Facilitating Special Event Congestion Management in Small Communities

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Planned special events (PSE), such as sporting events, concerts, etc. produce nonrecurring congestion as attendees attempt to simultaneously exit the event, overloading the local transportation network. These types of events can have a significant impact on traffic operations, particularly in small urban and rural environments, where limited infrastructure is available to access and egress the PSE venue.

The research presented here applied a variety of traffic management strategies to manage congestion resulting from football games at Montana State University in Bozeman, Montana, in the fall of 2007. This document discusses the technology and traffic mitigation strategies employed during the fall 2007 football season. Mitigation measures included the provision of real-time traveler information, road closures, traffic signal retiming, and real-time traffic monitoring. Data was also collected to determine the actual impact of the PSE on traffic flow on game days.

This document presents the results of the analysis of the mitigation measures employed. The overall results indicate that the traffic mitigation strategies selected could be successfully applied in a rural community to manage traffic congestion stemming from PSEs. Techniques such as traffic signal re-timing and manual traffic control accounted for significant improvements in traffic flow on approaches that serviced PSE traffic.

1. INTRODUCTION

Traffic management, particularly congestion management, is increasingly becoming a standard in traffic operations. Roadway expansion is no longer the primary solution for congestion; in fact, it can often increase congestion problems. In May of 2006, US Department of Transportation (DOT) Secretary Mineta announced the National Strategy to Reduce Congestion on America's Transportation Network. This strategy calls for a collective effort to reduce congestion [1]. In response, the overall goal of this project is to develop a model for reducing congestion through community collaboration and the use of advanced traffic management technologies. Specifically, this project addresses the congestion in small urban and rural communities that can accompany special events. It is important to recognize that congestion is not limited to large urban or metropolitan areas, and that due to the absence of alternate routes, congestion in rural and small urban areas can be as severe as that in urban areas [2]. The need particularly for applied research on managing congestion in such settings during special events is progressively becoming more important [3].

1.1. Congestion Management Strategies

There are two types of congestion: recurring, and non-recurring. Recurring congestion produces predictable delays caused by high traffic volumes during the same time frame and at the same locations on a daily basis. One example is the delay that occurs on an arterial in the late afternoon and early evening on weekdays as people head home from work. Non-recurring congestion results in unpredicted delays due to events such as incidents or weather conditions. Sporting events, concerts, etc. also produce non-recurring congestion as attendees attempt to simultaneously exit the event, overloading the local transportation network. These types of special events can have a significant impact on traffic operations, particularly in small urban and rural environments, where limited infrastructure is available to access and egress the special event venue.

The Federal Highway Administration (FHWA) has published a user guide for managing special event traffic entitled *Managing Traffic for Special Planned Events* [4]. In chapter 15 of this guide, FHWA defines criteria for special considerations for special events traffic management:

- Need for stakeholders to assume new and/or expanded roles.
- Need to work closely with all affected stakeholders in order:
  - to gain their help in identifying concerns and
  - to introduce them to mitigation measures that they may be unfamiliar with due to the rural nature of the area.
- Need to work closely with involved stakeholders so that a trust relationship is established, thus lessening sensitive feelings of an outsider coming in and imposing initiatives that could overlook the significance of local issues.
- Existence of limited road capacity to access the event venue and potentially limited parking capacity at the venue.
- Existence of fewer alternate routes to accommodate event and background traffic.
- Existence of limited or no permanent infrastructure for monitoring and managing traffic.
- Generation of trips from a multi-county region.

Additionally, the guide states that there are four main topics that need to be addressed when managing special events traffic [4] to ensure successful traffic management for the event:

- Event operations planning,
- Implementation and day-of-event activities,
- Post-event activities, and
- Program planning.

To date, FHWA has promoted a number of strategies aimed at reducing highway and special events congestion [1]. These have focused on traveler information, and improved coordination between agencies. The focus of these efforts have been improved coordination resulting in faster response times in addressing evolving conditions and improved traveler information that allows the end-user (the traveler) to make more informed travel decisions. In light of these successes, the Western Transportation Institute (WTI) sought to apply some of FHWA's recommended strategies for managing congestion in a small urban and rural application and address each of the four topics listed above.

The specific FHWA strategies that were applied in the project were:

- **Real-Time Traveler Information**. As the term implies, real-time travel information is both collected and disseminated in "real-time", so that travelers may make decisions based on current conditions. This includes current information that enables roadway users to select the best route to their ultimate destination. The overall goal is to reduce traffic congestion, and improve travel times.
- **Traffic Incident Management**. Traffic incident management is a collaborative effort between agencies. The goal is to clear traffic incidents in a safe, timely fashion thereby reducing traffic congestion.
- **Traffic Signal Timing**. The goal of this effort is to reduce traffic congestion through the implementation of adjusted signal timing to meet the needs of the current traffic flow. Signal timing should correspond to the current traffic patterns. This is often a collaborative effort between operating agencies [1].

The case study that was conducted involved the management of traffic congestion resulting from a sporting event in a small town, namely, Montana State University football games in Bozeman, Montana. The following report describes the collaborative efforts undertaken by WTI and stakeholders from Montana State University (MSU) the Montana Department of Transportation (MDT) and the City of Bozeman that identified areas of primary concern and defined, implemented and refined mitigation strategies. The result was the formation of new inter-agency relationships and a collaborative approach being taken to address the traffic congestion issues presented by a special event in a rural community.

1.2. Project Background

The original genesis of this project dates back to the fall of 2006. Ongoing growth in Bozeman, both in terms of population and traffic, prompted WTI and MSU examine the impacts that the additional traffic created by football games had on the roadway network in the city. This examination included travel time and intersection operational analyses conducted for both game and non-game events during the fall of 2006. This allowed for a comparison to be made between an ordinary Saturday with no special event versus one with a special event.

Travel times were collected using the floating car method along the three routes shown in Figure 1. The comparison of game and non-game travel times indicated that the primary route used by game attendees to travel to and from the stadium area was the 19th Avenue corridor. Pregame traffic was not heavy enough on any route to greatly affect travel times. However, postgame travel times were affected on both the 19th Avenue corridor and the College Street corridor (on the 11th Avenue link between the stadium parking lots and the intersection of 11th Avenue and College Street). These conditions indicated that travel was being hampered in the vicinity of campus immediately following the conclusion of a game, namely as a result of breakdowns in intersection operations.

Figure 1-1: 2006 travel-time study corridors (map courtesy of Google Maps)

Results of the intersection operational analysis indicated that three intersections immediately adjacent to campus, College Street and 19th Avenue, College Street and 11th Avenue and 19th Avenue and Lincoln Street all suffered operational breakdowns at the conclusion of a game. This was the result of the influx of traffic attempting to leave the stadium area at approximately the same time following the conclusion of a game. As the distance from campus increased, the impacts of post-game traffic on intersection operations were minimized. Only the intersection of 11th Avenue and College Street experienced operational breakdowns during the morning of a game. Other sites did not experience operational declines as it appeared that traffic tended to arrive in a staggered fashion to games.

Based on these results, all affected stakeholders met and agreed that proactive solutions were necessary to address special event (namely football) traffic problems before they became overwhelming. These meetings resulted in the identification and implementation of a number of different traffic management strategies that were ultimately employed to address the impacts of special events on traffic. These strategies will be discussed in further detail in subsequent sections of this report, but to inform the reader, they included road closures, manual traffic direction, signal timing changes, static signage, portable Dynamic Message Signs (DMS), closed circuit television (CCTV) monitoring and highway advisory radio (HAR).

1.3. Inter-agency Partnership

As previously mentioned, the FHWA's criteria include the need for stakeholders to assume new and/or expanded roles. In the context of this work, the participation of stakeholders was essential both in order to facilitate the application of the proposed traffic management strategies, as well as to ensure the overall success of the project. The specific stakeholders in this project included:

- MSU Administration,
- MSU Athletics,
- MSU Campus Police,
- Montana Department of Transportation (MDT),
- City of Bozeman Police
- City of Bozeman Public Works, and
- Western Transportation Institute.

Traditionally, these stakeholders, while working together on specific aspects related to football games and traffic, did not coordinate their efforts. As a result, the opportunity to establish a collaborative approach to addressing game-related traffic had not previously occurred. Instead, many stakeholders had no idea of what another party was doing. While this did not lead to any known cases of conflicting strategies being employed by multiple parties, it did create the potential for such instances to occur.

In light of the lack of extensive coordination between stakeholders, the primary goal of this project was to facilitate a means by which all parties were brought to the table to discuss what each agency was doing, as well as identify what could be improved and/or pursued with respect to traffic management. To this end, a series of meetings were held prior to, as well as during the football season to facilitate this coordination. The result of these meetings was a greater understanding of the roles which each stakeholder played during a game event, as well as the facilitation of a unified approach to addressing traffic issues resulting from that event.

1.4. Stakeholder Meetings

Several meetings were held with stakeholders to discuss traffic management strategies for planned special events. In several instances, pre- and postgame meetings were held. Postgame briefings were useful for determining which traffic management strategies were successful and identifying areas that needed improvement. It was particularly helpful to receive feedback from field personnel who could address issues observed and identify key areas that needed attention. A postseason meeting was held to evaluate the overall impact of the traffic control had on special event traffic. A final meeting was conducted in March of 2008 to discuss proposed improvements and traffic control strategies for the 2008 season.

Providing the stakeholders a forum in which they could compare past experiences, ideas, and observations, strategize and revise implementation plans proved invaluable to the overall success of the project and fostered a new collaborative approach to traffic management for special events. The meetings also provided stakeholder with insight as to the experience, observations, and challenges faced by partner agencies.

1.5. Similar Efforts

The application of transportation management strategies for special events at universities has precedent. While many universities take proactive steps to accommodate traffic for such events (i.e. traffic direction, manual signal control, etc.), only limited documentation has been made of them. The following are a limited set of examples of past and on-going work with respect to such activities.

University of Mississippi

The University of Mississippi in Oxford utilized traffic count data from more than 20 intersections during weekday traffic and special events (two football games in 2002) to create traffic models [5]. These models were used to examine the impacts which special events had on traffic flow, as well as to predict future traffic flow in response to new developments and roads. No traffic management strategies were employed and no prediction of the impacts of potential strategies was performed during the course of this work.

Iowa State University

On-going work at the Center for Transportation Research and Education at Iowa State University has focused on the impacts of traffic both before and after football games [6]. Traffic for such events was observed in both Ames (Iowa State University) as well as Iowa City (University of Iowa) from 2005 through the present. No traffic management strategies have been employed as the result of this research, and since it is on-going, no results have been published to date.

University of Washington

To address the impacts of a 1987 stadium expansion project, the University of Washington implemented a transportation management plan (TMP) to mitigate the potential increase in vehicle traffic and parking impacts [7]. The major components of the program included:

- Incentives to use public transit (free transit scrip good for use on all routes serving the stadium area);
- The creation of a park-and-ride system providing direct service from outlying areas to the stadium;
- Increased on-campus parking supply and lease of off-campus parking spaces (with free shuttle bus service to the stadium);
- Implementation of a special-event restricted parking zone in residential neighborhoods near the stadium; and
- A marketing program promoting increased use of non-automobile modes.

The program far exceeded expectations and was considered to be a success. Much of the success was attributed to the free transit program and park-and-ride system.

Texas A&M University

In 1994 a transportation management plan was drafted to address traffic during home football games at Texas A&M University [8]. While this plan was drafted as a graduate student research paper, it was of interest in that it recommended many of the strategies proposed for use in Bozeman. Specifically, the plan called for:

- Route diversion strategies;
- Highway advisory radio; and
- Reversible flow lanes.

While the plan itself was not implemented, over time several of its recommendations have been. One aspect which has been implemented is the “Go with the Green” plan which provides attendees with a map showing preferred post-game travel routes outlined in green on a map. Additionally, shuttle busses are employed to bring attendees to the stadium who had parked at an outlying mall.

1.6. Report Outline

This report is organized into seven chapters. Chapter 1 has provided an overview of the project. Chapter 2 will provide more detail on the research objectives and scope, the locale in which the work was performed, the special event, and the strategies employed to address traffic issues. Chapter 3 examines the technological aspects of the research, as well as the results of the technologies employed. Chapter 4 examines the changes which occurred to travel times as the result of the strategies employed, while Chapter 5 examines the impacts that traffic management had on intersection operations. Chapter 6 discusses the attendee survey results. Finally, Chapter 7 presents the conclusions that have been drawn as the result of the research.

2. METHODOLOGY

This chapter will discuss the objectives and scope of this research, in order to familiarize the reader with the rationale behind this project. This chapter also includes sections describing the location and event, as well as a detailed examination of each of the strategies employed.

2.1. Research Objectives and Scope

The overall goal of this project was to develop and field test strategies that small urban and rural communities across the country could use to reduce traffic congestion during special events. This goal was pursued by conducting a case study in which applied traffic management technologies and techniques to manage congestion at a major sporting event (football games) in a small, college town (Bozeman, MT). The congestion challenges faced at this event are typical of those encountered in many areas around the country, and the outcomes of this case study are intended provide small communities with practical information that will facilitate coordinated traffic management of their special events. The case study consisted of several components, including the development of a coordinated, multi-agency approach to traffic management (discussed previously), the implementation of various strategies to address the previously identified congestion issues (road closures, traffic signal retiming), and the deployment of advanced technologies to enhance real time monitoring and traveler information. The project was also expected to have indirect impacts beyond its immediate goals by illustrating:

- a collaborative approach to problem solving that can be applied to other traffic and transportation challenges in the community, and
- the benefits of active traffic management, many of which can be realized across a variety of traffic situations (e.g., construction project produced congestion, weather event related congestion, etc.)

Field work for this project was conducted during the Fall of 2007 (corresponding with the Fall football season), with analysis of the results and documentation completed in the Spring of 2008. The report presented here is consistent with the goal of the project; that is, to provide other small communities that host special events information that they will find useful in managing the associated traffic congestion.

2.2. The Setting

Bozeman, Montana, approximately 10 square miles in size, has a permanent population of approximately 32,414 residents [9]. Bozeman is home to Montana State University, one of Montana's two primary institutions of higher education, offering over 50 degree programs to a student population of 12,300. The University is on the south side of Bozeman, and the football stadium is on the southern edge of the campus (see Figure 2-1).

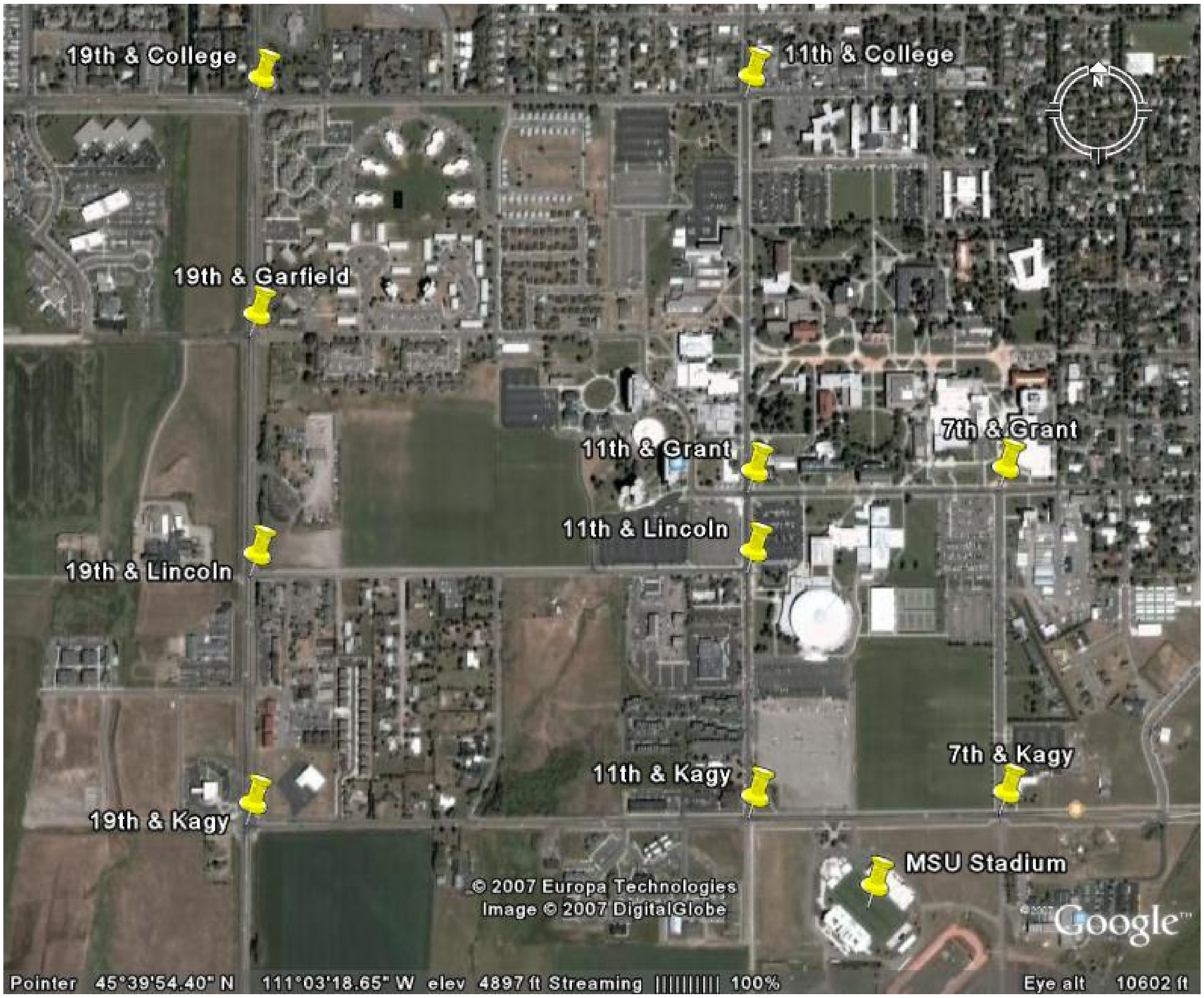


Figure 2-1: Map of area impacted by MSU football games – courtesy of Google Earth

To the south of the stadium is a residential area that extends a few miles to the foothills of the Hyalite Mountain range, which forms a natural barrier to further travel to the south (Figure 2-2).

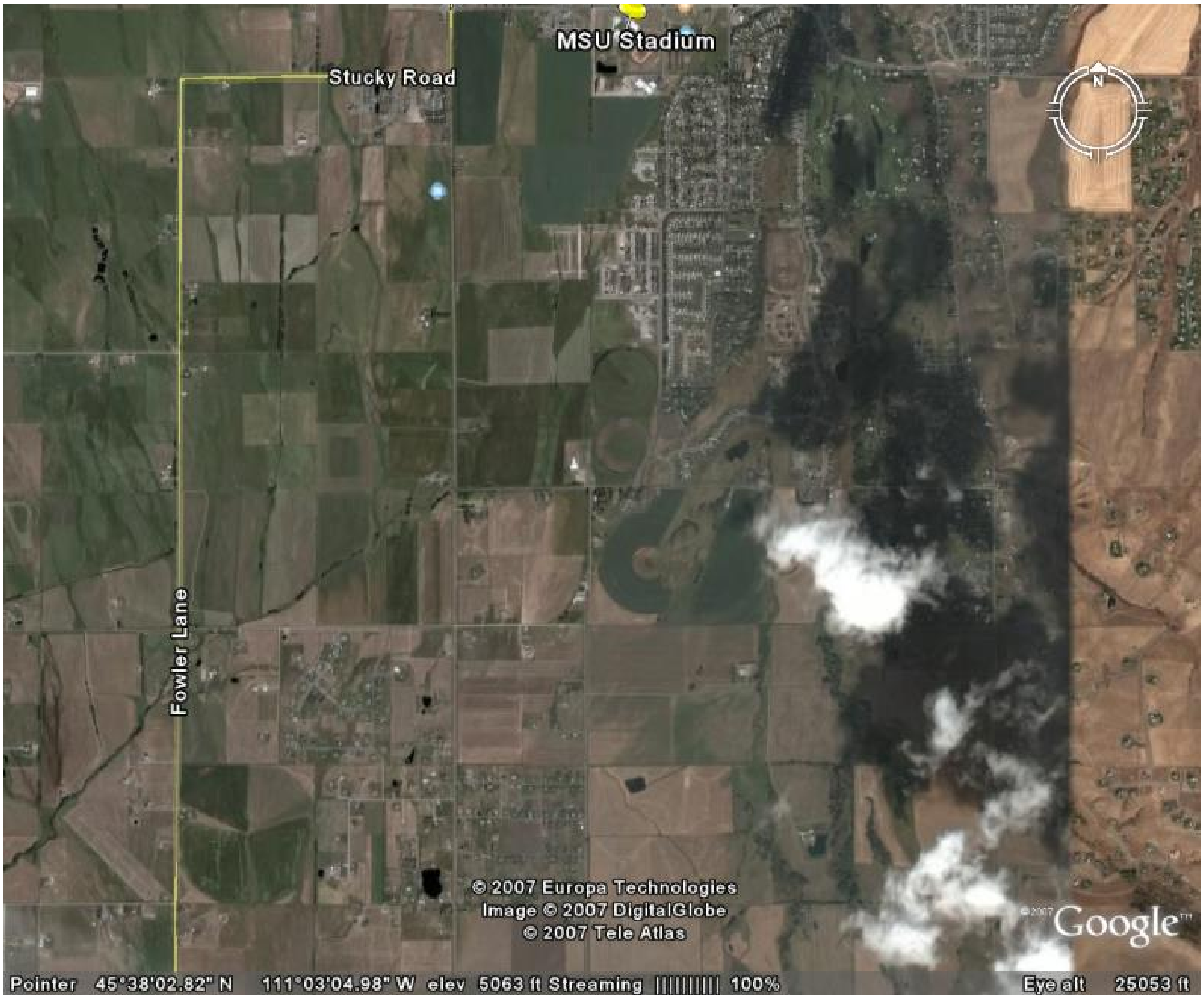


Figure 2-2: Southwest residential area – Hyalite – courtesy of Google Earth

North of the stadium is the main University campus, followed by city residential areas that are periodically crisscrossed by arterials lined with light commercial development (Figure 2-3).

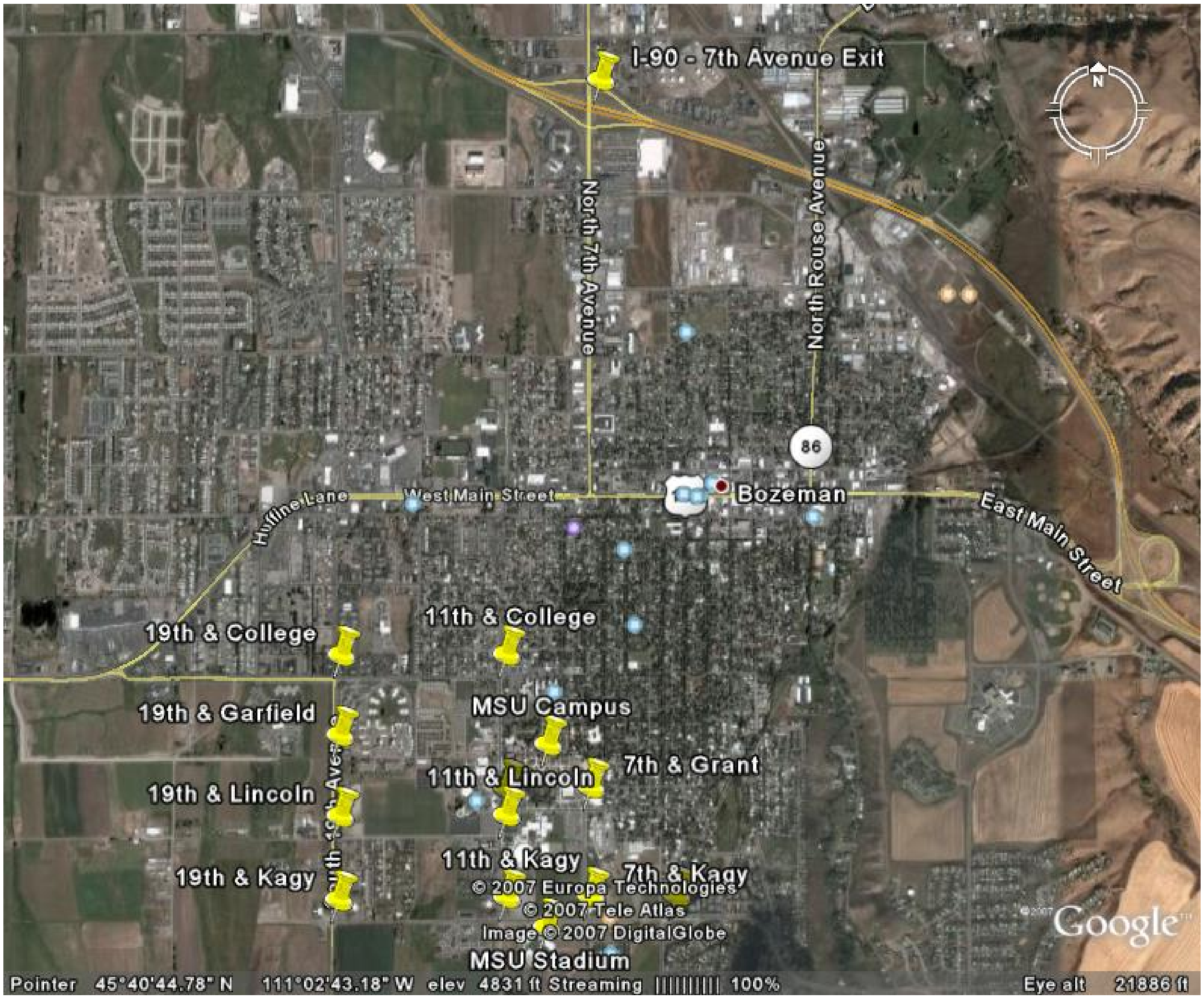


Figure 2-3: Residential area north of stadium – courtesy of Google Earth

Currently, the city extends north to Interstate 90, which is the primary east-west traffic corridor across Southern Montana. The majority of out-of-area travelers to Bozeman (i.e., coming from more than 10 to 15 miles away), access the city via Interstate 90.

The stadium is on the south side of Kagy Boulevard. This two lane facility is the southernmost east-west arterial in Bozeman. The stadium is bounded on the west by 11th Avenue, a two lane north-south minor arterial that terminates at the stadium to the south, and in the center of Bozeman, to the north. Other key routes in the vicinity include:

- 19th Street, a north-south arterial immediately west of the stadium that terminates to the north at Interstate 90,
- College Street, an east-west arterial on the north edge of the campus, and
- Willson Avenue, a north-south arterial that runs from Kagy to downtown Bozeman

2.3. The Event

In recent years, approximately 13,000 people have attended Montana State University Bobcat football games. The traffic control during special events such as this is the responsibility of the MSU Campus Police. Traditionally, traffic management during Montana State University home football games was limited to a few road closures aimed at pedestrian safety, some traffic control personnel, and static signage to inform motorists of detours and the road closure on Kagy Boulevard. The MSU Campus Police Department had and continues to have limited staffing resources, which could be better used for safety applications. Traffic management during special events was virtually non-existent, as the MSU Police did not have access to technologies for traffic monitoring such as closed circuit television (CCTV), highway advisory radio (HAR), dynamic message signs (DMS), and Traffic Management Center (TMC) monitoring and coordination.

Data collection performed during the 2006 football season quantified the extent of the problems created by game-related traffic [10]. Following a game with typical attendance, roadways in the vicinity of the MSU campus were inundated with traffic for approximately one and a half hours. In particular, intersections, both signalized and unsignalized, near the campus saw degraded Level of Service (LOS). The most telling observation made during the course of the 2006 data collection illustrates the problem: queues of vehicles stretching for approximately three quarters of a mile southward from College Street along both 19th and 11th Avenues. As no management strategies had been employed to address this influx of traffic, it had a tendency to move in a stop and go fashion.

Traffic issues during football games are exacerbated by among other things, the basic layout of Bozeman's streets and the explosive growth the community has experienced over the past several years. Relative to the street layout, limited (almost no) routes are available adjacent to, or even in the vicinity of the stadium. Only 19th Street (north-south) and Main Street (east-west) are continuous thoroughfares through Bozeman, and neither route passes adjacent to the stadium. Naturally, as thoroughfares these routes are also heavily traveled by non-special event traffic. Relative to explosive growth, population in the Bozeman area has increased by 34 percent over the past decade. While continuously being upgraded, the transportation system has been heavily strained by this growth, relative to keeping up basic capacity, signalization, etc. adequate to address the demands placed on it. During daily use, the city experiences significant congestion issues on arterials surrounding campus and on arterials that connect the campus to downtown and to Interstate 90. Additionally, new neighborhoods are being developed to the west and south of campus. Given the current roadway infrastructure and traffic conditions, as well as the location of the developments themselves, these new residents will be impacted by special events traffic. Non-static characteristics of the area of interest present limited opportunities for roadway expansion and alternative routing. Mitigating special events traffic congestion and educating the traveling public prior to further development of these areas will facilitate traffic management in the future.

These congestion challenges are typical to those faced by small communities and rural areas, suggesting that the case study presented here, in which new strategies and models for traffic management were developed and applied, will be appropriate to many areas around the country.

2.4. Strategies Employed

Based on previous work, WTI collaborated with MSU, the City of Bozeman and MDT to develop a traffic management plan for MSU home football games that incorporated, among other elements, the following congestion mitigation strategies put forth by FHWA:

- Interagency Event Coordination: Stakeholder meetings held before and after games and the season to plan and refine strategies.
- Real-Time Traveler Information: Provide information that enables roadway users to select the best route to their ultimate destination. The overall goal was to reduce traffic congestion, and improve travel times.
- Traffic Incident Management: Clear traffic incidents in a safe, timely fashion thereby reducing traffic congestion.
- Traffic Signal Timing: Reduce congestion through the implementation of adjusted signal timings to meet the needs of the event-related traffic flow. Signal timings were designed to correspond with the observed traffic patterns.

Figure 2-4 is a close-up satellite image of the area of interest for this project. Key intersections on and in the vicinity of campus are labeled. The stadium is located in the bottom right quadrant of the image and is outlined in yellow.

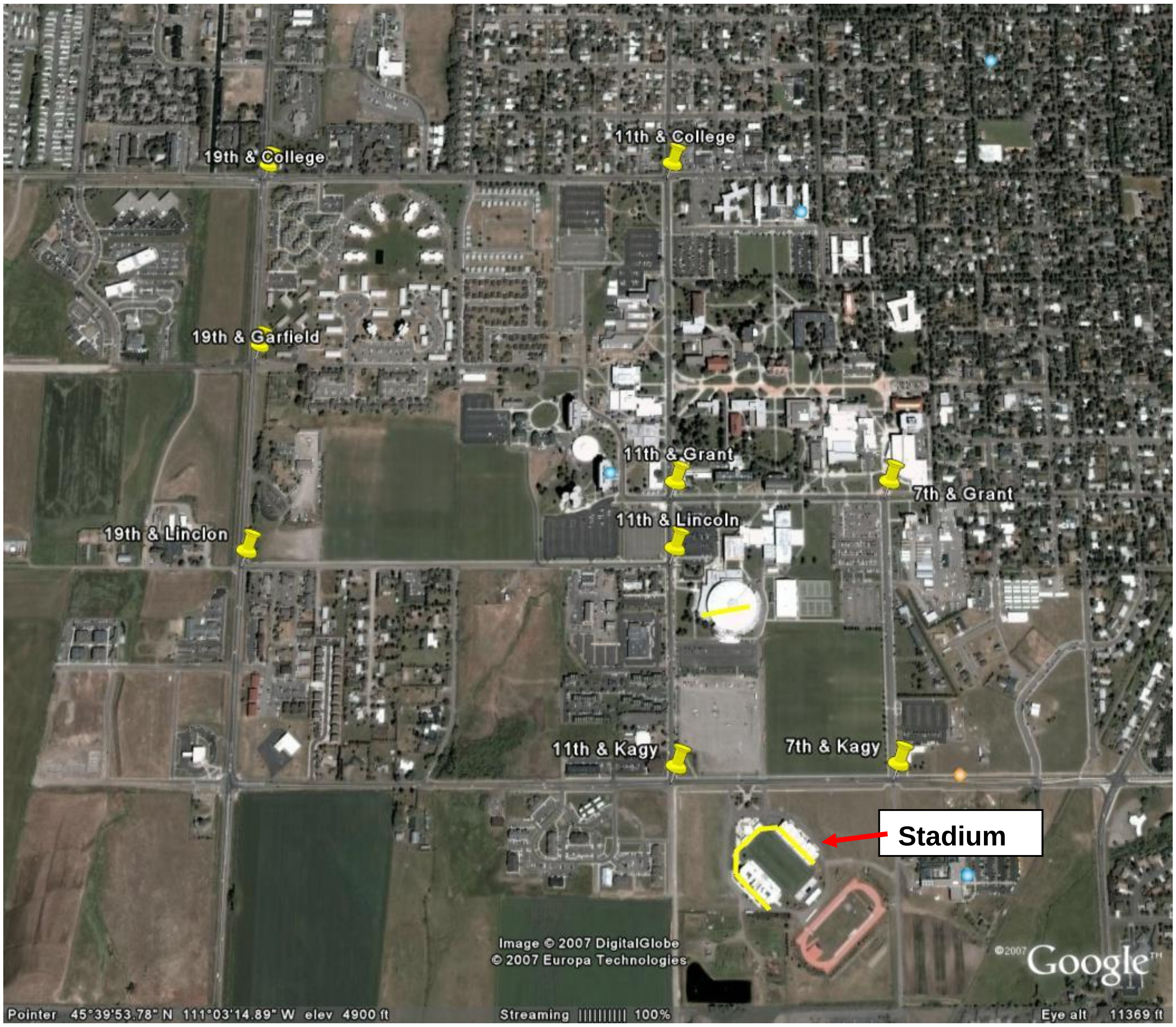


Figure 2-4: Map of impacted area - courtesy of Google Earth

Figure 2-5 is a map illustrating the traffic management strategies employed for MSU home football games. Two DMS signs were deployed on 19th Avenue. One DMS informed southbound (inbound) motorists of the Lincoln Street closure, and the second DMS advised northbound (outbound) motorists that planned to turn left at some point to travel west out of town to use Garfield Street as an alternate route. HAR was used to inform motorists of road closures and detours in the vicinity of campus. CCTV was deployed on portable trailers at five key locations to monitor traffic flow and queuing at critical intersections:

- 19th Avenue and Kagy Boulevard,
- 19th Avenue and College Street,
- 11th Avenue and College Street,
- 11th Avenue and Grant Street, and
- 11th Avenue and Kagy Boulevard.

Near the end of the 2007 season, a permanent CCTV was mounted on a twenty-seven foot pole located inside of the fence in the parking lot east of the stadium at 7th and Kagy Boulevard.

Lincoln Street was closed to through traffic between 19th Avenue and the Roskie Hall parking lots. This closure was designed to direct game traffic previously using Lincoln Street as a shortcut to reach 19th Avenue onto routes that were better suited to handle heavy influxes of traffic. These included Kagy Boulevard and 11th Avenue.

MSU police officers were stationed at the intersections of 11th and College Street (four-way stop control) and 19th Street and Garfield (two way stop control) to supervise and direct traffic flow as needed. The officer at the Garfield location was intended to facilitate left turns from 19th Street northbound onto Garfield, as these movements may not be presented with an adequate gap from southbound traffic. An additional officer was posted at the 11th Street and Grant intersection to facilitate traffic flow through the four-way stop when it was converted to a two way stop (north and southbound traffic given through movement) following games.

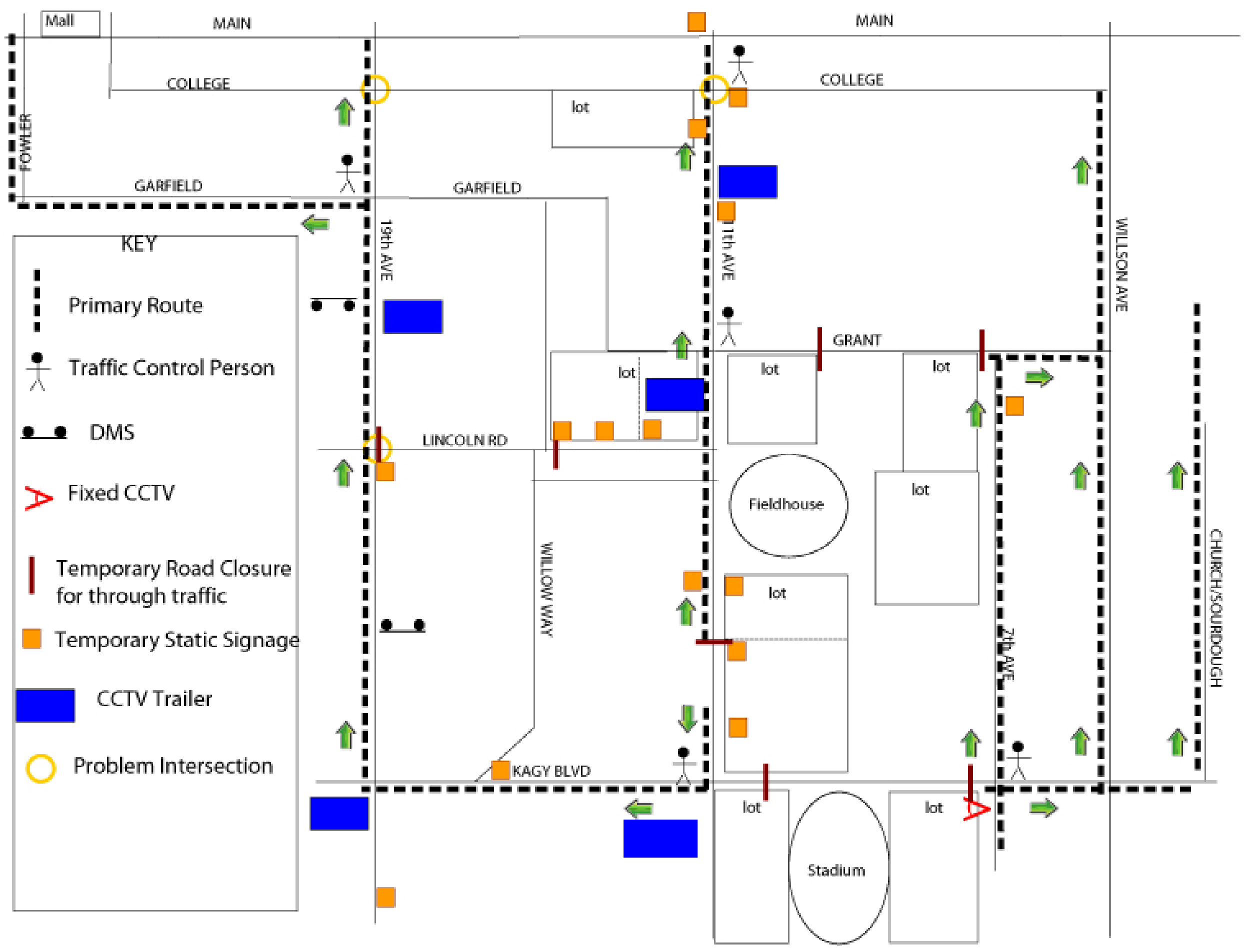


Figure 2-5: Traffic management strategies map

Extensive public outreach was also conducted to educate motorists and area residents of the temporary road closures and other traffic management strategies that they would encounter on game days. WTI coordinated the distribution of information to the traveling public and local area residents and businesses. Figure 2-6 is a map that has been prepared for the public illustrating routes and road closures on game days. This map was also printed in the Bozeman Daily Chronicle newspaper, along with an article discussing the changes that could be expected. The map was also be posted on the MSU Athletics web site, and issued to season ticket holders.

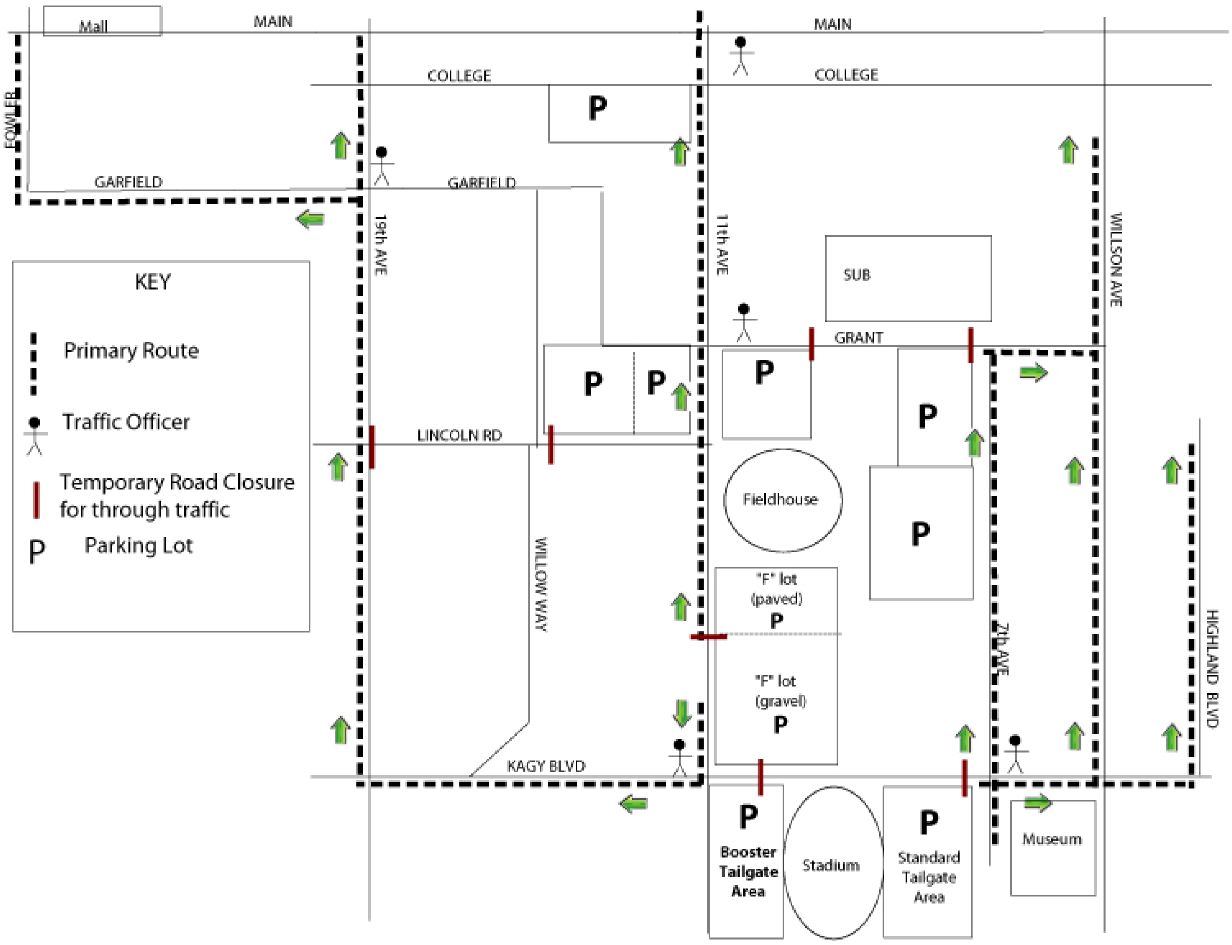


Figure 2-6: Public traffic routing and road closure map

Figure 2-7 presents the map that was prepared and distributed to the residents of the Lincoln Street area. The map illustrates alternate routes to be used for residential access on game days in light of the Lincoln Street closure. Public outreach in the form of a hand-delivered personal letter and the map was conducted for the residents of this area. Residents were also encouraged to contact WTI with any questions or concerns they may have had.

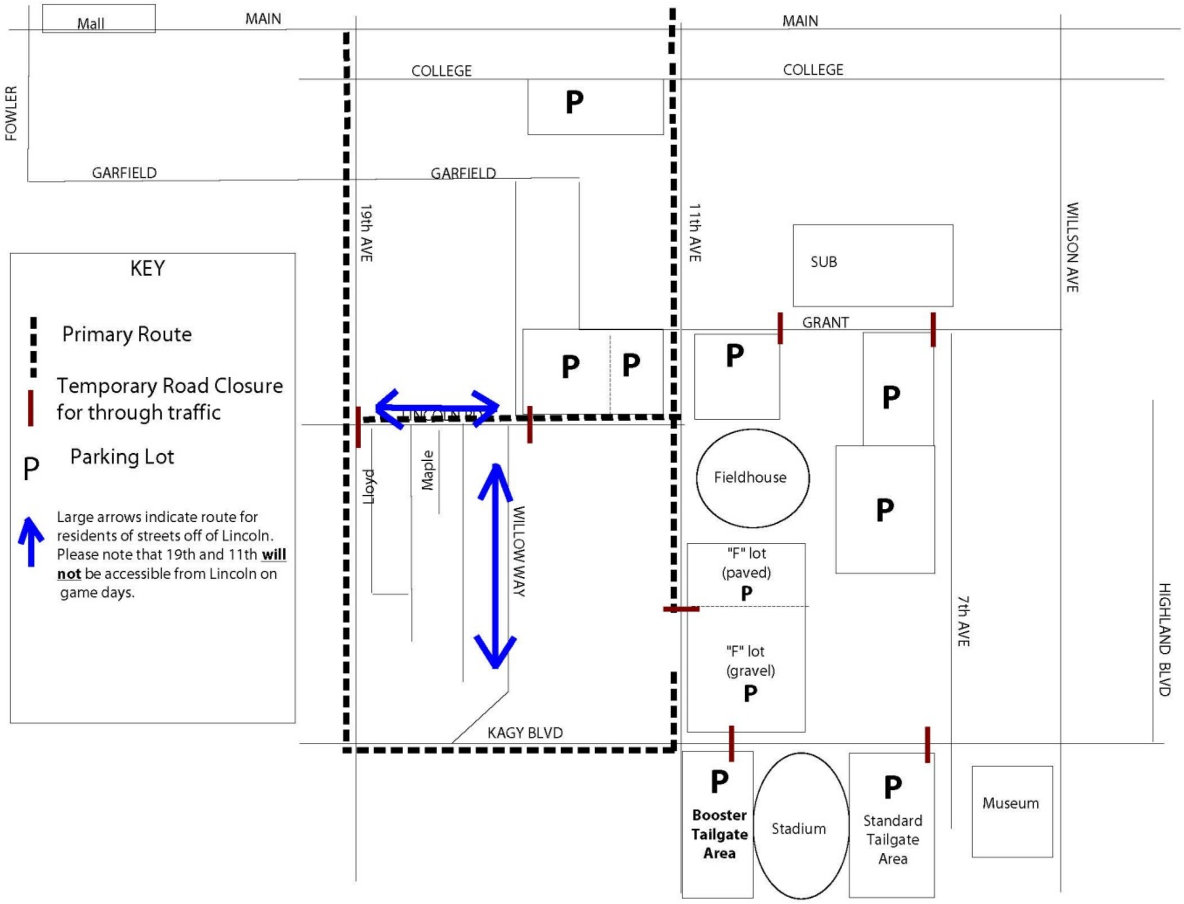


Figure 2-7: Map for local area residents

Figure 2-8 presents a map depicting the placement locations for temporary static signage and verbiage. This map was issued to traffic control personnel to facilitate setup. The static maps were intended to provide route guidance and way finding information to motorists en route and departing games. An additional map was created for traffic control personnel indicating which signs were to be deployed by 9 a.m. on game day, and which signs were to be in place by the start of the fourth quarter on game day. Note that Figure 2-8 presents all signs deployed without specifying the time period they were set up.

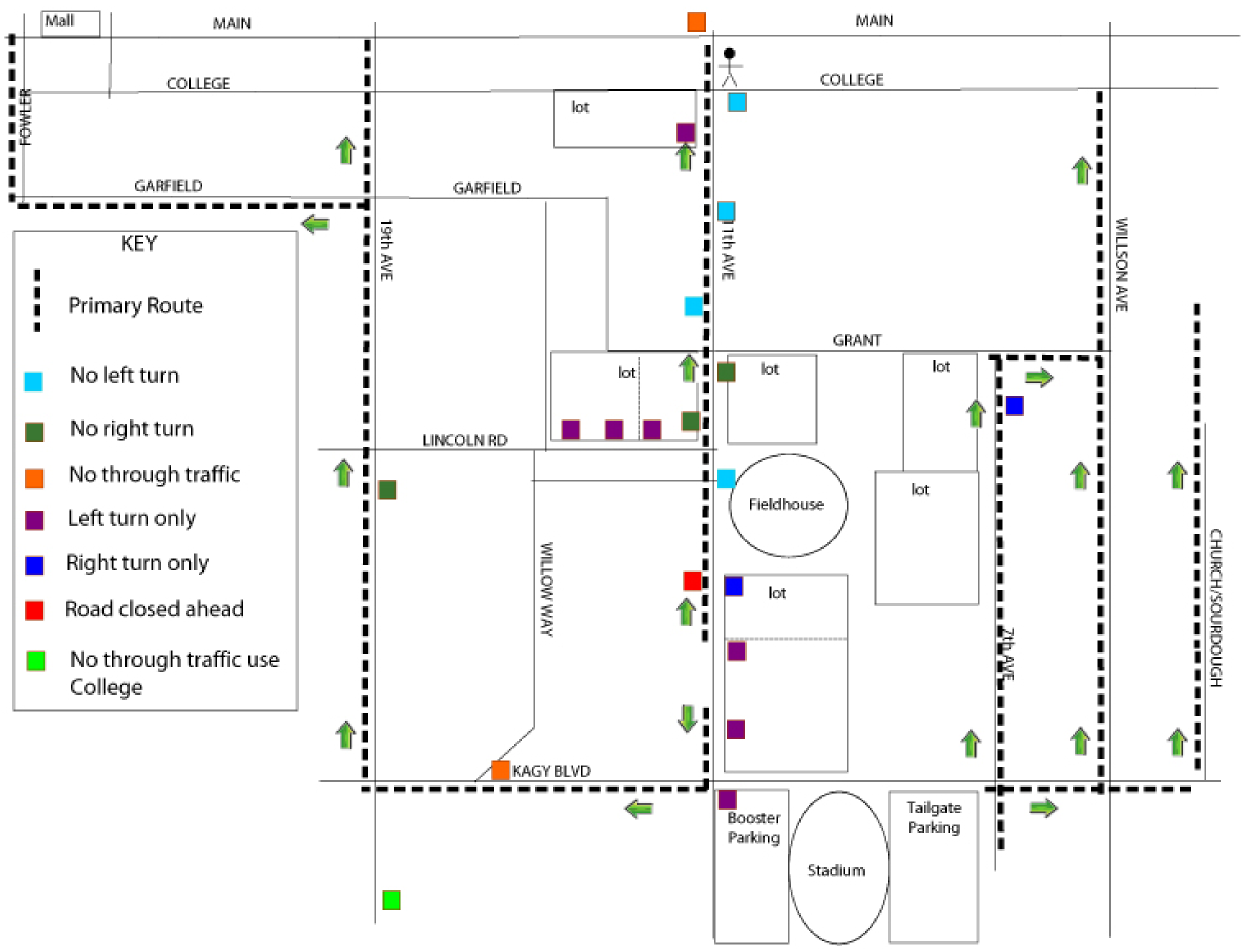


Figure 2-8: Map showing temporary static signage locations and verbiage

CCTV was used to monitor queuing at critical intersections and on key roadways. The monitoring of these intersections served a twofold purpose. First, it provided MSU police personnel with real time observations on which to base decisions, specifically, identifying and alerting field personnel of traffic queues forming at critical locations. This allowed MSU Campus police to determine when and where to deploy an officer in cases where traffic control for intersections and/or driveways was required. The second purpose of the CCTV was to monitor overall system performance from a traffic engineering standpoint. The CCTV network allowed WTI, MSU, MDT and City of Bozeman personnel to monitor operations and analyze the performance of traffic management strategies that had been employed (ex. signal timing changes, road closures, etc.). In this manner, CCTV monitoring allowed for the identification of what strategies are working, as well as where modifications/changes would be required as the season progressed..

3. TECHNOLOGY RESULTS

3.1. Portable Trailers

Five portable trailers were used as for surveillance and data collection over the course of the football season. Three trailers had existing Econolite Autoscope cameras and digital video recorders, but lacked communications equipment. The remaining two trailers were assembled by WTI and equipped with dual Autoscope cameras and Motorola Canopy 900MHz and cellular communications equipment. Video was transmitted to the Transportation, Research, Application and Integration lab (TRAIL) facility for traffic monitoring and traffic management before, during and after the special event. All video was able to be transmitted using the Motorola Canopy communications systems. The cellular systems were not needed for this project given that line-of-sight was able to be established between the trailers and the Motorola Canopy Access Points at all surveillance locations.

Figure 3-1: WTI Dual Camera Data Collection Trailers

The two trailers assembled by WTI (see **Error! Reference source not found.**) have crank up masts, equipment cabinets and solar charged battery supplies. The trailers also have extendable legs with weights and outriggers for stability. The equipment cabinet mounted on the back of the trailer contains a power inverter and battery charger as well as the communication and camera lightning suppressors, two 4 DC power supplies, one power strip and the camera interface modules. Given that two cameras and one communications antenna were to be mounted on the mast, it was necessary to purchase new mounting hardware. A T-cap solution was selected as it facilitated the removal and transport of the equipment (cameras and communications antenna). An example of the video transmitted by these trailers can be seen in Figure 3-2.

Figure 3-2: CCTV View from College Street and Kagy Boulevard at South 19th Avenue

As mentioned previously, three additional trailers were also deployed during the events to monitor traffic in real-time. WTI installed a Motorola Canopy 900 MHz subscriber module and cellular communications equipment in each of the three trailers and added an Axis video server (in each trailer) to enable the transmission of video back to the TRAIL lab. These trailers also have a crank-up mast and utilize a 4-leg stabilizer for deployment. Batteries are charged by means of a solar panel battery charger.

Figure 3-3: Single Camera Trailer Deployment

3.2. Portable Changeable Message Sign (CMS)

Two portable CMS was provided by the Montana Department of Transportation and set up by the City of Bozeman on game days. The CMS were set up on the primary northbound/southbound thoroughfare to access the stadium. One sign was used to advise travelers of a road closure. The second was more in evidence post-game for northbound travelers and provided them with information about an alternate routing selection.

Figure 3-4: CMS Sign

3.3. Permanent Mount Camera

WTI installed a permanent mount traffic monitoring camera at the corner of Kagy Boulevard and 7th Avenue in Bozeman, MT. The pole was purchased from and installed by Northwestern Energy. Montana Lines was contracted to install the Cohu i-Dome 3945 series traffic surveillance camera. Tropos Proxim WiFi equipment was installed for communications. The permanent mount camera was installed mid-season and greatly enhanced traffic monitoring capabilities.

Figure 3-5: Permanent Camera Installation

3.4. Traffic Management/Traffic Flow Monitoring

Imagery from the traffic monitoring systems was relayed wirelessly back to the TRAIL lab at WTI. The TRAIL lab was staffed during events by MSU Police and WTI technical staff. MSU Police officers were deployed post-game to key high-volume intersections for manual traffic control in efforts to disperse post-game traffic more efficiently. The officers stationed in the TRAIL lab monitored traffic flow imagery from the various cameras and communicated status updates in real-time to field officers. If officers stationed in the lab observed long queues forming along a particular route or notices a disabled vehicle via CCTV, they communicated this information to the field officers. Field officers were then able to modify traffic flow operations by allotting more time to specific movements in certain directions or facilitating incident management. Traffic flow/control operations were greatly enhanced by the ability to update field officers on real-time traffic conditions and enabled the field personnel to more effectively manage traffic, respond to incidents and coordinate traffic flow. Traffic management strategies were modified as the season progressed based on observations of traffic flow and behavior at key locations and along primary routes. Field officers were able to more readily respond to rapidly changing conditions based on CCTV observations which, in turn, promoted consistent travel times and enhanced traveler experience with regards to arrivals and departures.

Figure 3-6: TRAIL Lab Traffic Flow Monitoring

4. TRAVEL TIME ANALYSIS

One aspect of interest in terms of change between the 2006 and 2007 seasons was the travel times of vehicles along specific routes. For this work, two routes were examined based on observations of historical travel patterns on game days and anticipated route shifts due to the implementation of the traffic management strategies. These corridors were 19th Avenue and 11th Avenue. These corridors are illustrated in the map shown in Figure 4-1. Travel times along the routes were collected using the average car technique, where the driver was instructed to drive at the approximate speed of the traffic stream.

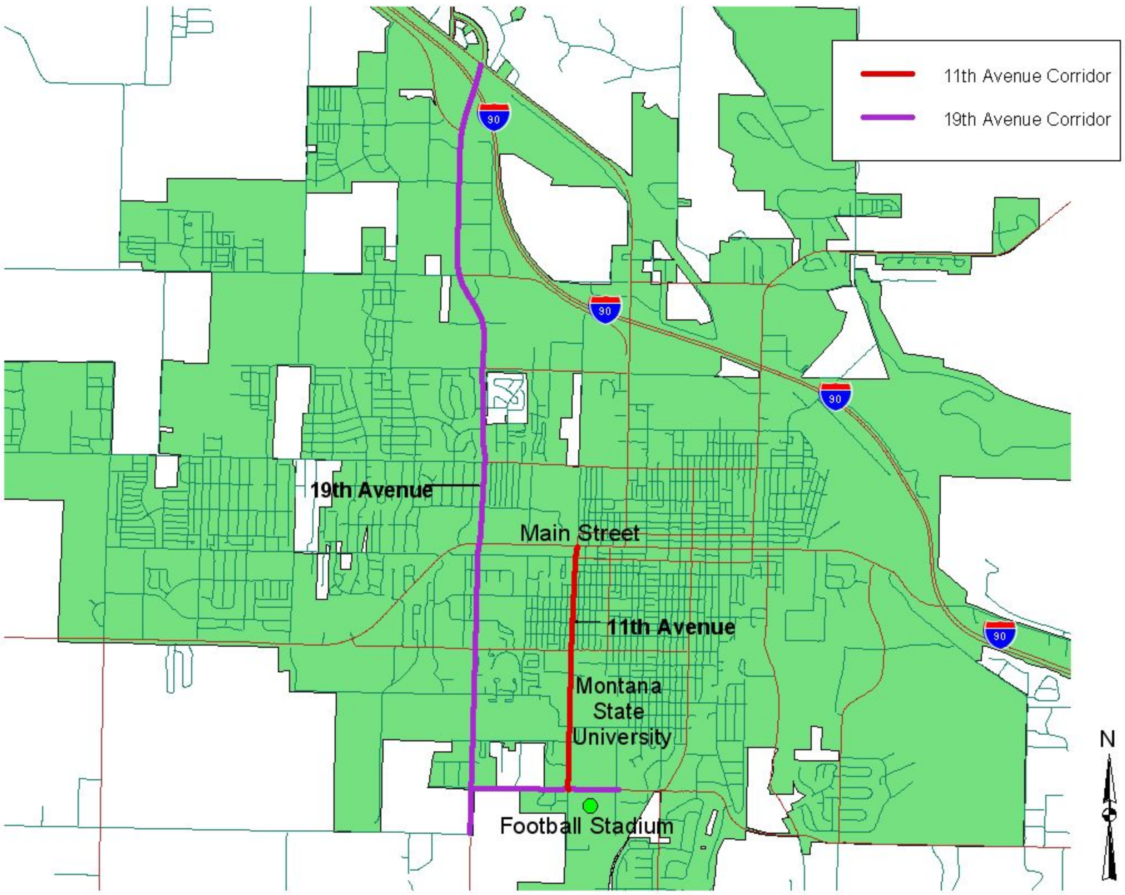


Figure 4-1: Primary travel corridors

Data for the 2006 game day were collected on September 23rd, 2006. Attendance for the game was 12,847, which is approximately 85% of stadium capacity. Data for 2007 were collected on October 20th (19th Avenue) and November 3rd, 2007 (11th Avenue). Attendance for these games was 14,167 (93% capacity) and 13,447 (89% capacity), respectively. Non game day data were collected on September 30th, 2006. This date was selected as no special events were occurring in Bozeman; as a result, it should reflect traffic conditions on an average non game day.

The morning data collection on these dates consisted of approximately ten intervals separated by 15 minutes. The first interval was collected at 10:30, the second at 10:45 and so forth, with the final interval collected at 12:45. The afternoon data collection followed the same strategy and consisted of five intervals, with collection beginning between 4:00

and 4:15 (the approximate time games were observed to end) and ending between 5:15 and 5:30.

Data collectors along each of the designated routes were provided with stopwatches and sheets to record the elapsed time at which they reached a specific checkpoint. The data collector started the stopwatch at the designated route starting point and subsequently recorded the elapsed time at each checkpoint once the stop bar of the intersection had been crossed.

The following sections will provide a comparison of game and nongame day travel times. The presentation of these is broken down into morning and afternoon, to correspond with pre and post-game timeframes. In addition, the reader should keep in mind that the 2006 game day travel times correspond to an event for which no traffic management strategies were employed, while the 2007 games did have such strategies in place. Following the overview of travel time data, a review of speed and volume trends along 19th Avenue is presented. This overview includes a review of changes in traffic volumes between game and nongame days, as well as changes to the speeds at which traffic was moving.

4.1. 19th Avenue Corridor

The 19th Avenue corridor is one of the primary routes to and from the Montana State University campus. As a result, this route is the most likely to experience deterioration in travel times both pre and post- game. Pervious measurements of travel times along this route were performed in the fall of 2006. These indicated that travel times were not greatly impacted during the morning, but in the afternoon, following the conclusion of a game, travel times did deteriorate. These previous measurements led to the traffic management strategies outlined in this report. The following sections examine the impacts that these strategies had on travel times during the fall of 2007 on game days.

4.1.1. Morning

In order to understand the arrival patterns of game attendees and the potential for morning delays, travel times between the I-90 interchange with 19th Avenue and the stadium area were examined for both 2006 and 2007 game days. To be concise, only travel times between the intersection of Main Street and 19th Avenue are presented in Figure 4-2. One feature to be cognizant of when viewing the corresponding graphics is that in 2006, construction at the intersection of 19th Avenue and Durston Street took that signal out of operation. As a result, traffic at this site on 19th Avenue was not required to stop at any time. The result was that shorter travel times were achieved as traffic that would normally be required to stop for a signal (and the associated queuing that would result) was not required to do so.

As the graphs indicate, travel times on both of the observed game days exceeded those of a non-game day in the majority of cases. In general, game day travel times were three to four minutes greater than those observed on a non-game day. During some intervals, 2007 travel times were greater than those of 2006 game days. This is further confirmed by the data presented in Table 4-1. Overall, the trends during both game day collection periods indicated that as the start of a game approached, travel times increased. This is due to an influx of traffic related to those who waited until a short interval prior to the game to arrive.

One other item of interest to point out is the trend for game day travel time to increase between the Main Street and College Street checkpoints/intersections. This stems from delay being incurred at the signals at these sites. It indicates that one future strategy to consider in addressing arrival traffic is signal synchronization between these sites.

One conclusion that can be drawn from viewing the travel time trends along 19th Avenue is that the traffic management strategies employed did not have an adverse impact in the morning. The closure of Lincoln Street required users to travel further South on 19th Avenue to Kagy Boulevard, where they turned east to reach the stadium area. In examining the travel times between College Street and the 11th Avenue parking lots, only minimal increases in travel times are noted. This is reassuring, as a significant added volume of traffic was shifted to Kagy Boulevard by the closure of Lincoln Street. That travel times did not significantly increase indicates that the closure had a minimal impact overall.

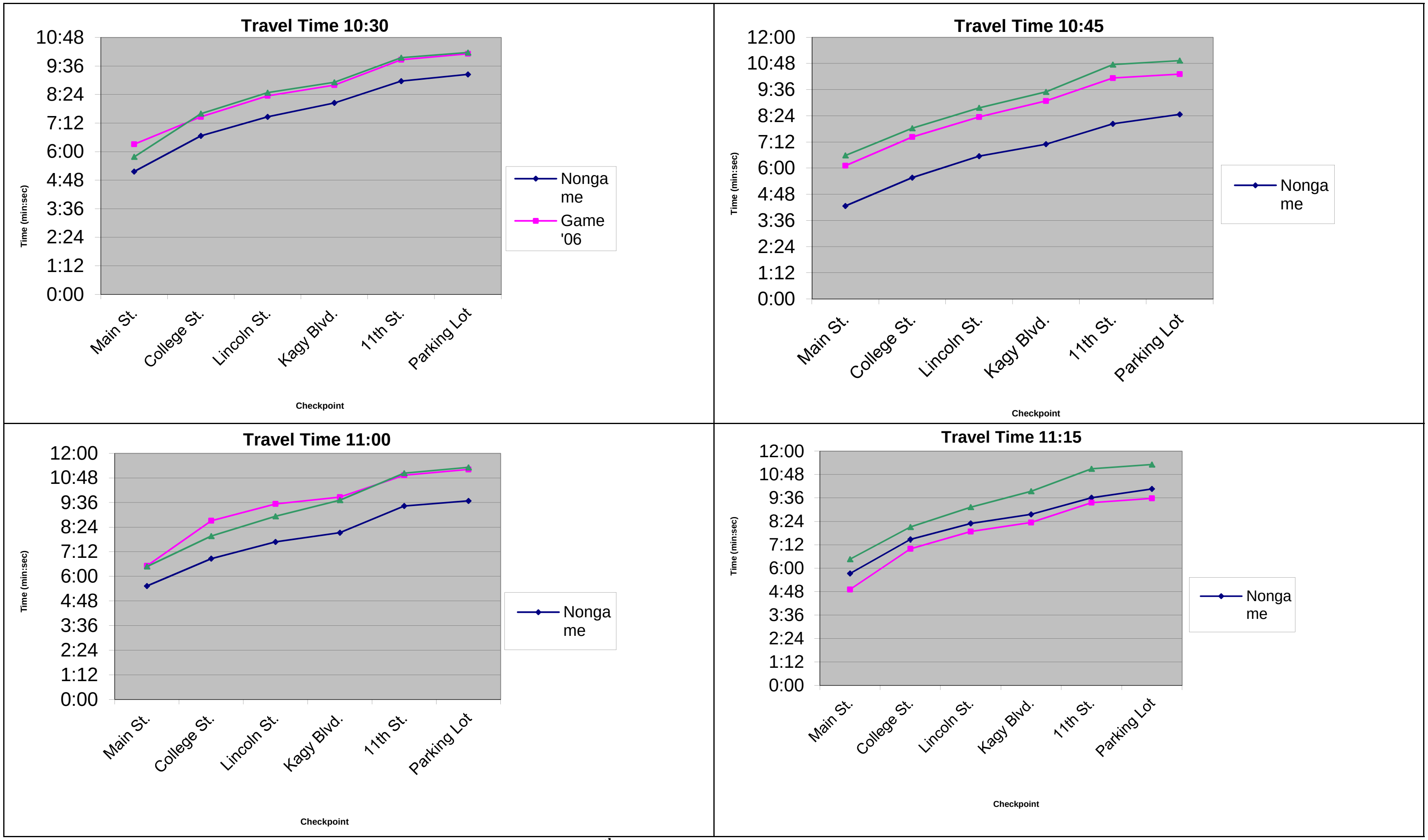


Figure 4-2: 19th Avenue corridor travel times (A.M.)

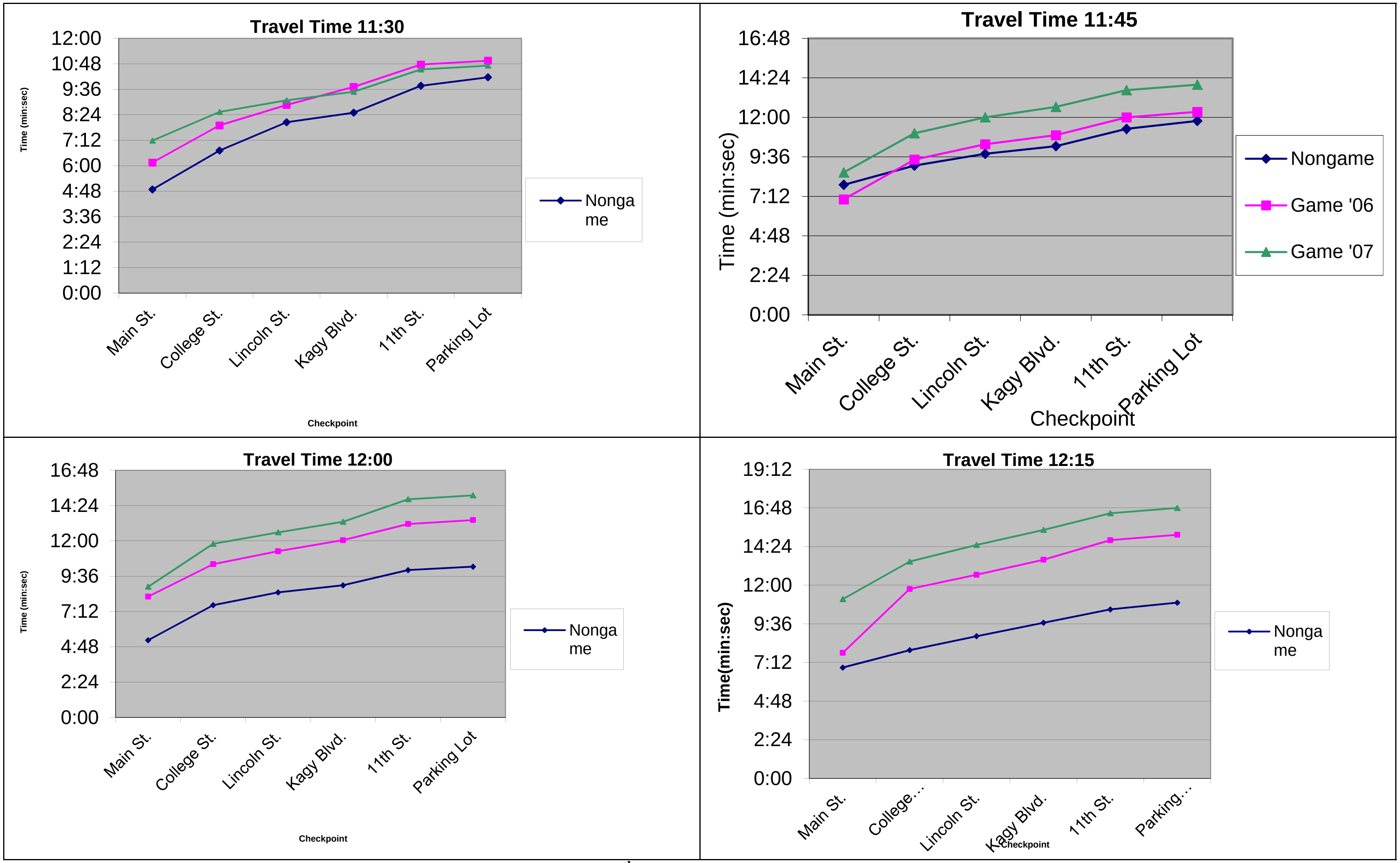


Figure 4-2 cont'd: 19th Avenue corridor travel times (A.M.)

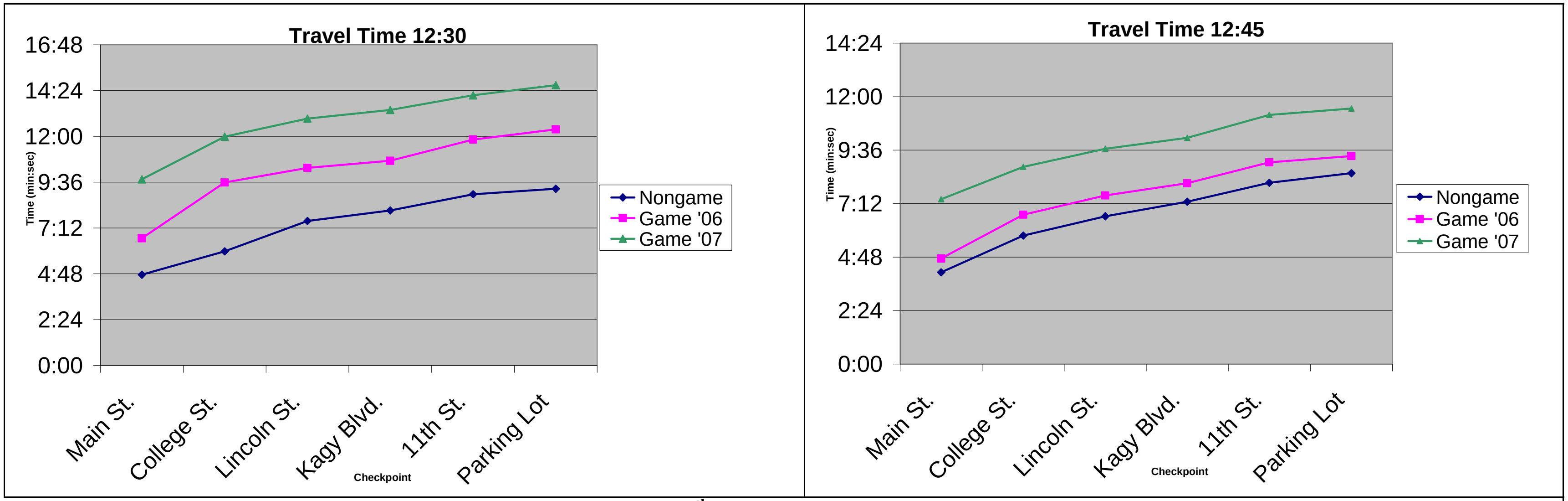


Figure 4-2 cont'd: 19th Avenue corridor travel times (A.M.)

Table 4-1: 19th Avenue corridor travel times and differences

(Bold green number indicates decreased travel time and bold red number indicates increased travel time on the game day)

2006/2007	10:30					10:45				
	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007
I-90 Interchange	0:00	0:00	0:00			0:00	0:00	0:00		
Baxter Rd.	1:38	1:47	1:39	**0:01**	**0:08**	1:26	1:40	1:23	**0:03**	**0:17**
Oak St.	2:22	3:09	3:10	**0:48**	**0:01**	2:24	3:17	3:40	**1:16**	**0:23**
Main St.	5:10	6:19	5:47	**0:37**	**0:32**	4:16	6:07	6:35	**2:19**	**0:28**
College St.	6:40	7:28	7:36	**0:56**	**0:08**	5:34	7:26	7:50	**2:16**	**0:24**
Lincoln St.	7:28	8:21	8:29	**1:01**	**0:08**	6:33	8:21	8:46	**2:13**	**0:25**
Kagy Blvd.	8:03	8:48	8:55	**0:52**	**0:07**	7:06	9:05	9:30	**2:24**	**0:25**
11th St.	8:58	9:52	9:57	**0:59**	**0:05**	8:02	10:08	10:45	**2:43**	**0:37**
Parking Lot	9:15	10:07	10:10	**0:55**	**0:03**	8:28	10:19	10:56	**2:28**	**0:37**

2006/2007	11:00					11:15				
	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007
I-90 Interchange	0:00	0:00	0:00			0:00	0:00	0:00		
Baxter Rd.	1:42	1:30	1:57	**0:15**	**0:27**	1:40	1:58	1:30	**0:10**	**0:28**
Oak St.	2:40	2:36	3:29	**0:49**	**0:53**	2:57	2:50	3:35	**0:38**	**0:45**
Main St.	5:32	6:31	6:29	**0:57**	**0:02**	5:44	4:55	6:28	**0:44**	**1:33**
College St.	6:52	8:43	7:58	**1:06**	**0:45**	7:29	7:00	8:07	**0:38**	**1:07**
Lincoln St.	7:41	9:32	8:56	**1:15**	**0:36**	8:18	7:53	9:08	**0:50**	**1:15**
Kagy Blvd.	8:08	9:52	9:43	**1:35**	**0:09**	8:46	8:21	9:57	**1:11**	**1:36**
11th St.	9:26	10:56	11:02	**1:36**	**0:06**	9:37	9:22	11:06	**1:29**	**1:44**
Parking Lot	9:41	11:13	11:19	**1:38**	**0:06**	10:04	9:35	11:19	**1:15**	**1:44**

Table 4-1 cont'd: 19th Avenue corridor travel times and differences (Bold green number indicates decreased travel time and bold red number indicates increased travel time on the game day)

2006/2007	11:30					11:45				
	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007
I-90 Interchange	0:00	0:00	0:00			0:00	0:00	0:00		
Baxter Rd.	1:38	3:10	1:16	**0:22**	**1:54**	2:53	2:20	2:03	**0:50**	**0:17**
Oak St.	2:40	4:00	2:20	**0:20**	**1:40**	4:59	3:06	4:53	**0:06**	**1:47**
Main St.	4:53	6:09	7:11	**2:18**	**1:02**	7:54	7:01	8:39	**0:45**	**1:38**
College St.	6:43	7:54	8:32	**1:49**	**0:38**	9:04	9:26	11:02	**1:58**	**1:36**
Lincoln St.	8:03	8:52	9:05	**1:02**	**0:13**	9:47	10:22	12:00	**2:13**	**1:38**
Kagy Blvd.	8:30	9:43	9:29	**0:59**	**0:14**	10:15	10:55	12:38	**2:23**	**1:43**
11th St.	9:46	10:46	10:32	**0:46**	**0:14**	11:18	12:00	13:39	**2:21**	**1:39**
Parking Lot	10:10	10:57	10:43	**0:33**	**0:14**	11:47	12:20	13:59	**2:12**	**1:39**
2006/2007	12:00					12:15				
	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007	Nongame	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007
I-90 Interchange	0:00	0:00	0:00			0:00	0:00	0:00		
Baxter Rd.	1:26	1:19	2:12	**0:46**	**0:53**	1:16	2:22	2:53	**1:37**	**0:31**
Oak St.	3:01	2:28	4:30	**1:29**	**2:02**	2:50	3:29	4:00	**1:10**	**0:31**
Main St.	5:15	8:13	8:53	**3:38**	**0:40**	6:53	7:48	11:08	**4:15**	**3:20**
College St.	7:38	10:25	11:48	**4:10**	**1:23**	7:58	11:46	13:28	**5:30**	**1:42**
Lincoln St.	8:30	11:18	12:35	**4:05**	**1:17**	8:50	12:39	14:30	**5:40**	**1:51**
Kagy Blvd.	8:59	12:03	13:18	**4:19**	**1:15**	9:40	13:35	15:26	**5:46**	**1:51**
11th St.	10:01	13:09	14:50	**4:49**	**1:41**	10:30	14:48	16:28	**5:58**	**1:40**
Parking Lot	10:15	13:25	15:06	**4:51**	**1:41**	10:55	15:08	16:48	**5:53**	**1:40**

Table 4-1 cont'd: 19th Avenue corridor travel times and differences
(Bold green number indicates decreased travel time and bold red number indicates increased travel time on the game day)

2006/2007	12:30					12:45				
	Nongame	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
I-90 Interchange	0:00	0:00	0:00			0:00	0:00	0:00		
Baxter Rd.	1:18	2:06	1:56	**0:38**	**0:10**	1:36	2:12	1:31	**0:05**	**0:41**
Oak St.	2:11	3:12	3:18	**1:07**	**0:06**	2:28	3:05	2:54	**0:26**	**0:11**
Main St.	4:45	6:40	9:45	**5:00**	**3:05**	4:07	4:44	7:24	**3:17**	**2:40**
College St.	5:59	9:35	11:59	**6:00**	**2:24**	5:46	6:42	8:51	**3:05**	**2:09**
Lincoln St.	7:34	10:21	12:56	**5:22**	**2:35**	6:38	7:34	9:40	**3:02**	**2:06**
Kagy Blvd.	8:07	10:43	13:23	**5:16**	**2:40**	7:17	8:07	10:09	**2:52**	**2:02**
11th St.	8:58	11:50	14:09	**5:11**	**2:19**	8:08	9:03	11:11	**3:03**	**2:07**
Parking Lot	9:15	12:22	14:41	**5:26**	**2:19**	8:34	9:20	11:28	**2:54**	**2:08**

4.1.2. Afternoon

2006/2007	4:15					4:30			
	Non game	Game '06	Game '07	Non game 2006 vs Game 2007	Game 2006 vs 2007	Nongame	Game '06	Game '07	Non g 2006 Game

Of greater concern in managing football traffic is removing the additional vehicles leaving a game as quickly as possible from the network. To this end, the traffic management strategies employed aimed to provide an efficient egress from the campus area. This included revisions to signal timings at intersections near campus, as well as road closures and other strategies previously detailed in this report. To measure if game related traffic was being cleared from the network more efficiently with traffic management strategies in place, postgame travel times were collected for one game during that 2007 season. Just as previously, for the sake of being concise, only travel times collected between the stadium parking lots and Main Street are presented in the graphs of Figure 4-3.

Parking Lot	0:00	0:00	0:00			0:00	0:00	0:00	
11th	0:17	0:45	0:20	0:03	0:25	0:19	0:45	0:45	
Kagy Blvd	1:32	3:25	1:36	0:04	1:49	1:25	2:07	2:59	
Lincoln St.	2:02	4:16	2:00	0:02	2:16	1:50	5:25	5:47	
College St.	3:00	8:30	4:00	1:00	4:30	3:02	7:32	7:03	
Main St.	5:54	10:55	5:31	0:23	5:24	4:58	12:05	11:16	
Oak St.	8:09	13:58	11:16	3:07	2:42	6:10	14:24	13:45	
Baxter Rd.	9:22	15:32	12:38	3:16	2:54	8:26	15:13	15:39	
I-90 EB Ramp	10:50	16:53	14:44	3:54	2:09	10:27	17:10	16:59	
I-90 WB Ramp	11:09	17:10	15:04	3:55	2:06	10:44	17:15	17:39	
2006/2007			**4:45**					**5:00**	
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non g 2006 Game**
Parking Lot	0:00	0:00	0:00			0:00	0:00	0:00	
11th	0:30	0:38	0:45	0:15	0:07	0:34	0:30	0:30	
Kagy Blvd	1:33	2:02	3:05	1:32	1:03	1:39	1:44	1:24	
Lincoln St.	2:00	2:31	3:25	1:25	0:54	2:06	2:36	2:40	
College St.	3:19	7:08	7:31	4:12	0:23	3:38	5:02	5:48	
Main St.	5:32	13:35	10:52	5:20	2:43	5:20	6:52	7:39	
Oak St.	7:07	16:32	18:15	11:08	1:43	7:26	9:43	12:27	
Baxter Rd.	8:01	18:15	19:55	11:54	1:40	8:19	10:24	14:07	
I-90 EB Ramp	9:11	19:22	21:37	12:26	2:15	10:24	11:45	15:37	
I-90 WB Ramp	9:41	19:37	21:55	12:14	2:18	10:46	12:01	15:58	

Table 4-2 subsequently illustrates that, until it reaches Oak Street, the traffic stream does not break up in such a manner as to allow free flow and .

The afternoon travel times collected on the 19th Avenue corridor reflect the nature of this route being the primary egress route following games. The major difference between 2006 and 2007 games was the closure of Lincoln Street. In 2007, this closure resulted in an increase in traffic on Kagy Boulevard between the stadium area and 19th Avenue. The result was an increase in travel times in 2007 up to a given point. Once this point (usually around the 19th Avenue/Lincoln Street intersection, although sometimes further downstream) was reached, travel times began to improve. The observed trend was for travel times to increase in the time period from 4:00 until 4:45, at which point traffic volumes began to taper off. After this period, traffic began to dissipate, although travel times did remain higher than a non-game day for both 2006 and 2007.

The data presented graphically illustrates the need for post-game traffic management in some form. Given that little headway was made in terms of improving travel times, much work remains to be done. It is encouraging that the closure of Lincoln Street did not significantly impact travel times along the 19th Avenue corridor. Rather, only minor deteriorations were observed despite the addition of traffic from the closed route. The data indicate that the closure of Lincoln Street aided in the flow of traffic on 19th Avenue (i.e.

the elimination of conflicts at that intersection resulted in a smoother flow). The downside to this is that the improved flow at the 19^{th} Avenue and Lincoln Street intersection served to move traffic northward more efficiently, resulting in backups when that traffic reached the intersection of 19^{th} Avenue and Main Street. The one lane nature of 19^{th} Avenue between Kagy Boulevard and Main Street only compounded this problem. While this portion of the route is slated to be converted to a four lane cross-section in the future, the intersection of 19^{th} Avenue and Main Street will remain a stumbling block unless its operations (and those of its neighbor, 19^{th} Avenue and Babcock Street) remain unaddressed.

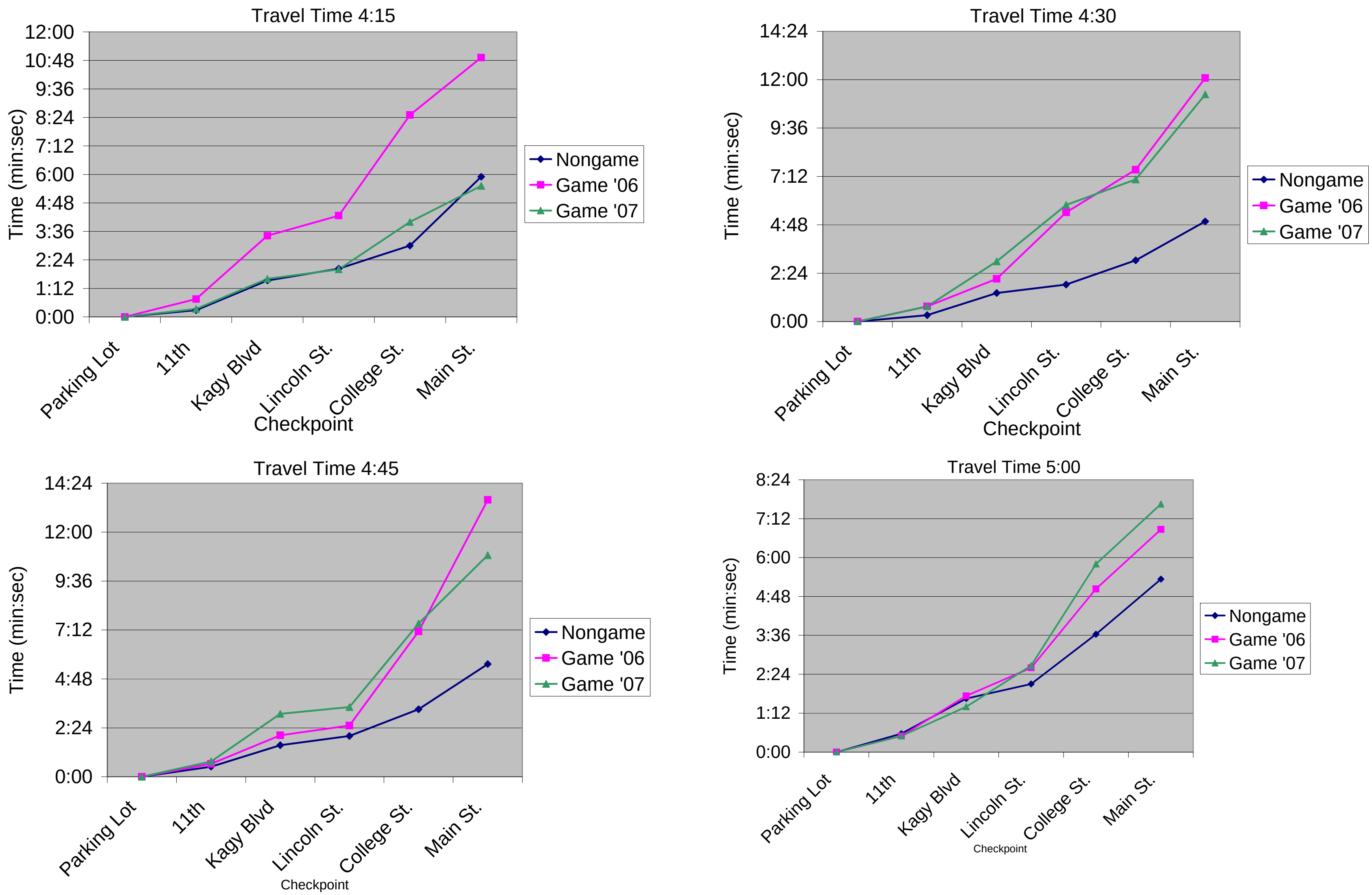


Figure 4-3: 19th Avenue corridor travel times (P.M.)

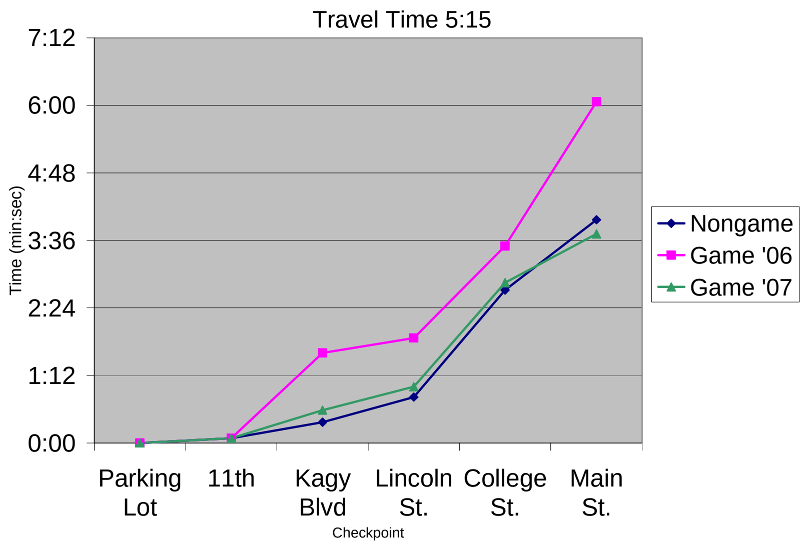


Figure 4-3 cont'd: 19th Avenue corridor travel times (P.M.)

Table 4-2: 19th Avenue corridor travel times and differences

(Bold green number indicates decreased travel time and bold red number indicates increased travel time on the game day)

2006/2007	4:15					4:30				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Parking Lot	0:00	0:00	0:00			0:00	0:00	0:00		
11th	0:17	0:45	0:20	**0:03**	**0:25**	0:19	0:45	0:45	**0:26**	0:00
Kagy Blvd	1:32	3:25	1:36	**0:04**	**1:49**	1:25	2:07	2:59	**1:34**	**0:52**
Lincoln St.	2:02	4:16	2:00	**0:02**	**2:16**	1:50	5:25	5:47	**3:57**	**0:22**
College St.	3:00	8:30	4:00	**1:00**	**4:30**	3:02	7:32	7:03	**4:01**	**0:29**
Main St.	5:54	10:55	5:31	**0:23**	**5:24**	4:58	12:05	11:16	**6:18**	**0:49**
Oak St.	8:09	13:58	11:16	**3:07**	**2:42**	6:10	14:24	13:45	**7:35**	**0:39**
Baxter Rd.	9:22	15:32	12:38	**3:16**	**2:54**	8:26	15:13	15:39	**7:13**	**0:26**
I-90 EB Ramp	10:50	16:53	14:44	**3:54**	**2:09**	10:27	17:10	16:59	**6:32**	**0:11**
I-90 WB Ramp	11:09	17:10	15:04	**3:55**	**2:06**	10:44	17:15	17:39	**6:55**	**0:24**
2006/2007	**4:45**					**5:00**				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Parking Lot	0:00	0:00	0:00			0:00	0:00	0:00		
11th	0:30	0:38	0:45	**0:15**	**0:07**	0:34	0:30	0:30	**0:04**	0:00
Kagy Blvd	1:33	2:02	3:05	**1:32**	**1:03**	1:39	1:44	1:24	**0:15**	**0:20**
Lincoln St.	2:00	2:31	3:25	**1:25**	**0:54**	2:06	2:36	2:40	**0:34**	**0:04**
College St.	3:19	7:08	7:31	**4:12**	**0:23**	3:38	5:02	5:48	**2:10**	**0:46**
Main St.	5:32	13:35	10:52	**5:20**	**2:43**	5:20	6:52	7:39	**2:19**	**0:47**
Oak St.	7:07	16:32	18:15	**11:08**	**1:43**	7:26	9:43	12:27	**5:01**	**2:44**
Baxter Rd.	8:01	18:15	19:55	**11:54**	**1:40**	8:19	10:24	14:07	**5:48**	**3:43**
I-90 EB Ramp	9:11	19:22	21:37	**12:26**	**2:15**	10:24	11:45	15:37	**5:13**	**3:52**
I-90 WB Ramp	9:41	19:37	21:55	**12:14**	**2:18**	10:46	12:01	15:58	**5:12**	**3:57**

Table 4-2 cont'd: 19th Avenue corridor travel times and differences

(Bold green number indicates decreased travel time and bold red number indicates increased travel time on the game day)

2006/2007	5:15				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Parking Lot	0:00	0:00	0:00		
11th	0:05	0:05	0:05	0:00	0:00
Kagy Blvd	0:22	1:36	0:35	**0:13**	**1:01**
Lincoln St.	0:49	1:52	1:00	**0:11**	**0:52**
College St.	2:43	3:30	2:51	**0:08**	**0:39**
Main St.	3:58	6:04	3:43	**0:15**	**2:21**
Oak St.	5:54	8:23	6:14	**0:20**	**2:09**
Baxter Rd.	7:03	9:10	7:38	**0:35**	**1:32**
I-90 EB Ramp	8:27	11:12	9:30	**1:03**	**1:42**
I-90 WB Ramp	9:02	11:23	9:49	**0:47**	**1:34**

4.2. 11th Avenue Corridor

In examining football-related traffic, a second major egress corridor is utilized by game traffic. This corridor, running along 11th Avenue from the Brick Breeden Fieldhouse parking lots northward to Main Street (parallel in many respects to 19th Avenue) carried a significant portion of traffic to and from games. As a result, travel time data was collected along this corridor both in 2006 and 2007. In 2006, baseline data was collected on a non-game as well as game day. Only game day travel times were collected in 2007.

4.2.1. Morning

In examining morning travel times, it should be noted that intervals were used in place of set times because of different start times for the 2006 game versus the 2007 game. In 2006, data was collected for a game that began at 1:05 pm; in 2007, the game began at 12:00 pm. Therefore, intervals were employed relative to the respected start times for the different years. For example, data collected at 12:45 was compared to data collected at 11:45 in 2007, as both of these periods were the final interval before the start of a game.

When morning travel times on the 11th Avenue corridor are compared to one another, it is evident that travel times on a game day were slightly greater than those of a nongame day. However, as the graphs in Figure 4-4 indicate, travel times were often shorter for the 2007 game day than those of 2006 for almost all time intervals. On a segment by segment basis, the differences were more varied, as evidenced in Table 4-3. The exception to this was the longer travel time observed for the run made during the third interval. These results suggest that, while traffic counts indicate that a portion of game-related traffic utilizes this route to reach the stadium area, the level of traffic on this route has not greatly impacted travel times.

One possible explanation for the observation of increased game day traffic concurrent with only slight increases in travel times is that traffic using this route is only being used in segments, and even then, only intermittently. For instance, vehicles might reach 11th Avenue via College Street, utilizing the route only from the intersection with College Street to reach the stadium. Of course, the minor impacts on travel times, particularly the decreases observed in 2007 versus 2006 game days, may also be indicative of the positive results that traffic management strategies have had.

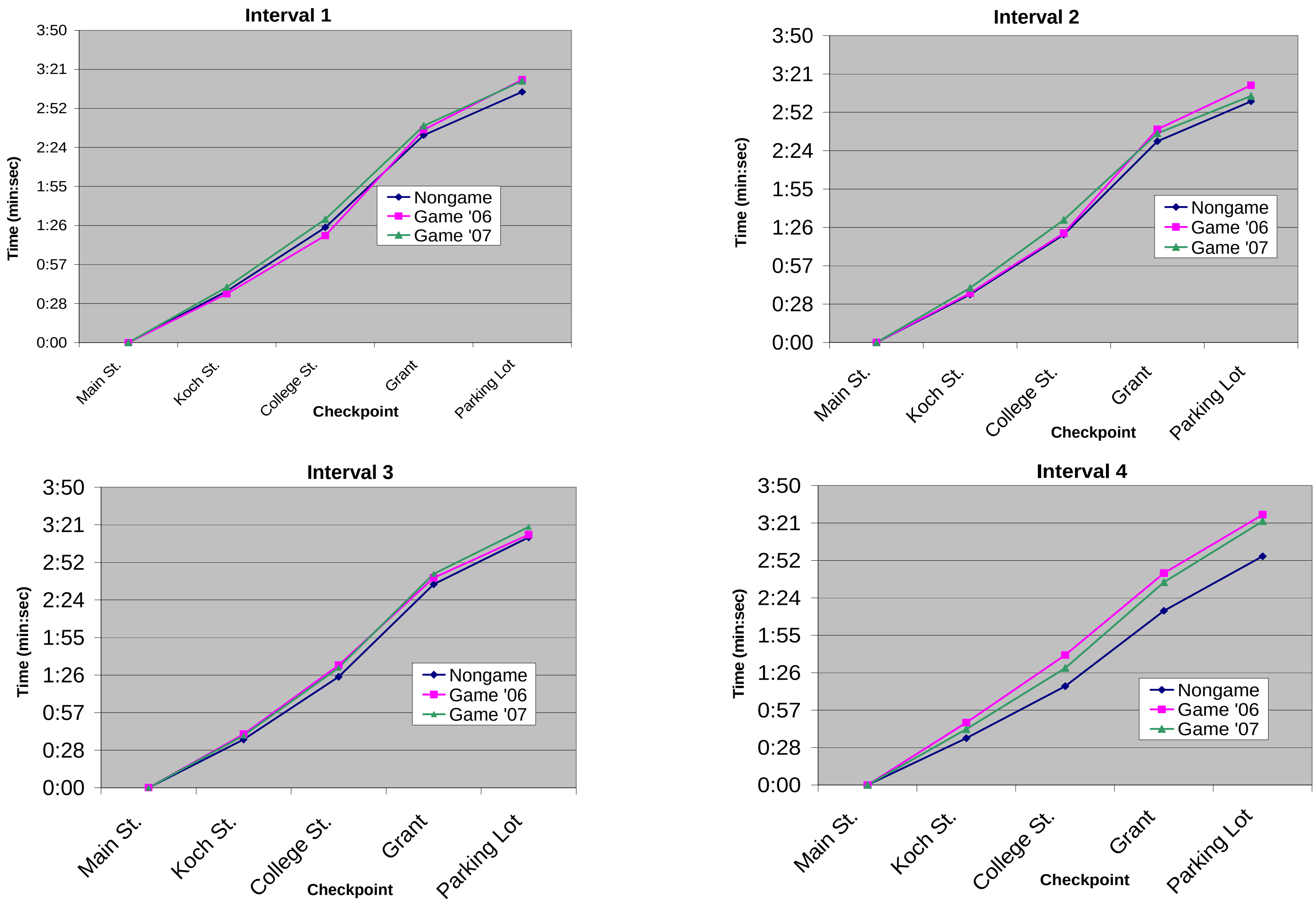


Figure 4-4: 11th Avenue corridor travel times (A.M.)

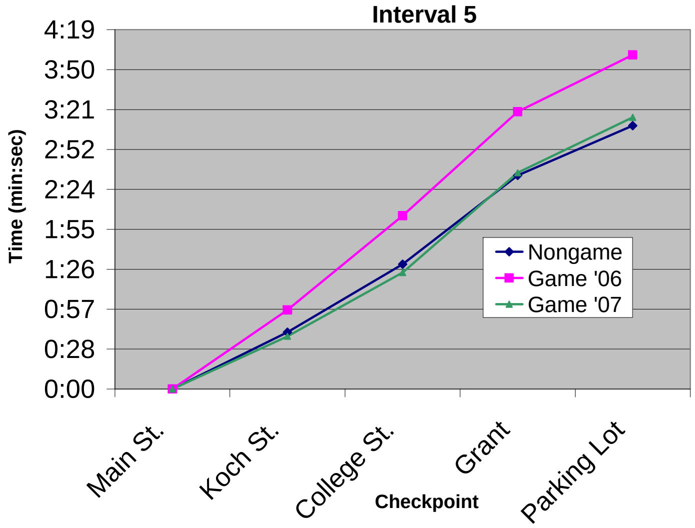


Figure 4-4 cont'd: 11th Avenue corridor travel times (A.M.)

Table 4-3: 11th Avenue corridor travel times and differences
(Bold green number indicates decreased travel time and bold red number indicates increased travel time on the game day)

2006/2007	Interval 1					Interval 2				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Main St.	0:00	0:00	0:00			0:00	0:00	0:00		
Koch St.	**0:38**	**0:36**	0:41	**0:03**	**0:05**	**0:36**	**0:37**	0:41	**0:05**	**0:04**
College St.	1:25	1:19	1:31	**0:06**	**0:12**	1:21	1:22	1:32	**0:11**	**0:10**
Grant	**2:33**	**2:37**	2:40	**0:07**	**0:03**	**2:31**	**2:40**	2:37	**0:06**	**0:03**
Parking Lot	3:05	3:14	3:13	**0:08**	**0:01**	3:01	3:13	3:05	**0:04**	**0:08**
2006/2007	Interval 3					Interval 4				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Main St.	0:00	0:00	0:00			0:00	0:00	0:00		
Koch St.	**0:37**	**0:41**	0:40	**0:03**	**0:01**	**0:36**	**0:48**	0:43	**0:07**	**0:05**
College St.	1:25	1:34	1:32	**0:07**	**0:02**	1:16	1:40	1:30	**0:14**	**0:10**
Grant	**2:36**	**2:41**	2:44	**0:08**	**0:03**	**2:14**	**2:43**	2:36	**0:22**	**0:07**
Parking Lot	3:12	3:14	3:20	**0:08**	**0:06**	2:56	3:28	3:23	**0:27**	**0:05**
2006/2007	Interval 5									
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**					
Main St.	0:00	0:00	0:00							
Koch St.	**0:41**	**0:57**	0:38	**0:03**	**0:19**					
College St.	1:30	2:05	1:24	**0:06**	**0:41**					
Grant	**2:34**	**3:20**	2:36	**0:02**	**0:44**					
Parking Lot	3:10	4:01	3:16	**0:06**	**0:35**					

4.2.2. Afternoon

During 2006 past game data collection activities, it quickly became evident that a major problem along the route was the extensive queue of vehicles that formed from the intersection of College Street and 11th Avenue Southward to the fieldhouse area. The cause of this queue of vehicles was the all way stop control in place at the intersection of College Street and 11th Avenue. To address this problem, the 2007 season saw a police officer dispatched to direct traffic at the site. This manual traffic control allowed for a continuous flow of departing vehicles to pass through the intersection uninterrupted, eliminating the previously observed queues. The impacts of this change are clearly observed in Figure 4-5 and Table 4-4.

Overall, the results of travel times along the corridor indicate that traffic moved much more quickly in 2007 compared to 2006. Motorists along the route saved anywhere from approximately 3 to 8 minutes of travel time, as well as the reduced frustration of sitting in stop and go traffic. As the results suggest, the use of manual traffic control at the intersection of College Street and 11th Avenue was quite successful and should be maintained in future seasons. Interestingly, the travel time gains observed were made while increased traffic utilized the route post-game. This indicates that, for the corridor, the traffic management strategies employed were effective at improving conditions overall.

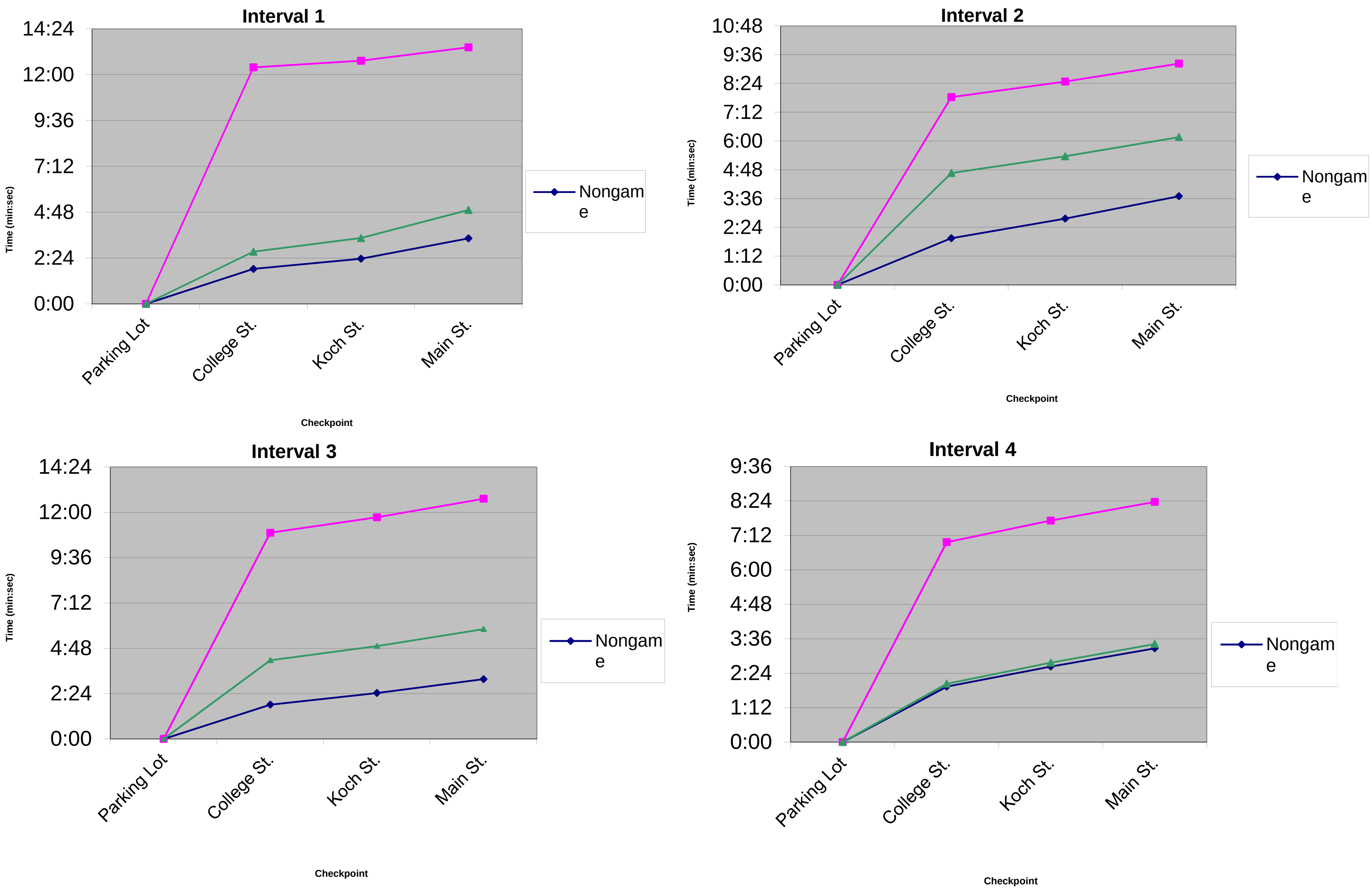


Figure 4-5: 11th Avenue corridor travel times (P.M.)

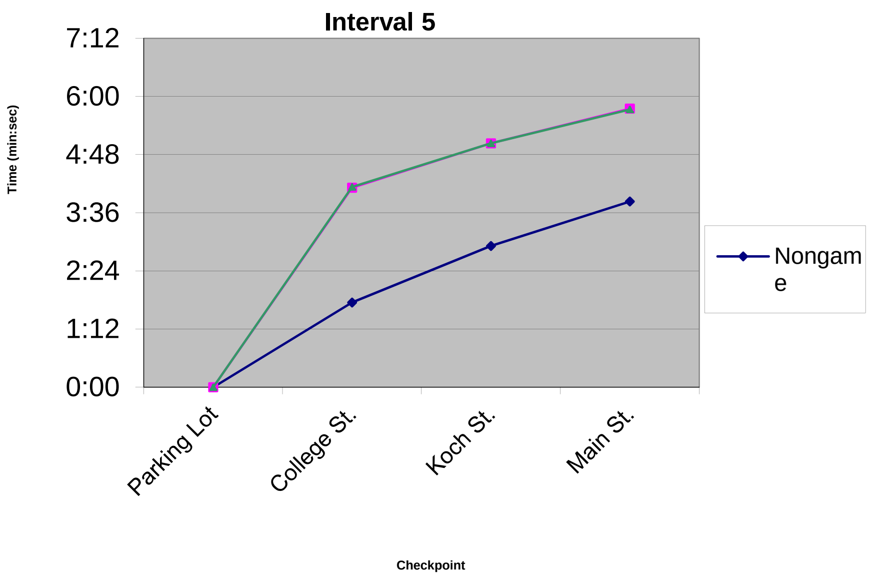


Figure 4-5 cont'd: 11th Avenue corridor travel times (P.M.)

Table 4-4: 11th Avenue corridor travel times and differences

(Bold green number indicates decreased travel time and bold red number indicates increased travel time on the game day)

2006/2007	Interval 1					Interval 2				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Parking Lot	0:00	0:00	0:00			0:00	0:00	0:00		
College St.	1:50	12:23	2:44	**0:54**	**9:39**	1:57	7:50	4:40	**2:43**	**3:10**
Koch St.	2:22	12:44	3:27	**1:05**	**9:17**	2:46	8:29	5:22	**2:36**	**3:05**
Main St.	3:26	13:26	4:55	**1:29**	**8:31**	3:42	9:14	6:10	**2:28**	**3:04**

2006/2007	Interval 3					Interval 4				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**	**Nongame**	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Parking Lot	0:00	0:00	0:00			0:00	0:00	0:00		
College St.	1:49	10:55	4:10	**2:21**	**6:45**	1:56	6:58	2:02	**0:06**	**4:56**
Koch St.	2:26	11:44	4:55	**2:29**	**6:49**	2:38	7:43	2:46	**0:08**	**4:57**
Main St.	3:10	12:43	5:49	**2:39**	**6:54**	3:16	8:22	3:25	**0:09**	**4:57**

2006/2007	Interval 5				
	Non game	**Game '06**	**Game '07**	**Non game 2006 vs Game 2007**	**Game 2006 vs 2007**
Parking Lot	0:00	0:00	0:00		
College St.	1:45	4:07	4:08	**2:23**	**0:01**
Koch St.	2:55	5:02	5:02	**2:07**	0:00
Main St.	3:50	5:45	5:44	**1:54**	**0:01**

4.3. Speed and Volume Trends

In addition to collecting travel times within the traffic stream, the researchers also examined data provided by Groundhog™ sensors placed in-pavement available. These sensors provide an hourly tally of vehicles that departed an intersection, as well as associated speed statistics related to that traffic (mean speed, 85th percentile speed, etc.). The data from these sensors is a useful compliment to the travel time data in that it provides another perspective of the overall trends that are occurring before and after a game.

4.3.1. 19th Avenue and Kagy Boulevard

The first location for which Groundhog data were available was the intersection of 19th Avenue and Kagy Boulevard. This location is the first major, signalized intersection that game traffic reaches when departing. Inbound game traffic heads east on Kagy Boulevard by turning left off of 19th Avenue. The bulk of postgame traffic at this site turned northbound onto 19th Avenue from the east approach (westbound movement) of Kagy Boulevard. As a result, this traffic slows to approximately 15 miles per hour, creating some spacing between vehicles as they begin to travel along 19th Avenue. The following sections cover the trends observed in traffic for both south and northbound traffic at this site, with southbound results being presented first. Note that because of sensor malfunctions, data from a limited number of dates are presented here.

Southbound

The trends observed for southbound traffic along 19th Avenue at Kagy Boulevard are somewhat varied. For the September 15th game, volumes were observed to fluctuate throughout the day, with a spike occurring following the conclusion of the game at 4:00. The 85th percentile vehicle speeds also varied throughout the day, with the greatest impact being seen once again at 4:00. The September 29th game showed a slightly different trend, with traffic increasing steadily throughout the day, with a spike once again corresponding to the conclusion of the game. Once again, 85th percentile speeds were most greatly impacted during this period as well.

The final two games for which data were available, November 3rd and 17th, displayed a trend of increasing traffic volumes as the day progressed. These were accompanied by periodic spikes, as volumes increased or declined. As in previous cases, a spike related to the conclusion of each game was observed, along with corresponding declines in 85th percentile speeds.

Of note in the case of southbound traffic at Kagy Boulevard is that this segment does not see nearly as great of game-related traffic volumes as the northbound direction. This is for two reasons: first, the limited development south of campus does not produce a significant number of trips to and from games. Second, because of the lack of development south of town, there is an absence of available egress routes for attendees to use to leave a game. The drops observed in vehicle speeds for southbound traffic are mainly tied to the nature of the game-added traffic heading Southbound. This traffic is turning left from Kagy Boulevard and only beginning to accelerate when it passes over the Groundhog puck. As a result, the drop in 85th percentile speeds has more to do with this than a capacity-related issue. As a result, game traffic has a limited impact on southbound traffic at this location.

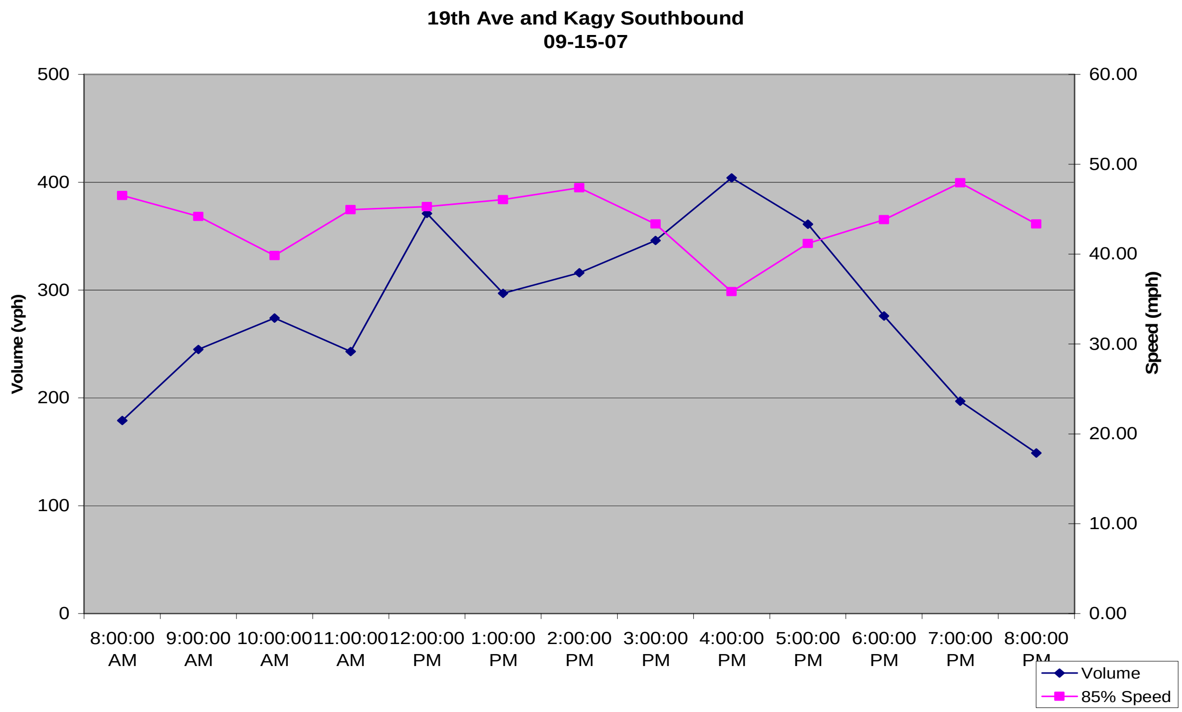


Figure 4-6: Speed and Volume trends, 19th Ave South of Kagy Blvd (September 15, 2007)

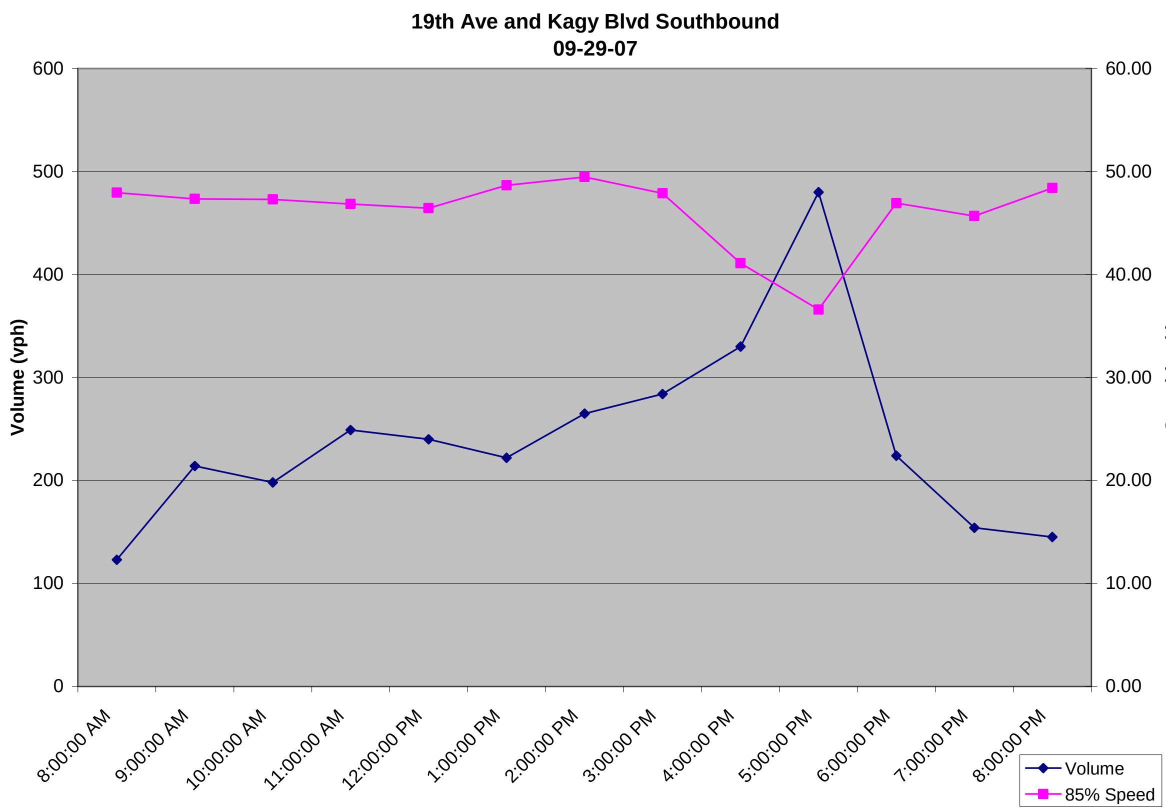


Figure 4-7: Speed and Volume trends, 19th Ave North of Kagy Blvd (September 29, 2007)

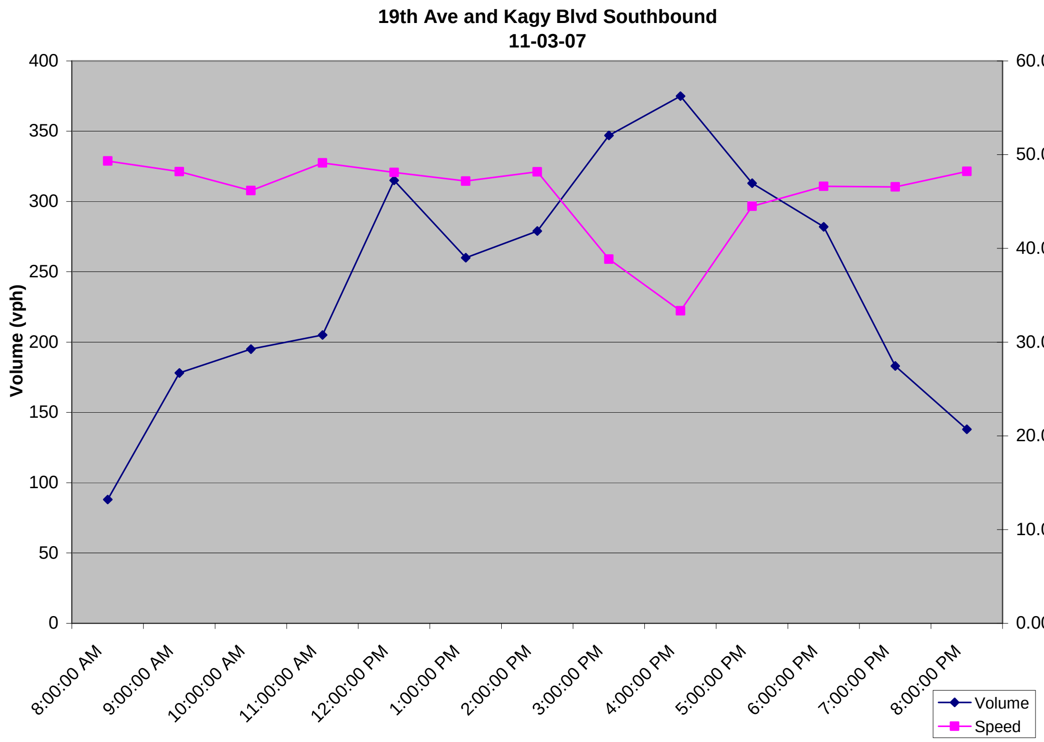


Figure 4-8: Speed and Volume trends, 19th Ave South of Kagy Blvd (November 3, 2007)

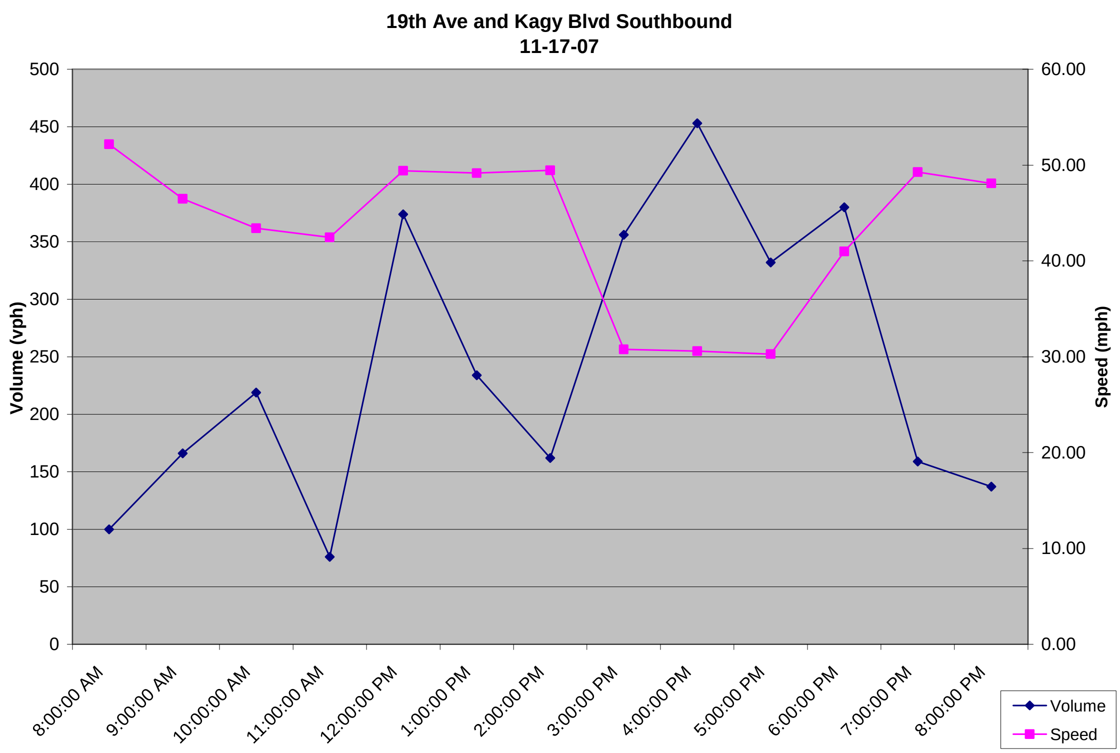


Figure 4-9: Speed and Volume trends, 19th Ave South of Kagy Blvd (November 17, 2007)

Northbound

A clearer picture of the impacts to traffic related to games is presented by the observations of northbound traffic on 19th Avenue at Kagy Boulevard. This is the primary egress route for game traffic, so it was not a surprise that this site observed significant volume spikes corresponding to the end of games. Of particular note is the prolonged spikes that occurred for the November 17th game. This game was Montana State versus Montana, which draws in the largest crowd of any game each year. As a result, it was not surprising to observe a 3 to 4 hour postgame spike in traffic occur for this game.

As has been witnessed previously, a significant decrease in 85th percentile speeds was observed to occur in conjunction with the surges in post-game traffic. At this site, the impact on speeds was more pronounced when compared to other locations. Generally, speeds fell from above 40 miles per hour down to below 35 miles per hour or lower. The November 17th game saw an even more dramatic drop, with speeds falling to below 30 miles per hour. This indicates that significant queuing may have been present at times, stretching back from the intersection of 19th Avenue and College Street.

Given the proximity of this site to the stadium, combined with the surge of traffic that attempts to leave games simultaneously, the observations made at this site were all expected. What is encouraging is that, aside from the final game observations, the speeds observed at the site indicated that slow moving or stopped queues of vehicles were not likely present. This is indicated by the tendency for speeds to remain in the range of the mid 30’s in the midst of the post-game traffic surge.

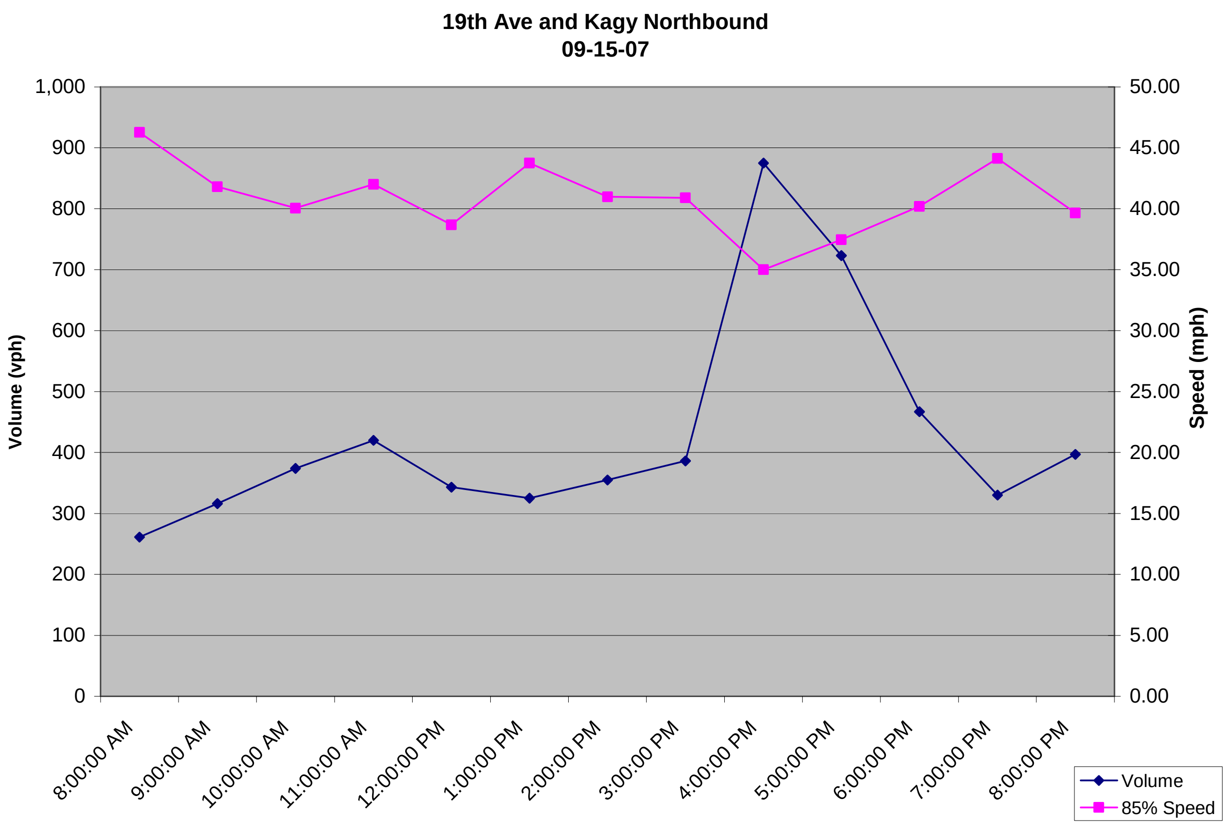


Figure 4-10: Speed and Volume trends, 19th Ave North of Kagy Blvd (September 15, 2007)

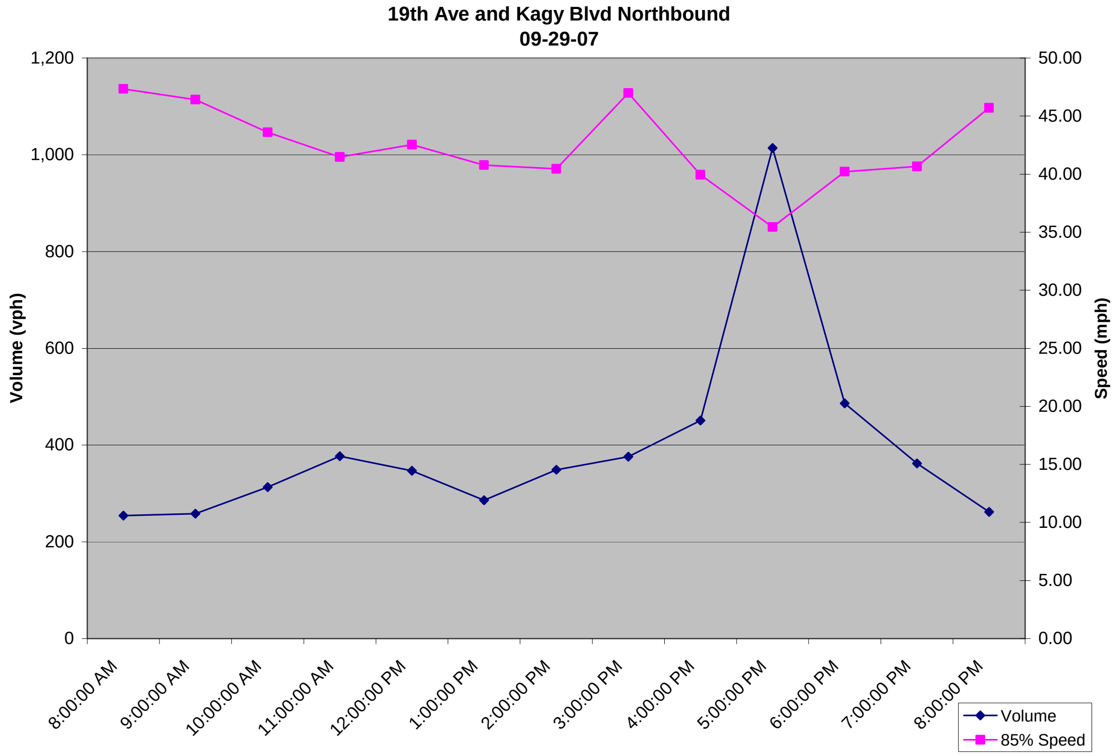


Figure 4-11: Speed and Volume trends, 19th Ave North of Kagy Blvd (September 29, 2007)

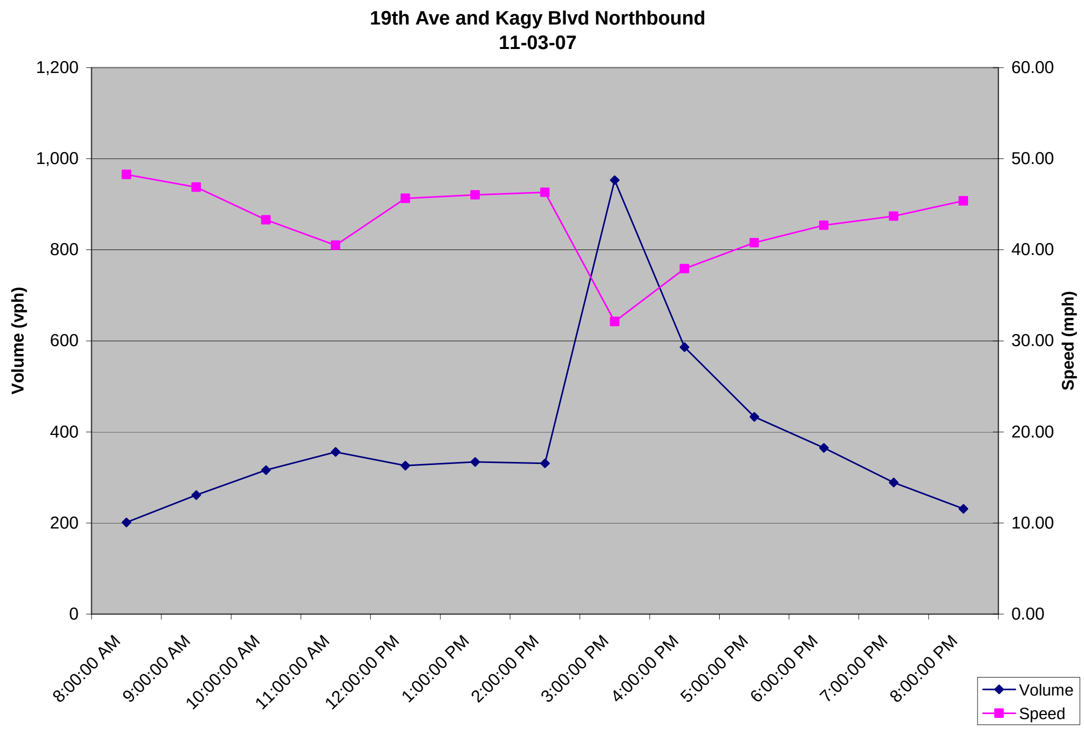


Figure 4-12: Speed and Volume trends, 19th Ave North of Kagy Blvd (November 3, 2007)

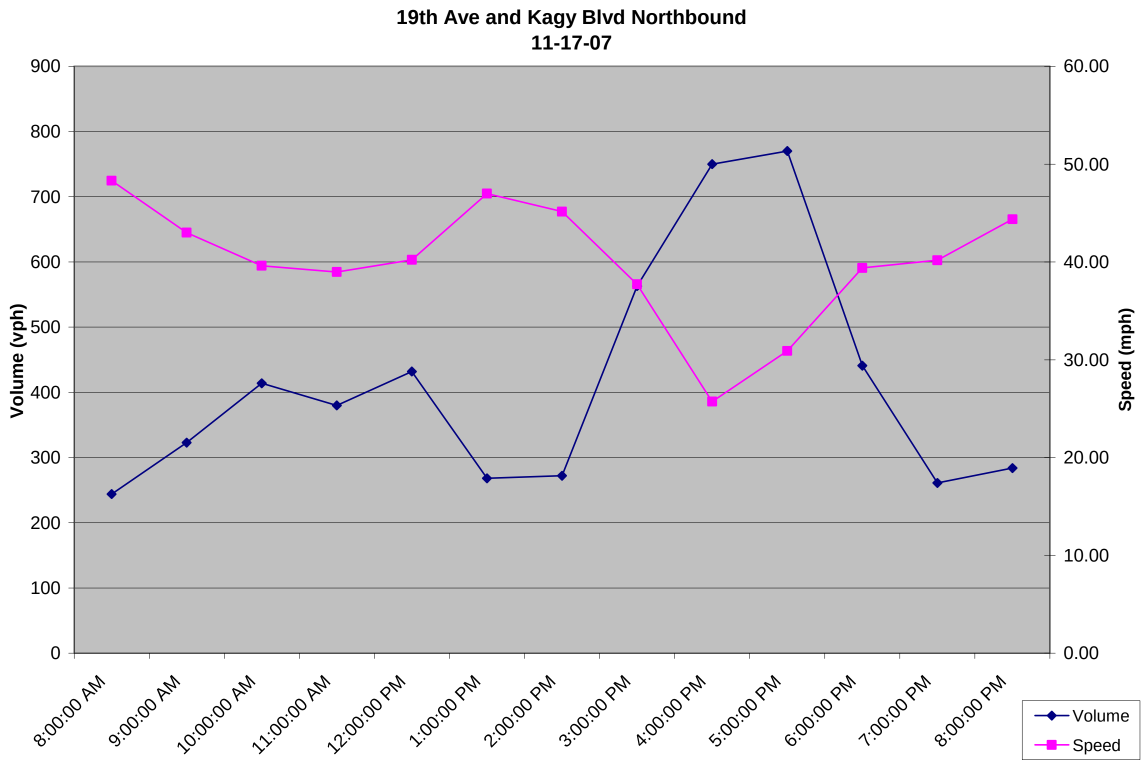


Figure 4-13: Speed and Volume trends, 19th Ave North of Kagy Blvd (November 17, 2007)

4.3.2. 19th Avenue and College Street

The second location for which Groundhog data were available was at the intersection of 19th Avenue and College Street. This location is at the periphery of campus, where vehicles are beginning to leave the area where game traffic has its primary impacts. The following sections cover the trends observed in traffic for both south and northbound traffic, with southbound results being presented first. Note that because of sensor malfunctions, data from a limited number of data are presented here.

Southbound

While the sensors only provided data for the first two games of the season for southbound (inbound to game), they illustrate the overall trends that were expected based on past observations. In general, two trends are observed related to games. The first trend is a gradual peaking of traffic in the morning, where a steadily increasing hourly volume of vehicles passes the sensors leading up to a game. At the same time, 85th percentile speeds (the speed at which 85 percent of all traffic is travelling) are seen to drop by approximately 3 to 7 miles per hour. Once the inbound game traffic drops off, speeds return to their normal state. The second trend is observed at the conclusion of games. The two figures presented represent entirely different conditions in that the September 15th graph is more representative of a typical game, while the September 29th graph represents the impacts that inbound traffic for another event (in this case, a concert on campus) has. On September 15th, volumes were observed to spike somewhat, resulting in a drop in 85th percentile speed. The increase in traffic on this date was surprising, as there should be no reason for such a dramatic increase in traffic heading Southbound toward the campus and stadium area. The September 29th volumes and their corresponding impacts on speeds were not surprising. However, the impacts of this additional traffic moving south while game traffic is heading north is troubling. In this case, the traffic heading to campus was often required to turn across outbound game traffic, resulting in further drops in vehicle speeds and ultimately, a longer period of time being required to clear game traffic from the system.

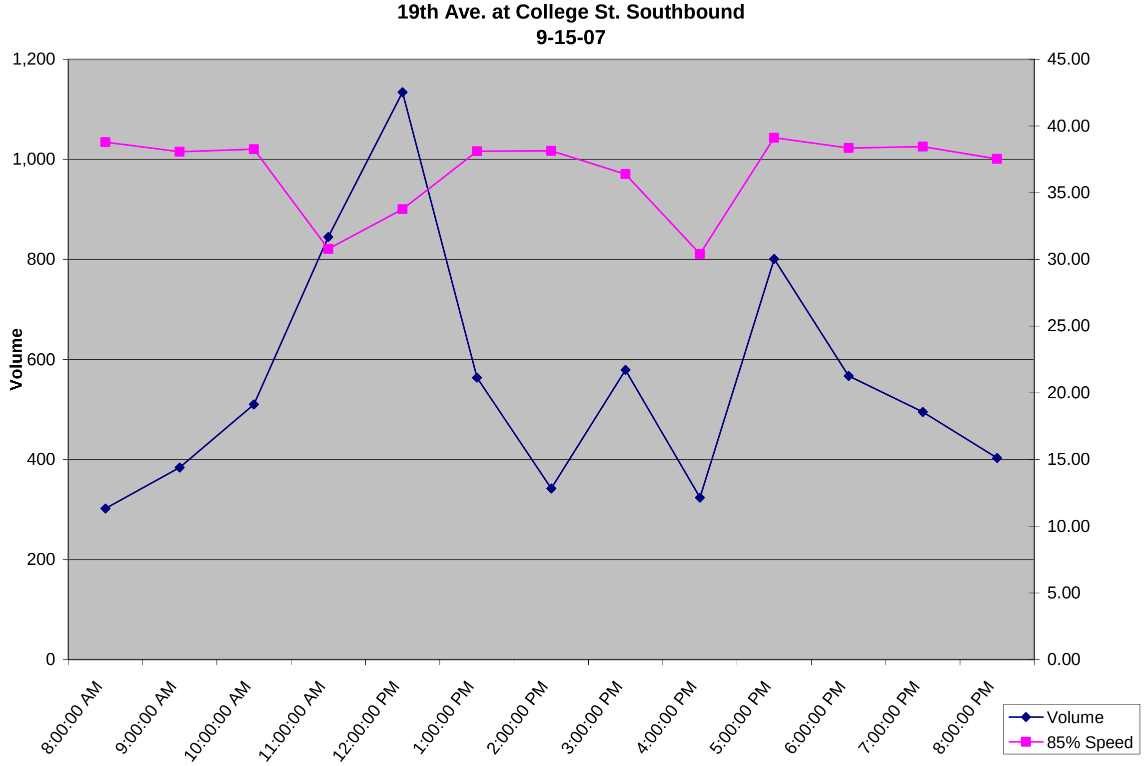


Figure 4-14: Speed and Volume trends, 19th Ave South of College St (September 15, 2007)

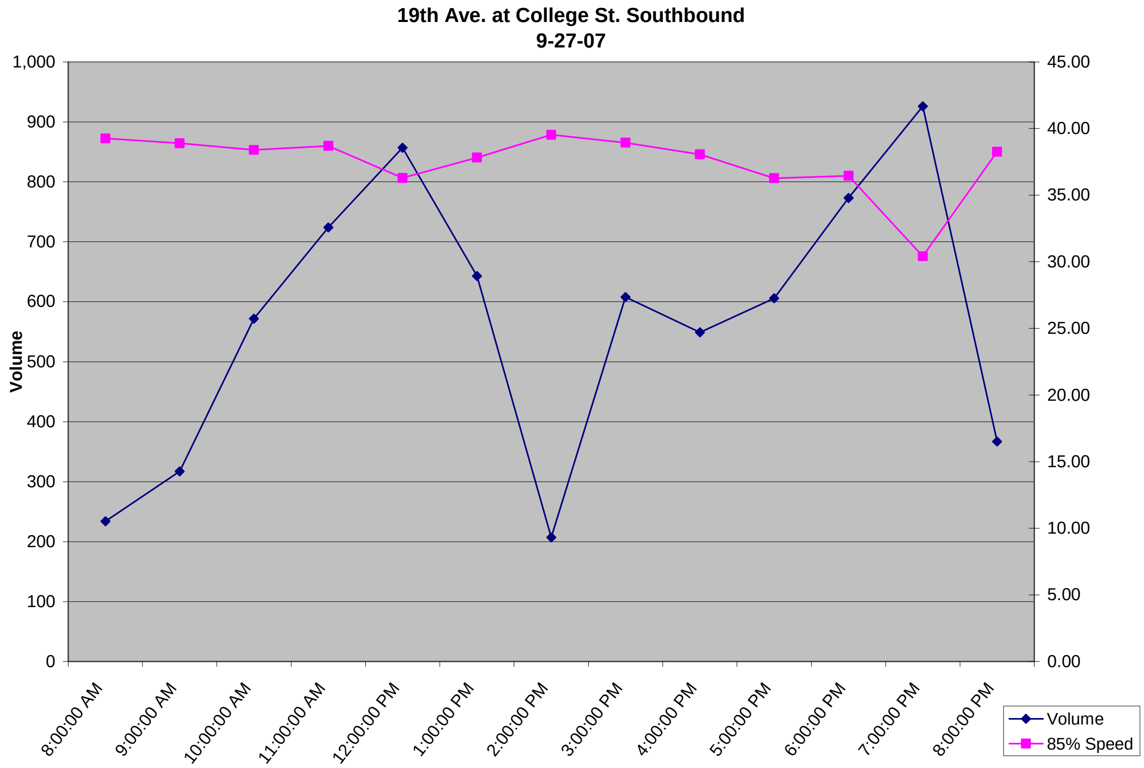


Figure 4-15: Speed and Volume trends, 19th Ave South of College St (September 29, 2007)

Northbound

When examining northbound traffic at the intersection of 19th Avenue and College Street, it is fairly evident that, while there is a traffic increase during the hours leading up to a game, the biggest impacts on the northbound traffic flow occur following a game. Throughout the day, 85th percentile speeds tend to fluctuate in the range between 30 and 35 miles per hour. However, when looking at the graphs, it is evident that the greatest impacts occur when the game ends. At this point, traffic is leaving campus nearly simultaneously. The proximity of 19th Avenue and College Street to campus is such that traffic has not yet begun to dissipate. In the 1 to 2 hour period following a game, a spike of approximately 700 vehicles can be observed with each game. Corresponding with this spike is a drop in 85th percentile vehicle speeds to approximately 30 miles per hour. While this drop may not appear significant, in light of the surge in volume being experienced, even a slight drop in speed results in decreased throughput at signalized intersections, as well as along segments. The end result is that a longer period of time is required to clear game traffic from the roadway system.

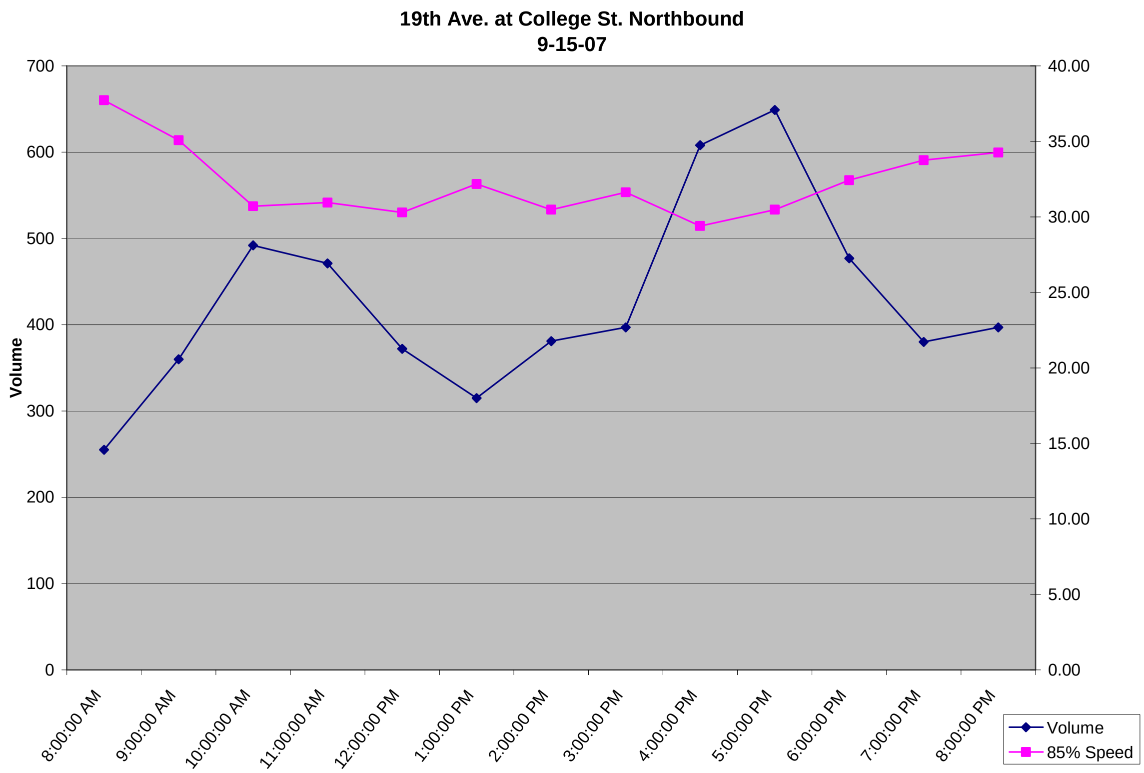


Figure 4-16: Speed and Volume trends, 19th Ave North of College St (September 15, 2007)

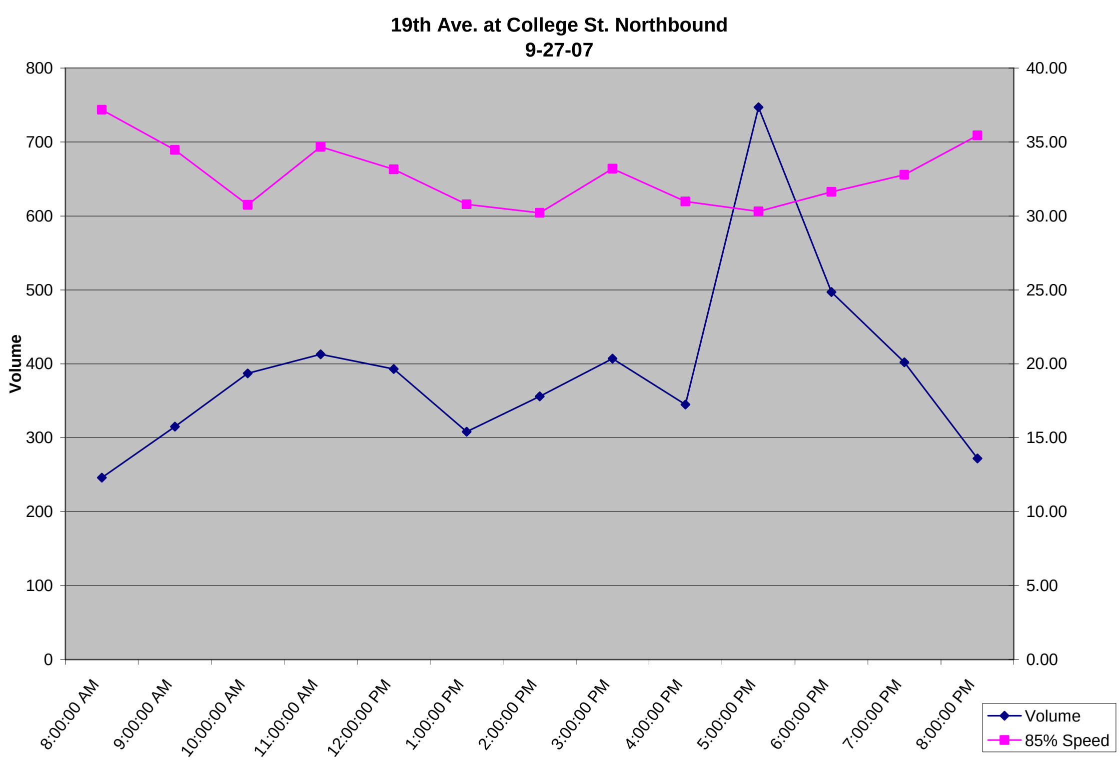


Figure 4-17: Speed and Volume trends, 19th Ave North of College St (September 29, 2007)

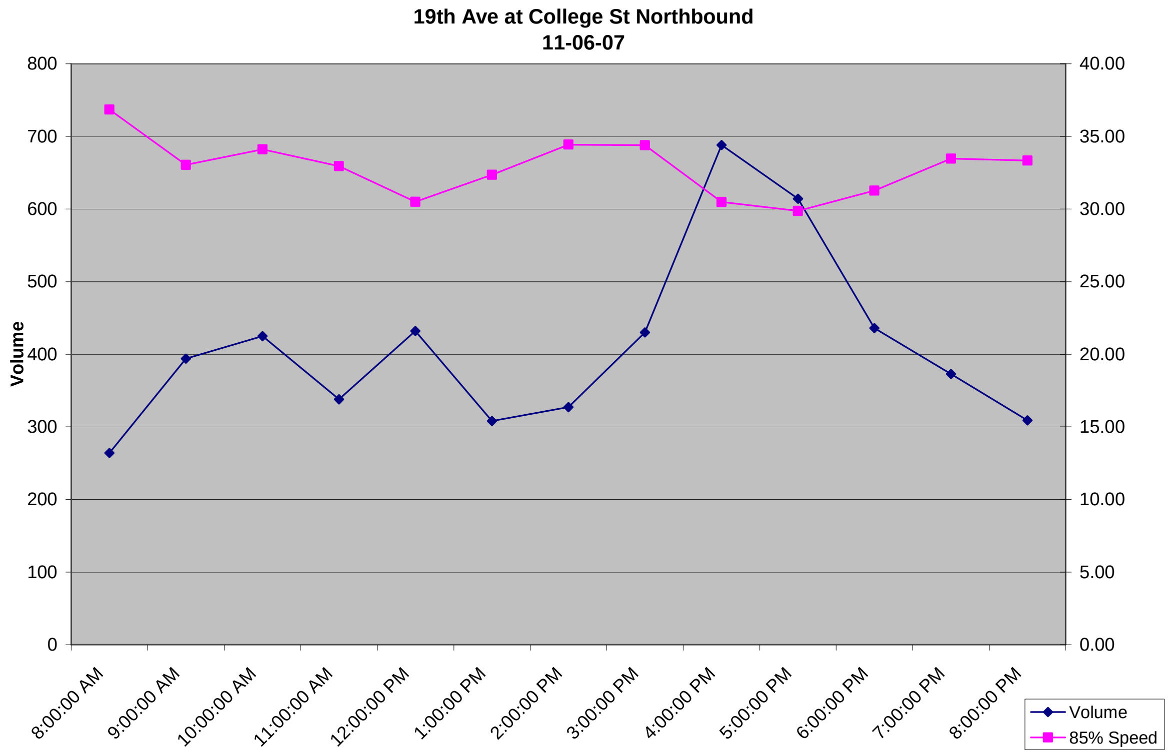


Figure 4-18: Speed and Volume trends, 19th Ave North of College St (November 6, 2007)

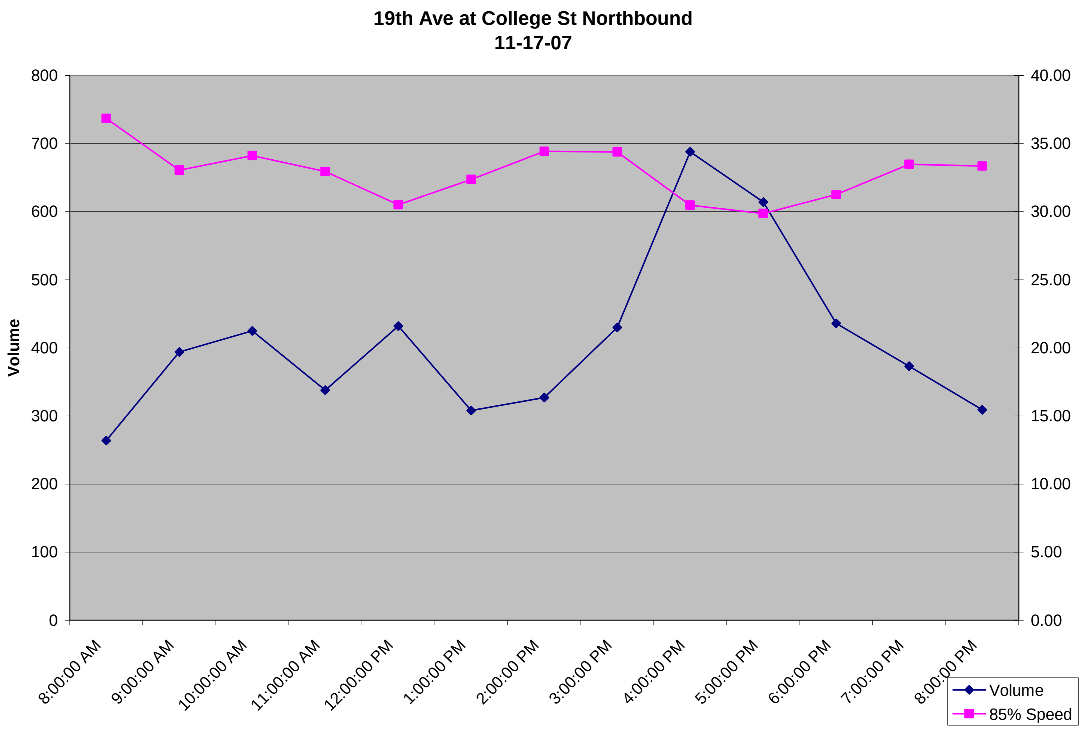


Figure 4-19: Speed and Volume trends, 19th Ave North of College St (November 17, 2007)

4.3.3. 19th Avenue and Main Street - Southbound

One critical choke point along the primary route to and from games (19th Avenue) is the intersection of 19th Avenue and Main Street. Each route services heavy volumes of vehicles, and, subsequently, only a finite number of vehicles can pass through the intersection during a given period of time. One means of understanding the performance of this site is to examine the speed and volume trends at it. Unfortunately, due to sensor problems, data for the site were only available for September 29, 2007.

Southbound

As Figure 4-20 indicates, distinct volume peaks occurred for southbound traffic both before and after the game on September 29th. This was not surprising, as this was the day a concert was held in the fieldhouse in the evening. The afternoon peaking of traffic heading south represents those vehicles heading to campus for the concert. Just as observed previously, there is a fluctuation of 85th percentile speeds throughout the day. As expected, speeds fall with the coinciding increase in traffic volumes during the pre-game period. Interestingly, while there was also an observed decline in speeds concurrent with the post-game peak, this drop was not as pronounced as that of the pre-gamepre-game period.

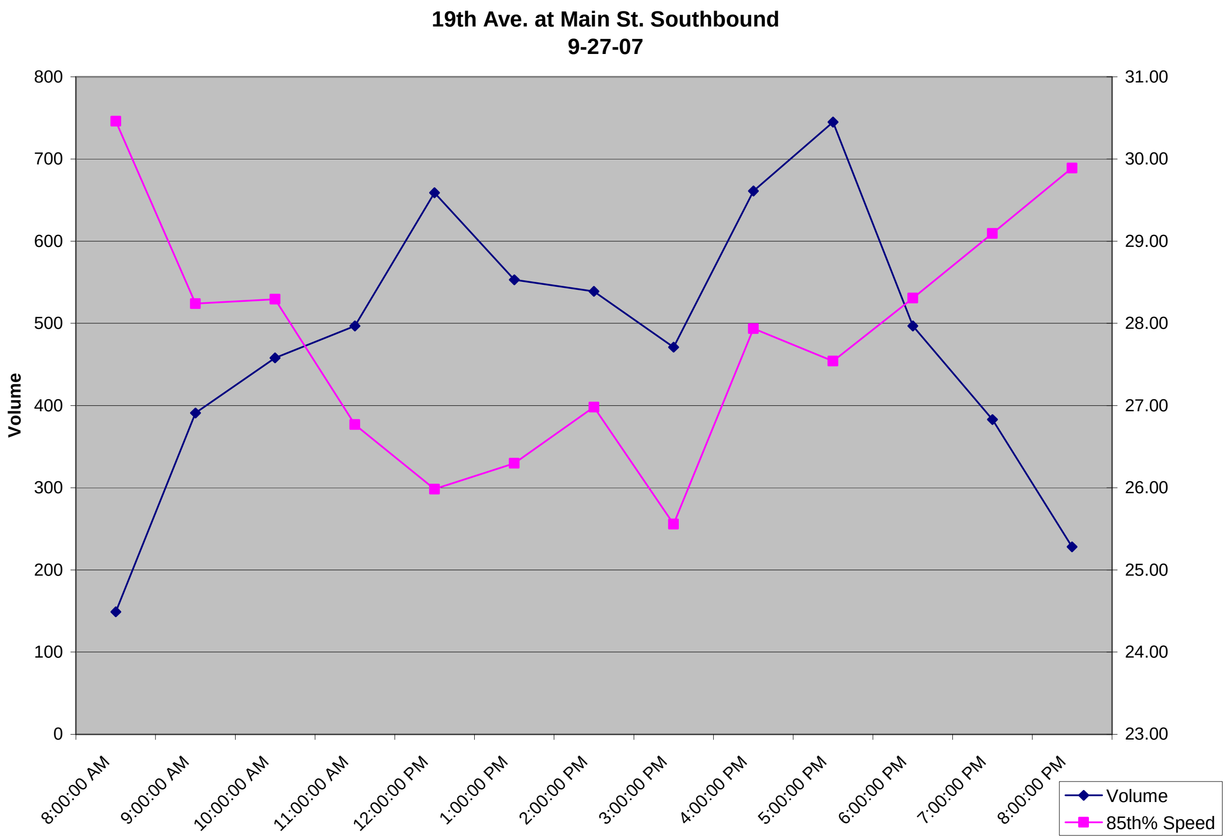


Figure 4-20: Speed and Volume trends, 19th Ave South of Main St (September 29, 2007)

Northbound

Figure 4-21 displays the volume and speed trends for northbound traffic on 19th Avenue at Main Street. As one would expect, the highest volumes passing along 19th Avenue occurred at the conclusion of the game, during the 5:00 hour. Interestingly, 85th percentile speeds during this period were higher than those observed during many other portions of the day. While no conclusive data was collected to confirm this, it is possible that heavy cross traffic on Main Street resulted in longer delays for vehicles on 19th Avenue. As a result, the observed speeds along this route would have been lower during other these periods. Overall, it is clear that, aside from the influx of game traffic, lower volumes of vehicles were being served throughout the day for which data were available.

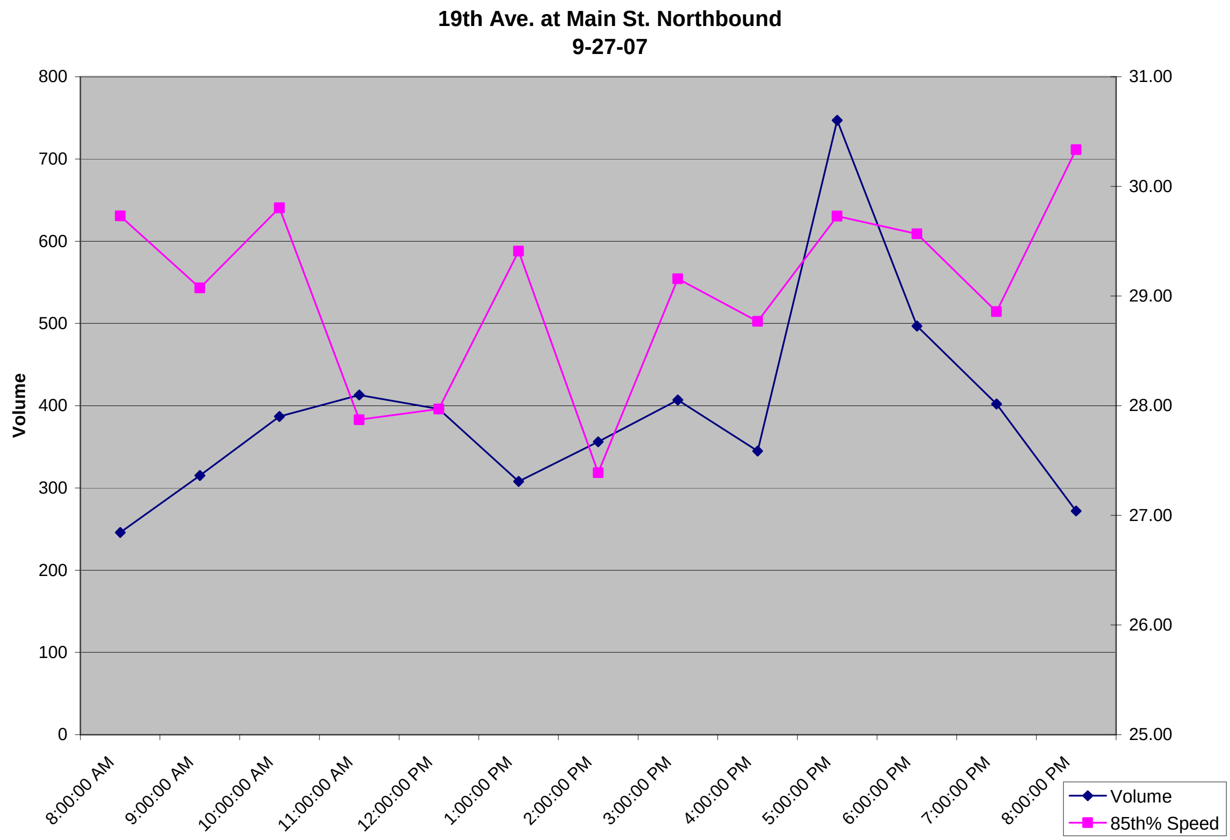


Figure 4-21: Speed and Volume trends, 19th Ave North of Main St (September 29, 2007)

4.4. Screenline Counts

In addition to the travel time and pavement sensor data, tube counts were conducted along two routes that were suspected to serve as alternatives for traffic leaving the stadium area and the city in general. The first route, Garfield Street, had been opened to traffic at the end of the 2006 season. This route provides a parallel alternative to College Street for vehicles traveling west from 19th Avenue. The second route, referred here as 11th Avenue, was essentially a shortcut which made a u-shaped formation around the south stadium area, passing through business parking lots. The concept behind this route was to provide a shortcut for eastbound traffic, as the closure of Kagy Boulevard near the stadium necessitates a lengthy detour to reach the east side of campus. The results of the tube counts, which simply counted vehicles passing a fixed location, are presented in Table 4-5.

Table 4-5: Usage of alternative routes

Garfield St			11th Ave		
Date	Period	Volume	Date	Period	Volume
9/15	4:00 - 5:15	346	9/15	N/A	N/A
9/29	4:00 - 6:30	434	9/29	N/A	N/A
10/20	4:10 - 6:25	415	10/20	3:45 - 4:30	84
11/3	3:00 - 5:45	453	11/3	2:45 - 3:30	226
11/17	2:30 - 5:15	746	11/17	3:25 - 5:10	219

As the results suggest, as the season progressed, usage of these alternatives increased. To this end, the availability of each route can be considered an asset, and their corresponding use a success in terms of alerting motorists to their existence. In the case of Garfield Street, the traffic that used this route would have ordinarily continued northbound on 19th Avenue before turning west at College Street or Main Street. In such a case, these vehicles would have required additional green time at these intersections, hampering flow on opposing approaches. Instead, Garfield Street is now serving to reduce the volumes that alternative routes are required to service. The 11th Avenue detour, while not removing a sizable portion of traffic, was viewed to lessen the flow of vehicles that had to be handled through the intersection of Kagy Boulevard and 11th Avenue. This site is presently controlled through manual traffic direction, so any lessening of volumes at the intersection is considered to be beneficial.

5. INTERSECTION ANALYSIS

In addition to the collection of travel times along designated corridors, the operation of individual intersections throughout Bozeman was examined. These included:

- 19th Ave. and Kagy Blvd;
- 19th Ave. and College St.;
- 19th Ave. and West Babcock St.;
- 19th Ave. and West Main St.;
- 19th Ave. and West Beall St.;
- 19th Ave. and Durston Rd.;
- 19th Ave. and Oak St.;
- 19th Ave. and Tschache Ln.;
- 19th Ave. and Baxter Ln.;
- 19th Ave. and Deadmans Gulch;
- 19th Ave. and Valley Center Dr;
- 11th Ave. and College St.

These locations are presented in Figure 5.1

Counts of individual vehicle movements (right turn, through, left turn) were collected in 5 minute intervals from 10:30 a.m. until 1:00 p.m. and 4:00 p.m. until 5:30 p.m. These periods were considered to be those in which a majority of game-related traffic was traveling to and from the stadium for a game. JAMAR boards were used to electronically record the movements, simplifying the tasks of the data collectors. Data were collected for 19th Avenue and College Street on September 15, 2007 and 19th Avenue and Kagy Boulevard on September 29, 2007. Remaining data were collected on November 17, 2007[1].

[1] Note that this date was the Montana State – University of Montana game, which draws larger crowds than normal home games. This was viewed to be advantageous, as operations on this day would represent a worst-case scenario.

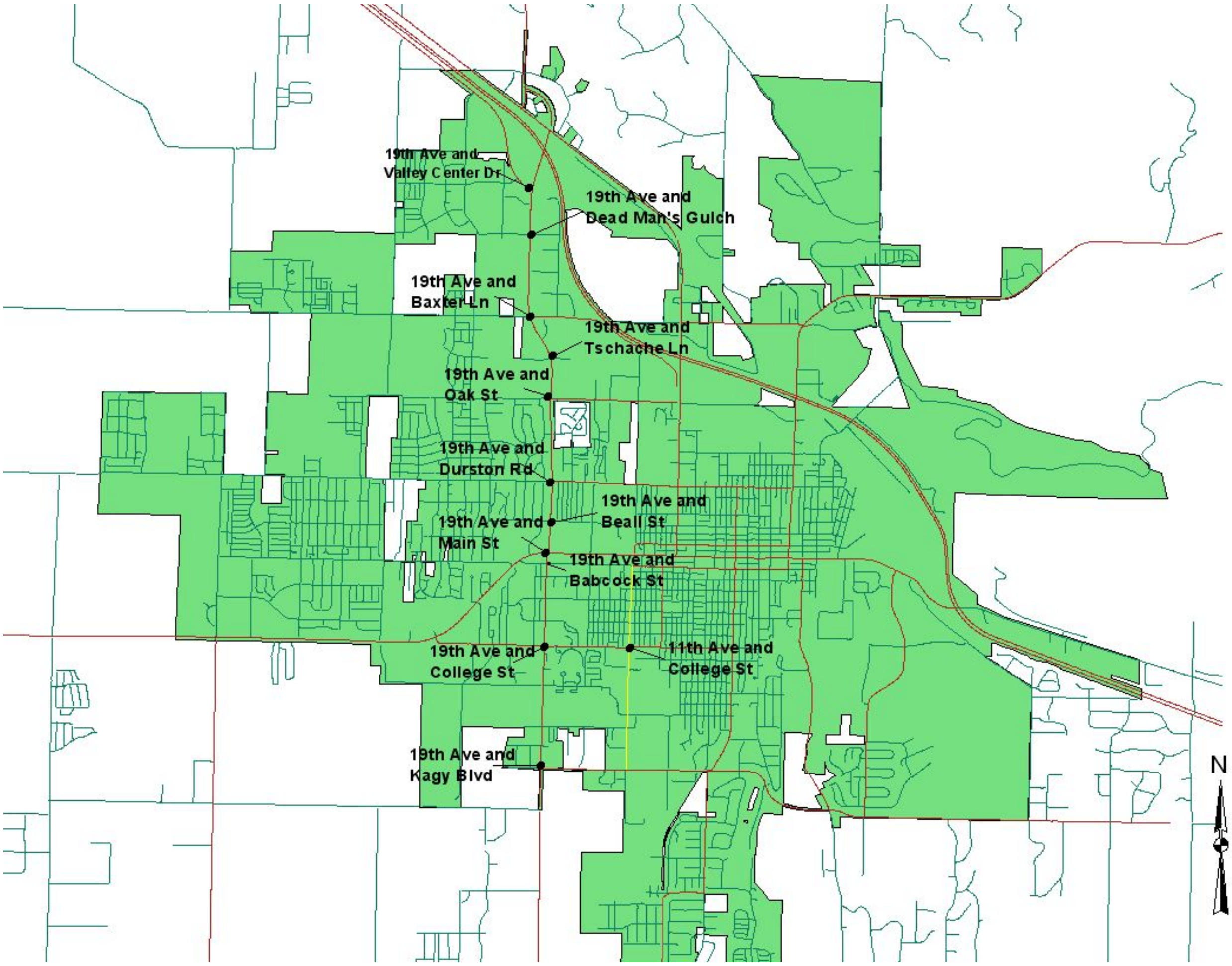


Figure 5-1: Traffic count locations

The intersections of 19th Avenue and Kagy Boulevard, 19th Avenue and College Street, and 11th Avenue and College Street were examined to determine the impacts that the traffic management strategies employed (signal retiming, manual traffic direction) had on the site. Remaining intersections were examined to determine if game traffic affected them and, if so, to what extent. Keep in mind that for these remaining sites, this analysis only examined game day impacts; no nongame day data were examined. In some cases, limited staff precluded the collection of data during mornings or afternoons.

5.1. 19th Avenue and Kagy Boulevard

Due to the closure of Lincoln Street to the North, it was anticipated that the intersection of 19th Avenue and Kagy Boulevard would see an increased volume of game-related traffic enroute to the stadium. To address this, a revised signal timing plan was put into place during the season to handle such increased volumes. Table 1 presents the results of intersection operations on game days in 2006 and 2007. For 2007, Level of Service (LOS) and delay figures are examined using the new, as well as old (2006) timing plans. In this manner, it was possible to determine how operations would have been impacted at the site had the old timing plan been left in place to handle increased traffic volumes.

Table 5-1: Delay and LOS results, 19th Avenue and Kagy Boulevard

Intersection	MOE	Approach	2006 Timing Plan	2007 Volume 2006 Timing Plan	2007 with Revised Plan
19th Ave and Kagy Blvd	**Control Delay (seh/veh) / LOS**	Morning			
		Peak Hour	11:55 - 12:55	11:10 - 12:10	
		West	25.6 / C	32.5 / C	38.0 / D
		East	13.9 / B	14.3 / B	23.0 / C
		South	13.5 / B	26.6 / C	40.7 / D
		North	6.3 / A	27.8 / C	21.0 / C
		Intersection	9.9 / A	25.9 / C	26.5 / C
		Afternoon			
		Peak Hour	4:00 - 5:00	4:45 - 5:45	
		West	12.2 / B	24.5 / C	45.0 / D
		East	7.8 / A	23.8 / C	14.0 / B
		South	16.0 / B	18.1 / B	34.4 / C
		North	11.8 / B	13.5 / B	23.4 / C
		Intersection	10.4 / B	20.2 / C	19.2 / C

As Table 5.1 indicates, the morning peak hour in 2007 deteriorated slightly as the result of increased traffic volumes. For the critical approach, the North, it was observed that under the new timing plan, delay increased from 6.3 to 21 seconds, with LOS falling to C. However, this was a better operational condition than what would have been experienced had the 2006 timing plan remained in place. Under that scenario, delay would have been an additional 6 seconds. Overall, the 2007 A.M. peak hour deteriorated from that of 2006. However, the intersection was servicing a larger volume of vehicles while operating at a respectable LOS and reasonable delay.

During the afternoon peak hour, the critical approach was the east. This approach saw nearly a doubling in delay, as well as a drop in LOS from A to B. The increased delay was minimal, although ancillary evidence, namely travel times along a route passing through the intersection suggest that movement through the site is a bit poorer than what the results here indicate. In addition, queuing could be observed from this intersection back to the stadium area following a number of games. As a result, the delay and LOS results for this site indicate that the day that traffic data were collected may have differed from other game days. Subsequently, these results should be viewed with caution.

5.2. 19th Avenue and College Street

A second critical intersection in the vicinity of campus is 19th Avenue and College Street. This site sees both roadways handle both pre and post-game-related traffic. Previous study of the intersection indicated that the signal timings required adjustments to accommodate the increased traffic that accompanies games, specifically in the afternoon. New timings were implemented to handle increased post-game traffic, and the results of these modifications on delay and LOS are presented in Table 5-2. Note that staffing limitations prevented a collection of data for the morning peak hour. Ancillary evidence (i.e. travel times) indicated that the staggered arrival of traffic pre-game did not adversely impact the intersection.

Table 5-2: Delay and LOS results, 19th Avenue and College Street

Intersection	MOE	Approach	2006 Timing Plan	2007 Volume 2006 Timing Plan	2007 with Revised Plan
19th Ave and Kagy Blvd	Control Delay (seh/veh) / LOS	Afternoon			
		Peak Hour	4:00 - 5:00	4:45 - 5:45	
		West	17.9 / B	13.8 / B	14.3 / B
		East	43.4 / D	22.5 / C	24.7 / C
		South	74.4 / E	80.7 / F	66.6 / E
		North	27.7 / C	19.7 / B	18.3 / B
		Intersection	49.2 / D	47.7 / D	41.3 / D

As the results presented above indicate, had no signal timing changes been implemented, further deterioration would have occurred at the site. This was particularly true of the South approach, which handles a majority of post-game traffic. With the revised timing plan put into place, some improvement was observed along this approach, as well as all others. As a result, the overall performance of the intersection improved, particularly in terms of decreased delay. Given the infrastructure constraints at this site (e.g. number of lanes), the fact that slight improvements were observed while traffic game attendance and traffic volumes grew, indicates that intersection operational problems have been kept at bay, at least in the short term. However, it must be noted that the limit has been reached in terms of signal timing changes that can be implemented. Instead, capacity constraints are now being reached that cannot be addressed by solely modifying signal timings.

5.3. 19th Avenue and West Babcock Street

The intersection of 19th Avenue and West Babcock Street presents an interesting operational problem. This intersection is in close proximity to the 19th Avenue and West Main Street intersection, with both sites being signalized. A true interconnect does not exist between these intersections; rather, the sites share a common controller and a signal timing plan that operates in a pseudo-synchronized manner. Table 5-3 presents the operational results for this site.

Table 5-3: Delay and LOS results, 19th Avenue and Babcock Street

19th Ave and Babcock St	Morning - 11:25 - 12:25		
	MOE	Delay	LOS
	West	96.5	F
	East	50.8	D
	South	9	A
	North	23.5	C
	Intersection	31.5	C
	Afternoon - 4:25 - 5:25		
	MOE	Delay	LOS
	West	99.3	F
	East	67.5	E
	South	251.1	F
	North	2.1	A
	Intersection	141.8	F

As the results indicate, the morning peak sees poor level of service on both the east and west approaches (Babcock Street). As stated previously, this intersection operates in tandem with 19th Avenue and Main Street. As a result, the timings for east-west movements on Babcock Street are somewhat constricted to facilitate north-south movements at both this site and 19th Avenue and Main Street. Consequently, the traffic volumes present on Babcock Street, while quite low, are not being adequately serviced regardless of what day of the week it is. With respect to game traffic, it passes through this site moving South on 19th Avenue. To this end, it is being adequately serviced, as indicated by the high LOS on the North approach.

The afternoon peak hour saw a complete deterioration of LOS on all approaches, except for the north. As expected, the approaches on Babcock Street functioned poorly, as did the south approach of 19th Avenue, which services post-game traffic. As the results indicate, excessive delay was experienced on this approach, primarily the result of large volumes of game-related traffic passing through the site in a relatively short period of time.

Overall, during the morning period, the intersection is effectively servicing game traffic. In the afternoon, game traffic is met with extensive delays. However, because of the closely spaced nature of the 19th Avenue and Babcock Street and 19th Avenue and Main Street intersections, little can be done in terms of signalization solutions to improve conditions specifically for game traffic. Such changes would produce further detrimental impacts on east-west traffic at both intersections. As a result, it is likely that continued operational problems will persist at this location into the foreseeable future, with further deterioration occurring over time.

5.4. 19th Avenue and West Main Street

As section 5.3 indicated, the intersections of 19th Avenue and West Main Street and 19th Avenue and West Babcock Street are in close proximity to one another. As a result, the heavy traffic flow of one intersection often tends to impact its neighbor. In the case of 19th Avenue and Main Street, the traffic volumes on each roadway are large. When game day traffic is added to these volumes, the result is extensive delay and deterioration in LOS. Table 5-4 presents the results of analysis for this site.

Table 5-4: Delay and LOS results, 19th Avenue and Main Street

	Morning - 11:35 - 12:35		
19th Ave and Main St	MOE	Delay	LOS
	West	538.3	F
	East	63.3	E
	South	67	E
	North	23.2	C
	Intersection	240.7	F
	Afternoon - 4:05 - 5:05		
	MOE	Delay	LOS
	West	82.5	F
	East	126.8	F
	South	193.5	F
	North	21.7	C
	Intersection	109.2	F

As the results indicate, this intersection functioned poorly both pre and post-game. This was expected, as the intersection presents operational problems during events similar in scope to game day traffic (i.e. morning and afternoon commute hours). Given that both 19th Avenue and

Main Street each service heavy volumes that are only increased on a game day, it is not surprising that extensive delay and poor LOS exist at the site. Simply stated, there is only so much green time that can be allocated to each movement without penalizing other movements. As a result, when an influx of game traffic reaches the site (particularly postgame), only a portion of that total volume is capable of being put through the intersection before other movements are serviced. Subsequently, delay increases and LOS declines.

In the morning, game traffic faces (approaching the site on the North approach) only a minimal delay and subsequently, experiences a reasonable LOS. However, the other approaches to the intersection are faced with extensive delay (1 minute plus) and in an extreme case, over 8 minutes (west approach)[2]. In the case of the west approach, a significant contributor to this delay are the geometric features of the site. The west approach includes two left turn bays which can only be serviced by a protected cycle. As a result, this movement receives a limited portion of the available cycle time for the intersection and subsequently, delay for the approach increases as vehicles are forced to wait for an opportunity to turn left.

In the afternoon, the site continues to operate poorly, with all traffic streams excluding the North approach facing extensive delay. Interestingly, the delay experienced on the west approach fell significantly from that calculated for the morning.

As was the case with the intersection of 19th Avenue and Baxter Street, because of the closely spaced nature of the 19th Avenue and Babcock Street and 19th Avenue and Main Street intersections, little can be done in terms of signalization solutions to improve conditions specifically for game traffic. Such changes would produce further detrimental impacts on east-west traffic at both intersections. As a result, it is likely that continued operational problems will persist at this location into the foreseeable future, with further deterioration occurring over time. As a result, this location, and the intersection of 19th Avenue and Main Street specifically, will remain the choke point for football traffic in the future.

5.5. 19th Avenue and Beall Street

The intersection of 19th Avenue and Beall Street is located approximately a quarter mile north of the 19th Avenue and Main Street intersection. Despite its close proximity to this site, the intersection does not appear to be impacted by the congestion that occurs at its neighbor. As the results for this site presented in Table 5-5 indicate, 19th Avenue and Beall Street operated reasonably well on a game day.

[2] This result is viewed to be a worst-case scenario resulting from the analysis program employed (Synchro) not being able to incorporate the vehicle behaviors exhibited on this approach (i.e. through traffic moving around vehicles extending outside the left turn lane bays rather than queuing behind).

Table 5-5: Delay and LOS results, 19th Avenue and Beall Street

	Morning - 11:15 - 12:15		
19th Ave and Beall St	MOE	Delay	LOS
	West	27.6	C
	East	20.7	C
	South	5.5	A
	North	7.2	A
	Intersection	8.4	A
	Afternoon - 4:15 - 5:15		
	MOE	Delay	LOS
	West	26.8	C
	East	19.4	B
	South	6.7	A
	North	5.4	A
	Intersection	7.9	A

Results for the morning peak hour indicate that the north approach, which serviced game traffic, operated exceptionally well. This is not surprising, as, unlike the previous intersection examined, 19th Avenue is the primary route and therefore, receives a majority of the available cycle time. During the morning, delay was quite low, resulting in a high LOS on all approaches and the intersection overall.

The afternoon peak hour produced similar results to those found from the morning. The critical movement in this instance was on the South approach, as game traffic travels Northward postgame to exit the city. This approach produced a low delay and a high LOS. This may be the result, in part, of a metering type of phenomenon occurring as the result of the proximity of this site to the intersection of 19th Avenue and Main Street. Given that only a limited number of vehicles moving northbound are able to pass through this site during a given cycle, the intersection of 19th Avenue and Beall Street only receives a limited number of vehicles from it which are easily serviced. During the afternoon peak hour, all non-critical approaches also function well, with low delay and high LOS, subsequently, the intersection as a whole was found to perform well.

Overall, the intersection is functioning well at present, with results from the morning peak hour at this site indicating that the additional traffic produced by a game does not create an operational problem. The conclusion that can be drawn in examining postgame results is that once traffic passes the chokepoint of the 19th Avenue and Main Street intersection, traffic platoons begin to dissipate while encountering intersections that function better than those previously encountered. Of course, the fact that 19th Avenue receives much of the allocated green time for this site also plays a crucial role in moving traffic northward continuously. As subsequent sites will demonstrate, when 19th Avenue does not receive a majority of a cycle's green time, traffic once again bunches up, with delay and LOS deteriorating. Results from the morning peak hour at this site indicate that the additional traffic produced by a game do not create an operational problem.

5.6. 19th Avenue and Durston Road

The intersection of 19th Avenue and Durston Road is another site where all approaches contribute significant volumes to the total passing through the site. Once again, this results in a case where scarce cycle time must be allocated between all movements in a manner that minimizes delay. When game day traffic is added to that of a normal Saturday, the result is deterioration, as the results of Table 5-6 illustrate.

Table 5-6: Delay and LOS results, 19th Avenue and Durston Street

	Morning - 11:20 - 12:20		
19th Ave and Durston Rd	MOE	Delay	LOS
	West	46.7	D
	East	49.9	D
	South	38	D
	North	49.9	D
	Intersection	45.8	D
	Afternoon - 4:25 - 5:25		
	MOE	Delay	LOS
	West	36.2	D
	East	57.4	E
	South	55.7	E
	North	45.7	D
	Intersection	49.8	D

During the morning peak hour, vehicles on all approaches experienced varying amounts of delay. Subsequently, LOS reached a point where performance could be considered poor. However, compared to an intersection such as 19th Avenue and Main Street, this site is still functioning in a reasonable manner.

During the afternoon peak hour, postgame traffic loads were such along the critical approach (South) that delays of nearly a minute were incurred, resulting in a poor LOS. The deterioration at this site is likely the result of the amount of cycle time allocated to adequately service approaches on Durston Road. Since northbound traffic is forced to stop at the intersection, it begins to bunch up once again, similar to what was observed to occur South of the 19th Avenue and Main Street intersection. Given that the postgame peak volumes last for a finite length of time before returning to normal levels, changes to signal timings might yield improvements on 19th Avenue, but further deteriorate operations on Durston Road in the short term.

The primary conclusion examining the operations of this site is that, contrary to what was previously thought, the intersection of 19th Avenue and Main Street was not the dividing point where the impacts of game-related traffic began to be minimized. Rather, as subsequent results will illustrate, the dividing line appears to be the intersection of 19th Avenue and Durston Road.

5.7. 19th Avenue and Oak Street

Data for the intersection of 19th Avenue and Oak Street was only collected for the afternoon peak due to staffing limitations. Once again, this site is host to two major roadways, requiring cycle time to be allocated in a manner that addresses their respective volumes. The delay and LOS results for this site are presented in Table 5-7.

Table 5-7: Delay and LOS results, 19th Avenue and Oak Street

	Afternoon - 4:15 - 5:15		
19th Ave and Oak St	MOE	Delay	LOS
	West	29.4	C
	East	24.5	C
	South	15.8	B
	North	15.4	B
	Intersection	18.2	B

As the results indicate, the intersection functioned well, with the critical approach (South) experiencing little delay and a high LOS. Overall, the remaining approaches also performed will in terms of delay and LOS. These results provide an initial indication that North of Durston Road is the point where traffic begins to dissipate. This would indicate that perhaps the view that distance from campus minimizes the impacts of traffic might yet be valid; the error in the previous belief was that the intersection of 19th Avenue and Main Street was the "tipping point" where game-related traffic impacts ended.

5.8. 19th Avenue and Tschache Lane

The intersection of 19th Avenue and Tschache Lane primarily serves commercial retail parking lots. As such, the timing plan for this site focuses on the movement of traffic primarily on 19th Avenue, with only a portion of the cycle focusing on Tschache Lane. Due to staffing limitations, only data for the morning peak were collected. These results are presented in Table 5-8.

Table 5-8: Delay and LOS results, 19th Avenue and Tschache Lane

	Morning - 11:20 - 12:20		
19th Ave and Tschache Lane	MOE	Delay	LOS
	West	40	D
	East	33.8	C
	South	14.3	B
	North	15.2	B
	Intersection	18.4	B

As the results presented indicate, the critical approach (North) for pregame traffic functioned well. This was expected, as this movement was heavily factored in the timing plan. The only approach that appeared negatively impacted was the west, where moderate delay and lower LOS were experienced. However, as a whole, the site performed well handling the peak hour of traffic pregame.

5.9. 19th Avenue and Baxter Road

The intersection of 19th Avenue and Baxter Road is a site where 19th Avenue is the major roadway, with Baxter Road contributing only a portion of the traffic passing through on a game day. As a result, this intersection was expected to function well, which it did, as indicated in Table 5-9.

Table 5-9: Delay and LOS results, 19th Avenue and Baxter Street

	Morning - 11:25 - 12:25		
19th Ave and Baxter Rd	MOE	Delay	LOS
	West	26.5	C
	East	15.4	B
	South	15.3	B
	North	20.5	C
	Intersection	18.9	B
	Afternoon - 4:25 - 5:25		
	MOE	Delay	LOS
	West	29.1	C
	East	25.3	C
	South	14.7	B
	North	12.1	B
	Intersection	15.6	B

During the morning peak hour, the critical approach (North) experienced a slight delay and moderate LOS. This was not surprising, and as a whole, the intersection functioned well in handling pregame traffic. For postgame traffic, the critical approach (South) functioned well, with minimal delay and a high LOS. Remaining approaches also functioned well. As a result, it can once again be concluded that the further from campus a vehicle is, the lesser the impacts that are experienced.

5.10. 19th Avenue and Dead Man's Gulch

The intersection of 19th Avenue and Dead Man's Gulch is one where the majority of traffic serviced is on 19th Avenue. As a result, it was anticipated that delay and LOS metrics would be positive on 19th Avenue, and the results presented in Table 5-10 confirm this assumption. Note that staffing issues prevented collection of morning data.

Table 5-10: Delay and LOS results, 19th Avenue and Dead Man's Gulch

	Afternoon - 4:15 - 5:15		
19th Ave and Dead Man's Gulch	MOE	Delay	LOS
	West	15.1	B
	East	23.2	C
	South	7.2	A
	North	14.6	B
	Intersection	10.3	B

As the results indicate, during the postgame peak hour, the critical approach (South), functioned the best of any approach at the site, with minimal delay and high LOS. The remaining approaches also performed well. These results further strengthen the contention that distance from campus minimizes the impacts that games have on traffic.

5.11. 19th Avenue and Valley Center Drive

The final intersection along the 19th Avenue corridor that was examined was 19th Avenue and Valley Center Drive. This is a site where each roadway serves large volumes of traffic. Additionally, its proximity to the I-90 interchange results in most traffic turning from Valley Center Drive onto 19th Avenue. Given that each roadway required a portion of the available cycle time, it was anticipated that this site may have been impacted by game traffic. However, as the results presented in Table 5-11 indicate, this was not the case.

Table 5-11: Delay and LOS results, 19th Avenue and Valley Center Drive

19th Ave and Valley Center Drive	Morning - 11:00 - 12:00		
	MOE	Delay	LOS
	West	30.8	C
	East	12.8	B
	South	24.3	C
	North	19.6	B
	Intersection	23.8	C
	Afternoon - 4:20 - 5:20		
	MOE	Delay	LOS
	West	34.8	C
	East	10.6	B
	South	26.7	C
	North	16.1	B
	Intersection	24.9	C

During the morning peak hour, the critical approach (North) performed well, experiencing minimal delay and high LOS. Keeping this approach fluid is critical, as clearing the vehicles traveling South through it is an important aspect of preventing queues from forming upstream on the west I-90 off ramp. To this end, the intersection performed adequately, as no such queuing was observed by the data collector at this site. Overall, the additional approaches also performed well in the morning, indicating that game-related traffic had a minimal impact at the site.

Afternoon results also indicated that the critical approach (South) was functioning adequately, with only moderate delay and an acceptable LOS. The remaining approaches also performed acceptably, indicating that at this distance from campus, the impacts of game traffic are indeed minimized.

5.12. Signalized Intersection Conclusions

The broad conclusion that can be drawn from the analysis of intersections along the 19th Avenue corridor is that distance from campus does minimize the impacts of game traffic on signalized intersections. It would appear from the data that until the intersection of 19th Avenue and Durston Road is reached, game traffic contributes heavily to delay at signalized intersections. Once this site has been reached, the platoons of vehicles begin to break up and become more dispersed in the traffic stream. Subsequently, intersections north of 19th Avenue and Durston Road function much better, with lower delays and high LOS.

Overall, the signalized intersections north of 19th Avenue and Durston road all operated well in both the morning and afternoon. Additionally, the intersection of 19th Avenue and Beall Street also operated well, despite falling between two poorly operating intersections.

The intersections in close proximity to campus that saw modified signal timing plans put into place to address game traffic performed moderately well, at least to the extent which could be expected. Some improvements, albeit slight, we observed. More importantly, under increased seasonal attendance (and theoretically, additional vehicular traffic), no deterioration was observed. Additionally, the road closures put into place do not appear to have had an adverse impact on operations at the signalized intersections near campus.

Baseline data were not collected on a nongame Saturday due to staffing limitations. Such baseline data would allow for an understanding of how the results produced by game day traffic might differ from those of a nongame day. Regardless, the majority of data collected (all 19th Avenue intersections north of College Street) were collected the day of the Montana State-Montana game, which traditionally has produced the largest crowds and, consequently, the largest volumes of traffic. In this respect, the analysis of these intersections was made under a worst case scenario, where the maximum amount of game traffic was likely traveling the corridor.

5.13. Manual Traffic Control

In addition to examining the performance of signalized intersections, the performance of a critical stop-controlled intersection on the Northern edge of campus, 11th Avenue and College Street, was also examined. In this instance, the intersection only functioned as a stop-controlled site pre-game. Post-game, it was controlled by a police officer who manually directed traffic. A detailed presentation of the manual control analysis performed is presented in Appendix A.

5.13.1. All-way Stop Control (Morning)

Pregame, the intersection was allowed to operate under all-way stop control. When compared to the observations made in 2006, conditions in 2007 did not improve greatly. The delay and LOS results for each year are presented in Table 5-12. When examining the results, a few interesting observations may be made. First, dramatic improvement was observed on the east approach (westbound traffic) in 2007. Delay fell by over 1 ½ minutes, and subsequently, LOS improved. This change is the result of a decrease in traffic volumes utilizing the approach, although the reason for this drop is unclear. Traffic using this approach would, in theory, not be impacted in any way by the traffic management strategies (i.e. road closures) implemented on the west side of campus.

An increase in delay was observed on the west approach, which was expected due to traffic shifts that were influenced by road closures. By the date of data collection (November 3, 2007), attendees were familiar with which roads had been closed and modified their travel routes accordingly. As a result, the west approach of this site saw an increase in volume and subsequently, was impacted in terms of delay and LOS.

The South approach functioned similarly between 2006 and 2007, which was expected, as only a limited volume of traffic was using this approach to leave campus. The north approach exhibited a trend similar to that of the east approach; delay fell significantly (by nearly 60 seconds). The reason for this decrease is once again, unclear. It is possible that the traffic using this route in 2006 shifted to the parallel route of 19th Avenue.

Table 5-12: Delay and LOS results, 11th Avenue and College Street

Intersection	MOE	Approach	2006	2007
11th Ave and College St	Control Delay (seh/veh) / LOS	Morning		
		Peak Hour	11:45 - 12:45	11:07 - 12:07
		West	146.14 / F	128.3 / F
		East	125.06 / F	26.6 / D
		South	57.36 / F	60.9 / F
		North	93.32 / F	34.3 / D
		Intersection	101.1 / F	69.2 / F

In reviewing the operations of 11th Avenue and College Street during the morning, it remains clear that all-way stop control is inefficiently servicing the volumes passing through the site. Given the volumes that are using each approach, it might be advisable to consider deploying a police officer to the site to direct traffic as has been successfully done during the postgame period (as will be seen briefly). However, unlike the postgame deployment, where game traffic leaves campus immediately following the conclusion of a game, it is unclear when the morning peak will occur. This is because of the staggered nature of pregame arrivals. As a result, the pregame peak hour at this site may occur any time during the morning, making it difficult to pinpoint the optimal time for an officer to be deployed. However, given the observations over the past two seasons, the time is approaching when considerations must be given to the improvement of operations at this site during the pregame period.

5.13.2. Manual Control (Afternoon)

Examining the performance of this intersection postgame, when manual traffic control was employed, was challenging. This was the result of no established methodology to analyze such a control strategy being available (i.e. HCM metrics). Rather, a simulation of the officer's traffic control strategies was employed by setting up a pre-timed signal plan for the intersection, which closely mimicked what was observed in the field. Field observations were recorded on video for later reference with respect to the amount of time allocated by the officer for each movement, traffic volumes performing each movement, and other information.

After investigation of the video footage, it was found that there were two phases during each cycle of manual operation: one was for northbound-southbound traffic and the other was for eastbound-westbound traffic. During the time period between 3:36 p.m. and 5:12 p.m., 24 cycles of manual traffic control were observed. For each cycle, the cycle length and green time allocations for the two phases were tracked and recorded. In this study, green time refers to the amount of time allocated to a particular movement by the police officer.

The mean cycle length during manual operation was observed to run as long as four minutes. Overall, the mean allocated time for northbound and southbound traffic was one-half minute longer than that of eastbound and westbound, which was reasonable since the traffic volume on northbound and southbound approaches was greater. Eastbound and westbound green times had larger variations than those of the northbound and southbound approaches.

The video data showed that there were some differences between manual and pre-timed signal traffic control. For example, the officer occasionally would stop eastbound traffic to allow a left-turning vehicle on the westbound leg to pass. Under signal traffic control, left-turning vehicles would be yielded to opposite through vehicles. The other observed difference was in the allocation of green time to different phases. Conversely, pre-timed traffic signal control does not change phase splits. However, in manual operation, it was observed that the officer assigned green times based on the observed queues on the approaches. The officer did not change phases until all vehicles in the queues were discharged. In some cases, the officer assigned more green time to approaches when there were no queues but observed vehicles approaching. As a result, cycle lengths were increased.

In addition, manual operation has impacts on the speed of turning vehicles. It was observed that speeds of left-turning vehicles appeared to be greatly reduced due to the presence of the officer in the intersection. Drivers had to be more careful when passing the officer at lower speeds.

Compared with left-turning vehicles, right-turning vehicles appeared to have lower speed reductions. In the simulation, turning speeds were set as 10 mph. Right Turn on Red (RTOR) was allowed to remain consistent with the observations of the intersection under field manual operation.

The results of the simulated manual control were compared to results of the intersection under all-way stop control, which would have been the operating scenario had manual control not been employed. These results are presented in Table 5-13.

Table 5-13: Delay and LOS results, 11th Avenue and College Street

Outputs		AWSC	Manual Control
Cycle Length (sec)		N/A	235
Total Split (sec)	East - West	N/A	103
	North - South	N/A	132
Control Delay (sec/veh)/LOS	West	23 / C	59 / E
	East	26 / D	68 / E
	South	164 / F	53 / D
	North	14 / B	28 / C
	Intersection	80 / F	55 / E

As the results indicate, for the critical postgame approach (South) significant improvements were observed under manual control. In the case of this approach, over 100 seconds of delay was eliminated, with a subsequent improvement in LOS. However, this improvement came at a price; delay increased on the east and west approaches, with corresponding deterioration in LOS. This was expected however; in implementing manual control at this site, it was anticipated that traffic on these approaches would be penalized in order to remove as much game-related traffic as possible from campus via the South approach to the intersection. To this end, manual control was successful, and should be continued at this site in the future.

Figure 5-2 presents the total traffic flows, by movement, for the intersection of 11th Avenue and College Street during their postgame peak hour. In examining at the total volume of vehicles moved through the intersection under manual control, it was found that during the peak hour, approximately 3% more vehicles were moved through the intersection via the South approach compared to 2006. Coinciding with this increase were decreases in the volumes of traffic moving through the intersection on the east (13%) north (34%) and west (23%) approaches. What this indicates is that, while servicing approximately the same peak hour volumes between each year on the critical approach (South), declines in traffic volume on the remaining approaches reduced the direction task load of the officer performing manual control. Regardless of declines in volume, the implementation of manual control serviced similar volumes of traffic in a more efficient manner, minimizing delay to motorists.

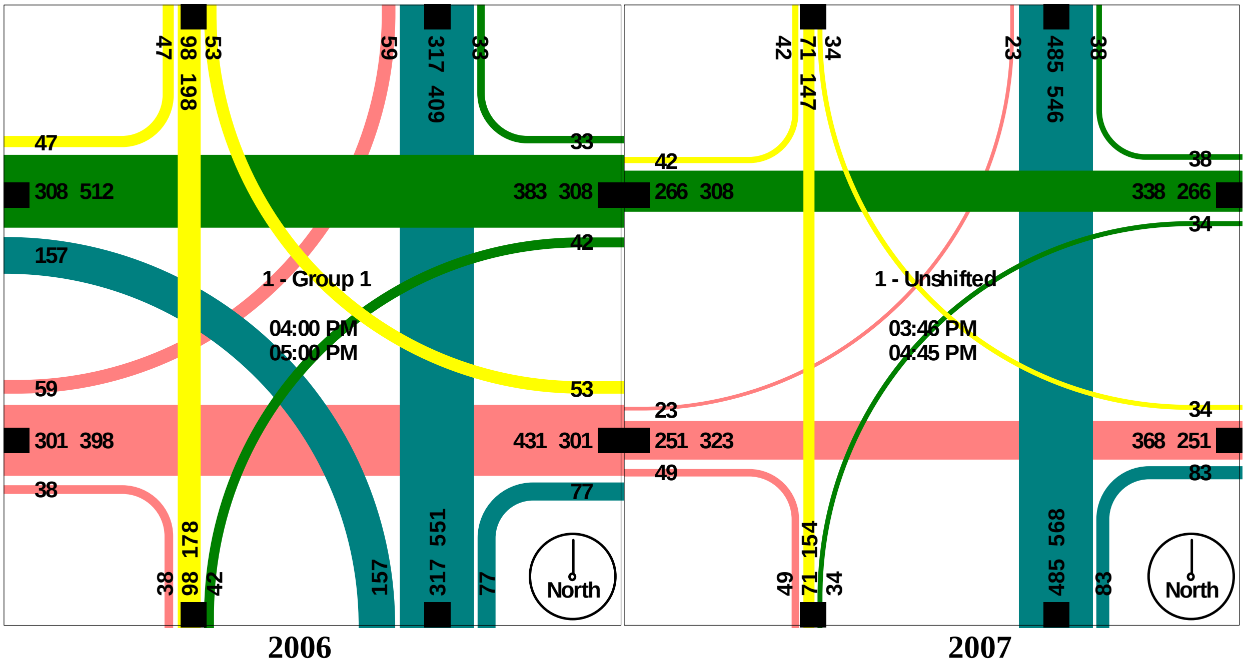


Figure 5-2: Comparison of Peak Hour volumes 2006 (left) and 2007 (right)

Figure 5-3 presents the total traffic flows, by movement, for the intersection of 11th Avenue and College Street during the 1 1/2 hours immediately following a game. In looking these over, it was found that approximately 14% more traffic passed through the intersection in 2007 versus 2006. The largest increase, as one might expect, was on the south approach, where approximately 32% more traffic was serviced.

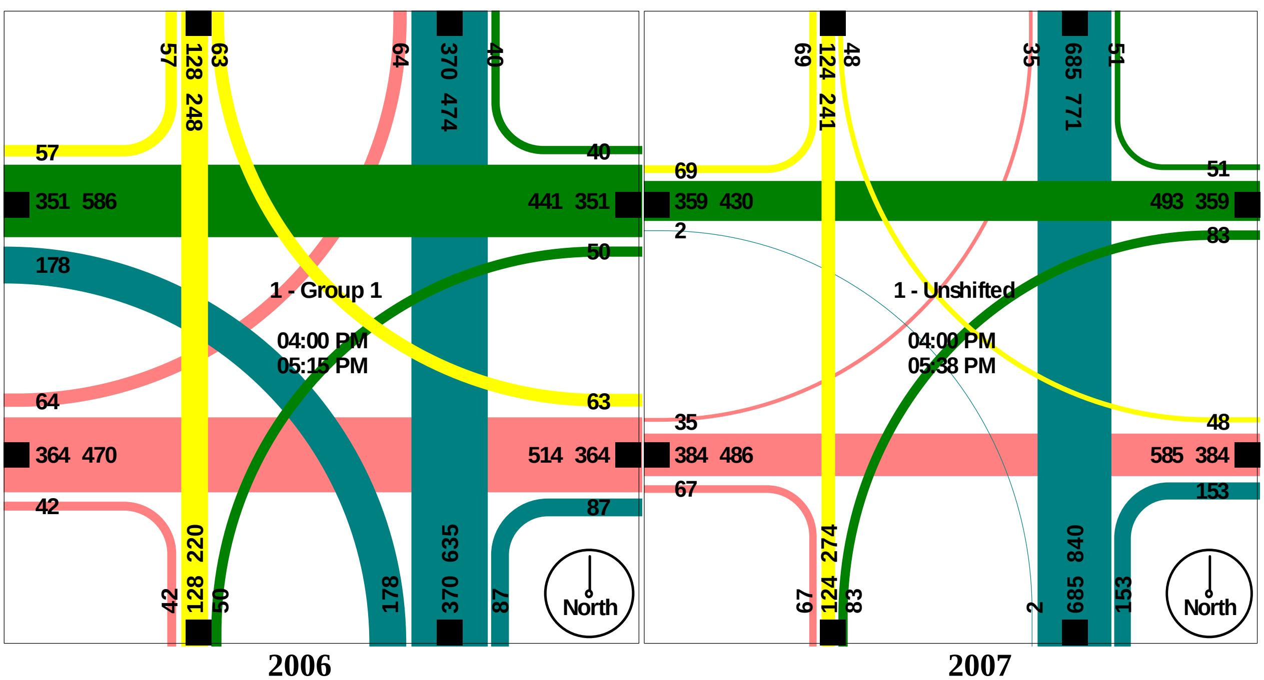


Figure 5-3: Comparison of total volumes 2006 (left) and 2007 (right) for 1 ½ hours postgame

6. ATTENDEE SURVEY

On November 3, 2007, a survey was conducted to obtain game attendee feedback with respect to the traffic management plan that had been implemented for the 2007 football season. To this end, the survey asked participants for basic information related to items such as the number of games attended, the routes taken to the game, perceived time savings (if applicable) and other traffic management items of interest. The survey form that was distributed is presented in Appendix B. Students distributed and collected surveys near each of the stadium entrances prior to the start of the game. Additionally, collection boxes were placed at various locations throughout the stadium to gather completed surveys. In total, 107 surveys were completed; for some questions, a smaller number of responses were obtained as some respondents did not provide an answer. Overall, this was a small sample, and as a result, statistically significant conclusions cannot be drawn from it. However, the results of the survey do present at a minimum a general overview of what game attendees views were with respect to the strategies implemented, their effectiveness, and improvements that can be made going forward.

6.1. Respondent Characteristics

Figure 6-1 presents a breakdown of the population categories of respondents. As the figure illustrates, a majority of respondents were “Season Ticket Holders”. This was followed by the “Other” category (namely Alumni). The third most common group was “Booster Members”, which could also be considered season ticket holders. The final categories included “Students” and “Staff”, which combined represented about ten percent of respondents. The conclusion that may be drawn from this figure is that the majority of the sample population attended games frequently (i.e. Season Ticket Holders). These respondents were very likely exposed to the implemented traffic strategies prior to the day of the survey.

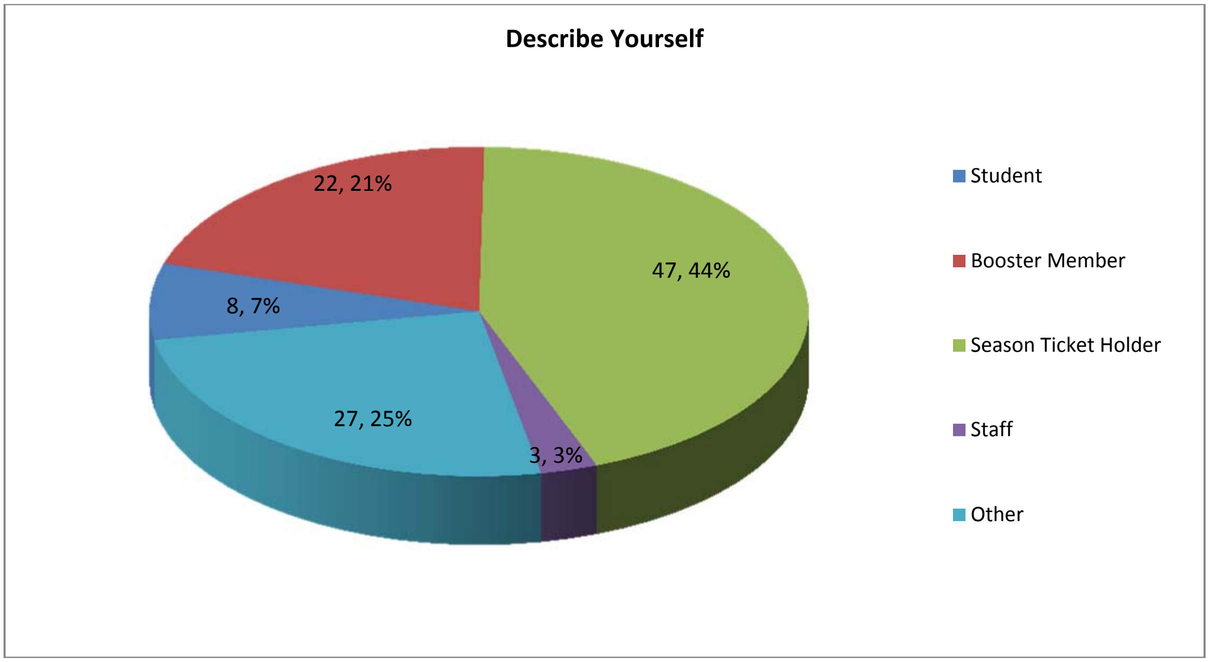


Figure 6-1: Respondent population

6.2. Game Attendance

Figure 6-2 displays the total number of games each respondent had attended during the 2007 season. As the figure indicates, the majority of respondents attended four or more games during the year. This result was expected, as the two highest respondent categories in the previous section were "Season Ticket Holders" and "Boosters", both groups that could be expected to regularly attend games. The results from this figure reinforce that the sample population is one that had experienced the traffic management strategies over the course of the season and, as a result, offered a somewhat reliable viewpoint with respect the their experiences.

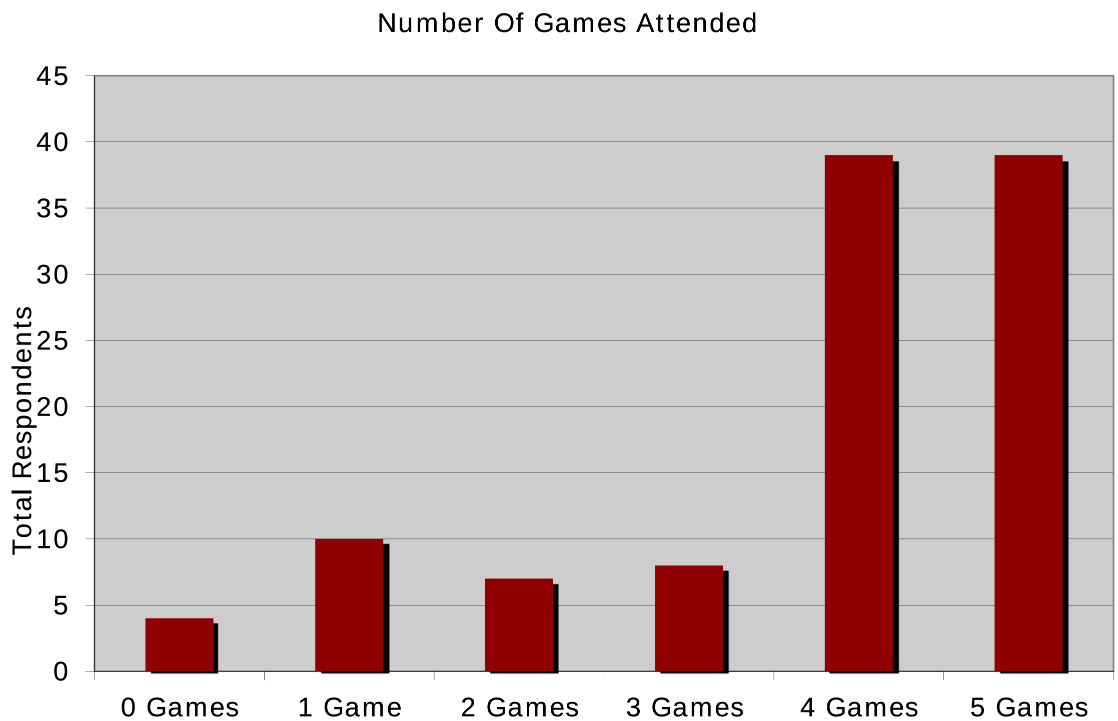


Figure 6-2: Respondent game attendance

6.3. Number of Passengers in Vehicle

Of interest to traffic management for special events is the extent to which vehicles traveling to the event are carrying more than one person. Multiple passengers help to eliminate unnecessary vehicles from the traffic stream, thereby increasing the capacity of the system and improving traffic flow. To obtain an understanding of the extent to which this occurs for MSU football games, respondents were asked how many people were riding in the car they arrived in. Figure 6-3 indicates that a majority of respondents arrived in vehicles carrying two people (themselves and one other). Smaller numbers of respondents indicated that three or more persons were in the vehicle they traveled in. Additionally, there was a small portion of the population that travelled alone to the game. These results indicate that it is likely that a number of vehicles are carrying multiple passengers to games; however, these vehicles are not arriving with a full load of passengers. The end result is that the low number of passengers in many vehicles is adding traffic and resulting in capacity being sapped from the roadway system.

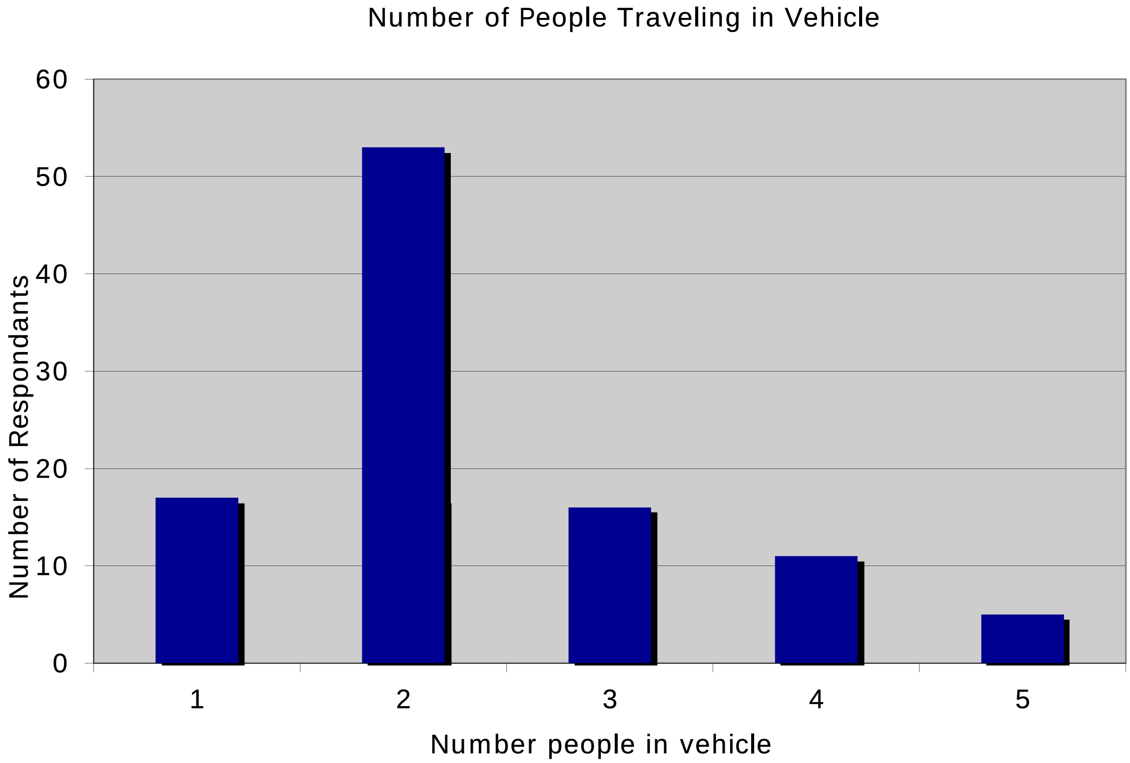


Figure 6-3: Number of passengers in vehicle

6.4. Arrival Times

Also of interest was the time that the respondent arrived at a respective parking lot prior to the game. This is of interest as it provides an understanding of the times at which the heaviest pregame traffic occurs. Such an understanding can assist in developing adaptive signal timing plans and other strategies to address waves of potential congestion. As Figure 6-4 indicates, most respondents arrived between 10:00 a.m. and 12:00 p.m. (the game began at 1:00). Respondents who arrived to the game during this time presumably experienced the peak of the traffic flow and the longest duration of travel on roadways adjacent to campus. Based on the limited data available, it appears that strategies that address traffic flow peaks beginning approximately 2 ½ hours prior to the start of a game would be beneficial in addressing potential congestion.

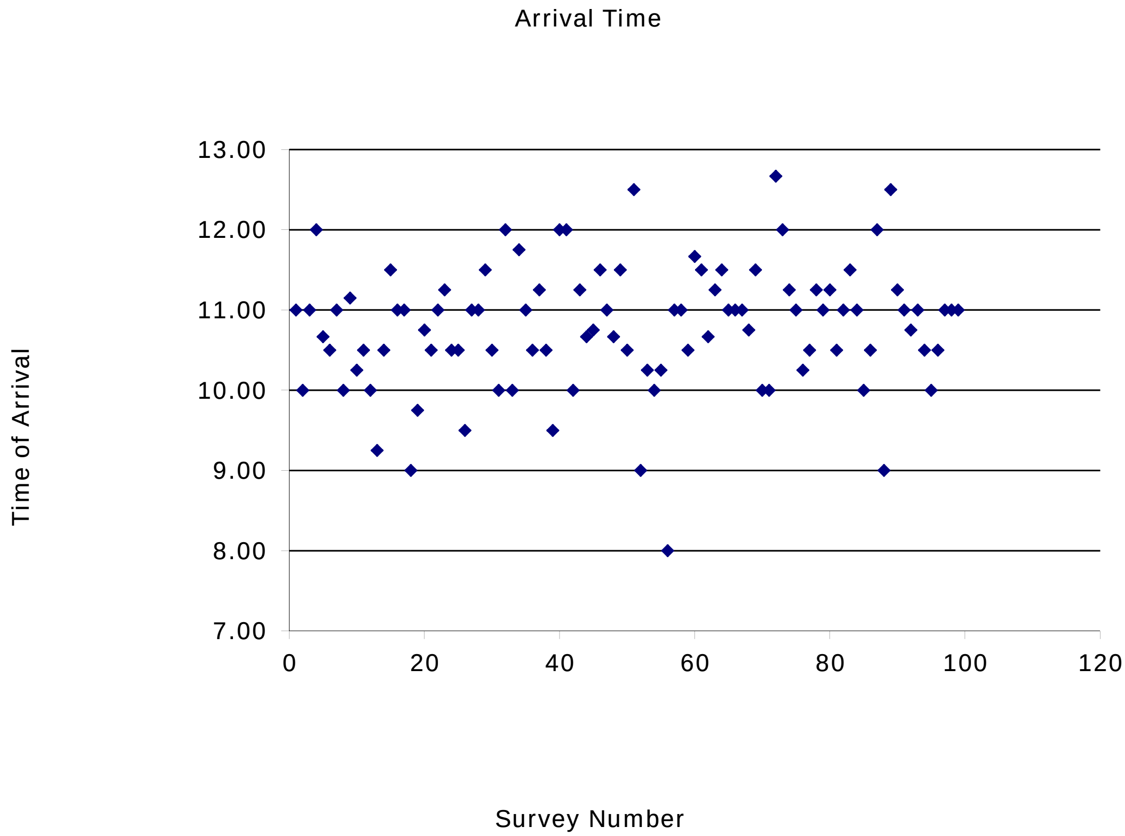


Figure 6-4: Arrival times

6.5. Travel Routes

Figure 6-5 presents the results of a question posed to respondents related to the route(s) that were taken to the game. Of the routes presented to respondents, the 19th Avenue/Kagy Boulevard combination was most frequently cited as the route utilized that day. This was expected based on past observations and traffic counts. The route combination of 7th Avenue/Main Street/11th Avenue was also indicated by a fair number of respondents as the route employed that day. This was a somewhat surprising indication, as previous observations and travel time studies did not indicate an increased volume of traffic on this route on game days. Respondents indicated that the remaining routes presented were utilized to lesser extents. This was not surprising, as the previously indicated routes were utilized by over half of the total respondent population and represent the two primary north-south routes to and from Interstate 90.

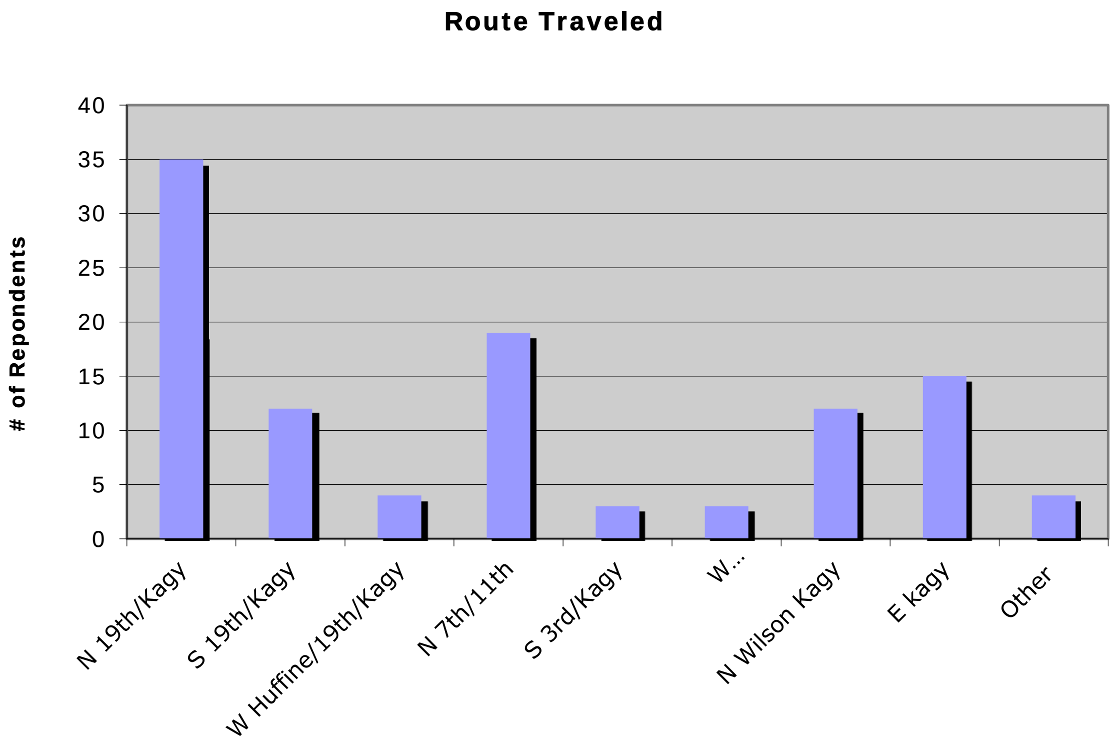


Figure 6-5: Travel route utilization

6.6. Awareness of Traffic Management Strategies

Figure 6-6 presents the results of a survey question posed to respondents pertaining to their awareness of the traffic management strategies that had been employed for the 2007 season. From this figure, it is apparent that over two-thirds of respondents were aware of the new strategies. This result was expected, as earlier results had indicated that a majority of survey participants were regular game attendees. As a result, by the time the survey was administered (late in the season) it was expected that awareness of the strategies would be fairly widespread. It could be surmised that those who were not aware of the strategies were primarily those who were attending their first game of the year.

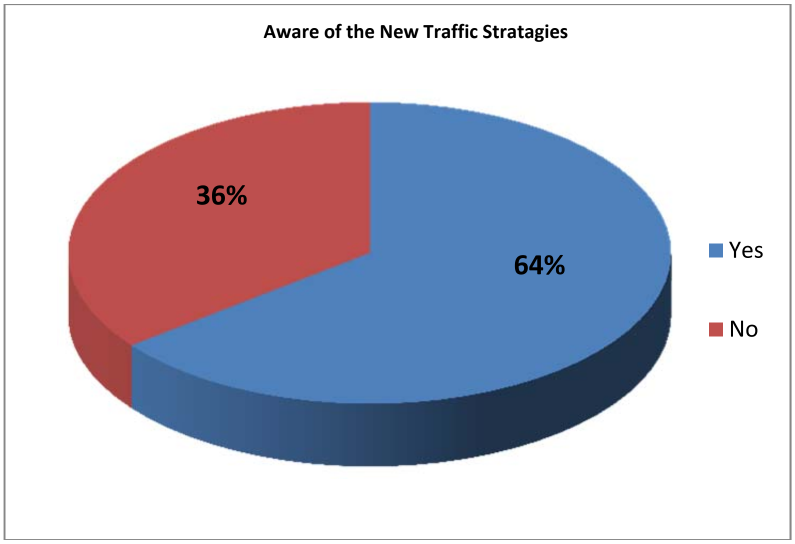


Figure 6-6: Strategy awareness

6.7. Traffic Strategy Information Sources

To expand upon the previous question, respondents were asked where they learned of the traffic management strategies. Figure 6-7 displays the responses to this question. As indicated, the most predominant sources of information were via newspaper and radio. These media were the focus of the public relations campaign carried out to inform ticket holders of the new strategies. Radio was especially of interest, as brief messages were run during post-game shows covering what could be expected on the roadways surrounding campus. That respondents indicated that this was the source of their information indicates that these messages were reaching at least a portion of the target audience. Aside from these, the MSU website and television were also sources of information. In general, it can be concluded from these results that the most effective media for reaching game attendees is via newspaper and the internet (and to a lesser extent, television) before a game, and radio before and after a game.

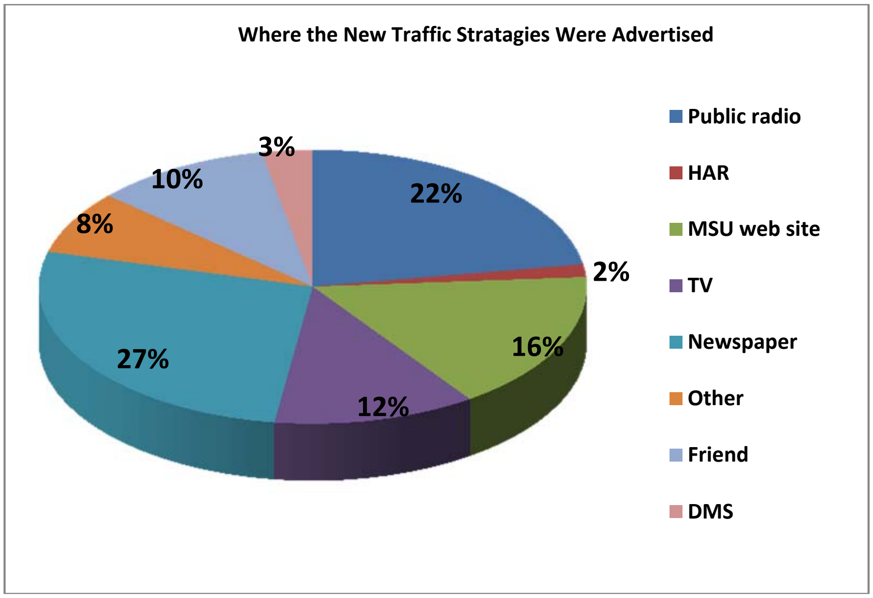


Figure 6-7: Information source(s)

6.8. Departure Time

Figure 6-8 presents the times that respondents indicated they left a game. As one would suspect, the majority of respondents indicated that they leave within 15 minutes of the end of a game. When combined with respondents who indicated that they leave 15 to 30 minutes after a game, it becomes evident that a majority of game attendees leave as soon as possible following a game's conclusion. The end result is a heavy traffic flow attempting to utilize the limited roadway infrastructure in the vicinity of campus to egress the event simultaneously. In light of this observation, it becomes evident that traffic management strategies must be in place in advance of the end of a game in order to address the influx of traffic that occurs shortly thereafter.

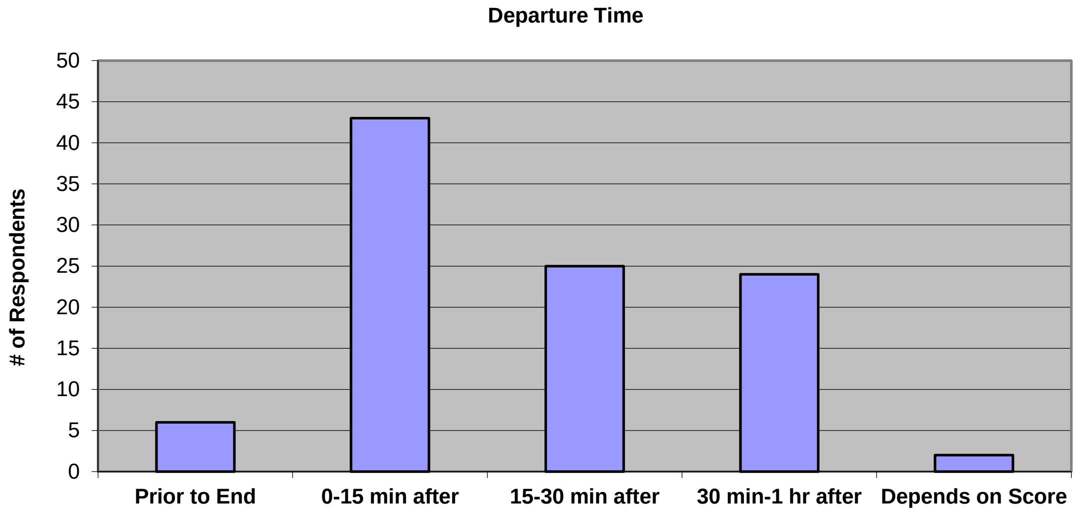


Figure 6-8: Departure times from games

6.9. Perceived Time Savings

Figure 6-9 presents the results of a question posed to respondents of whether or not they perceived that they were saving time leaving a game due to the new traffic management strategies. Forty-one percent of respondents believed that they were saving time, twenty-three percent felt that that were not, and thirty-six percent did not answer. The high number of respondents who did not answer this question may have been the result of the way the question itself was presented. In other words, when responding to part A of the question, it may have been unclear that a response to part B was also required; regardless of how part A was answered. In any event, the results of indicate that a sizeable proportion of the sample population did believe they were saving travel time following the implementation of traffic management strategies.

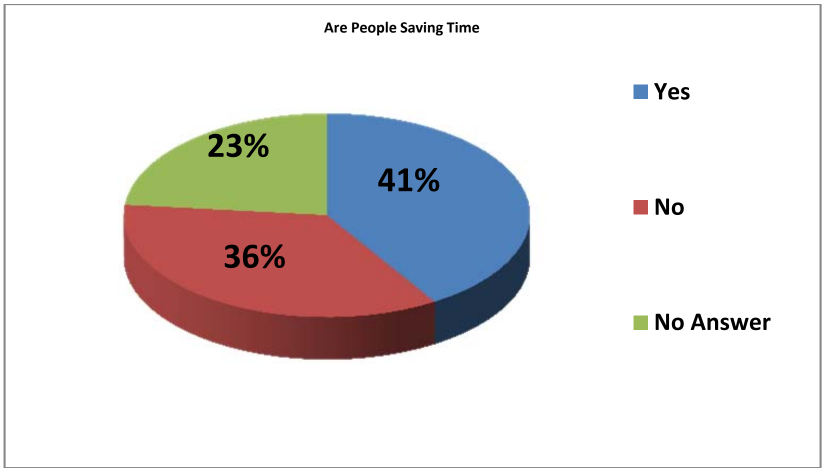


Figure 6-9: Perceived time savings

6.10. Rate of Satisfaction

Figure 6-10 provides a summary of respondent rankings of satisfaction with the traffic management strategies implemented. As indicated, the majority of respondents indicated that they were either unsatisfied or neutral to the strategies. This indicates that, at least from the limited sample population that was surveyed, there was not a great deal of acceptance of the strategies. While those who indicated they are neutral in terms of satisfaction cannot be considered for or against the strategies, the clear absence of a majority that are satisfied in any way is indicative that user acceptance to the changes made is still in progress.

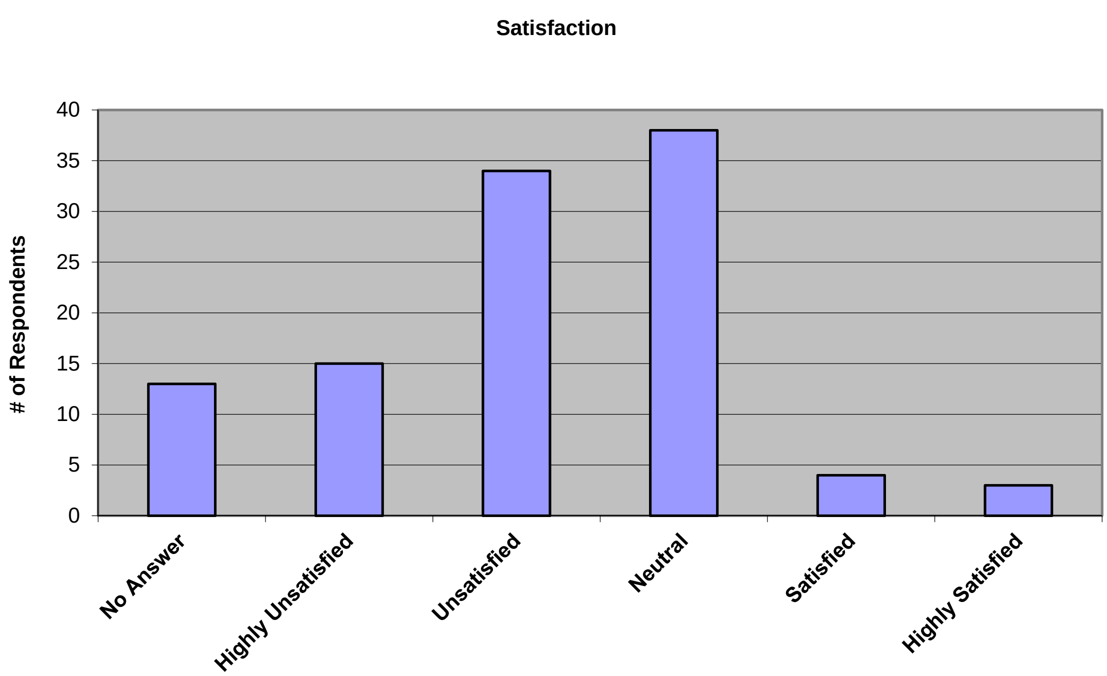


Figure 6-10: Respondent satisfaction with traffic management strategies

6.11. Route Taken Versus Satisfaction

Figure 6-11 is a representation of the route taken by respondents versus their rate of satisfaction with the traffic management strategies employed. When interpreting the figure, bear in mind that the two primary routes utilized to arrive and depart games in terms of responses obtained were 19th Avenue/Kagy Boulevard and 11th Avenue/Main Street/7th Avenue. As a result, these are the two portions of the analysis to focus on. Overall, the trends depicted indicate that there was limited satisfaction with the traffic management strategies, regardless of the route that was utilized. This was particularly true for 19thAvenue/Kagy Boulevard, which was the primary route used by attendees. Given the heavy traffic volumes along this route, it is not surprising that respondents viewed the strategies poorly. The expectation was likely that, if traffic management strategies were in place, why is traffic still crawling along? In spite of improvements in travel times that were noted in the vicinity of campus, few, if any motorists were able to detect such improvements. In general, the trends observed indicate that even on lesser traveled routes (ex. Kagy/South 19th), the strategies are not being met with approval. Whether this is the indicative of a reluctance to change, the need for greater publicity in terms of the improvements that have been observed, or some other factor is unclear.

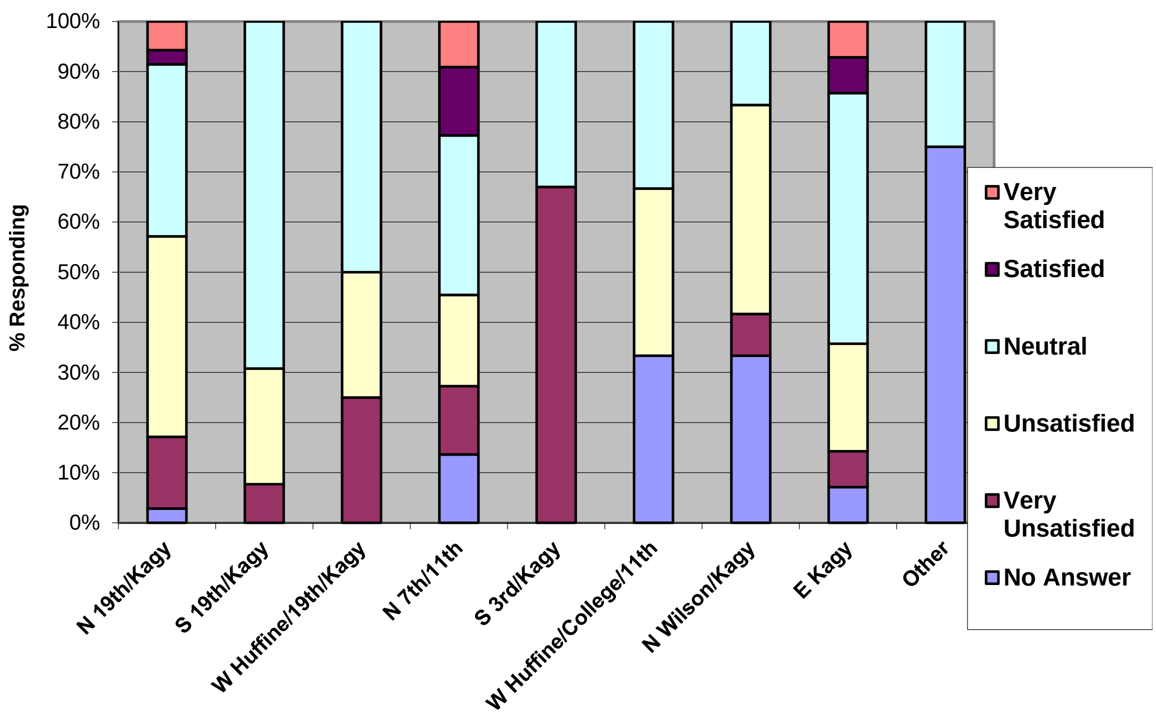


Figure 6-11: Percent of satisfaction respective to route

6.12. Shuttle Bus Use

Figure 6-12 presents the results of a question that asked respondents whether they would consider the use of a shuttle bus from an outlying parking lot (i.e., the Gallatin Valley Mall or a similar location). Only twenty percent of respondents indicated that they would consider using such a shuttle bus, with remaining respondents not inclined to use such a service. This finding is not surprising, in that tailgating activities are very popular prior to football games. Parking at an outlying lot reduces the opportunity to participate in such activities, as the associated equipment and supplies (grills, food, etc.) are not items that are transportable via a shuttle bus. Additionally, the proximity of existing parking lots to the football stadium has created a situation where it is more convenient to drive to the game and park nearby. As attendees are spoiled by this parking arrangement (in contrast to larger universities, where parking near a stadium is limited) there is a reluctance to use something such as shuttle bus that is perceived as being less convenient.

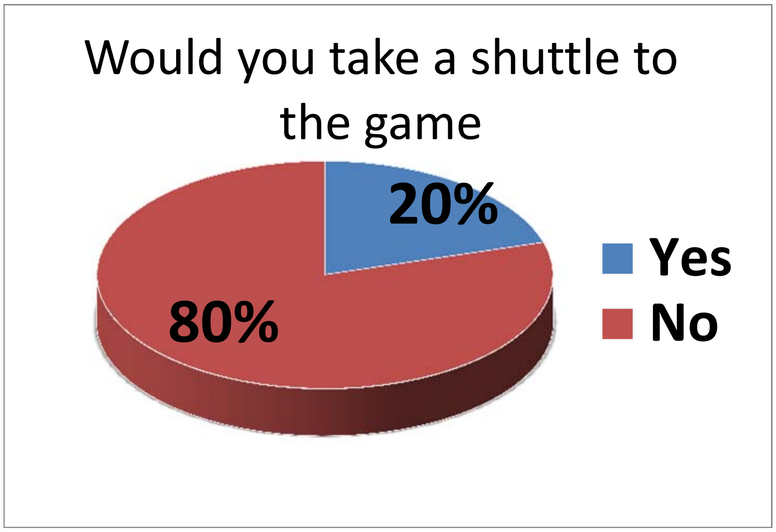


Figure 6-12: Respondents willing to use shuttle bus

6.13. Shuttle Bus Cost

Figure 6-13 displays the results of a question posed to respondents related to how much they would be willing to pay for the use of a shuttle bus. These results should be viewed with caution, as only 23 survey participants answered this question. As the results indicate, there was a good deal of variation in terms of what respondents were willing to pay, with $1.00 to $2.00 being the most widely favored costs. As one would expect, the price that a respondent was willing to pay dropped from there, although a decent percentage indicated they would be willing to pay $5.00. Given the low support for the shuttle bus observed previously, it is unlikely that the results presented in this section are conclusive in any way.

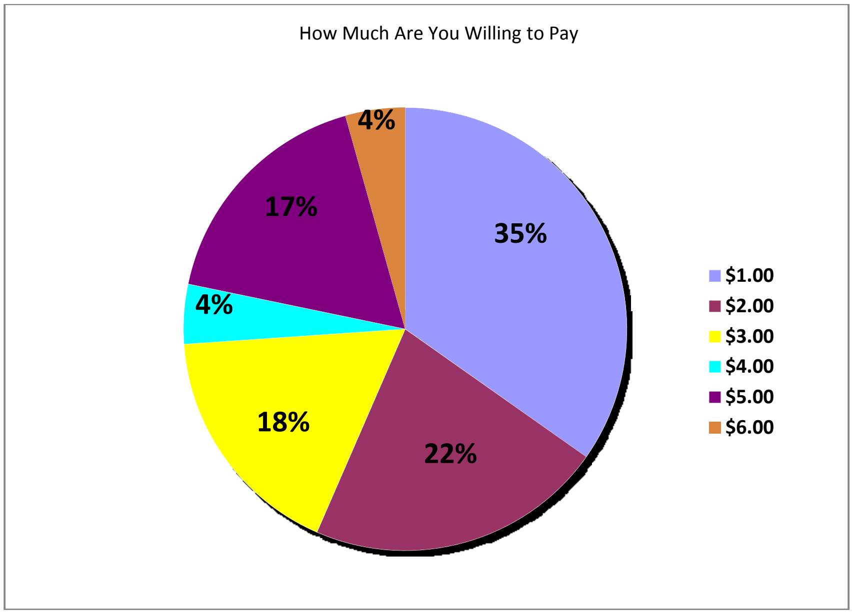


Figure 6-13: Shuttle bus pricing

7. CONCLUSION AND RECOMMENDATIONS

The management of traffic from Montana State University football games presented the opportunity to implement and examine the results of traffic management strategies in rural locales. Based on the work completed during the course of this project, several conclusions may be drawn. The following sections briefly summarize the major results stemming from the work, as well as the conclusions that may be drawn from them.

7.1. Interagency Partnership

Central to the success of the project was the establishment of interagency partnerships. During previous seasons, the different agencies involved with various aspects of special events generally operated autonomously; little to no coordination of efforts occurred. This was one of the first issues that was addressed by the project; all agencies that were stakeholders and/or performed activities in some capacity related to traffic management were brought to the table to establish relationships and develop consensus on the approaches and strategies to employ in addressing the issues stemming from special event traffic.

To this end, the project yielded tangible benefits. Stakeholders that had previously been unaware of what other agencies did during a special event obtained an understanding of their counterparts' activities. This understanding led to a more collaborative approach in terms of the sharing of equipment and labor (ex. MDT providing use of the portable DMS, with City of Bozeman personnel setting them up), as well as identifying solutions to problems. The end result was that a coordinated effort was made by all agencies to address the traffic issues which result from special events in the city.

7.2. Real-Time Traveler Information

To gage the effectiveness of real-time traveler information (and pre-trip/game information provided via various media), a survey of game attendees was conducted. While the overall sample size was small (107 respondents), the surveys did provide at least an indication of whether traveler information was reaching the intended audience and via what medium. Results indicated that over two-thirds of respondents were aware of the new strategies. This result was expected, given that a majority of survey participants were regular game attendees. The most predominant sources of information were via newspaper and radio, which were the focus of the public relations campaign carried out before the season and during it. Radio was especially of interest, as brief messages were run during post-game shows and via HAR covering what could be expected on the roadways surrounding campus. The MSU website, television and DMS were also sources of information, but to a lesser extent than newspapers and radio.

7.3. Traffic Signal Timing

Based on anticipated (and subsequently observed) traffic volumes at two signalized intersections adjacent to campus, signal timing plans were revised. Primarily, additional green times were allocated to the approaches servicing game-related traffic. This was done in order to accommodate added traffic volumes resulting from road closures in other areas of campus, as well as to address deficiencies observed during previous seasons.

Signal timings for 19th Avenue and Kagy Boulevard were revised to address both morning and afternoon game-related traffic flows. In the morning, this consisted of added green time for southbound left turning movements; in the afternoon, westbound movements were given additional green time. Signal timing modifications for the intersection of 19th Avenue and College Street were made only for the afternoon period, as this was when problems had been observed to occur in the past. At this site, additional green time was provided to northbound movements, as these were game-related flows. The results of the timing changes on Level of Service (LOS) and delay are presented in Table 1. Note that, since timing modifications were made at 19th Avenue and Kagy Boulevard for the morning and afternoon, results from both periods are presented; similarly, as only changes were made in the afternoon for 19th Avenue and College Street, only results for this period are presented.

Table 7-1: Operational results of signal timing changes

*Note that results are for only one game (19th Avenue and College Street: September 15, 2007; 19th Avenue and Kagy Boulevard: September 29, 2007)

Intersection	MOE	Approach	2006 Observed Performance	2007 Volume 2006 Timing Plan	2007 with Revised Plan
19th Ave and Kagy Blvd	Control Delay (seh/veh) / LOS	Morning			
		Peak Hour	11:55 - 12:55	11:10 - 12:10	
		West	25.6 / C	32.5 / C	38.0 / D
		East	13.9 / B	14.3 / B	23.0 / C
		South	13.5 / B	26.6 / C	40.7 / D
		North	6.3 / A	27.8 / C	21.0 / C
		Intersection	9.9 / A	25.9 / C	26.5 / C
		Afternoon			
		Peak Hour	4:00 - 5:00	4:45 - 5:45	
		West	12.2 / B	24.5 / C	45.0 / D
		East	7.8 / A	23.8 / C	14.0 / B
		South	16.0 / B	18.1 / B	34.4 / C
		North	11.8 / B	13.5 / B	23.4 / C
		Intersection	10.4 / B	20.2 / C	19.2 / C
19th Ave and College Street	Control Delay (seh/veh) / LOS	Afternoon			
		Peak Hour	4:00 - 5:00	4:45 - 5:45	
		West	17.9 / B	13.8 / B	14.3 / B
		East	43.4 / D	22.5 / C	24.7 / C
		South	74.4 / E	80.7 / F	66.6 / E
		North	27.7 / C	19.7 / B	18.3 / B
		Intersection	49.2 / D	47.7 / D	41.3 / D

As the results of the table indicate, changes to signal timing plans produced mixed results. The overall objective of modifying signal timings was to provide better service to game-related traffic flows. To this end, the changes that were implemented were a success. As the results show, had the original (2006) timing plans remained in place, additional deterioration would have been experienced. This is particularly true in the afternoon for the east approach of 19th Avenue and Kagy Boulevard and the South approach of 19th Avenue and College Street. Instead, the revised signal timings that were employed produced modest improvements or at least held conditions steady on approaches serving game-related movements. Of course, other approaches did suffer deterioration in some cases; this was deemed acceptable in light of the efforts being made to remove game-related traffic from the campus area (and city) as quickly as possible.

7.4. Manual Traffic Control

In addition to signal timing changes, manual traffic control by a police officer was implemented at the All Way Stop Control (AWSC) intersection of 11th Avenue and College Street. To analyze the performance of the intersection under manual control, a simulation of the officer's traffic control strategies was employed by setting up a pre-timed signal plan for the intersection, which closely mimicked what was observed in the field. Observations indicated that there were two phases during each cycle of manual operation: one was for northbound-southbound traffic and the other was for eastbound-westbound traffic. A mean cycle length of 235 seconds was observed in the field and employed when developing the simulations. Results of the analysis are presented in Table 2. This table also includes results of intersection operation had AWSC remained in place.

Table 7-2:: Operational results of manual control

*Note that results are for only one game (November 17, 2007)

Outputs		AWSC	Manual Control
Cycle Length (sec)		N/A	235
Total Split (sec)	East - West	N/A	103
	North - South	N/A	132
Control Delay (sec/veh)/LOS	West	23 / C	59 / E
	East	26 / D	68 / E
	South	164 / F	53 / D
	North	14 / B	28 / C
	Intersection	80 / F	55 / E

As the results indicate, the south approach, which services game-related traffic, benefitted greatly from the manual control strategy employed. While LOS and delay were still poor, they were a dramatic improvement over what would have occurred had manual control not been employed. As was the case with signalized intersections, the primary objective of manual control was to remove game-related traffic as quickly as possible from campus. Subsequently, remaining approaches at the intersection suffered deterioration in LOS and delay to accommodate movement on the South approach.

7.5. Road Closures

A critical strategy of the traffic management plan was road closures. In previous seasons, road closures were employed primarily as a mechanism to promote pedestrian safety. For this project, they were employed to direct game-related traffic to routes that were best suited to handle it. Such shifts would increase the volumes of traffic traveling on established routes that were already handling a significant portion of traffic, potentially impacting travel times. As a result, the metric employed to determine the impact of road closures was travel time on established routes utilized by game-related traffic.

Based on observations and measurement from previous seasons, two primary routes were used by game-related traffic: 19th Avenue/ Kagy Boulevard and 11th Avenue. In addition, prior to the 2007 season, Lincoln Street was employed as a shortcut to 19th Avenue, circumventing Kagy Boulevard; the traffic using this route often produced extensive queuing while trying to enter 19th

Avenue at a Two Way Stop Controlled (TWSC) intersection. Based this observation, along with supporting LOS and delay information for the intersection of 19th Avenue and Lincoln Street, it was determined that Lincoln Street would be closed all day to promote use of Kagy Boulevard, running parallel and was better equipped to handle game traffic, as well as 11th Avenue, which was expected to be used by a portion of former Lincoln Street users.

Based on the expected traffic shifts to these two routes, floating car travel time studies were performed to determine what impact the closure had on overall travel times. Previous travel time studies had been conducted for one game in 2006, allowing for a comparison to be made of the impacts that the road closure may have had on each route in 2007. The results of these are presented in Table 3.

Table 7-3:: Changes in travel times between 2006 and 2007 (single game)
*Bold italics denote an improvement over previous season

	19th Avenue			**11th Avenue**		
	Morning			**Morning**		
Time	2006	2007	Change	2006	2007	Change
10:30	10:07	10:10	0:03	N/A	N/A	N/A
10:45	10:19	10:56	0:37	N/A	N/A	N/A
11:00	11:13	11:19	0:06	N/A	N/A	N/A
11:15	9:35	11:19	1:44	N/A	N/A	N/A
11:30	10:57	10:43	***0:14***	3:14	3:13	***0:01***
11:45	12:20	13:59	1:39	3:13	3:05	***0:08***
12:00	13:25	15:06	1:41	3:14	3:20	0:06
12:15	15:08	16:48	1:40	3:28	3:23	***0:05***
12:30	12:22	14:41	2:19	4:01	3:16	***0:35***
12:45	9:20	11:28	2:08	N/A	N/A	N/A
	Afternoon			**Afternoon**		
4:15	17:10	15:04	***2:06***	13:26	4:55	***8:31***
4:30	17:15	17:39	0:24	9:14	6:10	***3:04***
4:45	19:37	21:55	2:18	12:43	5:49	***6:54***
5:00	12:01	15:58	3:57	8:22	3:25	***4:57***
5:15	11:23	9:49	***1:34***	5:45	5:44	***0:01***

As the results of the table indicate, there were some minor increases in morning travel times along the 19th Avenue corridor (running from the I-90 interchange South to the stadium parking lots on 19th Avenue/Kagy Boulevard, approximately 4.5 miles) between 2006 and 2007. Along the 11th Avenue corridor (running between Main Street and the stadium parking lots, approximately 1.3 miles) travel times were approximately equal between 2006 and 2007. These findings were expected, as game traffic arrives in a staggered fashion and does not create extensive congestion problems, even with road closures in place.

In the afternoon, travel times along the 19th Avenue corridor were found to be approximately the same between 2006 and 2007, with only minor differences of approximately four minutes of less occurring. This was encouraging, as a majority of traffic previously using the road that was closed (Lincoln Street) shifted to this route. This was evidenced by observations of increased volumes in 2007 intersection movement counts compared to those collected in 2006. That travel times remained approximately the same indicates that this shift in traffic was not detrimental and were favorably impacted by other implemented strategies (i.e. signal retiming). Furthermore, results from the 11th Avenue corridor, which received additional traffic due to the closure, were also encouraging. During all collection periods, travel times decreased between 2006 and 2007. This was due primarily to the use of manual traffic control at the intersection of 11th Avenue and College Street. Still, given the additional traffic using this route, such improvements were encouraging.

7.6. Real Time Monitoring

While no quantifiable data were collected with regard to the performance of CCTV monitoring, experience indicates that this was a worthwhile tool for managing game traffic throughout the day. Real time monitoring allowed for adjustment of management strategies to occur quickly, allowing for better control of traffic as conditions evolved. For example, observations of queuing along 11th Avenue resulted in communication with the officer performing manual control at the intersection of 11th Avenue and College Street to modify the times they were allocating to specific movements. In addition, real time monitoring allowed for observation of general traffic flow along specific routes and at key choke points. Based on such observation, adjustments were made as the season progressed to address issues that had been previously seen.

7.7. Traffic Incident Management

The occurrence of traffic incidents held the potential to disrupt the movement of game-related traffic at critical times (namely post-game). Addressing such incidents quickly was critical in maintaining an orderly egress following games. To this end, the ability to perform real time monitoring via CCTV once again was beneficial. Although only limited instances of incidents occurred (primarily vehicles stalling), real time monitoring allowed for their identification and the dispatching of personnel to quickly handle the situation. As a result, costly delays were eliminated, allowing for more orderly arrivals and departures and consistent travel times.

7.8. Conclusions

The foremost conclusion that may be drawn from this work is that the strategies outlined by the FHWA's guide for managing special event traffic can be successfully applied in a rural community. While some of the strategies employed in this project may not be applicable to smaller, rural communities (i.e. portable CCTV network), many are. Several low-cost strategies were found to yield tangible benefits, namely signal retiming, manual traffic control and road closures. Central to the successful application of the strategies discussed was interagency partnerships. Such partnerships allow agencies to identify the equipment, personnel, etc. that can be leveraged in managing a particular special event.

Strategies such as signal retiming, manual traffic control and road closures were straightforward to implement and made a significant difference compared to previous seasons. These strategies were not extremely labor intensive (with the exception of manual control), but produced improvements or, at very least, prevented further deterioration in operations from occurring. Given that game attendance increased during 2007 (from an average of 13,000 to an average of 15,000), preventing operational deterioration despite increased traffic volumes and route shifts is evidence that the FHWA strategies were effective.

While these strategies were successful overall, it is important to recognize that there is always room for improvement. Some strategies will not work out as planned (in the case of this work, further signal timing adjustments will be needed, both at intersections adjacent to campus, as well as at sites further away), and will require modification. In addition, while several strategies are low-cost, financial resources are still required for their implementation. Thus, it is crucial for the party responsible for the event (e.g. a university, athletic department, etc.), to recognize that their event is a source of disruption and it is their responsibility to bear the costs of mitigating its impact. Without such recognition, the momentum of previous efforts and interagency partnership will be lost, as will the opportunity to proactively manage the traffic associated with an event.

8. APPENDIX A: MANUAL CONTROL SUMMARY[3]

8.1. Introduction

As defined by the National Highway Institute in 1998, a special event is an occurrence that “abnormally increases traffic demand”; it is different from an incident or construction and maintenance activities that restrict roadway capacity (*11*). Special events can consist of frequent events (e.g. sporting events, concerts, etc.) or infrequent events (e.g., parades, fairs) (*11*). Because of the increased traffic demand, a special event can cause non-recurring congestion and hence, requires additional traffic management strategies. A variety of traffic management techniques and tools such as temporary traffic lane closures, portable static signs, traffic management teams, and law enforcement service patrols are available for managing traffic during special events.

For signalized intersections, signal timing plans may be temporarily adjusted to improve traffic control during special events. This strategy however, is not applicable to unsignalized intersections. Exhibit 10-15 of the 2000 Highway Capacity Manual (HCM) indicates that when the two-way peak-hour traffic volumes on major and minor streets of stop-controlled intersections exceeds certain levels, traffic signal control (or a roundabout) may be more appropriate for the intersections [12]. This chart may also be used for judging whether additional traffic management strategies are necessary at stop-controlled intersections during special events; however, it does not provide guidance as to what those strategies might be.

The provision of police officers or other trained personnel to direct traffic at stop-controlled intersections is a frequently employed strategy to increase vehicle throughput for short duration periods associated with special events. This method of control is referred to as Positive Traffic Control (PTC), or manual traffic control. FHWA’s “*Managing Travel for Planned Special Events Handbook*” states that this control method allows officers to guide motorists through an intersection while minimizing the headways between vehicles [13]. The result is a potential reduction in/elimination of stops related to driver confusion. Concurrently, the officer is able to command the driver’s attention and control the speed of vehicles utilizing the intersection. Although traffic control officers can make dynamic changes to traffic flow, this type of control is subjective rather than objective in that a human directs traffic and makes decisions primarily based on personal observations and judgments.

Stakeholders often opt for manual traffic control as a traffic management strategy for special events based on previous experiences and/or observations of its successful application for other special events. While past observations are a useful data point to consider, when resources (both personnel and financial) are scarce, careful consideration must be made as to how to allocate them efficiently. Traffic management for special events is often constrained by a limited budget, particularly in smaller communities (in many instances, university towns). In such cases, it is desirable to maximize the use of resources to obtain the greatest benefits. However, when it comes to manual traffic control, no criteria exist regarding what to expect with respect to the benefits that may be achieved through the application of this strategy. Indeed, one likely source, the Manual on Uniform Traffic Control Devices (MUTCD), only focuses its guidance on manual

[3] This text is a paper submitted for presentation and publication with the 2009 Transportation Research Board Annual Meeting

traffic control with respect to work zones [14]. In light of this absence of guidance, there is a need to evaluate the effects of manual control operation in the field. Such an evaluation will provide a better understanding of when such control is appropriate, as well as provide guidance as to how it should be conducted. This information will subsequently provide decision-makers with preliminary guidance specific to deploying manual control at intersections.

To accomplish these objectives, this study first investigates saturation flow rate under manual operation. Following this analysis, a simulation method is employed to replicate manual traffic control under the identified saturation flow. This method will be applied to field data collected from a special event in Bozeman, Montana to evaluate manual traffic control. The method will be used to identify optimum cycle lengths that should be employed when manual control is implemented at all-way stop-controlled (AWSC) intersections.

8.2. Background

To date, few studies have investigated manual traffic control. Mahalel et al. [15] compared manual traffic control with actuated traffic signal control and found that manual operation improved the operation of congested signalized intersections, as measured by the degree of saturation and total throughput. It was also found that the use of long cycle times resulting in a decrease in lost time during congestion was the major advantage of manual operation. Using long cycle lengths is effective for oversaturated signalized intersections, but may not be true for congested stop-controlled intersections, as will be demonstrated later by a case study.

Al-Madani [16] conducted a vehicle delay comparison between a police-controlled roundabout and a traffic signal. The study revealed that traffic signals operated poorly at queue lengths of less than 80 m (262 ft) compared to roundabouts, but were much more efficient in servicing longer queue lengths. The findings from this study provided a basis which can assist in making judicious decisions regarding control types (e.g., signal, roundabout).

Flaggers are most commonly used for manual traffic control of single lane closures on two-lane, two-way highways. Some studies have investigated the efficiency of using traffic control strategies such as single or multiple flaggers, stop sign, pre-timed signal control, and adaptive sign control at maintenance or reconstruction locations [17, 18, 19]. Traffic control for this type of lane closure is similar to that at intersections in that conflicting movements are coordinated to use a common space that cannot be shared by more than one movement at a time [17].

Aside from this past work, the literature review did not find any studies that examined manual traffic control at AWSC intersections. In light of this, the purpose of this study is to investigate and help improve manual traffic control at AWSC intersections, based on the exploration of a four-way stop-controlled intersection with single-lane approaches following a special event. The results of this study will assist agencies in planning and operating AWSC intersections in a more efficient manner during special events.

8.3. Methodology

Under manual operation, the most important task for a traffic control officer is to decide how and when to direct traffic for each approach (or lane group) at an intersection. In practice, this is mainly decided based on the judgment of the number of (turning and through) vehicles present on all approaches. Thus, an officer is presented with a significant amount of information to process without a complete understanding of actual traffic volumes on the different approaches that they are directing. Even with accurate information, it is still difficult to allocate the appropriate "green" times for different approaches (or lane groups).

One way to obtain appropriate "green" times is through signal timing simulation and optimization. The signal simulates a police officer directing traffic following a special event. Pre-timed control is the appropriate type for such simulation, as will be demonstrated by a case study. Simulating the intersection as a fixed time signalized intersection allows for the optimization and proposal of appropriate signal timing plans, as well as the evaluation of manual traffic control. With an optimized signal timing plan, the appropriate control strategy for manual traffic control can be obtained.

Simulating manual traffic control, however, is not as simple as simulating stop-controlled or traffic signal control in that it is influenced by human behaviors and authority presence. Subsequently, these elements influence the overall performance of the intersection. One key traffic parameter that is affected by manual operation is the saturation flow rate (or discharge headway). In light of this influence, it is important to identify the appropriate saturation flow rates for lane groups under manual traffic control. These rates are the basis for signal timing design, capacity estimation for intersections and approaches, and evaluation. Almost all simulation software uses saturation flow rate as one of the principal input parameters for signal timing design and analysis [20].

8.3.1. Saturation Flow Rate

Saturation flow rate is defined as "the equivalent hourly rate at which previously queued vehicles can traverse an intersection approach under prevailing conditions, assuming that the green signal is available at all times and no lost times are experienced" [12]. In the 2000 HCM [12], the saturation flow rate for each lane group is computed using the following equation, assuming that the green phase was displayed 100 percent of the time.

$$s = s_0 N \prod_{j=1}^{11} f_j \tag{1}$$

where s is the saturation flow rate for subject lane group, s_0 is the base (ideal) saturation flow rate per lane, N represents the number of lanes, and $\{f_i \mid i = 1,...,11\}$ are adjustment factors for non-ideal conditions (e.g., lane width, left and right turns in a lane group, heavy vehicles in traffic stream). Exhibit 16-17 of the 2000 HCM presents the calculation of these adjustment factors.

The base saturation flow rate is usually calculated empirically by measuring vehicle departures from the queue after the first three to five vehicles have passed, to ensure that no lost times are experienced (*20*). The 2000 HCM uses 1,900 passenger cars per hour per lane (pc/h/ln) as the base saturation flow rate at signalized intersections. This value corresponds to the saturation headway of 1.9 sec. The 2000 HCM also summarizes more than a dozen studies conducted between the 1960s and the 1990s (see References 21, 22, and 23). These studies reported a range of saturation flow rates of 2,000 to 1,500 ph/h/ln (saturation headway ranges from 1.8 sec to 2.4 sec). Several recent studies have also explored saturation flow rate, saturation headway, and start-up lost times at signalized intersections [20, 24, 25, 26, 27].

Hebert conducted a study of saturation headway at AWSC intersections [28]. The author found that the volume split on both streets affects the saturation headway. Similarly, a more recent study shows that saturation flow at AWSC intersections depends on vehicle presence at other approaches [29]. For example, when traffic is not present on other approaches, the saturation flow rate on a single-lane approach is 1,100 vehicles per hour (veh/h); for evenly loaded approaches and base conditions, 2,000 veh/h has been reported [29]. Kyte at al. [30] measured saturation headways from several AWSC intersections (1.8 sec for passengers cars, 2.0 sec for light truck, 3.0 sec for heavy trucks, and 1.5 sec for motorcycles). The results were applied to a later study that simulated AWSC intersections [31].

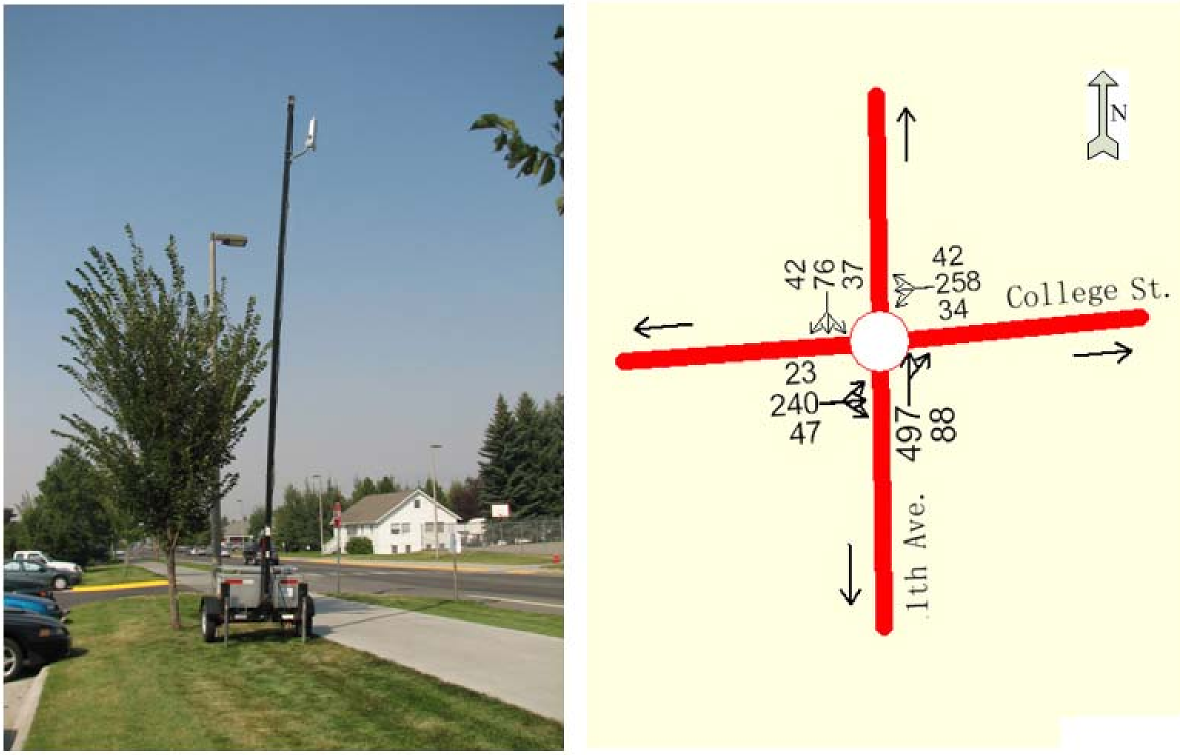
While significant research has been completed on signal control and stop-controlled intersection, studies have not reported saturation flow at AWSC intersections with manual operation. Thus, one objective of this study is to examine the base saturation flow rate for this type of traffic control through investigation of field data.

8.3.2. Data Acquisition and Analysis

Montana State University (MSU) in Bozeman, Montana, hosts a number of special events throughout the course of a year. Foremost among these in terms of attendance and exposure are football games. Several roadways and intersections in the immediate vicinity of the MSU campus are adversely impacted by traffic from these events. To address the strain placed on the roadway network by increasing game attendance, various strategies, including temporary road closures, static and dynamic signage, and manual traffic control have recently been implemented to manage traffic in a more efficient manner [32].

One of the intersections most significantly impacted by game day traffic is the 11th Avenue and College Street intersection - an AWSC intersection on the north side of campus. This intersection consists of four single-lane approaches, with high traffic delay, particularly on the northbound (NB) approach, incurred due to AWSC. Thus, one solution identified and implemented was the use of traffic control officers to reduce vehicle delay and keep operations fluid. Traffic lanes at the site consist of 12 ft or wider lane widths, with the northbound approach also hosting a 4 ft bike lane. Free flow speeds on the approaches are approximately 25 mph. The westbound approach is slightly downgrade, with grades on the other three legs basically level.

On November 17, 2007 (the final football game of the season), a video-collection trailer was positioned in a parking lot in the southeast quadrant of the previously discussed intersection. The trailer was equipped with a video camera, as shown in Figure 1(a), and digital video recorder to record traffic and queues (primarily of the northbound approach) during the course of the event. The trailer was located approximately 500 ft southeast of the intersection, with the video camera mounted at a height of 30 ft.



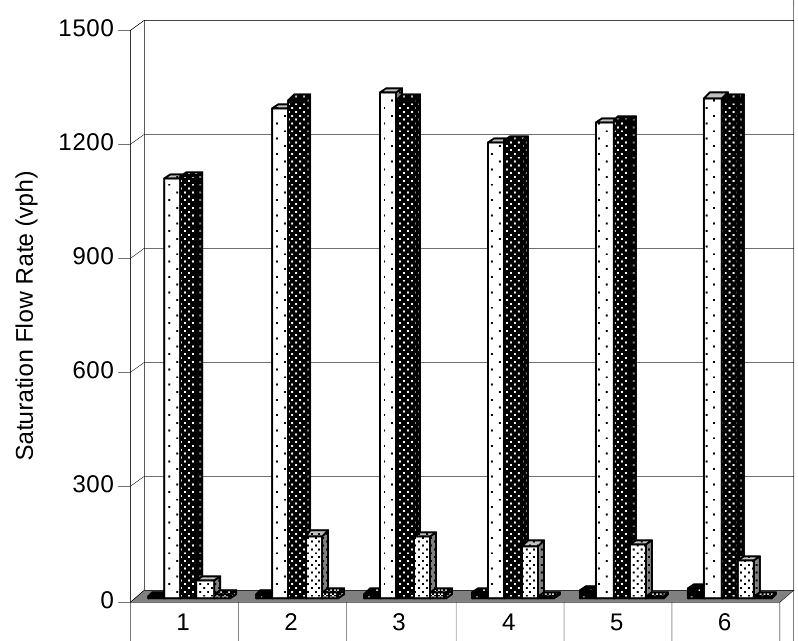
(a) (b)

Figure 8-1: (a) Video-collection trailer. (b) Peak hour traffic at the intersection.

Video was recorded from approximately 9:30 a.m. until 6:00 p.m. during the event. Only a portion of the video (3:30 p.m. to 5:30 p.m.) was used for this study, as it covered the period of time when the intersection was under the manual control of a police officer. Traffic count information was also collected for each approach during this time period and was aggregated into eight 15-minute flows. Based on the flow data, the peak hour (3:45 p.m. to 4:45 p.m.) traffic volume data for each approach were calculated and are shown in Figure 8-1(b). Note that left-turning movements on the northbound approach were prohibited as the right-of-way was occupied by the police officer. The northbound approach had the heaviest traffic (as this approach serviced vehicles leaving the game), with the peak hour volume being 585 veh/h and approximately 15 percent of right-turning vehicles. Traffic volumes on 11th Avenue and College Street were 740 veh/h and 644 veh/h during the peak hour, respectively. The Peak-Hour Factor (PHF) was computed for each leg based on the peak 15-minute flow during the peak hour. The PHF's were 0.94 for northbound, 0.92 for eastbound, 0.82 for southbound, and 0.88 for westbound. As not all intersection movements peaked at the same time, a PHF of 0.90 (the approximate mean of the approaches) was used for the intersection.

To explore the saturation flow rate for manual traffic control, one and a half hours of the video (3:45 p.m. to 5:15 p.m.) was used to examine the discharge time of queues on the northbound approach. Discharge times were counted for every four vehicles departing the stop line of the approach. The number of through and right-turning vehicles was also counted. The video could be played at half of the normal speed (two frames per second), allowing for a close examination of discharges and movements. Because the site was not a signalized intersection, the start time of queue dispersion was set to one second before the visible movement of the first vehicle.

The sample sizes of discharge times with and without turning vehicles were 52 and 24, respectively. Discharge times with right-turning vehicles were removed from analysis to minimize the effects of turning vehicles on saturation flow rate. The rest of the discharge times were converted to saturation flow rates. The sample size, mean and median saturation flow rates and standard deviation of each queue position are shown in Figure 8-2. The mean and median values of saturate flow are very close to one another. Due to start-up lost times, the saturation flow of the first four vehicles was the lowest observed. Mean discharge rates in the second and third intervals increased significantly, and were approximately 1,300 veh/h, but the average discharge rate in the fourth interval decreased to approximately 1,200 veh/h. Beyond this interval, the average discharge rates increased again in the fifth and sixth intervals.



	1	2	3	4	5	6
Queue Position	4	8	12	16	20	24
Mean Saturation Flow Rate	1101	1284	1328	1196	1248	1315
Median Saturation Flow Rate	1108	1309	1309	1200	1255	1309
Standard Deviation	48	164	162	138	139	98
Sample Size	10	13	13	6	6	4

Figure 8-2: Queue discharge rate at the intersection.

The 46 samples obtained from the second to the sixth groups of four vehicles were used to calculate the saturation flow rate of the intersection under manual operation. The statistics of these samples are summarized in Table 8-1. The mean saturation flow rate was 1,280 veh/h and the minimum and maximum sample values were 1,039 veh/h and 1,600 veh/h, respectively. During the measurement of discharge times, no heavy vehicles or bicycles were observed in the traffic stream. Considering that right-turning vehicles could affect the movement of through vehicles, it is recommended that 1,300 veh/h/ln of the base saturation flow rate in Equation 1 be used for manual traffic control at this AWSC intersection or other similar intersections.

Table 8-1: Statistics of Saturation Flow Rate

	Mean (veh/h)	Median (veh/h)	Standard Deviation (veh/h)	95% Confidence Interval (veh/h)
Saturation Flow Rate	1280	1309	151	(1232, 1329)

With 1,300 veh/h of the base saturation flow rate, the time headway would be equal to 2.8 seconds, which is 0.9 seconds greater than the time headway (1.9 sec) presented in the 2000 HCM for signalized intersections. The average time headway of the first four vehicles was 3.3 seconds and the start-up lost time is approximately 2 seconds.

8.4. Simulation Study

In this study, the macroscopic traffic software Synchro was used for simulating traffic control at the intersection of 11th Avenue and College Street. Synchro is a traffic signal optimization software package that replicates the signalized intersection capacity analysis as specified in the 2000 HCM [33]. The software has several advantages for signal timing design and analysis including:

- Synchro includes several windows (e.g., lane window, volume window, and timing window) that can be easily manipulated;
- Output reports are easy to create;
- Synchro simulations can be transferred to a Highway Capacity Software (HCS, a macroscopic traffic software packaged based on the 2000 HCM) file and SimTraffic (a microscopic traffic software package produced by Trafficware).

8.4.1. Simulation Scenarios

The simulation study includes the following three scenarios:

- Scenario 1: AWSC control.
- Scenario 2: Manual traffic control.
- Scenario 3: Optimized traffic control.

The following sub-sections present detailed descriptions of these scenarios.

Scenario 1: AWSC Control

This scenario assumes that manual traffic control was not employed on game day. The data in Figure 8-1(b) were used as traffic volume inputs. Traffic parameters such as ideal saturation flow rate, PHF, and total lost time were set to default values. For example, the ideal saturation flow rate was 1900 veh/h/ln and the total lost time was 4 seconds.

Scenario 2: Manual Traffic Control

To simulate manual traffic control, it is important to have the information on cycle length, phase split, and so on. These could be obtained through investigating the process of manual traffic control as recorded by the video data. After investigation, it was found that there were two phases during each cycle of manual operation: one was for northbound-southbound traffic and the other was for eastbound-westbound traffic. During the time period between 3:36 p.m. and 5:12 p.m., 24 cycles of manual traffic control were observed. For each cycle, the cycle length and green time allocations for the two phases were tracked and recorded, and are illustrated in Table 8-2. In this study, green time refers to the amount of time allocated to a particular movement by the traffic officer.

Table 8-2: Cycle Length and Phase Split of Manual Traffic Control

	Mean (sec)	Coefficient of Variation (%)	95% Confidence Interval	
			Lower (sec)	Upper (sec)
Cycle Length	235	25	210	260
NB-SB Green	132	25	118	146
EB-WB Green	103	35	88	118

The mean cycle length during manual operation was observed to run as long as four minutes; an extra normal test shows that the observed cycle lengths had a good fit with the normal distribution. The mean allocated time for northbound and southbound traffic was thirty seconds longer than that of eastbound and westbound, which was reasonable since the traffic volume on northbound and southbound approaches was greater. Eastbound and westbound green times had larger variations than those of the northbound and southbound approaches.

The video data showed that there were some differences between manual and pre-timed signal traffic control. For example, the officer occasionally would stop eastbound traffic to allow a left-turning vehicle on the westbound leg to pass. Under signal traffic control, left-turning vehicles would be yielded to opposite through vehicles. This caused some lost times for eastbound traffic but at the same time, decreased delay for westbound vehicles. The other observed difference was in the allocation of green time to different phases. Conversely, pre-timed traffic signal control did not change phase splits. However, in manual operation, it was observed that the officer assigned green times based on the observed queues on the approaches. This was similar to the operation described in the study by Mahalel [15]: the officer did not change phases until all vehicles in the queues were discharged. In some cases, the officer even assigned more green time to approaches when there were no queues but observed vehicles approaching. As a result, cycle lengths were increased.

In addition to saturation flow rate, manual operation has impacts on the speed of turning vehicles. It was observed that speeds of left-turning vehicles appeared to be greatly reduced due to the presence of the officer in the intersection. Drivers had to be more careful when passing the officer at lower speeds. Compared with left-turning vehicles, right-turning vehicles appeared to have lower speed reductions. In the simulation, turning speeds were set as 10 mph. Right Turn on Red (RTOR) was allowed to remain consistent with the observations of the intersection under field manual operation.

The recorded video showed that the unused clearance time was not longer than that of signal traffic control, as the officer changed green phases once he thought it was safe for the vehicles in the intersection to be cleared. Thus, 4 seconds (default value) of total lost time was also used for manual traffic operation.

Scenario 3: Optimized Traffic Control

In this scenario, the input parameters were the same as Scenario 2, but the signal timing was optimized by Synchro.

8.4.2. Analysis of Simulation Results

The aforementioned three scenarios were run in Synchro, with the simulation results presented in **Error! Reference source not found.**. With AWSC, the control delay of the intersection was high, with a Level of Service (LOS) of F, which was primarily caused by vehicle delay (164 sec/veh) on the northbound approach. The results confirm that AWSC was not suitable and additional traffic management strategies were necessary.

Table 8-3: Comparison of Simulation Results

Outputs		AWSC	Manual Traffic Control	Optimized Traffic Control
Cycle Length (sec)		N/A	235	60
Total Split (sec)	EB - WB	N/A	103	25
	NB - SB	N/A	132	35
Control Delay (sec/veh)/LOS	EB	23/C	59/E	29/C
	WB	26/D	68/E	38/D
	NB	164/F	53/D	26/C
	SB	14/B	28/C	7/A
	Intersection	80/F	55/E	28/C
50% Queue Length (ft)	EB	N/A	386	93
	WB	N/A	446	107
	NB	N/A	663	144
	SB	N/A	109	19
95% Queue Length (ft)	EB	N/A	579	251*
	WB	N/A	651	282*
	NB	N/A	1257*	428*
	SB	N/A	217	57

* 95th percentile volume exceeds capacity, queue may be longer.

With manual traffic control, it was observed that the intersection control delay (55 sec/veh) was lower than AWSC (80 sec/veh) and the intersection LOS was improved from F to E. This was due to significantly decreased control delay of the northbound traffic, although control delays on other approaches increased. Thus, the use of manual operation did improve the performance of the intersection. The 95th percentile queue length of NB traffic exceeded 1257 ft. This length generally agreed with observations made by field personnel who had observed traffic at the site under manual control throughout the season.

The results from the optimized traffic control show that the optimum cycle length was 60 seconds, much shorter than the interval employed during manual operation. The intersection control delay was reduced from 55 sec/veh to 28 sec/veh. Also, the 50 percent and 95 percent queue lengths were significantly decreased. Overall, the performance of the intersection was greatly improved through optimization. The results demonstrate that the cycle length with manual operation is unnecessarily long and that the performance of the intersection may be improved by using shorter cycle lengths when under manual control.

The above findings are useful for providing guidance for field operations. However, it should be noted that the traffic control officer may not always employ the optimized cycle length, as the demands placed on the officer (directing vehicles, observing queues, remaining safe) can be taxing over a period of time. As such, auxiliary tools that can automatically inform the officer to change phases may warrant investigation. It is also necessary to investigate the sensitivity of the intersection performance to cycle lengths. Sensitivity analysis can help identify the acceptable range of cycle lengths that will result in uniform intersection performance. In the simulation study, different cycle lengths were assigned to the scenario of manual traffic control, varying from 40 sec to 235 sec. The optimized green/cycle (g/c) ratios for northbound-southbound and eastbound-westbound phases, control delay, and intersection LOS are displayed in **Error! Reference source not found.**.

Table 8-4: Sensitivity Analysis

Cycle Length	g/c Ratio		Control Delay (sec/veh)					Int. LOS
	EB - WB	NB - SB	EB	WB	NB	SB	Int.	
40	0.38	0.42	19	23	199	8	95	F
45	0.33	0.49	27	34	43	7	33	C
50	0.32	0.52	32	42	30	7	31	C
60	0.33	0.53	31	39	28	7	29	C
70	0.34	0.54	32	38	28	8	29	C
80	0.35	0.55	32	38	28	8	29	C
90	0.34	0.57	37	43	26	9	31	C
120	0.36	0.58	42	48	30	12	35	C
130	0.36	0.58	45	50	31	13	37	D
160	0.37	0.58	51	56	35	16	42	D
200	0.38	0.58	60	66	41	20	49	D
235	0.38	0.58	59	68	53	28	55	E

When cycle lengths vary from 45 seconds to 90 seconds, control delay and g/c ratios show relatively small variations. Concurrently, the intersection LOS is remained at level C. Cycle lengths of 60, 70, and 80 seconds produce nearly the same results. Cycle lengths outside this interval increasingly affected the performance of the intersection, especially with the cycle length was decreased to 40 seconds or less which produced an LOS of F. In general, the use of longer cycle lengths seems to be safer than shorter ones.

8.5. Discussion

In this study, the ideal saturation flow rate was identified using a single intersection and data from one event. Thus, it is necessary to collect more information to develop a more confident value (or interval) of the ideal saturation flow rate at AWSC intersections under manual operation during special events. The collection of such data is usually restricted due to the frequency of events and availability of traffic monitoring (e.g., video-recording/detection). The value of 1,300 veh/h/ln proposed in this study is reasonable because the traffic flow on the northbound approach only included approximately 15% of right-turning vehicles and no left-turning vehicles. Moreover, the analysis of saturation flow rate was based on those data that only considered through vehicles, which will decrease the influence of turning vehicles.

Although the identified improvements in timing plans have not been implemented in field operation for evaluation, the analysis results did show that the cycle lengths observed in the video footage collected for this study of manual control were unnecessarily long. Based on traffic volume data for each approach and the ideal saturation flow rate, the sum of the ratios (observed flow/saturation flow rate) for critical lane groups was 0.722, including consideration of left-turn and right-turn adjustment factors. This value implies that the intersection was not oversaturated and the long cycle lengths employed increased intersection delay. Using appropriate smaller cycle lengths may improve the intersection LOS.

To develop a better manual control timing plan during special events, it is necessary to obtain historic traffic data or forecast traffic demand. Of course, the potential difference between historic data and current/potential data should be considered. The accuracy of the forecasted traffic demand will affect the effectiveness of the developed plan. Moreover, the implementation of the improved strategy needs inter-agency cooperation, including that between the police department(s), the organization responsible for planning the special event, and the entities responsible for management of the roadway (i.e., the City and state DOT).

8.6. Conclusion

This study proposed a simulation method for improving manual traffic control at AWSC intersections during special events. To better simulate manual traffic control, this study investigated saturation flow rate for this type of control based on the analysis of traffic data collected during a special event (football game) in Bozeman, Montana. It was found that the base saturation flow rate for manual traffic control was approximately 1,300 veh/h/ln (with a discharge headway of 2.8 sec). Through simulations in Synchro of manual traffic control during the special event, it was found that the cycle length of manual operation was much longer than what optimized cycle length should be. This case study demonstrated that the simulation method is useful for developing more effective traffic management strategies with respect to manual control, as well as for the evaluation of intersection performance under such conditions.

9. APPENDIX B: EXAMPLE ATTENDEE SURVEY

MONTANA STATE UNIVERSITY Western Transportation Institute

MSU Traffic Management Strategies Survey

MONTANA STATE UNIVERSITY College of ENGINEERING

This survey is being conducted by the Western Transportation Institute at Montana State University, in cooperation with the City of Bozeman, the Montana Department of Transportation, the Bozeman Police Department, Gallatin County, MSU Athletics, and the MSU Police. The purpose of the survey is to obtain information about the traffic management strategies in place during MSU football games and special events. PLEASE take a few minutes to answer the questions below and deposit this form in the boxes located at the stadium entrances.

---

1) Which of the following categories best describes you?

_____Student _____Booster member _____Season ticket holder _____Staff

_____Other_______________________________.

2) How many home games have you attended (including this game) this season?

_____1 _____2 _____3 _____4
5

3) How many persons (including yourself) traveled in your vehicle today?________________________.

4) Please provide the approximate time you arrived at your parking location?________________________.

5) Which of the following routes did you take en-route to the game?

_____From North(19th/Kagy) _____From North(7th/11th) _____From North(Wilson/Kagy)

_____From South(19th/Kagy) _____From South(3rd/Kagy) _____From East(Kagy)

_____From West(Huffine/19th/Kagy) _____From West(Huffine/College/11th) _____Other
.

6) Have you attended a home game prior to this season? If "no", proceeded to question # 11.

_____Yes _____No

7) **In order to address when traffic management strategies need to be in place, please provide when you typically leave a game?**

_____Prior to the end _____0-15 min. after _____15-30 min after

_____30min.-1hr. after _____Depends on the score of the game _____Other

8) Were you aware of the new traffic management strategies which have been implemented?

_____Yes _____No

If yes, how did you learn about the strategies?

_____Public Radio _____TV _____Friend, Co-worker, etc.

_____HAR (highway advisory radio) _____Newspaper _____DMS (electronic signs)

_____MSU web site _____Other______________________________.

9) Do you feel that you are saving travel time compared to previous seasons?

_____Yes _____No

If yes, generally how much time do you feel you saved?_______________________.

10) How would you rate your overall satisfaction with the new traffic strategies?

_____Very satisfactory _____Satisfactory _____Neutral _____Unsatisfactory
Very unsatisfactory

11) If a public transit shuttle service was implemented, would you use the shuttle service next year?

_____Yes _____No

If yes, what is the maximum fare you would be willing to pay for use of this shuttle?

_____$1 _____$2 _____$3 _____$4 _____$5 _____Other

12) If remote lots were available for shuttle service, which location would be most convenient? (Select one)

_____Gallatin Valley Mall _____Costco _____Wal-Mart _____Hospital

_____Other______________________________.

13) If subsidized who should pay for bus service? (Select one)

_____MSU _____Students _____Local Businesses _____City/State

_____Other ______________________________.

14) Do you have any suggested improvements to complement the strategies? Please comment in the space below or on the back of this sheet.

Thank you very much for giving us your time! Please deposit this survey in the boxes located at the stadium entrances.

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