555	809	0	460	34	253	45	30	0
% heavy vehicles, % HV		2			2			1			1	
Peak-hour factor, PHF		1			1			1			1	
Pretimed (P) or actuated (A)		P			P			P			P	
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)	40			40			40			40		
Approach bicycle volume,[2] v_{bic} (bicycles/h)	25			25			25			25		
Parking (Y or N)	N			N			N			N		
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)	10			10			10			10		

Signal Phasing Plan



	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM				streetcar signal				
Timing	G = 20 Y = 4	G = 20 Y = 4	G = 16 Y = 4	G = 2 Y = 0	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 70 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description: Jackson + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	44	561	252	555	809	0	460	34	253	45	30	0
Peak-hour factor, PHF		1.0			1.0			1.0			1.0	
Adjusted flow rate, v_p = V/PHF (veh/h)	411	561	252	555	809	0	460	34	253	45	30	0
Lane group												
Adjusted flow rate in lane group, v (veh/h)		857			1361			747			75	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.05	-	0.29	0.67	-	0	0.62	-	0.34	0.6	-	0
Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)												
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		2			2			1			1	
Lane width adjustment factor, f_w		0.96			0.96			0.98			0.98	
Heavy-vehicle adjustment factor, f_{HV}												
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.99			0.99			0.9			0.9	
Right-turn adjustment factor, f_{RT}		0.98			—			0.98			—	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.957	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		3525			3597			1636			1669	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General information

Project Description Jackson + St. Charles

Capacity Analysis

Phase number	1	2	3	3							
Phase type											
Lane group											
Adjusted flow rate, v (veh/h)	857	1361	747	75							
Saturation flow rate, s (veh/h)	3525	5597	1636	1669							
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	4	4							
Effective green time, g (s), $g = G + Y - t_L$	20	20	16	16							
Green ratio, g/C	0.29	0.29	0.23	0.23							
Lane group capacity,[1] c = s(g/C), (veh/h)	1022	1043	376	383							
v/c ratio, X	0.838	1.304	1.987	0.196							
Flow ratio, v/s	0.266	0.378	0.457	0.045							
Critical lane group/phase (√)	√	√	√								
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)	1.101										
Total lost time per cycle, L (s)	12										
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$	1.329										

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	857	1361	747	75
Lane group capacity,[2] c (veh/h)	1022	1043	376	353
v/c ratio,[2] X = v/c	0.838	1.304	1.987	0.196
Total green ratio,[2] g/C	0.29	0.29	0.23	0.23
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1,X)g/C]}$ (s/veh)	23.237	28.374	38.218	21.73
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1)+\sqrt{(X-1)^2+\frac{8klX}{cT}}]$ (s/veh)	8.1	143.83	453.6	1.05
Initial queue delay, d_3 (s/veh) (Appendix F)				
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.714	0.714	0.833	0.833
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	24.7	164.1	485.4	19.1
LOS by lane group (Exhibit 16-2)	C	F	F	B
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	24.7	164.1	485.4	19.1
LOS by approach (Exhibit 16-2)	C	F	F	B
Approach flow rate, v_A (veh/h)	857	1361	947	75
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	200	Intersection LOS (Exhibit 16-2)		F

Notes

1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

Felicity + St. Charles

INPUT WORKSHEET

General Information

Analyst ______

Agency or Company ______

Date Performed ______

Analysis Time Period ______

Site Information

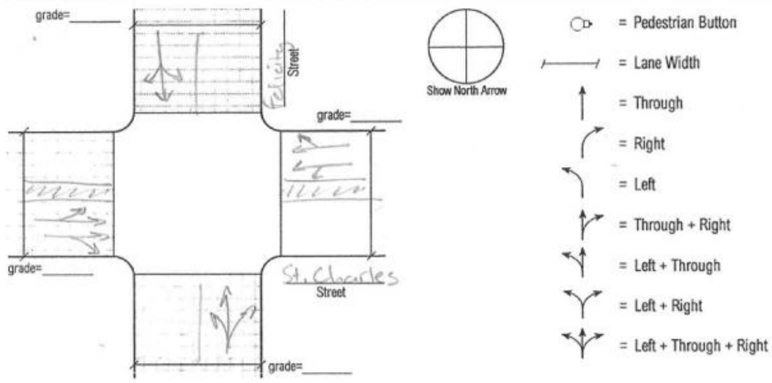
Intersection: Felicity + St. Charles

Area Type: ☐ CBD ☐ Other

Jurisdiction ______

Analysis Year ______

Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	127	680	0	10	1222	153	0	0	0	111	0	117
% heavy vehicles, % HV		2			2			1			1	
Peak-hour factor, PHF		1.0			1.0			1.0			1.0	
Pretimed (P) or actuated (A)		P			P			P			P	
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)		40			40			40			40	
Approach bicycle volume,[2] v_{bic} (bicycles/h)		25			25			25			25	
Parking (Y or N)		N			N			N			N	
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)		10			10			10			10	

Signal Phasing Plan

DIAGRAM	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
				Streetcar Signal				
Timing	G = 20 Y = 11	G = 20 Y = 4	G = 16 Y = 4	G = 2 Y =	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 70 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Felicity + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	127	680	0	0	1222	153	0	0	0	111	0	117
Peak-hour factor, PHF	1.0	→										→
Adjusted flow rate, v_p = V/PHF (veh/h)	127	680	0	0	1222	153	0	0	0	111	0	117
Lane group												
Adjusted flow rate in lane group, v (veh/h)		807			1375			0			228	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.153	-	0	0	-	0.13	0	-	0	0.49	-	0.51

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB			WB			NB			SB		
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		2			2			1			1	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.96			0.96			0.98			0.98	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.992			—			—			0.976	
Right-turn adjustment factor, f_{RT}		—			0.9805			—			0.924	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		3379			3563			1855			1672	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General information

Project Description ~~Fele~~ Felicity

Capacity Analysis

Phase number	1	2	3	3								
Phase type	P	P	P	P								
Lane group												
Adjusted flow rate, v (veh/h)	802	1375	0	228								
Saturation flow rate, s (veh/h)	3379	3563	1855	1672								
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	4	4								
Effective green time, g (s), $g = G + Y - t_L$	20	20	16	16								
Green ratio, g/C	0.29	0.29	0.23	0.23								
Lane group capacity,[1] c = s(g/C), (veh/h)	980	1033	426	385								
v/c ratio, X	0.823	1.33	0	0.59								
Flow ratio, v/s			0									
Critical lane group/phase (√)	✓	✓		✓								
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)												
Total lost time per cycle, L (s)												
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$												

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	802	1375	0	228
Lane group capacity,[2] c (veh/h)	980	1033	426	385
v/c ratio,[2] X = v/c	0.828	1.33	0	0.59
Total green ratio,[2] g/C	0.29	0.29	0.23	0.23
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1, X)g/C]}$ (s/veh)	23.18	28.7	20.75	24
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	7.75	155.25	0	6.75
Initial queue delay, d_3 (s/veh) (Appendix F)				
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.714	0.714	0.833	0.877
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	24.3	175.74	17.3	26.7
LOS by lane group (Exhibit 16-2)	C	F	B	C
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	24.3	175.74	17.3	26.7
LOS by approach (Exhibit 16-2)	C	F	B	C
Approach flow rate, v_A (veh/h)	802	1375	0	228
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	111	Intersection LOS (Exhibit 16-2)		F

Notes

1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

MLK

INPUT WORKSHEET

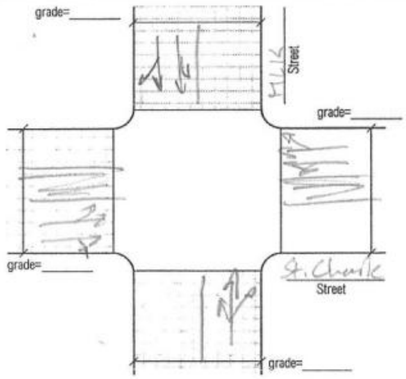
General Information

Analyst ______
Agency or Company ______
Date Performed ______
Analysis Time Period ______

Site Information

Intersection: MLK + St. Charles
Area Type: ☐ CBD ☐ Other
Jurisdiction ______
Analysis Year ______

Intersection Geometry



= Pedestrian Button
= Lane Width
= Through
= Right
= Left
= Through + Right
= Left + Through
= Left + Right
= Left + Through + Right

Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	145	590	0	0	964	380	0	0	0	13	0	375
% heavy vehicles, % HV		2			2			1			1	
Peak-hour factor, PHF												
Pretimed (P) or actuated (A)												
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)		40			40			40			40	
Approach bicycle volume,[2] v_{bic} (bicycles/h)		25			25			25			25	
Parking (Y or N)		N			N			N			N	
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)		10			10			10			10	

Signal Phasing Plan

DIAGRAM	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
				Streetcar signal				
Timing	G = 20 Y = 4	G = 20 Y = 4	G = 16 Y = 4	G = 2 Y = 0	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns / Pedestrian — Cycle length, C = 70 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description MLK + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	145	590	0	0	964	380	0	0	0	13	0	375
Peak-hour factor, PHF	1.0	→										
Adjusted flow rate, v_p = V/PHF (veh/h)	145	590	0	0	964	380	0	0	0	13	0	375
Lane group												
Adjusted flow rate in lane group, v (veh/h)		735			1344			0			388	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.2	-	0		-	0.28		-		0.03	-	0.97

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB			WB			NB			SB		
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		2			2			1			2	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.96			0.96			0.98			0.98	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.99			—			—			0.998	
Right-turn adjustment factor, f_{RT}		—			0.958			—			0.855	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.999			0.999			0.999			0.999	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		3597			3481			1454			3165	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General information

Project Description MLK + St. Charles

Capacity Analysis

Phase number	1	2	3	3								
Phase type	P	P	P	P								
Lane group												
Adjusted flow rate, v (veh/h)	735	1344	0	388								
Saturation flow rate, s (veh/h)	3597	3481	1854	3165								
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	4	4								
Effective green time, g (s), $g = G + Y - t_L$	20	20	16	16								
Green ratio, g/C	0.29	0.29	0.23	0.23								
Lane group capacity,[1] c = s(g/C), (veh/h)	1043	1009	426	727								
v/c ratio, X	0.71	1.33	0	0.53								
Flow ratio, v/s												
Critical lane group/phase (√)												
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)												
Total lost time per cycle, L (s)	12											
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$												

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	735	1344	0	388
Lane group capacity,[2] c (veh/h)	1043	1009	426	727
v/c ratio,[2] X = v/c	0.71	1.33	0	0.53
Total green ratio,[2] g/C	0.29	0.29	0.23	0.23
Uniform delay, $d_1 = \frac{0.50\,C\,[1 - (g/C)]^2}{1 - [\min(1, X)g/C]}$ (s/veh)	22.22	28.7	20.752	23.43
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1) + \sqrt{(X-1)^2 + \frac{8klX}{cT}}]$ (s/veh)	1.04	154.35	0	3.07
Initial queue delay, d_3 (s/veh) (Appendix F)				
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.714	0.714	0.833	0.833
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	16.9	174.8	17.28	22.75
LOS by lane group (Exhibit 16-2)				
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	16.9	174.8	17.28	22.75
LOS by approach (Exhibit 16-2)	B	F	B	B
Approach flow rate, v_A (veh/h)	735	1344	0	388
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	103.8	Intersection LOS (Exhibit 16-2)		F

Notes

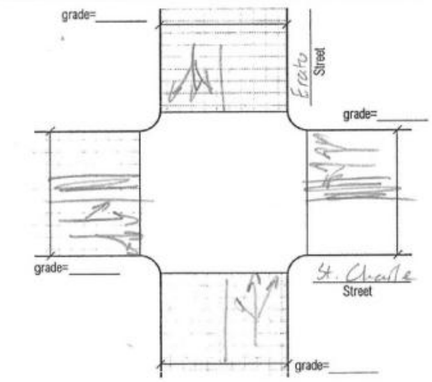
1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

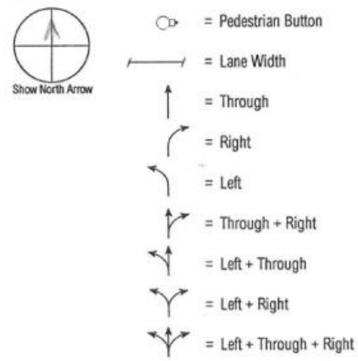
Erato

INPUT WORKSHEET

General Information		**Site Information**	
Analyst		Intersection	Erato + St. Charles
Agency or Company		Area Type	☐ CBD ☐ Other
Date Performed		Jurisdiction	
Analysis Time Period		Analysis Year	

Intersection Geometry





Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	60	697	0	0	1178	377	0	0	0	65	0	304
% heavy vehicles, % HV		2			2			1			1	
Peak-hour factor, PHF												
Pretimed (P) or actuated (A)												
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		5			5			5			5	
Approach pedestrian volume,[2] v_{ped} (p/h)	40			40			40			40		
Approach bicycle volume,[2] v_{bic} (bicycles/h)	25			25			25			25		
Parking (Y or N)	N			N			N			N		
Parking maneuvers, N_m (maneuvers/h)												
Bus stopping, N_B (buses/h)												
Min. timing for pedestrians,[3] G_p (s)	10			10			10			10		

Signal Phasing Plan

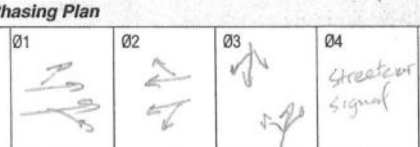


DIAGRAM	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
				streetcar signal				
Timing	G = 20 Y = 4	G = 20 Y = 4	G = 16 Y = 4	G = 2 Y =	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns / Pedestrian — Cycle length, C = 70 s

Notes

1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description Erato + St. Charles

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	60	697	0	0	1178	377	0	0	0	65	0	304
Peak-hour factor, PHF	1.0											
Adjusted flow rate, v_p = V/PHF (veh/h)	60	697	0	0	1178	377	0	0	0	65	0	304
Lane group												
Adjusted flow rate in lane group, v (veh/h)		757			1555			0			369	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.06	-	0	0	-	0.24	0	-	0	0.18	-	0.82

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Base saturation flow, s_o (pc/h/ln)		1900			1900			1900			1900	
Number of lanes, N		2			2			1			1	
Lane width adjustment factor, f_w												
Heavy-vehicle adjustment factor, f_{HV}		0.96			0.96			0.98			0.98	
Grade adjustment factor, f_g												
Parking adjustment factor, f_p												
Bus blockage adjustment factor, f_{bb}												
Area type adjustment factor, f_a												
Lane utilization adjustment factor, f_{LU}												
Left-turn adjustment factor, f_{LT}		0.996			—			—			0.991	
Right-turn adjustment factor, f_{RT}		—			0.964			—			0.877	
Left-turn ped/bike adjustment factor, f_{Lpb}		0.997			0.997			0.997			0.997	
Right-turn ped/bike adjustment factor, f_{Rpb}		0.995			0.995			0.999			0.995	
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$		3619			3503			1855			1619	

Notes

1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

CAPACITY AND LOS WORKSHEET

General information

Project Description Erato + St. Charles

Capacity Analysis

Phase number	1	2	3	3								
Phase type												
Lane group												
Adjusted flow rate, v (veh/h)	757	1555	0	269								
Saturation flow rate, s (veh/h)	3619	3503	1855	1619								
Lost time, t_L (s), $t_L = l_1 + Y - e$	4	4	4	4								
Effective green time, g (s), $g = G + Y - t_L$	20	20	16	16								
Green ratio, g/C	0.27	0.29	0.23	0.23								
Lane group capacity,[1] c = s(g/C), (veh/h)	1050	1016	426	372								
v/c ratio, X	0.721	1.531	0	0.999								
Flow ratio, v/s			0									
Critical lane group/phase (√)	✓	✓		✓								
Sum of flow ratios for critical lane groups, Y_c $Y_c = \Sigma$ (critical lane groups, v/s)												
Total lost time per cycle, L (s)	12											
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$												

Lane Group Capacity, Control Delay, and LOS Determination

	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	757	1555	0	369
Lane group capacity,[2] c (veh/h)	1050	1016	426	372
v/c ratio,[2] X = v/c	0.721	1.531	0	0.999
Total green ratio,[2] g/C	0.29	0.29	0.23	0.23
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1,X)g/C]}$ (s/veh)	22.5	31.72	20.752	26.94
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1)+\sqrt{(X-1)^2+\frac{8klX}{cT}}]$ (s/veh)	4.35	244	0	46.4
Initial queue delay, d_3 (s/veh) (Appendix F)				
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.714	0.714	0.873	0.837
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	20	266	17.1	67.7
LOS by lane group (Exhibit 16-2)	B	F	B	E
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	20	266	17	68
LOS by approach (Exhibit 16-2)	B	F	B	E
Approach flow rate, v_A (veh/h)	757	1555	0	369
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	169.3	Intersection LOS (Exhibit 16-2)		F

Notes

1. For permitted left turns, the minimum capacity is $(1 + P_L)(3600/C)$.
2. Primary and secondary phase parameters are summed to obtain lane group parameters.
3. For pretimed or nonactuated signals, k = 0.5. Otherwise, refer to Exhibit 16-13.
4. T = analysis duration (h); typically T = 0.25, which is for the analysis duration of 15 min.
   I = upstream filtering metering adjustment factor; I = 1 for isolated intersections.

Vita

Vivek Shah is a candidate for Masters in Urban and Regional Planning at the University of New Orleans. Vivek grew up in New York, and received his undergraduate degree from the University of Rochester. While studying Anthropology and Chemical Engineering as an undergraduate, Vivek become interested in the intersection of transportation and urban development and focused as much on the technical aspect of transportation systems as well as the policy side of urban development.