Southwest Region University Transportation Center

Predicting the Incremental Effects of Transit Ridership Due to Bus-On-Shoulder Operations

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16. Abstract

Bus-On-Shoulder (BOS) operations are an extremely effective method for increasing the quality of a bus service; allowing for a bus to use a freeway shoulder as a bypass lane not only decreases bus travel time but also increases the bus service's overall performance. BOS has also been found to increase bus ridership. The modern BOS system began in the Minneapolis-Saint Paul area almost 20 years ago. Using the extensive data available from Minneapolis-Saint Paul, ridership changes due to BOS operations were explored. The data showed that with 90% confidence, ridership will increase by at least 4.5% and as much as 14.3%. This report explores how the citizens of Austin, Texas would respond to a BOS operation on local freeways. A stated preference survey was administered to a sample of Austin commuters. It was determined that potential riders would desire a time savings of 7 or more minutes. Typically, it is challenging for persons to accurately predict time savings, therefore it was concluded that, for a BOS operation to be successful, it was necessary for there to be a perceived time savings.

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Predicting the Incremental Effects on Transit Ridership Due to Bus-On-Shoulder Operations

by

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Research Report SWUTC/10/476660-00073-1

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ABSTRACT

Bus-On-Shoulder (BOS) operations are an extremely effective method for increasing the quality of a bus service; allowing for a bus to use a freeway shoulder as a bypass lane not only decreases bus travel time but also increases the bus service's overall performance. BOS has also been found to increase bus ridership. The modern BOS system began in the Minneapolis-Saint Paul area almost 20 years ago. Using the extensive data available from Minneapolis-Saint Paul, ridership changes due to BOS operations were explored. The data showed that with 90% confidence, ridership will increase by at least 4.5% and as much as 14.3%. This report also explores how the citizens of Austin, Texas would respond to a BOS operation on local freeways. A stated preference survey was administered to a sample of Austin commuters. It was determined that potential riders would desire a time savings of 7 or more minutes. Typically, it is challenging for persons to accurately predict time savings, therefore it was concluded that for a BOS operation to be successful it was necessary for a there to be a perceived time savings.

EXECUTIVE SUMMARY

Public transportation is a means of lessening single occupant vehicles on roadways and decreasing traffic congestion. In some cities transit is the norm; in others, transit is only used by those who have no other choice. Transit agencies, along with many other organizations, are always trying to find inexpensive and efficient ways to increase transit ridership, get cars off the road, and improve transit service. The modern Bus-On-Shoulder (BOS) concept, started in the early 1990's in the Twin Cities of Minneapolis and Saint Paul, allows a transit bus to bypass slower traffic on freeway main lanes by using a freeway shoulder at reduced speeds.

The BOS concept has been studied for use in the city of Austin, Texas as a short-term solution to help Capital Metro buses bypass traffic congestion on freeways and to determine if the implementation of a BOS system would be feasible, beneficial, and cost effective.

The goal of this study was to determine the incremental effects BOS has on transit ridership by exploring historical data from Minneapolis-Saint Paul and Miami, Florida areas.

A survey was created and distributed to Austin citizens in order to better understand how BOS would be received in the Austin area. The survey recorded citizen reaction to a BOS system and what benefits each expected.

This report concludes with a discussion of a nationwide survey which is currently being conducted. The survey is an initial step in looking at BOS as a nationwide solution. As most transportation and transit agencies are facing budget shortfalls, BOS is a cost effective project that cannot only benefit current riders, but help increase transit ridership and get single occupant vehicles off the road. The goal of the nationwide survey is to gather information that can be used to develop a national model capable of predicting incremental transit ridership changes due to BOS implementation.

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Chapter 1: Introduction

Congestion is a widely recognized problem for most urban freeways in the United States. Most transportation system operators believe that solutions to urban freeway congestion involve a multi-faceted approach and public transportation should be one of those solution elements.

Public transportation is a means of getting single occupant vehicles off the road and encouraging smarter transportation. In some cities transit is the norm; in others, transit is only used by captive riders, that is, those who have no other choice. Transit agencies along with many other organizations are always trying to find inexpensive and efficient ways to increase transit ridership, get cars off the road, and improve transit service. The modern Bus-On-Shoulder (BOS) concept started in the early 1990's in the Twin Cities of Minneapolis and Saint Paul, and allows a transit bus to bypass slower traffic on freeway main lanes by using a freeway shoulder at reduced speeds. The project can be implemented at minimum costs if a suitable freeway shoulder is already present. The project in Minneapolis has been a huge success and now there are over 257 BOS designated shoulder miles in the Twin Cities.

Starting in the mid 2000's many other United States cities started looking into implementing BOS systems. Starting in 2007, the concept had been discussed and explored in the city of Austin, Texas. The research that predated this report focused on

> "[determining] if the implementation of a BOS system is feasible, beneficial, and cost (Austin, Texas local transit agency) effective as a short-term solution to help Capital Metro buses bypass traffic congestion on highways in Austin, TX. This being the case, the secondary objective is to recommend specific sections of freeways for a BOS pilot program." (Snell 2009)

This report begins at the end of the research preformed by Tara Snell, and looks past just where and how BOS should be implemented in Austin and explores the effects BOS could have on transit ridership.

The goal of this research is to determine the incremental effects BOS has on transit ridership by exploring historical data from the most successful BOS system in the nation—The Twin Cities. Along with analyzing historical data from the Mineapolis-Saint Paul area in Chapter 3, data from Miami, Florida will be briefly discussed in Chapter 4. Chapter 4 will also explore how findings from the Twin Cities data will affect the Austin transit system.

To better understand how BOS would be received in the Austin area, a survey was created and distributed to Austinites. Chapter 5 discusses the stated preference survey that was administered via the WEB and targeted groups that would provide cross-sections of the potential rider population. The survey was able to gage the reaction Austinites would have to a BOS system and what benefits they would expect.

This report concludes with a discussion of a nationwide survey which is currently being conducted. Chapter 7 discusses creating a nationwide survey; the survey is an initial step at looking at BOS as a nationwide solution. As most transportation and transit agencies are facing budget shortfalls, BOS is a very cost effective project that cannot only benefit current riders but help increase transit ridership and get single occupant vehicles off the road. The goal of the nationwide survey is to gather information that can be used to develop a national model capable of predicting incremental transit ridership changes due to BOS implementation.

Chapter 2: Introduction to BOS and Previous Work

2.1 History and Operation of BOS

In 1992, the Twin Cities of Minneapolis and Saint Paul started a transit program named Bus-On-Shoulder (BOS). Bus-On-Shoulder, also called Bus-Only-Shoulder, was developed as a means to increase transit reliability as well as decrease bus travel times. While the Twin Cities are acknowledged as the creators of BOS as it is known today, Seattle, Washington allowed buses to utilized shoulders to bypass congestion as far back as the 1970's. Unlike the Minneapolis-Saint Paul based BOS systems, the Seattle system allowed for carpools as well as buses and did not establish the same speed protocol as that used in Minneapolis.

The "modern" definition of a BOS system was developed by Team Transit which is an entity created in 1991 that operates under the Minnesota Department of Transportation (MnDOT.) The BOS system was created out of a need to increase ridership by reducing bus travel time. Team Transit started a pilot project in 1991 on an arterial roadway. Soon after, BOS started operating on Minnesota-Saint Paul area freeways. As of 2006, the total active miles exceeds 257 (Team Transit). At the start of the program, shoulders were retrofitted for BOS operations; today whenever a new freeway is being built or renovated in the area it is constructed to enable BOS implementation. Therefore many new shoulder sections are available for BOS when future conditions warrant. (Jensen, 2009)

During the mid 2000's many transit agencies in the United States started exploring the possibility of implementing BOS systems in their jurisdictions. Since 2005, there have been at least 7 new programs. (Snell 2009) When compared to the Minnesota system, all of these new systems are quite small, but the spread, popularity and success of BOS cannot be ignored. The process followed by most cities begins by implementing BOS on one or two corridors as pilot projects and then growing that system. There are currently 16 BOS systems operating worldwide. (Snell 2009) These 16 cities along with the year BOS started and the total mileage are:

1. Seattle, Washington (started 1970's, 4.9 miles)
2. Minneapolis/St. Paul, Minnesota (started 1991, over 270 miles)
3. Auckland, New Zealand (started 1991, unknown total mileage)
4. Ottawa, Ontario, Canada (started 1992, 14 miles)

5. Dublin, Ireland (started 1998, 50 to 70 miles)
6. Vancouver, British Columbia, Canada (unknown start year, unknown total mileage)
7. Maryland-Washington D.C. (unknown start year, 3 miles)
8. Fairfax County, Virginia (started 2000, 1.3 miles)
9. Toronto, Ontario, Canada (started 2003, 3 miles)
10. Atlanta, Georgia (started November 2005, 12 miles)
11. San Diego, California (started December 2005, 4 miles)
12. Columbus, Ohio (started November 2006, 10 miles)
13. Old Bridge, New Jersey (started December 2006, 3 miles)
14. Miami, Florida (started March 2007, 9 miles)
15. Cincinnati, Ohio (started July 2007, 11.7 miles)
16. Cleveland, Ohio (started June 2008, unknown total mileage)

Geometric and Operational Characteristics

In the United States, most BOS operations follow the example set forth by The Twin Cities. Team Transit created a list of criteria that are used to determine where and when a bus can use a shoulder as a bypass lane. A 10 feet minimum shoulder width was established, with an 11.5 feet minimum width for bridges. While 10 feet is the minimum, a 12 feet lane is desired and currently all new shoulders built on Minnesota and Saint Paul freeways are a minimum of 12 feet. To ensure the structural integrity of the freeway pavement, a minimum pavement thickness of 7 inches of asphalt is required for a shoulder to be designed suitable for BOS. The normal cross slope for chosen corridors should be between 2 and 5 %. There is a 0 feet horizontal clearance for obstructions and a 14 feet vertical clearance for overpasses. The required safe stopping sight distance is 250 feet and super elevation of the shoulder should never exceed 0.06. (Douma, 2007)

The protocol for a bus to use a shoulder includes that the speed of freeway main lanes must drop below 35mph. Therefore, corridors should be chosen that have "predictable congestion delays…during peak periods." (MnDOT) Congestion delays must occur one or more days per week. A minimum of 6 transit buses must travel the corridor per day. Team Transit also suggests that an average time savings of eight or more minutes per mile should be provided. (MnDOT)

Typically, the right shoulder is used as the BOS lane; however, Cincinnati and San Diego use the left shoulder. In most cities there is no minimum length of continuous shoulder, but Miami instituted a minimum length of 2,500 feet. Buses always yield to emergency service or disabled vehicles on the shoulder. Cars are to yield to buses at exit and entrance ramps. (Snell) Minnesota states that a bus can only use a shoulder if main lane speeds drop below 35mph, and a bus can never travel more than 15 mph faster than the mainline traffic, with a maximum speed of 35mph.

Table 1 lists the Twin Cities as well as San Diego, Columbus and Miami and states the speed requirements for their BOS systems. The guidelines and requirement of each BOS service vary from city to city, but the basic principles are consistent across all systems.

Table 1: Speed Characteristics of BOS Systems

	Twin Cities, Minnesota	San Diego, California	Columbus, Ohio	Miami, FL
Max/Design Speed	35 mph	35 mph	35 mph	35 mph
Can use Shoulder when speeds drop below	35 mph	35 mph (Original) 30 mph (2009 Expansion)	35 mph	25 mph
Max Speed Differential with Mainline Traffic	15 mph	10 mph	15 mph	15 mph

Cost

One very appealing characteristic of BOS implementation is its cost. BOS is a very inexpensive project that can produce tremendous benefits. The cost breakdown for the Twin Cities is shown in Table 2. If no structural improvements need to be made to a corridor with a shoulder that meets the minimum width of 10 feet, the cost of implementation is approximately $1,500 per mile. The cost covers only necessary signage and striping. BOS is not only typically inexpensive, but the process of implementation is very simple; all that is needed is just a few signs and new stripping.

Table 2: Minnesota/Twin Cities Cost Break-Down (Douma, 2007)

Condition	Costs plus signing and striping
Shoulder width and bituminous depth are adequate. Catch basins do not need adjustment. Signing and striping are only requirements.	$ 1.500 per mile – Freeway $ 2.500 per mile - Expressway
Shoulder width and bituminous depth are adequate. Minor shoulder repairs and catch basin adjustments are needed.	$ 5.000 per mile – Freeway $ 5.000 per mile – Expressway
Shoulder width is adequate but bituminous depth requires a 2" overlay. This assumes shoulder and roadway can be overlayed at the same time.	$ 12.000 per mile – Freeway $ 12.000 per mile - Expressway
Same as above but adjacent roadway is not being overlayed. Shoulder must be removed. granular base adjusted and increased bituminous depth replaced.	$ 80.000 - $ 100.000 per mile
Shoulder width and depth replacement are required.	$ 42.000 - $ 66,000 per mile for both freeway and expressway
Installing a 12 ft shoulder rather than a 10 ft shoulder in a new construction project.	$ 30.000 per mile for both freeway and expressway

Safety

One of the biggest concerns about BOS is safety. The Twin Cities system has consistently shown that it is a safe system. The key to safety is the speed at which the buses and adjacent cars travel. Because the buses travel at slow speeds and adjacent cars are traveling even slower, if an accident does occur, damage is minimal. Between 1993 and 2001 only 20 crashes were reported to the state patrol. From 1993 to 2003 MnDOT only recorded 21 collisions and 19 sideswipes. In the first 17 years of operation there has been only 1 injury as a result of a collision. (Conover)

2.2 BOS IN AUSTIN

2.2.1 Recommendations for Austin

All of the operational characteristics from existing BOS operations were assessed and 9 operational requirements and characteristics were recommended for an Austin pilot program. The 9 requirements recommend by Snell are:

1. All BOS shoulders be at least 10 ft in width and have adequate pavement depth to support bus usage;
2. Buses use the right shoulder and continuous shoulder segments be at least 2,500 ft (buses will utilize auxiliary lanes when present, instead of shoulders);
3. Buses not to exceed 35 mph on the shoulder or 15 mph faster than traffic in the main lanes;
4. BOS signs be placed on ramps and along BOS corridors;
5. Bus operators be trained properly for BOS and only use the shoulder if comfortable doing so;
6. Buses yield to emergency vehicles or stalled vehicles stopped on the shoulder,
7. At least six buses travel along the corridor per day;
8. A BOS corridor should need no structural improvements to the shoulder and minimal restriping;
9. And the Texas Transportation Code be updated to allow a BOS Pilot Program.

2.2.2 Possible Austin Test Corridors

Identification of Possible Test Corridors

Starting in the summer of 2008, Austin area freeway corridors were being evaluated as possible locations for BOS implementation. Three of Austin's major freeways were chosen as possible test corridors: IH-35, MoPac (Loop1), and US-183. Each of these three corridors was closely evaluated. During the evaluation, three main categories of information were collected: The corridor's roadway geometry, the bus volume traveling along the corridor and the average vehicle speed during peak periods.

Roadway geometry was determined via Google Earth® as well as windshield surveys. Bus volumes were determined from examining Capital Metro bus route schedules. The average vehicle speed on each corridor was determined by driving each corridor during peak travel times and recording times between exit and entrance ramps). These travel times were then converted to average speeds from the known distance between each exit and entrance ramp. From this analysis, four candidate corridors for BOS were chosen. These corridors were ranked by evaluating the costs and benefits associated with each corridor.

Costs and Benefits

The costs and benefits of implementing each of the four candidate corridors were explored. The costs associated with each corridor are shown in Table 3. These costs are only for signage. Costs for repaving and restriping were also calculated for each of these corridors, but these sections were chosen because restriping and repaving was not required. Table 3 also shows the benefits associated with each corridor. Benefits were calculated by comparing the values of time ($14.50 per hour) with the average time savings associated with each corridor (calculated from speed data from each of the corridors). The last column depicts how many days were required for costs to equal the benefits. This table shows that a BOS system in Austin will pay for itself in only a matter of days (Snell 2009).

Table 3: Cost and Benefits for 4 proposed Austin BOS pilot corridors (Snell 2009)

Test Corridor	Capital Costs (Signage Only)	Benefits						Costs = Benefits (# Days)
		Value of Time ($/hr)	*Time Savings (min/mile)*	*Ridership (rider-miles)*	*Daily Time Savings (min/day)*	*Rider Savings $/Day*	*Rider Savings ($/Year) (255 Days/Year)*	
1. IH-35 SB	$5,670	$14.60	$1.00	620.20	620.20	$150.91	$38,483.26	37.57
2. Mopac SB	$5,895	$14.60	$1.30	1,383.62	1,798.70	$437.68	$111,609.34	13.47
3. US-183 NB	$5,775	$14.60	$1.00	618.96	618.96	$150.61	$38,406.47	38.34
4. US-183 SB	$5,265	$14.60	$0.74	507.50	375.55	$91.38	$23,302.88	57.61

When costs were compared to benefits, one corridor emerged as an obvious winner. Therefore, the ranked final corridor recommendations from Snell are:

1. Mopac SB: Exit to Loop 360/US-183 N to the exit for RM 2222 (3.93 mi)
2. IH-35 SB: Exit to US-183 to IH-35 split (3.78 mi)
3. US-183 NB: Exit to Burnet to Exit for Duval (3.85 mi)
4. US-183 SB: On-ramp from Anderson Mill to on-ramp from Duval (3.51 mi)

2.2.3 Legislation

For BOS to be implemented in Austin, legislative approval was required. The Texas Transportation Code needed to be altered.

In 2007, a first attempt at passing BOS legislation occurred during the 80th session of the Texas legislature. Unfortunately, the bill never made it out of the House. (Snell 2009) In January 2009, another BOS bill was introduced by Senator Wentworth. SB 434 was "Relating to the establishment and operation of a public transit motor-bus-only lane pilot program in certain counties." (SB 434) The bill was passed by the Senate Committee on March 2, 2009 with a unanimous vote and was subsequently passed by the Senate on March 19, 2009. After conference committee activity, the bill was approved in the Senate on June 2, 2009 and approved in the House on June 3, 2009. The bill reached the Governor's desk on June 3, 2009. It was vetoed by Governor Perry on June 19, 2009. The veto has been attributed to a lack of education and knowledge of the project in the Governor's office. There is hope that a new bill will be reintroduced in 2011 and that the conclusions from this report will better convince lawmakers of the benefits associated with BOS.

Chapter 3: Determining Ridership Changes in Minneapolis Transit Ridership due to BOS Implementation

3.1 Data Collection

The analysis of the Minneapolis-Saint Paul data was route based. The routes that were used were determined from the assessment of three main data sets. First, information describing the characteristics and location of each BOS section and when it opened was obtained from Team Transit. Second, speed data for all major corridors in the region was obtained from the Minnesota Department of Transportation (MnDOT). Third, route specific ridership data was obtained from two separate transit agencies in the Minneapolis-Saint Paul region.

3.1.1 BOS Segment Data Collection

Team Transit is an organization within the Minnesota Department of Transportation (MnDOT), which is behind the success of BOS in the Minneapolis-Saint Paul metropolitan region. A list of all BOS sections was obtained from Team Transit along with the section lengths, date opened, and in the case of a few sections, when closed. The master list of all BOS sections in Minneapolis-Saint Paul is in Appendix A.1. The BOS system in the Twin Cities is extremely extensive with over 257 miles. More recently, the addition of BOS lanes has been a result of freeway expansion in the area. If possible, whenever a new freeway is being built in the area, it is built with the intension of the shoulder being BOS accessible. Therefore, many new freeway sections may not currently warrant BOS, but will most likely in the future. (Jensen, 2009) While there may be over 257 miles of BOS lanes in the area, the speed protocol and the bus driver decisions to use or not use the available BOS lane determines actual use. Unfortunately, there is no record that tells if a selected bus uses a BOS lane or not. Without interviewing drivers or visual observations, the best indication of use is historical speed information of all corridors with BOS lanes.

3.1.2 Speed Data Collection

Speed data was desired to determine the average speeds traveled by vehicles on BOS corridors during typical congestion periods (the morning and evening peak periods). It was assumed that if speed on a corridor dropped below 35mph then the BOS lane was being utilized.

It is also important to note that while BOS lanes not only come in handy during congested peak periods, they are also useful as a means for a bus to bypass congestion due to incidents on controlled access corridors. This study primarily looked at how often the BOS lanes were likely used during peak periods. Therefore, data was only collected for peak travel periods as a means of determining how much time could be saved by a bus using a BOS lane, and if a time savings was a factor in ridership increases.

Luckily, MnDOT has an extensive and advanced ITS system. MnDOT provides a software program that can be downloaded which allows extraction of historical speed data from any sensor installed on any of the Twin Cities freeways. The majority of freeways in the Minneapolis-Saint Paul area are fitted with sensors along the main lanes as well as entrance and exit ramps. The corridors identified in the master list provided by Team Transit (Appendix A.1) were cross referenced with corridors that were fitted with speed sensors. For ease and convenience, MnDOT provided a document that depicts the location of every sensor. Figure 1 shows a screen caption of the information the document supplied for the intersection of I-35E and Pilot Knob Road.

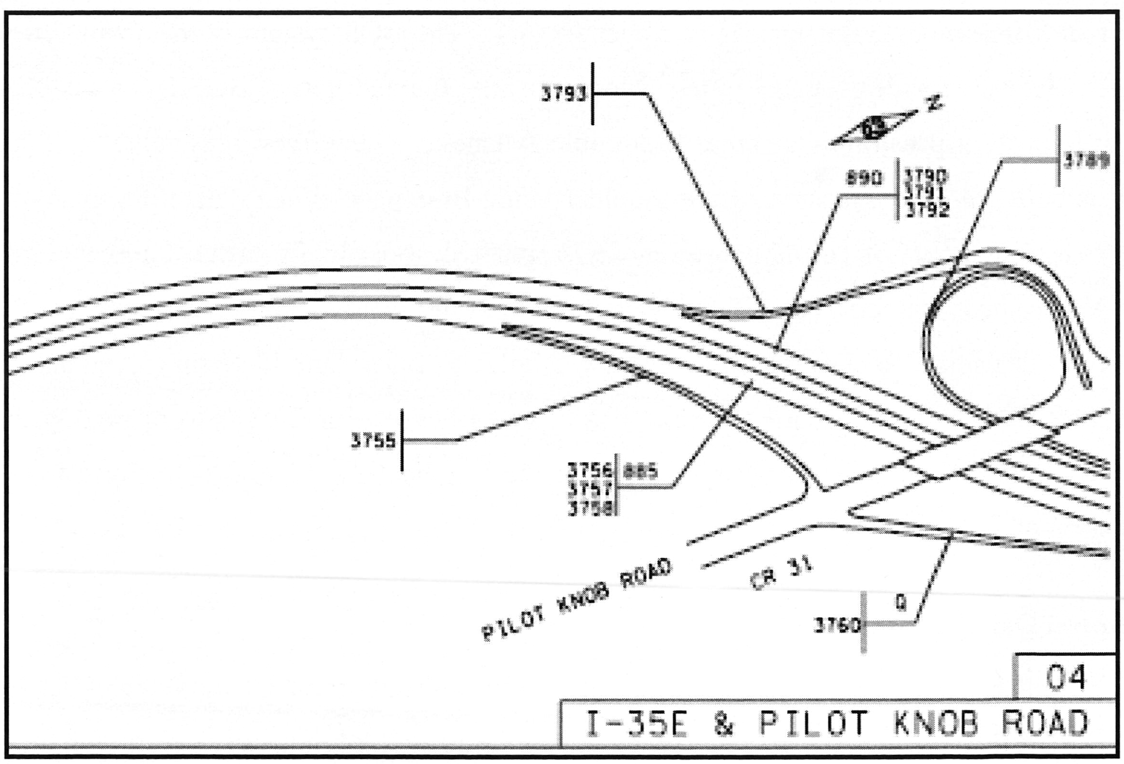

Figure 1: Screen Caption of MnDOT Road Sensor Location Document (MNDOT)

The earliest available data for a majority of the sensors is January 1994. The master list provided by Team Transit lists BOS sections that opened prior to 1994. For speed analysis of these corridors, the most recent speed data was used. It was assumed that speed and congestion did not vary substantially along a corridor from year to year. Therefore, for the few analyzed corridors that opened prior to 1994, 1994 or 1995 speed data was used.

Data could be extracted for any day and any time period. (Minnesota Department of Transportation, 2009) For all BOS sections, data was extracted for extended morning (6:30-9:30am) and evening (4:30-7:30pm) peak periods for every Tuesday, Wednesday and Thursday. Speed data was taken for every minute during the designated time periods. Data was not obtained for national holidays that fell in the middle of the week. Holidays that often fell in the middle of the week were New Year's Day, July 4th, Thanksgiving and Christmas Day. The entire week of Thanksgiving and the entire week between Christmas and New Years were excluded from the analysis. Figure 2 shows a screen caption of the MnDOT software program used to extract data. The figure is demonstrating the extraction of data for the sensors on I-35E at Pilot Knob Road.

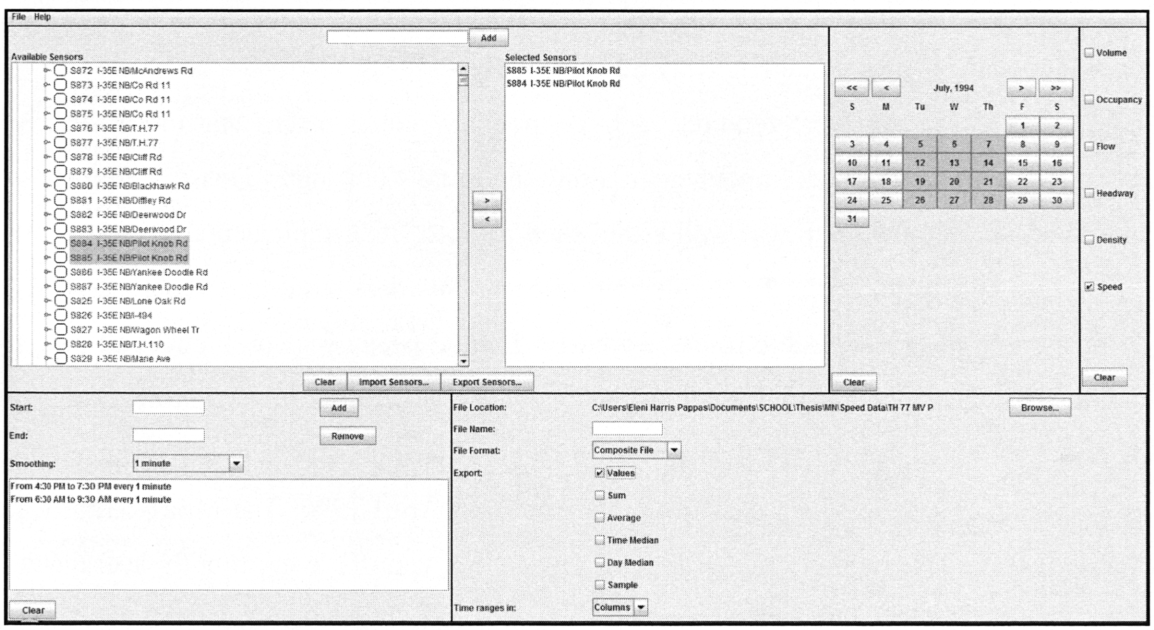

Figure 2: Screen Caption of MnDOT Speed Extraction Program

Regrettably, there were some discrepancies in the extracted speed data. For some days and times, detectors were clearly not working and returned negative values, and other times the detectors returned speed values over 90mph. It was assumed when very high speeds were detected, the detector was not working properly. Due to the discrepancies, determining real time savings was not possible. Despite the discrepancies, the data was still useful. Section 3.2 discusses how the MnDOT speed data was still used.

3.1.2 Ridership Data Collection

The locations of road sensors as well as the time period for which data was available were cross referenced with the location of BOS lanes from the supplied Team Transit BOS history. From the combination of the location of sensor and the location of BOS lanes, a few specific corridors were identified. From these corridors, historical route based data was requested from two transit agencies in the Minneapolis-Saint Paul region. Metro Transit is the primary transit agency in the area and operates the majority of routes through the area. There are eight minor transit agencies which focus on bus commuter routes from the suburbs into the Twin Cities. (Metro Transit) One of these smaller agencies is the Minnesota Valley Transit Authority (MVTA). The MVTA is based within five cities south of the Minneapolis-Saint Paul metropolitan region and operates 22 routes. (Abegg, 2009) Route data was obtained from these two transit agencies for the majority of routes along North and South Interstate 35 West, North and South Interstate 35 East, State Highway 62 and Truck Highway 77.

For analysis, routes were required to have monthly ridership data starting at least two years prior to the year BOS was implemented along the route's corridor. This requirement was to ensure that the route ridership was well established prior to BOS implementation and allowed for an easier identification of the BOS ridership effects. This data requirement also limited the number of useable routes. Useable routes were also limited because of problems and errors in the supplied data. In 2004, Metro Transit did major route restructuring on its southern routes; as a result very few routes had ridership data prior to 2004. (Metro Transit) For the few routes that did exist prior to 2004, the oldest data available was from April 1996. The Metro Transit data was also limited because monthly ridership records were not kept for every month; average daily ridership, (along with days operated during each month), were only recorded for 2 or 4 months out of every year. (Carlson, 2009) To allow for the Metro Transit ridership data to still be used, steps were taken to fill in the blanks for the 4 analyzed Metro Transit routes.

The National Transit Database (NTD) supplies an online record of all the major transit agencies in the United States. For each transit agency, the NTD records contain the total unlinked passenger trips (UPT) for every month starting in January 2002. For 2002 onward, the system wide Metro Transit monthly totals were used to fill in the blanks of missing monthly totals for the 4 Metro Transit Routes. It was assumed that the month to month trends (percent difference between each month) experienced by the system as a whole, were also experienced by each of these individual routes. The 12-point moving average was also used as a tool to recreate the historical data extending back to April 1996.

The MVTA data was much cleaner and more comprehensive than the Metro Transit ridership data. MVTA supplied total monthly ridership for each month starting in January 1991. (Abegg, 2009) Due to the higher quality of MVTA data, the majority of routes assessed were MVTA commuter routes. A total of eighteen routes (4 from Metro Transit and 14 from MVTA) fit the criteria dictated by the constraints of the three data sources.

As previously mentioned, for a corridor to be analyzed it must have a BOS lane, it must contain road sensors, and bus routes with useable monthly ridership data that must operate along the corridor. When all of these corridors were compiled, the list in Table 4 was created and it includes 23 useable corridors. The ID of each corridor was created based on the corridor's location as well as the transit provider that provided the most transit service along the corridor. The list includes the length of each corridor and when it opened. There are 18 routes which travel along the 23 corridors listed in Table 4.

Table 4: List of Evaluated BOS Sections' Location and Road Sensors

ID	Direction	Corridor	From	To	Miles	Opened	Detectors
I35W MT A	Southbound	I-35W	Franklin Ave.	26th Street	0.5	2001	4,3
I35W MT B	Southbound	I-35W	95th Ave	Co Road I	2.2	2002	678, 679, 680, 681
I35W MT C	Southbound	I-35W	TH 280	8th St SE	3.1	1998	577, 579, 580, 581
I35W MT D	Northbound	I-35W	8th St. SE	Stinson Blvd	0.9	1998	570, 572, 573
I35W MT E	Northbound	I-35W	Stinson Blvd	Cleveland Ave	2.1	2004	574, 652, 653
I35W MV E	Southbound	I-35W	26th St.	Lake St.	0.4	1996	5,6
I35W MV F	Southbound	I-35W	35th St.	60th St.	3.3	1996	7,8,9,10,11,12,14
I35W MV G	Southbound	I-35W	66th St.	76th St.	0.9	1996	19,20,21,22
I35W MV H	Northbound	I-35W	76th St.	66th St.	0.9	1996	45,46,47,48
I35W MV I	Northbound	I-35W	57th St.	44th St.	1.4	1996	53,54,55,56
I35 E MV A	Southbound	I-35E	West of Kellogg	Randolph	2.2	2001	846, 849
I35 E MV B	Northbound	I-35E	T.H. 110	T.H. 13	1.3	1995	828, 830, 831
I35 E MV C	Northbound	I-35E	South of Randolph	Grand	2.4	2001	835, 838
H62 MV J	Eastbound	Hwy. 62	Portland	Hwy. 77	1.01	2005	322, 323, 324
H62 MV K	Westbound	Hwy. 62	Hwy. 77	Portland	1.01	2005	333, 334, 335
TH 77 MV L	Southbound	TH 77	I-494	Old Shakopee	1.6	2003	540, 541, 542, 543
TH 77 MV M	Southbound	TH 77	Old Shakopee Rd.	T.H. 13	2.1	1993	807,808,809, 810, 811
TH 77 MV N	Southbound	TH 77	TH 13	I-35E	2.4	2003	812, 813, 927
TH 77 MV O	Northbound	TH 77	138th St.	I-35E	2.1	2003	920, 921, 922
TH 77 MV P	Northbound	TH 77	I-35E	Old Shakopee Rd.	4.9	1993	797, 798, 799, 800, 801, 802, 803
TH 77 MV Q	Northbound	TH 77	Old Shakopee	73rd St.	1.9	2003	524, 526
TH 77 MV R	Northbound	TH 77	73rd Street	66th Street	0.7	1997	527, 529
TH 77 MV S	Northbound	TH 77	66th St.	T.H. 62	0.9	1994	531

3.2 Data Analysis

To identify and analyze ridership increase, each route was considered individually. Therefore, the 18 routes identified from the 23 corridors in Table 4 were further analyzed. To determine the incremental effect a BOS lane has on bus ridership, it is necessary to look at each route during the time that a BOS lane was opened. Therefore, the ridership data for the 18 routes was further broken down; from the 18 routes, 42 separate data sets were created by treating each route as a separate entity for each year that a BOS lane was active along that route. For example, if a route had a BOS lane added in 1994 and 1996, there would be two different data points, one for each year. From these 42 data sets, 10 were removed due to data irregularities discussed in Section 3.2.2. The final set of data included 32 data sets compiled from 15 routes.

3.2.1 Removing Seasonality

The primary goal of this study was to find the incremental effect that incorporating a BOS lane onto a corridor has on a route's ridership. It was determined that the best predictor for this would be percent change in ridership. The data provided by Team Transit regarding when each BOS section opened only stated the opening year; therefore, the percent difference calculated was for the change from the year prior to BOS to the year after implementation. It was determined that this yearly assessment would identify the incremental and short term effects BOS has on ridership, and determining changes over shorter periods of time would not be necessary.

Ridership can be affected by many elements, some predictable and some not. One predictable effect on ridership is seasonality. Typically, ridership is higher in spring and fall and lower in summer and winter. (Haire 2009) The seasonality of ridership was extensively addressed in work done on the short term effects of fuel prices by Dr. Ashley Haire. Haire calculated monthly seasonal variables by following a process referred to as seasonal decomposition. The seasonal adjustment factors used were based on system wide monthly ridership data obtained from the National Transit Database (NTD). The factors used in this report were calculated from Metro Transit system wide ridership numbers. Compared to other transit agencies, Metro Transit shows low seasonal variation. This means that ridership trends do not change much from month to month and season to season. The NTD only compiles monthly ridership data from larger transit agencies; as a result the MVTA does not report their system wide monthly ridership data to the NTD. It was assumed that the Metro Transit trends would be the same as the MVTA trends and the seasonal adjustment factors calculated for Metro Transit were applied to both the Metro Transit and MVTA ridership data. Table 5 shows the Metro Transit seasonal adjustment factors (SAF) that were used on all analyzed routes to remove seasonality from monthly ridership data.

Table 5: Seasonal Adjustment Factors for Metro Transit

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.00%	-0.15%	-2.05%	1.34%	1.17%	-0.05%	-0.08%	0.93%	-0.22%	-0.01%	-0.66%	-0.21%

Due to a variety of inherit trends in all ridership data, Haire was unable to perform the additive season decomposition on the unlinked passenger trip (UPT) data obtained from the NTD. Haire used the percent difference in the logarithm (base 10) values of the UPT (*PDLOGUPT*) as the basis for her analysis. Therefore, the SAF values must be applied to the ridership data that is transformed into a *PDLOGUPT* series. The transformation of ridership data for a particular point in time (month), Y_t, to the *PDLOGUPT* series was achieved from equation 3.1.

$$PDLOGUPT_t = \frac{logY_t - logY_{t-1}}{logY_{t-1}} \times 100\% \qquad [3.1]$$

Therefore, to create a seasonally-adjusted time series, SAS_t, for each route, the SAF values in Table 5 were subtracted from the $PDLOGUPT_t$ time series. Using the arithmetic properties of logarithms, the seasonally adjusted series was easily converted back into the simpler to comprehend total monthly ridership values. (Haire 2009)

The seasonally-adjusted total yearly ridership for the year before BOS implementation and the year after BOS implementation is shown in Table 6 for each route data set corresponding to a BOS section's opening year. The table also includes the calculated percent difference between these values. The percent difference is the dependent variable used in this data analysis.

Table 6: Identification Information and Dependent Variable Values for Each Route

Route	Year	Traveled Section's IDs	Before	After	Percent Difference
135	2001	MT A/MV D	66,157	79,837	20.68%
250	2004	MT E	368,014	474,355	28.90%
270 (a)	1998	MT C, MT D	157,029	253,455	61.41%
270 (b)	2004	MT E	261,993	270,719	3.33%
440	2003	MV L, MV Q	18,244	13,647	-25.20%
442	2003	MV L, MV Q, MV N	64,481	62,002	-3.84%
444	2003	MV L, MV Q	116,609	133,464	14.45%
445	2003	MV L, MV Q	68,320	70,203	2.76%
460	1996	MV E ,MV F, MV G, MV H, MV I	206,748	240,911	16.52%
464	1996	MV E,MV F, MV G, MV H, MV I	30,439	30,844	1.33%
470 (a)	1994	MV S	101,881	121,353	19.11%
470 (b)	1996	MV E, MV F , MV I	121,353	129,329	6.57%
470 (c)	1997	MV R	119,752	150,274	25.49%
470 (d)	2001	MT A/MV D	162,148	142,522	-12.10%
470 (e)	2005	MV J, MV K	151,912	146,618	-3.48%
472 (a)	1994	MV S	131,519	137,866	4.83%
472 (b)	1996	MV E, MV F, MV I	137,866	132,893	-3.61%
472 (c)	1997	MV R	140,715	129,490	-7.98%
472 (d)	2001	MT A/MV D	93,162	122,378	31.36%
472 (e)	2003	MV N, MV L	122,378	102,802	-16.00%
472 (f)	2005	MV J, MV K	102,802	102,950	0.14%
476 (a)	2001	MT A/MV D	113,469	106,733	-5.94%
476 (b)	2003	MV L, MV N, MV Q	106,733	113,766	6.59%
476 (c)	2005	MV J, MV K	113,766	141,573	24.44%
477 (a)	1993	MV M, MV P	139,661	187,528	34.27%
477 (b)	1994	MV S	161,729	202,823	25.41%
477 (c)	1996	MV E, MV F, MV I	202,823	236,910	16.81%
477 (d)	1997	MV R	219,086	244,476	11.59%
477 (e)	2003	MV L, MV O, MV Q,	309,804	342,015	10.40%
477 (f)	2005	MV J, MV K	342,015	365,036	6.73%
480	2001	MV C, MV A	35,533	42,056	18.36%
484	2001	MV C, MV A	37,749	35,074	-7.09%

3.2.2 Applying 12 point Moving Average

From service changes to fare increase, and also strikes, there are many factors that affect transit ridership data. There are three major events that were accounted for during the process of data analysis. During the time period evaluated (1992 until today) the Minneapolis-Saint Paul area experienced two transit strikes as well as the tragic Interstate 35 bridge collapse on August 1, 2007. The two strikes occurred within the Metro Transit agency and luckily only slightly affected the MVTA bus routes. One strike occurred in the fall of 1995 and the second occurred in March 2004. Since no data was available for Metro Transit from 1995, this strike may have only affected the MVTA bus routes from this year. Due to limited information, any effects are unknown. The strike in 2004 may have effects on two data sets (Route 250 and Route 270 in 2004) of Metro Transit bus ridership. The bus routes clearly show a dip in ridership during and after the strike, but the routes still experienced positive percent changes in total yearly ridership from 2003 to 2005, so the data points were not removed for the set of analyzed data.

While the two major strikes that occurred at Metro Transit were identified, many other external factors that affect ridership were not. To help reduce the effect of other external factors, a 12-point moving average was applied to all 18 routes analyzed. The 12-point moving average smoothed the data so that the effect due to BOS was easier to identify. It also helped to identify significant ridership changes that were not due to BOS; changes that were a result of strong external factors that could not be determined.

Figure 3 and Figure 4 show monthly ridership for MVTA Route 464. The double headed arrows along the horizontal axis show the years in which BOS was implemented along the route. Route 464 travels along IH-35W from the southern suburbs into Minneapolis. Figure 3 depicts the ridership starting in January 1991. Both figures clearly show the smoothing effect of the 12-point moving average. BOS sections along the 464 route opened in 1996 and in 2001. To better see the ridership increase in 1996, Figure 4 shows the monthly ridership from 1995 through 1997 for Route 464. The figure clearly shows a visible jump near March of 1996. It was determined that this jump is the short term ridership effect experienced by Route 464 due to BOS implementation. Similar jumps are seen on many other routes, but a jump like this one is not always visible during BOS implementation years.

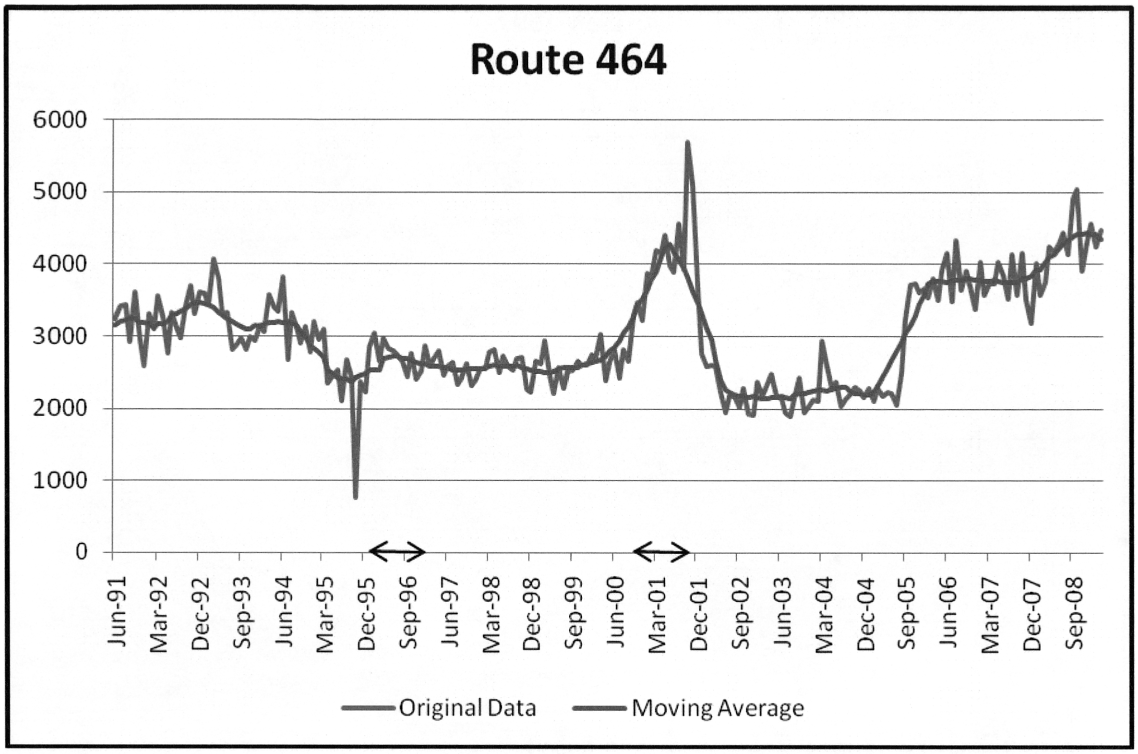

Figure 3: MVTA Route 464 Ridership from 1991 to Oct 2008

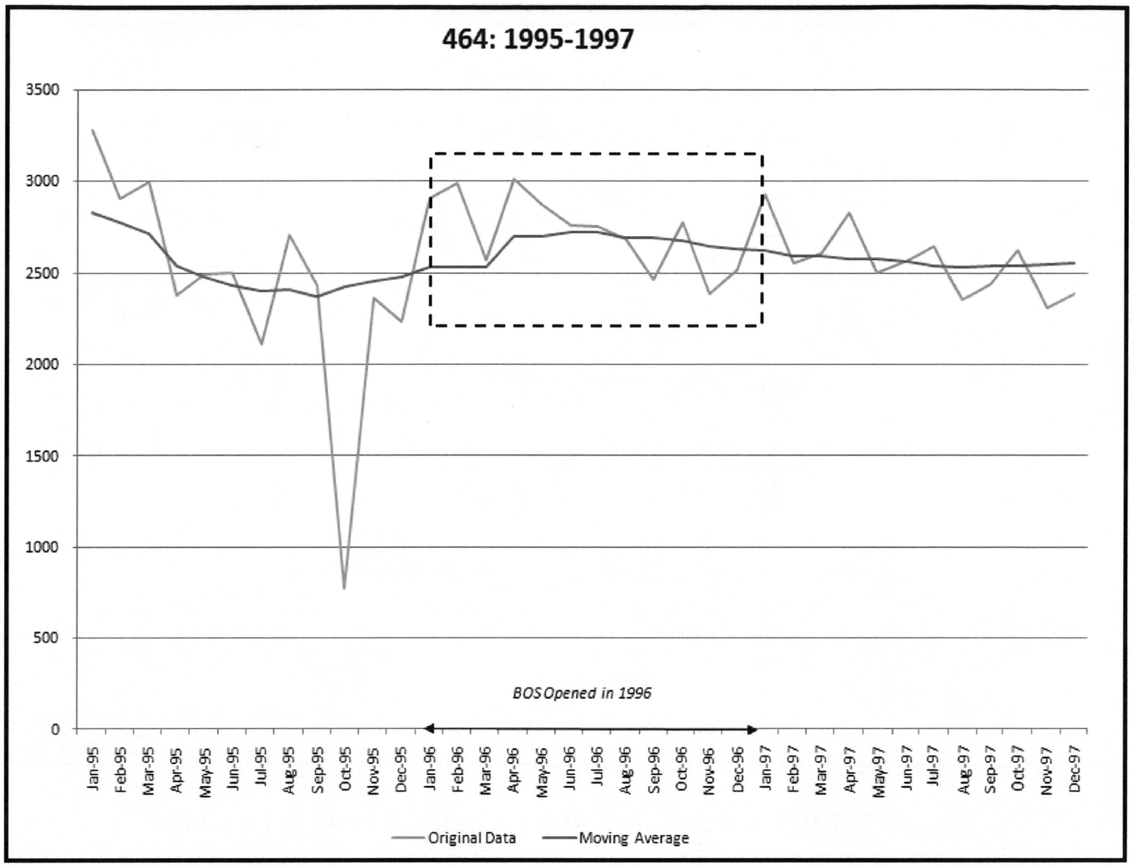

Figure 4: MVTA Route 464 Ridership from 1995 to 1997

Figure 3 shows a high peak around July of 2001. BOS was implemented along Route 464 in 2001. It is not plausible to assume the March 2001 peak is due to BOS implementation. This peak is most likely the effect of other factors that cannot be determined from the data alone. If routes showed strong irregular behavior, like Route 464 in 2001, then that data set was removed. A total of 10 data sets were removed because of unidentifiable irregular behavior. These 10 data sets show that there are external factors affecting the ridership data that cannot be identified without more information. While other data sets may not clearly show irregular behavior like Route 464 in 2001, they could be also experiencing affects of external factors. Unless there was clearly irregular behavior, like the peak for Route 464, the data set was not removed, but caution was taken in analyzing the ridership changes.

3.3 INDEPENDENT VARIABLES

As previously stated, a total of 32 data points were compiled. Each data point was for a route during a certain year of BOS implementation. Each route was observed as an independent loop where each loop incorporated the inbound and outbound travel of that route.

Six potential predictor variables were identified for each data set. The first was a binary that stated whether that route had a BOS section on it previously. A 1 was given if a section of BOS had not been operational along the route previous to that year, and a 0 was given to routes which previously operated on BOS sections. The second variable is related to the first; if a BOS section existed previously (and had a value 0), then the second variable states how many years since the previous section was opened. The third is the total length of BOS section(s) along a route's loop.

The final three variables are all related to the speed data obtained from the MnDOT extraction program. As previously mentioned, there were some discrepancies, and because of these data inconsistencies, calculated average speeds would not be accurate. Therefore, the average number of minutes in each day in which the speed was below 35 mph was determined. Then the average speed was calculated for the times which the speeds were below 35mph. The sixth independent variable was the average time a bus was saved by using the shoulder when the freeway speed was below 35 miles per hour. This value was derived from the maximum possible speed differential between personal vehicles traveling at the average speed (when below 35mph) and a bus allowed to travel up to 15mph faster along the shoulder (with a max speed of 35mph). Time saving values ranged from 0.213 minutes per mile to 1.596 minutes per mile. Table 7 shows each route data set with its corresponding year along with each of the 6 identified independent variables.

Table 7: Independent Variables for each Route Data Set

Route	Year	First Year for BOS?	Length of BOS section(s)	Years from Previous	Average Min/Day speed below 35mph	Average speed when below 35mph	Average Time Savings when speed below 35(min/mile)
135	2001	0	0.5	5	35.96	27.46	0.470
250 (a)	2002	0	2.2	2	55.31	19.47	1.341
250 (b)	2004	0	4.3	4	55.13	17.64	1.564
260	2004	1	2.1	0	55.13	17.64	1.564
270 (a)	1998	0	4	1	19.72	24.32	0.752
270 (b)	2004	0	6.1	7	55.13	17.64	1.564
440	2003	1	3.5	0	32.75	18.32	1.475
442	2003	0	12.9	19	25.63	18.42	1.462
444	2003	0	3.5	10	32.75	18.32	1.475
445	2003	0	10.5	10	32.75	18.32	1.475
460	1996	1	6.9	0	67.88	21.25	1.109
464	1996	1	6.9	0	67.88	21.25	1.109
470 (a)	1994	1	0.9	0	26.39	26.04	0.590
470 (b)	1996	0	6	2	92.97	20.73	1.181
470 (c)	1997	0	6.7	3	27.29	23.23	0.868
470 (d)	2001	0	7.2	7	35.96	27.46	0.470
470 (e)	2005	0	9.22	11	56.74	23.39	0.851
472 (a)	1994	0	0.9	1	26.39	26.04	0.590
472 (b)	1996	0	6	3	92.97	20.73	1.181
472 (c)	1997	0	6.7	4	27.29	23.23	0.868
472 (d)	2001	0	7.2	8	35.96	27.46	0.470
472 (e)	2003	0	10.9	10	27.90	19.04	1.389
472 (f)	2005	0	12.92	12	56.74	23.39	0.851
476 (a)	2001	0	0.5	8	35.96	27.46	0.470
476 (b)	2003	0	6.4	10	25.63	18.42	1.462
476 (c)	2005	0	8.42	12	56.74	23.39	0.851
477 (a)	1993	1	7	0	19.95	31.12	0.213
477 (b)	1994	0	7.9	1	26.39	26.04	0.590
477 (c)	1996	0	13	3	92.97	20.73	1.181
477 (d)	1997	0	13.7	4	27.29	23.23	0.868
477 (e)	2003	0	19.3	10	37.92	17.41	1.596
477 (f)	2005	0	21.32	12	56.74	23.39	0.851
480	2001	0	5.9	6	36.43	19.77	1.310
484	2001	0	4.6	6	36.43	19.77	1.309

3.4 Prediction Models

To find the incremental effects of BOS, three methods were used to analyze the 34 data points: a multi-variable model, single-variable models, and a confidence interval. As previously stated, the dependent variable was percent change in ridership from the year prior to BOS implementation to year after implementation. The independent variables were:

1) A binary variable representing the inaugural year of BOS
2) The years since a previous BOS section's implementation
3) The length of total BOS sections on a corridor
4) The minutes per day that the freeway speed was below 35 mph
5) The average speed of traffic when speeds are below 35 mph
6) The average time savings for a bus on a BOS route when using the shoulder.

3.4.1 Multi-variable Model

Using the statistical computer program SPSS, the 32 data points were examined with the goal of finding a multi-variable model using some or all of the previously discussed independent variables. The sample of data points, at 32, was low, and before starting a multi-variable model analysis it was determined that the probability of creating a statistically strong multi-variable model was very low. Despite the low probability of creating a good model, the data set was larger than the widely accepted critical threshold of 30 (for samples being able to create a predictive model). Therefore, it was desirable to examine a multi-variable predictive model. In addition to the small sample size, the number of predictor variables can cause problems in creating predictive models. The number of predictor variables is directly linked to the degrees of freedom associated with the model. With smaller degrees of freedom, the ability of a model to predict real world trends becomes unfeasible.

The percent difference values from Table 6 were combined with the independent variables from Table 7 and input into SPSS. A linear regression analysis was preformed. The linear regression for these six independent variables (Regression I) yielded an R^2 value of 0.168; a low value. The ANOVA and Coefficients tables output by SPSS are shown below in Table 8 and Table 9, respectively.

Table 8: ANOVA Table for Regression I

Model	Sum of Squares	df	Mean Square	F	Sig
Regression	0.166	6	0.028	0.91	0.503
Residual	0.82	27	0.03		
Total	0.985	33			

Table 9: Coefficients Table for Regression I

Model	Non-standardized Coefficients		Standardized Coefficients	t	Sig
	B	Std. Error	Beta		
Constant	-0.883	2.8		-0.316	0.775
Binary	-0.078	0.99	-0.176	-0.792	0.435
Length	0.005	0.008	0.142	0.662	0.514
Years	-0.014	0.009	-0.386	-1.514	0.142
Min_Day	-0.001	0.002	-0.129	-0.664	0.512
Avg_Speed	0.037	0.089	0.794	0.422	0.676
Time	0.245	0.799	0.572	0.306	0.762

While none of the independent variables appear to have a strong significance in the model, three variables do stand out as having relatively strong significance. These three variables are: Binary (a binary variable representing the inaugural year of BOS), Years (the years since a previous BOS section's implementation), and Avg_Speed (the average speed of traffic when speeds are below 35 mph). The three variables with relatively weak significance (and low *t* values) were considered to not be good predictors in this multi variable model.

Another linear regression analysis was performed using the three variables with stronger significance and higher *t* values. This regression resulted in an R^2 value of 0.142, slightly lower than Regression I. The SPSS ANOVA table and Coefficients Table are shown below in Table 10 and Table 11, respectively.

Table 10: ANOVA Table for Regression II

Model	Sum of Squares	df	Mean Square	F	Sig
Regression	0.14	3	0.047	1.653	0.198
Residual	0.846	30	0.028		
Total	0.985	33			

Table 11: Coefficients Table for Regression II

Model	Non-standardized Coefficients		Standardized Coefficients	t	Sig
	B	Std. Error	Beta		
Constant	-0.107	0.199		-0.538	0.595
Binary	-0.061	0.091	-0.138	-0.676	0.504
Years	-0.01	0.008	-0.271	-1.307	0.201
Avg_Speed	0.012	0.008	0.257	1.482	0.149

Like in Regression I, Regression II did not produce very significant values for the predictor variable. These two multiple regression models show that none of the six independent variables are good predictors. This is most likely due to the limited number of data points and the amount of scatter within the data sets. As previously mentioned, there are many other external factors that can affect transit ridership. While a strongly significant model could not be created, the second regression model created with only three variables had relatively strong significance. Therefore, the multi-variable regression model for the data set is shown in equation 3.2.

$$Y_{Percent\ Change} = -0.107 - 0.061X_{Binary} - 0.01X_{Years} + 0.012X_{Avg\_Speed} \qquad [3.2]$$

According to the model, the percent change in yearly route ridership due to BOS is a function of any previous BOS sections along that route and the average speed traveled by vehicles in the main lanes when speeds drop below 35 mph. According to the model, if the BOS section was the first along a bus route, it will have a negative effect on percent change by a factor of 0.061. Also, more years since the opening of BOS sections along a bus route will have a negative effect on percent change in ridership. The most curious finding from the multi-variable model is the fact that the higher the average speeds of the main lane traffic, the higher the percent change. This finding was echoed and further discussed in section 3.4.2. Despite the lack of success in creating a strong multi-variable model to predict the ridership changes, the 32 data points can still be used to create predictions about the effects of BOS on ridership.

3.4.2 Single-variable model

A multi-variable model appeared not to be the best way to model the incremental effects on ridership due to BOS. Therefore, each independent variable was separately compared to the dependent variable, percent change. Comparisons were done using the Pearson correlation coefficient, *r*. Table 12 shows the correlation coefficients for each independent variable compared to percent difference, as well as the Student's t-value.

Table 12: Correlation Coefficient and T-Stats for Each X Value Compared to Percent Difference

	A: First Year – Binary	B: Length	C: Years from Previous	D: Average Min/Day Speed below 35mph	E: Average Speed when below 35mph	F: Average Time Savings when Speed below 35mph (min/mile)
r	0.0292	-0.0823	-0.2489	-0.1409	0.3048	-0.2993
t	0.165	-0.467	-1.453	-0.805	1.810	-1.77

The variables with the strongest correlation to the percent change in ridership are variables E and F. Both of these values have signs that are counter intuitive of what one would assume. The correlation coefficient for variable E is positive; this means when speeds increase (from 0 to 35mph) the percent difference in ridership also increases. The correlation coefficient for variable F is negative, meaning when the time savings decreases the percent change in ridership increases. While the trends may be counterintuitive, a t-test on these values determined them to be somewhat significant. For a two tailed t distribution, t_{90} is equal to 1.694 and t_{95} is equal to 2.037. Therefore, the correlation coefficient is significant at 90%, but not at 95%.

Because of the counterintuitive nature of the correlation coefficients, scatter plots were used to better understand the distribution of the data points. Figure 5 and Figure 6 are scatter plots of percent change in ridership versus average bus time savings when freeway speed is below 35mph (variable F), and average freeway speed when below 35mph (variable E), respectively. Both figures also depict the trend line of the scatter plots. The trend lines correspond with the correlation coefficients' sign.

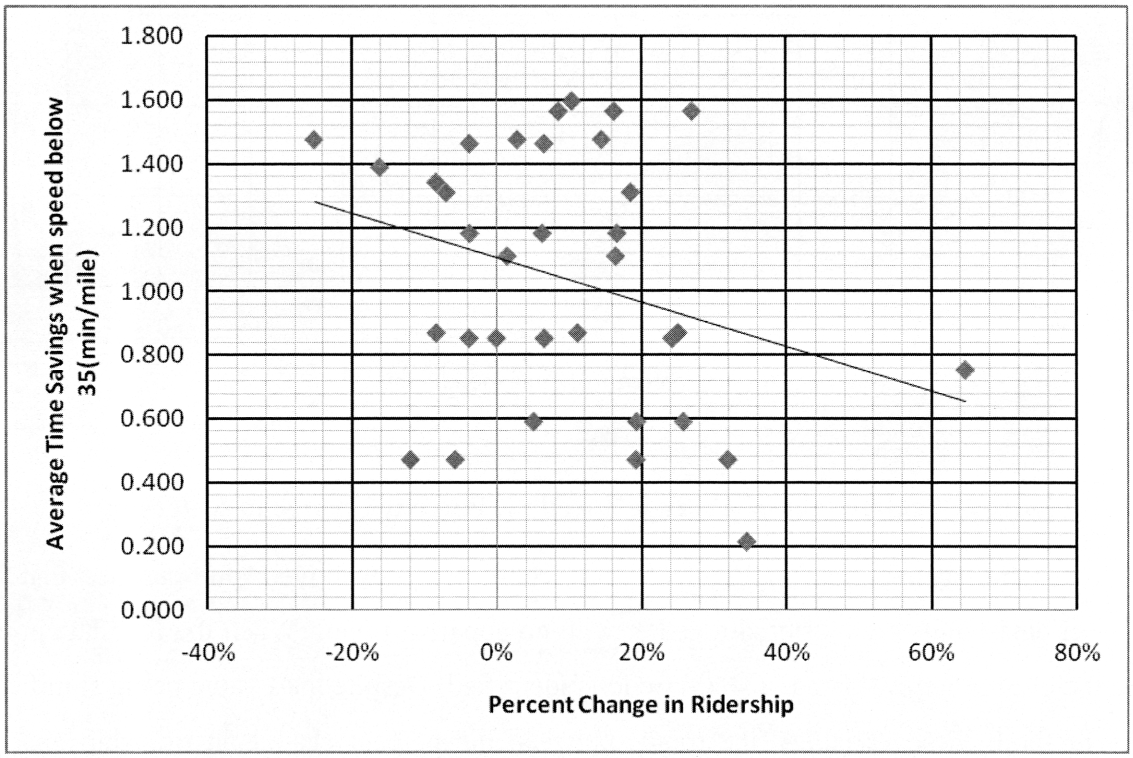

Figure 5: Scatter Plot of Average Time Savings vs. Percent Change in Ridership

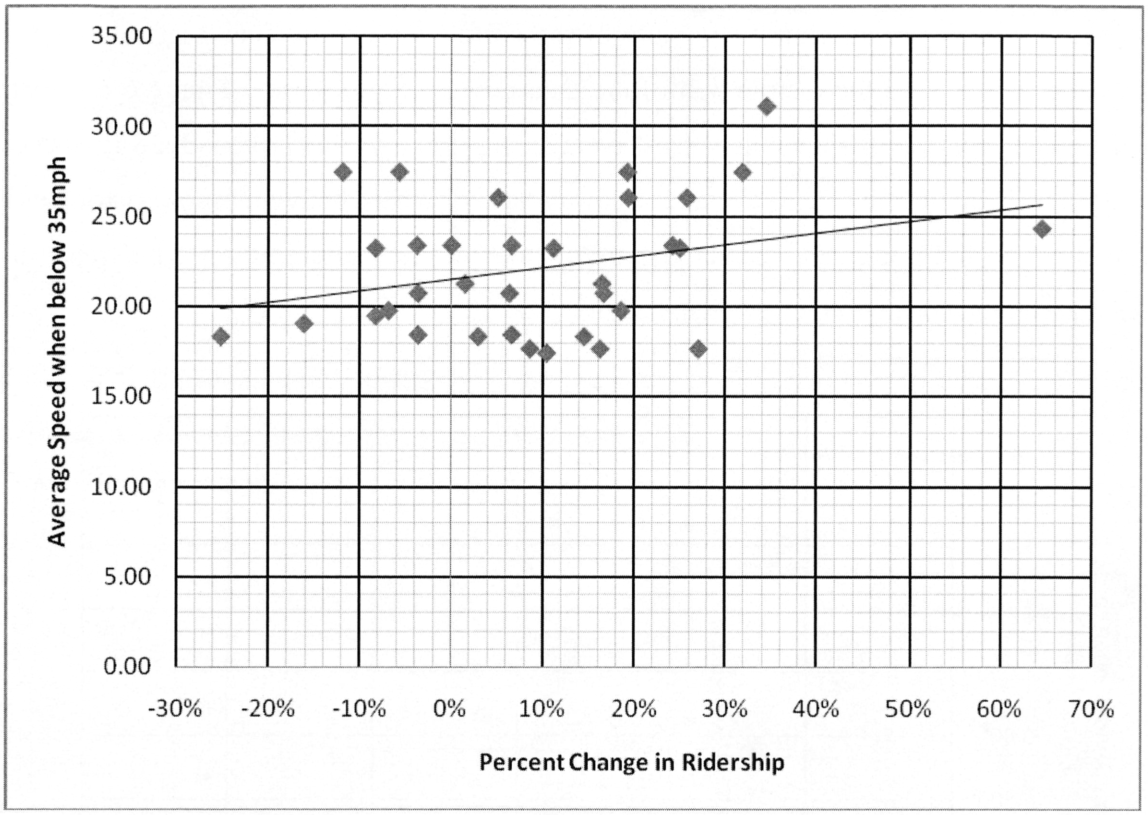

Figure 6: Scatter Plot of Average Speed vs. Percent Change in Ridership

When the scatter plots in Figure 5 and Figure 6 are examined, one can see that the majority of data points are clustered together with no apparent trend. When the few data points outside the cluster are evaluated, a slight trend is identified. Despite the t value being significant at 90% for both these variables, the trends between the percent change in ridership and the independent variables E and F are determined by only a few data points. A small part of the data set is providing all the correlation. A closer examination of the scatter plots determines that there is not a strong relationship between these values and percent difference. Therefore, the correlation determined by the r and t values in Table 12 is not considered to be a good evaluation of the real data.

Like the multi-variable model, the scatter plots show that the small sample size used in this data analysis makes creating predictive models vary challenging. There is also substantial scatter due to unknown external factors. While some data that exercised effects from external factors were eliminated prior to analysis, there are many inherent factors that are challenging to remove without extensive analysis. Examples of some of these factors are: fuel costs, service changes, ticket cost changes, weather, and the economy. The purpose of looking at percent change from the year before and the year after BOS implementation was to decrease the effect of these external factors. Clearly, these factors are still present.

The scatter plots were useful in determining benefits associated with BOS implementation. A count of the observations with increases in ridership versus those with decreases indicates that there is a 71% chance that the route ridership will increase after BOS implementation. Also, if there is an increase in ridership, the average increase is 17%. When the average freeway speed is between 15mph and 25mph, and the times savings is greater than 0.5 minutes per mile, the probability of an increase in ridership is 76% with an average increase of 15%.

3.4.3 Confidence Interval

A confidence interval was calculated from the mean and standard deviation of the sample. The mean percent difference was 9.41% and the standard deviation was 0.173. A 90 percent confidence interval returns a range of values from 4.5% to 14.3%. Therefore, with 90 percent confidence, implementation of a BOS section will increase yearly ridership on a single route by at least 4.5% and as much as 14.3%.

3.5 CONCLUSION

Due to the limitations of the data set, creating a reliable and statistically significant multi-variable or single-variable model was not possible. In most cases, there is clear indication of ridership increase after BOS implementation. The plot of route 464 in Figure 4 shows how BOS can instantly affect monthly ridership. The selected predictor variables were chosen based on the available data as well as experience based hypotheses. The lack of statistically significant relationships shows that predicating human behavior is very difficult. While time savings, average speed and the time in which speeds are below 35 mph can be calculated based on empirical data, the average commuter likely responds only to perceptions of these values.

The data indicate with 90% confidence, ridership will increase by at least 4.5% and as much as 14.3%. There is 71% chance of ridership increase as a result of BOS implementation;

and if there is a positive change in ridership it will be an average increase of 17%. Creating a forecasting model based on people's perceptions has been shown to be challenging. It appears that people will be willing to switch to BOS because of the perceived benefits, not the actual benefits.

Chapter 4: Ridership Changes in Miami, Florida and Applying Predictive Results to Austin, Texas

4.1 Analysis of Miami Data

Miami started BOS operation in March 2007. The transit agency in Miami has made ridership data available to the public allowing for an analysis of the data in this paper. The analysis cannot be as in-depth as the Twin Cities analysis due to limited BOS routes (only 3) and limited years of operation. Miami started BOS as a pilot program on two freeway corridors in the area: SR-874 and SR-878. The total length of BOS sections is 9 miles.

While there is only limited available Miami data, it can still be used to tell how BOS has performed in Miami. Table 13 is a summary of the analysis performed on the Miami data. Percent change from the year prior to BOS implementation, to the year after BOS, were calculated similar to the method used in Chapter 3. A three month analysis was also preformed, comparing the total ridership for the three months prior to implementation and three months after. These values were seasonally adjusted by the values in Table 14.

Table 13: Miami Ridership Summary Table

	Year Analysis			Three Month Analysis		
	2005 Total[1]	2007 Total[2]	Percent Difference	Before	After	Percent Difference
204: Killian	476,810.41	471,554.07	-1%	121,605.87	121,225.44	0%
272: Sunset	353,883.36	287,983.14	-23%	79,538.53	75,017.43	-6%
288: Kendall	205,081.19	198,448.75	-3%	51,372.02	53,332.37	4%
Average	-9%			-1%		
Stand. Dev.	0.120			0.049		
Confidence	0.114			0.046		
Upper Bound	2%			4%		
Lower Bound	-20%			-6%		

Table 14: SAF values for Miami (Haire 2009)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.19%	-0.19%	0.63%	-0.47%	0.09%	-0.41%	-0.04%	0.11%	0.07%	0.25%	-0.33%	0.01%

[1] (Miami Date Transit 2005)
[2] (Miami Dade Transit 2007)

The percent difference values do not show any significant increase in ridership. After further research, a report was found which discusses the BOS implementation process in Miami. The table shown in Figure 7 helps explain the low percent difference in ridership as a result of BOS. Around the time of implementation of BOS, service cuts were made to all three BOS routes. Despite service cuts on routes 204 and 288, the average weekday ridership, after BOS, increased. Route 272, which appears to have experienced the largest service cuts, had a negative ridership change.

TABLE 3-1
BUS-ON-SHOULDERS SERVICE EVALUATION
PRE/POST SERVICE CONDITIONS

Description	Route 204 Killian KAT	Route 272 Sunset KAT	Route 288 Kendall KAT
Service Period	Weekdays – Peak hours	Weekdays – day long	Weekdays – Peak hours
Prior to Bus-on-Shoulders – September 2006			
Number of Trips	60-round trips	50-round trips	28-round trips
Frequency	6-minute headways	10 to 40-minute headways	12-minute headways
Hours of Operation	5:30 – 9:30 AM 3:00 – 9:00 PM	5:45 AM – 7:30 PM	6:00 – 9:00 AM 4:00 – 7:00 PM
Average Weekday Ridership	2,032	1,549	902
After Bus-on-Shoulders – September 2007			
Number of Trips	54-round trips	38-round trips	24-round trips
Frequency (peak-period)	8-minute headways	10-minute headways	15-minute headways
Hours of Operation	5:30 – 9:30 AM 3:30 – 9:10 PM	5:45 – 9:20 AM 3:25 – 7:00 PM	5:45 – 9:00 AM 4:30 – 7:10 PM
Average Weekday Ridership	2,235	1,330	967
Ridership Change 2006-2007	+10%	-14%	+7%

Figure 7: Screen Caption from Miami BOS Report (Parsons 2009)

The major conclusion from the Miami data analysis is that external factors, such a service cuts, have huge factors on ridership. These external factors greatly affected the data analysis in Chapter 3. BOS is considered a success in Miami despite not having an increased ridership for all routes.

4.2 Possible BOS Effects on Austin Bus Ridership

Chapter 2 presented the four corridors that were chosen as possible pilot applications for a BOS in Austin, Texas. While the project was put on hold due to legislative issues, there is still a chance that a BOS system will come to Austin in the future. If the project continues, the possible pilot corridors will be the same or similar to the ones previously presented. The four most likely BOS pilot corridors in Austin are:

1. Mopac SB: Exit to Loop 360/US-183 N to the exit for RM 2222 (3.93 mi)
2. IH-35 SB: Exit to US-183 to IH-35 split (3.78 mi)
3. US-183 NB: Exit to Burnet to Exit for Duval (3.85 mi)
4. US-183 SB: On-ramp from Anderson Mill to on-ramp from Duval (3.51 mi)

Chapter 2 and previous work done by Snell clearly outline the cost effectiness of BOS. When a benfit cost analysis was done for the four corridos, it was determeind that each corridor could pay for itself within a year due to time saving benefits. BOS not only results in time savings (and increases realibilty), but it can also increase ridership, as was seen by the analsysis of the ridersihp data form the Twin Cities in Chapter 3. Chapter 3 concluded that (with 90% confidence) ridership will increase by at least *4.5%,* and as much as *14.3%.* The average change in ridership for the Minneapolis Data was *9.41%.* Also, there is a 71% chance of ridership increasing as a result of BOS implementation; and if there is a positive change in ridership, it will be an average increase of *17%.* This section will use these percentage increases in yearly route ridership to determine the ridership increase that would result on the four test corridors if the effects of BOS in Austin are similar to Minneapolis-Saint Paul.

A total of 13 bus routes travel along the four possible test corridors in Austin. Some routes only travel along one corridor while some use up to three of the four proposed corridors. Weekday ridership totals were obtained for these 13 routes. Due to errors in the data, no ridership data could be collected for route 990. Ridership data was obtained for August of 2008, (Perteet 2009). These numbers were compared to the total August 2008 ridership for the entire Capital Metro bus system obtained from the NTD (National Transit Database). Comparing the route ridership data to the total system data gives the percentage of the total Capital Metro ridership that is related to each route. It was assumed that the percentages of total system ridership for August 2008 are consistent for the entire year. Therefore, these percentages were used with the system wide NTD total 2008 ridership to find the 2008 ridership totals for each route. Table 15 lists the 13 routes along with which corridors they use, their average August 2008 daily ridership, the cost of a one-way rider and the calculated percentage of the entire Capital Metro transit ridership that used that route. It should be noted that there is a very high percentage of travel that occurs on the University of Texas Shuttle Route FW (Far West).

Table 15: Route Summary

Route	Corridors	Aug 2008 Avg. Weekday Ridership[3]	Cost of One-Way Ride[4]	% of Total Cap Metro Ridership
137	IH-35 SB	280	$0.75	0.21%
142	IH-35 SB	260	$0.75	0.20%
174	IH-35 SB	322	$0.75	0.24%
FW/661	MoPac SB	4073	$ 0	3.06%
PRC/652	MoPac SB	326	$ 0	0.25%
CR/651	IH-35 SB	1166	$ 0	0.88%
935	IH-35 SB	589	$1.50	0.44%
982	MoPac SB	1021	$1.50	0.77%
983	MoPac SB, US-183 SB	849	$1.50	0.64%
984	IH-35 SB, US-183 NB, US-183 SB	151	$1.50	0.11%
986	US-183 NB, US-183 SB	109	$1.50	0.08%
987	MoPac SB, US-183 SB, US-183 NB	439	$1.50	0.33%
990	IH-35 SB	--	--	--

The ridership changes calculated in Chapter 3 were applied to the yearly ridership values (for 2008) for each route. Table 16 shows the changes to ridership that can be a result of BOS. Table 17 shows the possible increase in revenue as a result of BOS. It should be noted that the All Routes row is not a summation row. Since some bus routes use more than one corridor, this row only sums the total for all 12 routes (since no data is available for 990). The MoPac SB

[3] (Perteet 2009)

[4] (Capital Metro n.d.)

corridor currently has the highest ridership and will, therefore, benefit most from BOS. The IH-35 SB corridor comes in second, with US-183 SB third, and US-183 NB fourth.

Table 16: Changes to Ridership due to BOS for Austin BOS Pilot Corridors

Test Corridor	Length	Capital Costs	CI Upper Bound 14.6%	CI Lower Bound 4.5%	Average 9.41%	Increase 17%	Rank
IH-35 SB	3.78 mi	$5,670	112,664.85	33,182.11	72,614.81	131,185.10	2
Mopac SB	3.93 mi	$5,895	273,033.17	80,413.88	175,975.49	317,915.34	1
US-183 NB	3.85 mi	$5,775	28,451.13	8,379.44	18,337.34	33,128.03	4
US-183 SB	3.51 mi	$5,265	63,007.66	18,557.05	40,609.73	73,365.08	3
All Routes			112,664.85	33,182.11	72,614.81	131,185.10	

Revenue increase calculations were also preformed. The revenue calculations were based on the prices for one-way tickets. Capital Metro does offer day passes which will allow a passenger to travel a round trip for a discounted rate. However, the day passes were not taken into consideration for these calculations. The revenue calculations were based solely on what a one-way standard fair ticket costs. The resulting calculations are summarized in Table **17**. MoPac SB still came in as the corridor that would benefit most from BOS implementation. Despite the fact that shuttle ridership is free, MoPac SB buses still draw the most revenue and BOS implementation could generate revenue between $50,000 and $164,000. US-183 SB ranks second in revenue creation due to BOS. This is likely because all routes on this corridor are express routes which charge $1.50 per ride.

Table 17: Possible Revenue Generation due to BOS on Austin Pilot Corridors

Test Corridor	Length	Capital Costs	CI Upper Bound 14.6%	CI Lower Bound 4.5%	Average 9.41%	Increase 17%	Rank
IH-35 SB	3.78 mi	$5,670	$71,494.15	$ 21,056.50	$ 46,079.45	$ 83,246.61	3
Mopac SB	3.93 mi	$5,895	$140,973.52	$ 41,519.60	$ 90,860.33	$ 164,147.25	1
US-183 NB	3.85 mi	$5,775	$42,676.70	$ 12,569.16	$ 27,506.01	$ 49,692.04	4
US-183 SB	3.51 mi	$5,265	$94,511.48	$ 27,835.57	$ 60,914.59	$ 110,047.62	2
All Routes			$71,494.15	$ 21,056.50	$ 46,079.45	$ 83,246.61	

The total fare box revenue generated by the entire Capital Metro system in fiscal year 2008 was $6 million (Capital Metropolitan Transporation Authority FY 2008). As previously stated, there are options for reduced fares with day passes which would reduce the actual revenue generation. Also, the University of Texas students ride for free, which will also decrease possible revenue. Despite these facts that can decrease the estimated revenue, there is no doubt that the readership increase predicted in Chapter 3 can have advantageous effects on fare box revenue.

While the revenue calculations do not take into account students and all day passes, there is still a substantial increase in fare box revenue, as well as ridership in general. Chapter 3 data analysis of the Twin Cities transit data shows that BOS can have a very advantageous effect on transit ridership.

Chapter 5: Austin Stated Preference Survey

As discussed in Chapter 3, BOS operations have affected ridership in the Minneapolis-Saint Paul metropolitan area. Characteristics of transit systems and transit ridership vary from city to city. Therefore, to characterize the city of Austin and how Austinites would respond to a BOS system, a stated preference survey was created.

5.1 Goals of Survey

The primary goal of the survey was to gage how Austin citizens would respond to buses using a freeway shoulder during times of congestion. Prior to the creation of the Austin-based survey, a few objectives were outlined to meet the survey's primary goal. The survey needed to be:

- Easy to distribute
- Short
- Easy to understand and answer
- Representative of potential users

An online survey platform was used to administer the survey that was no more than 10 questions. The survey was a stated preference survey with single occupancy vehicle (SOV) drivers as its targeted respondents. Austin is a city with a transit mode split below 5%, resulting in most Austinites not only driving to work, but also having a relatively low understanding of Austin's bus service. Therefore, it was essential for the survey to make sure the respondent understood the BOS concept as well as its advantages. A great deal of effort was put into not only getting numerous responses but also obtaining a set of responses that represented Austin as a whole, not just a particular group.

5.2 Survey Creation and Distribution

There are two main advantages to BOS; it allows for increased reliability and decreased travel time for a bus service. The survey was targeted at persons who currently drive alone in their personal vehicles. While the advantages of BOS over conventional bus service are well defined, the advantages over personal vehicles are variable. Advantages for drivers are related to the individual's current commute trip. Therefore, understanding a person's typical morning commute was necessary. Questions were asked about congestion, total travel time, and freeway usage as a means to characterize current travel. Questions were also asked about the importance of reliability to a respondent as well as the travel time incentive they would require to be enticed to switch modes. For clarity and consistency among respondents, questions were specifically asked about a driver's morning commute.

The importance of reliability is subjective; every person perceives reliability differently. While reliability is gauged differently by different people, one thing is for sure, travel times on Austin's freeways are not reliable. Therefore, the possibility of increased reliably was seen as a way to entice people to try BOS. To address reliability in the survey, three reliability-focused questions were asked. The first of the three asked if a person had flexibility in their work place arrival time. Many people's place of employment does not allow for flexible arrival times, so the individual usually incorporates a "cushion" into their morning commute time to ensure they arrive on time. The second of the reliability questions asked about a typical "cushion" time. The final reliability question asked if a person would be willing to try BOS, knowing it will increase reliability in their travel time.

When asked about increased travel time, it was important for a respondent to understand that taking the bus would most likely increase travel time, over travel in a single occupancy vehicle (SOV), due to access time related with taking the bus. As previously mentioned, the low transit mode split in Austin results in many Austinites being unfamiliar with their local bus services. Explaining access time was a priority to ensure respondents could accurately assess what their travel time would be if they were to use transit. With the explanation of access time, a question was asked about how much time a driver would need to save on the freeway section of their typical commute to try a BOS bus service.

A survey of nine questions was created that addressed the previously stated goals and objectives. Table 18 gives a summary of the 9 multiple choice questions asked; the complete survey is attached in Appendix B.1. It was administered via an online survey platform: kwiksurveys.com. The link to the survey was spread via email to friends and colleagues in the Austin area with the hope that they would send the link to their friends and colleagues. The survey was also distributed via online groups. The survey results, broken up by each question, are shown in Appendix B.2.

Table 18: Austin State Preference Survey Questions

Austin Survey Questions
1. Do you currently drive alone and use Loop 1 (MoPac), IH-35 or US183 during the AM (7:00-9:00AM) traffic peak period?
2. How long is your typical door to door commute time (include parking, walking to and from your car, etc)?
3. What percentage of your trip is spent using Loop 1 (MoPac), IH-35 or US183?
4. What percentage of your trip do you spend in congestion?
5. Would you try a transit service knowing it will be able to use a shoulder to bypass congestion on the freeway?
6. Do you have any flexibility in what time you arrive at your place of employment?
7. If your place of employment does not allow for flexibility in your arrival time, how much earlier to do you leave home to ensure you are on time to work?
8. Knowing that taking a bus-on-shoulder option will guarantee you a consistent travel time in the morning, would you switch from driving to taking the bus?
9. How much time would a bus need to save on the freeway section of its route for you to use transit in the morning commute?

Questions 1 through 4 were intended to get an understanding and characterization of the respondent's morning commute. Questions 6 through 8 were used to determine the importance of reliability for commuters. Question 9 was asked to help determine what commuters would expect in time savings if they were to switch modes. Question 5 was used as the determinate in whether a person would try the transit service using BOS.

The survey received 295 responses from Austin residents. Despite the low response rate, it was felt that the survey gave a good overview of the typical Austin commuter. Contingency tables and cross classification of survey responses were used to evaluate the survey. Initially, all questions were cross classified with Question 5 to get an understanding of the commuting characteristics of persons who would try a transit system using BOS. The Chi Squared Test was also used to identify any strong correlation among survey responses. The survey identified three factors for enticing drivers to try transit: 1) the typical commute time, 2) the percentage of trip spent in congestion and 3) the driver's desired time savings.

The initial goal of Question 1 was to filter out respondents who would not be the target audience for a BOS service, to remove those who do not commute as drivers in single occupancy vehicles (SOVs). It was also intended to filter out respondents who did not travel the three main roadways considered for BOS implementation in Austin. After the commencement of the survey, it was realized that filtering out persons who do not travel on these three main corridors was not good practice. Therefore, the responses to Question 1 were disregarded.

5.3 Typical Commute Time

The second question asked about the respondent's typical commute time. The five possible answers were, (a) less than 10 minutes, (b) 10-20 minutes, (c) 21-30 minutes, (d) 31-40 minutes, (e) Greater than 41 minutes. It should be noted that responses are most likely perceived and approximate travel times. The majority of respondents, 54%, had a commute time between 10-30 minutes. When the responses to question 2 were cross classified with question 5 (asking if a person would try a BOS service), it was noted that as commute time increased, the probability of a person trying the bus increased. Figure 8 shows this trend.

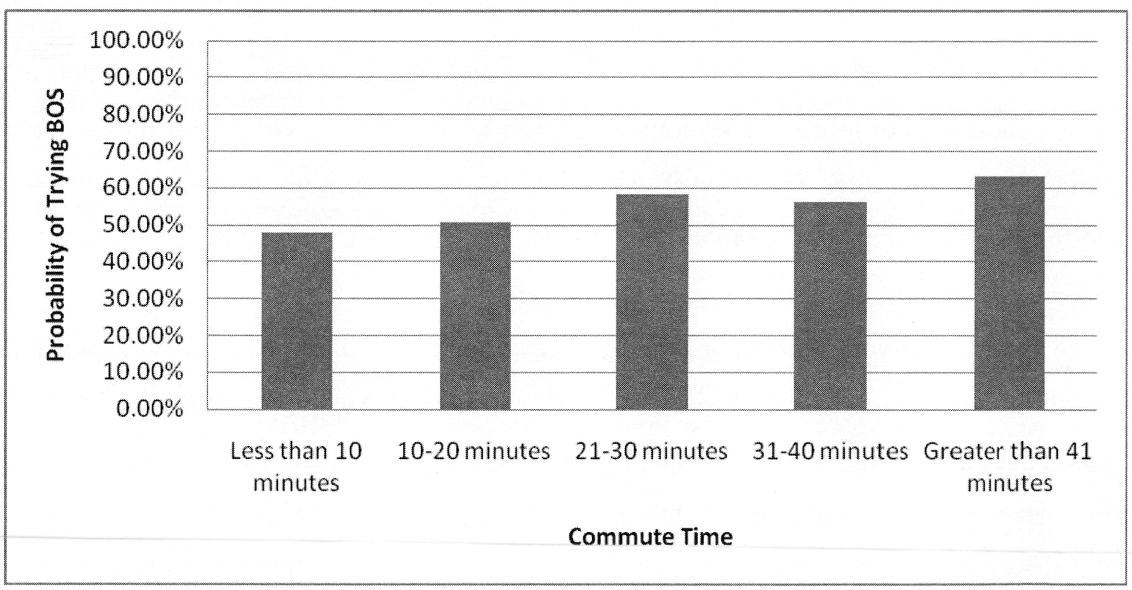

Figure 8: Probability of a driver trying the bus for a range of commute times

5.4 PERCENT OF COMMUTE ON FREEWAY

Question 3 asked about the perceived percentage of time the respondent typically spends in congestion during their morning commute. There were four possible responses: three percentage brackets (0-33%, 33%-66%, 66%-100%) and an option for drivers who do not use any of the three major freeways in Austin. Figure 9 is a bar chart which shows the probability that a driver will try a BOS service for each percentage bracket. Figure 9, along with The Chi Squared Test performed on these responses, determined that there is no correlation between the percentage of time spent on a freeway and a driver's willingness to switch to BOS. Therefore, when targeting persons to try BOS, it is necessary to target a wide range of potential riders. Targeting freeway commuters, as well as drivers on arterials and collectors, is necessary.

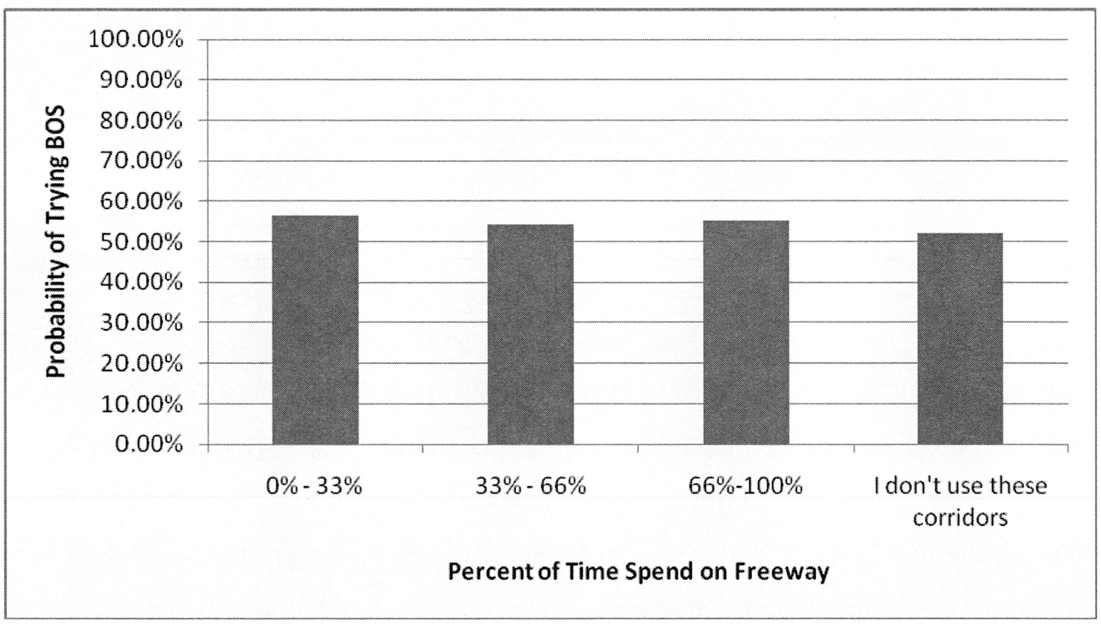

Figure 9: Probability of a driver trying the bus for a range of percent time spend on major Austin freeways

5.5 PERCENT OF COMMUTE IN CONGESTION

Question 4 addressed the amount of time a driver spent in congestion. The multiple choice question had three possible answers. The answers were percentage brackets that represented the perceived percentage of a person's total trip spent in congestion. Like typical travel time, this is a perceived value. Traveler definitions of congestion vary as well as their perceptions of the durations of congested travel. Figure 10 shows the probably of a driver trying a BOS transit service with respect to their time spent in congestion.

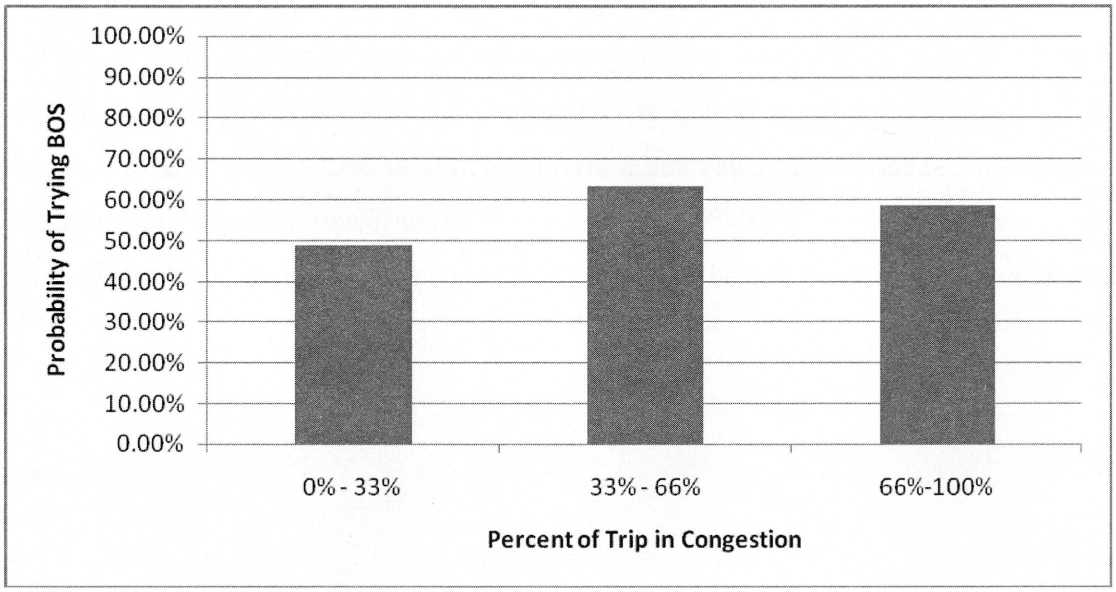

Figure 10: Probability of a driver trying BOS Transit with respect to congestion

Figure 7 indicates that drivers who perceive that more than 33% of their trip is spent in congestion are more likely to try transit than drivers who perceive congestion at less than 33%. A Chi Squared Test was also preformed on the responses to question 4 in relation to question 5 (asking if a person would try BOS). The Chi Square Test showed a strong association between willingness to try transit and time spent in congestion at a 10% level of significance.

5.6 SIGNIFICANCE OF RELIABILITY

Question 6, 7 and 8 are all linked in determining the importance of reliability. Question 6 asked whether a person's employer allowed flexibility in their arrival time. If their employer did not allow flexibility, they were asked how much extra time the respondent adds to their trip to ensure they get to work on time. Question 8 asked if an increase in reliably would entice a person to switch modes. The goal of these questions was to determine not only the importance of reliability, but also a measure of how much reliability-based time savings would be required to entice the respondent to try the service. Question 8 asked if a person would switch to BOS knowing it would increase their commute reliability, 44% said yes and 56% said no. These results coupled with the results from question 6 and 7 indicate that reliability is not a major factor for the typical commuter's mode choice.

While reliability does not appear to be a major factor for the typical commuter, the responses to Question 7 show commuters who do require a larger "cushion" in their travel time would be more willing to try the service. Figure 11 shows the relationship between Question 7 and Question 8. It appears that commuters who add at least 10 minutes to their commute time would be willing to try a transit service if reliability was guaranteed.

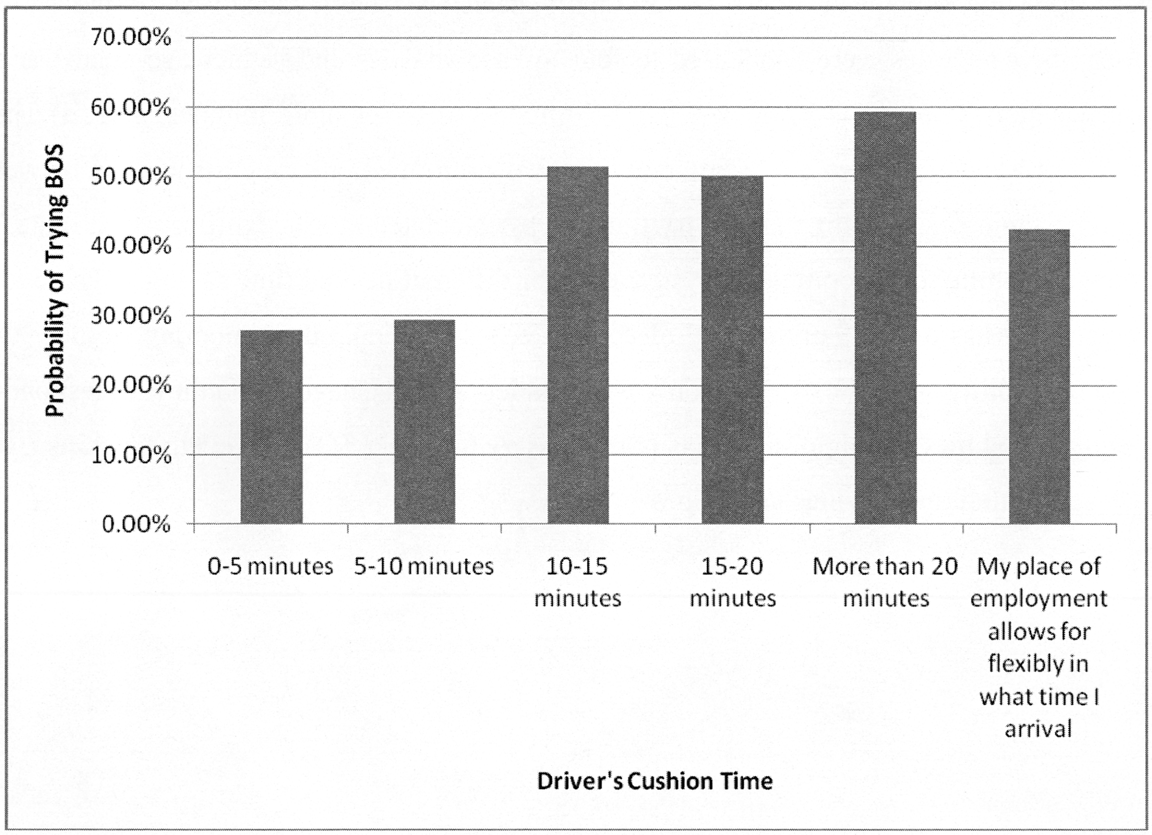

Figure 11: Probability of a driver with certain "cushion" times would try a bus because of reliability

A possible response error may have occurred for these three questions. In Question 6, 64% of responders said their employer allowed for flexibility in their arrival time, while in

Question 7, 58% of responders said their place of employment allowed for flexibility. Despite possible response error, the results still indicate that reliability is not a major factor for the typical commuter when making their travel choice.

5.7 Desired Time Savings

Question 9 asked what the desired time savings would be for the freeways section of a person's commute for them to consider trying a BOS service. The survey had 7 multiple choice answers, each representing a different range of minutes. The seven categories were (a) 0 minutes, (b) 1-3 minutes, (c) 3-5 minutes, (d) 5-7 minutes, (e) 7-10 minutes, (f) Greater than 10 minutes, (g) Time savings is not a factor in my decision. During analysis of the survey responses, the categories were condensed to four to ease analysis and to increase significance. The four categories are (a) 0-5 minutes, (b) 5-7 minutes, (c) 7 or more minutes, and (d) Time savings is not a factor. When a Chi Squared Test was preformed, a strong association between desired time savings and willingness to try transit was calculated at 5% significance. Figure 12 shows the probability of a commuter trying transit for different desired time savings. The 5 to 7 minute category has a 100% probability of commuter's switching. It is important to note that while the probability is 100%, there are only 5 responders in this category and they all responded yes. Figure 12 shows that time savings is not necessary to attract SOV drivers to try transit, but having a substantial time savings can help.

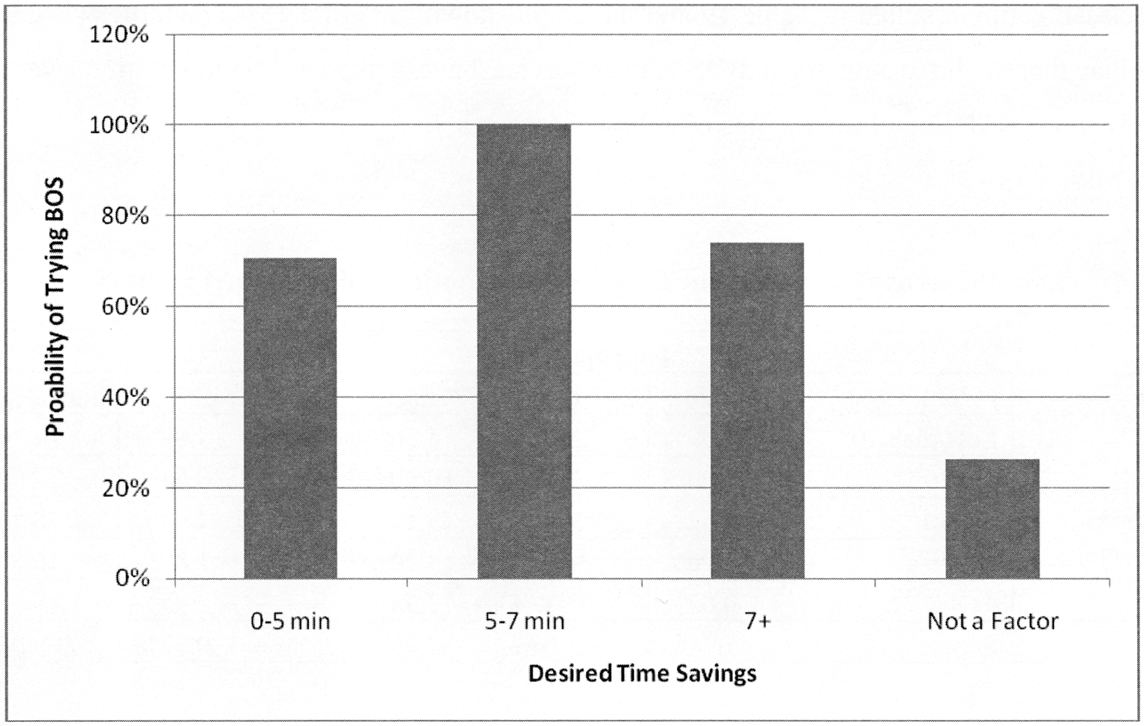

Figure 12: Probability of Switching to Transit for a Range of Desired Time Savings

5.8 CONCLUSIONS

The Austin-based stated preference survey illustrates that there are 3 deciding factors for enticing drivers to try transit: (1) the typical commute time, (2) the trip time percentage spent in congestion, and (3) the driver's desired time savings. Persons with longer commutes are more willing to try a BOS service. In addition, persons who spend a larger perceived percentage of time in traffic were more willing to try a BOS service. It was also observed that possible BOS service riders would like to see a time savings as a result of their switch from their personal vehicle.

While analyzing the data in the previous sections, there appeared to be a relationship between commute time and desired time savings for respondents who would be interested in trying BOS (answered "YES" to Question 5). Therefore, all the responses that chose "YES" for Question 5 were further analyzed.

To better understand the relationship between the responses for Question 2 (typical commute time) and Question 9 (desired time savings) the responses were cross classified. This cross classification resulted in Table 19 and the graph shown in Figure 13. The table and graph show that those who would try a BOS transit service have a typical commute time over 21 minutes and they desire a time savings of at least 7 minutes.

Table 19: Cross Classification Table for Respondents Willing to Try BOS

		Time Savings				
		0-5min	5 -7 min	7+ min	Not a Factor	Sum
Typical Commute Time	Less than 10	3.09%	2.47%	5.56%	3.09%	14.20%
	10+20	3.09%	2.47%	10.49%	8.64%	24.69%
	21+30	0.62%	3.70%	19.14%	4.94%	28.40%
	31+40	0.00%	0.62%	14.20%	1.85%	16.67%
	41 +	0.62%	0.00%	13.58%	1.85%	16.05%
	Sum	7.41%	9.26%	62.96%	20.37%	100.00%

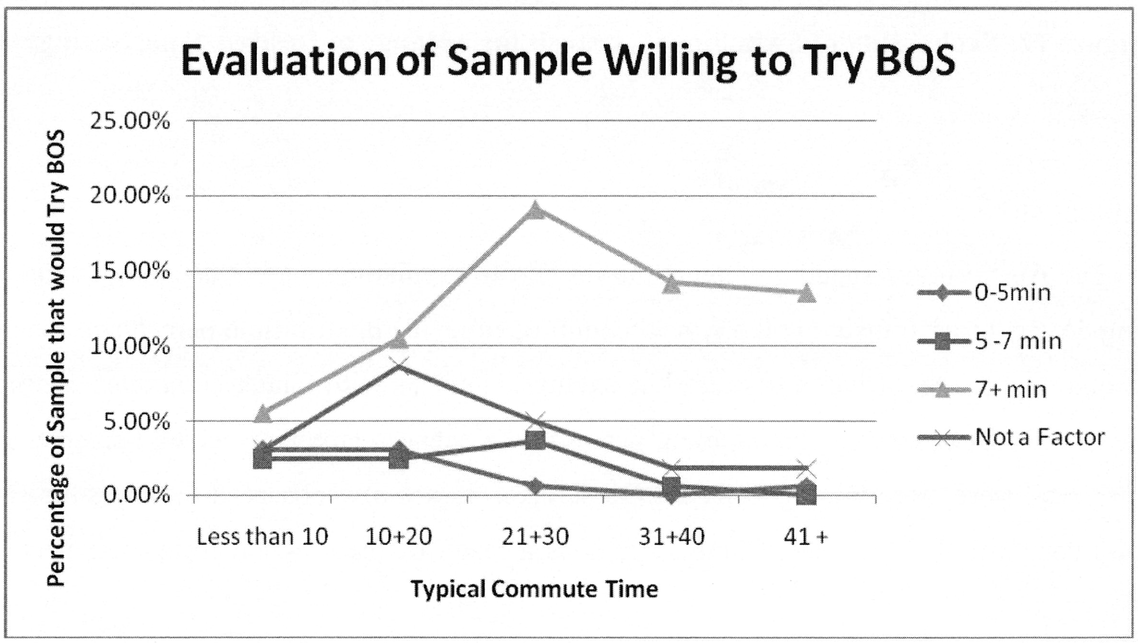

Figure 13: Cross Classification of Question 2 and 9 for Drivers Willing to Try Transit

Figure 13 depicts the characterization of Austin created from the survey. If a BOS service is to be successful in Austin, Capital Metro should target persons with commute times over 20 minutes and should ideally shoot for creating a 7 minute time savings. Capital Metro should also look at marketing toward persons who add a "cushion" time of more than 10 minutes to their commute. While people claim they want a time savings of 7 or more minutes, it is important to note that people cannot generally notice a time savings lower than a few minutes. Therefore, taking what was learned from the survey, and practically applying the results shows that commuters want to be able to *perceive* a timesaving if they are going to switch modes. The perceived time savings has been given a value of 7 or more minutes.

Chapter 6: Nationwide Stated Preference Survey

The Austin-based stated preference survey served two main purposes. The first and primary purpose was as a tool to understand the Austin driver and how they would receive a BOS option in the City of Austin. The second purpose was as a pilot project for a nationwide survey. Travel characteristics not only vary from region to region, but also from city to city. BOS is a cost effective and easy to implement solution for transit agencies which operates in congested cities. While the benefits of BOS have been well documented for Minneapolis-Saint Paul, and documentation has started for other cities with BOS, the benefits of BOS that can be experienced at a national level have yet to be determined. Creating a nationwide survey is an initial step toward considering BOS as a nationwide solution. As most transportation and transit agencies are facing budget shortfalls, BOS is a cost effective project that cannot only benefit current riders but help increase transit ridership and get single occupant vehicles off the road. The goal of the nationwide survey is to look for any possible nationwide or regional trends with relation to BOS. The survey can act as a tool to identify areas that would positively respond to a BOS service. The process of distributing and analyzing the Austin survey, along with feedback from respondents, allowed for determining which questions were effective and which questions were not. Creating and distributing the Austin survey not only helped characterize the commuters in Austin, but also allowed for the creation of a better nationwide survey. The survey platform, kwiksurveys.com, was used for the nationwide survey for two reasons; the first was because of the websites simplicity, and the second was due to the ease of analyzing the results in the output file.

The objectives for the nationwide survey were basically the same as the ones for the Austin survey: easy to distribute, short, easy to understand and answer for respondents and obtain a strong profile of the respondents. There was an additional objective to the nationwide survey, to obtain as much information as possible (within a strict question limit) from the respondent about where they live and their travel behavior. In Austin, this was much easier due to the fact that the survey was administered by Austinites to Austinites. This will not be the case to the nationwide survey; therefore, as much information as possible must be obtained about the travel characteristics of, not just the responder, but where the responder lives.

6.1 LESSONS LEARNED FROM AND IMPROVEMENTS TO AUSTIN SURVEY

Many lessons were learned from the Austin survey. The administration and analysis of the responses to the Austin survey allowed for a better understanding about how to gain information from the nation as a whole. This section will go over the main lessons learned from the Austin survey and how these lessons were applied to the nationwide survey.

In the Austin survey, the target audience was stated at the beginning of the survey. The Austin survey targeted single occupancy vehicle (SOV) drivers, but still allowed for respondents to answer the questions even if they used other modes. It was determined that a mode choice question should be included in the nationwide survey.

The perceived percentage of a person's total commute spent on freeways was asked in Question 3 in the Austin survey. The perceived percentage of time spent on the freeway had no correlation to a person's willingness to try BOS. It still seemed necessary to know if a person did use a freeway, and it was decided that any freeway-relevant question in the nationwide survey should be a binary. The freeway question in the nationwide survey (Question 5) only asks if a freeway is used.

In the Austin survey the question asking about a person's willingness to try BOS was Question 5. For the nationwide survey this question was moved to the end of the survey. A respondent should have all the necessary information about a BOS service prior to making a decision if they would be willing to try the service. Question 11 in the nationwide survey asked if a person would be willing to try a BOS service, knowing that it would increase reliability and possibly travel time.

As mentioned in section 5.5, possible response error was experienced in the three questions which were used to determine the importance of reliability. It was determined that possible response error was not a result of the format of the questions. The questions were kept for the nationwide survey but a "skipping" option was used when creating the survey on kwiksurveys.com. As a result, persons who stated they did have flexibility in their work place arrival time would not be able to answer the question asking about what "cushion" time an individual added to their commute time to ensure an on time arrival at their place of employment. This skipping tool will hopefully remove any response error associated with the reliability questions.

Question 9 in the Austin survey asked: How much time would a bus need to save on the freeway section of its route for you to use transit in the morning commute? Prior to the question, a paragraph discussed the effects of access time (while not actually stating the term access time).

The wording of Question 9 (and the paragraph explaining access time) was slightly altered and included as Question 10 in the nationwide survey. The main change was that Question 10 asked how much of the total commute time a driver would like to save to switch modes. The process of a BOS bus bypassing slower traffic was emphasized.

Another change from the desired time savings question between the Austin and nationwide survey was the time brackets for each multiple choice answer. Most commuters think about their travel time in 5 minute increments. The new brackets were intentionally created so as to not be in the typical 5 minute increments. This was done to hopefully cause the respondent to think about their typical commute time more thoroughly and give a more thoughtful response to Question 10. The multiple choice answers for Question 10 are (a) 0-4 minutes, (b) 4-7 minutes, (c) 7-10 minutes, (d) 10-14 minutes, (e) Greater than 14 minutes, and (f) Time savings is not a factor in my decision.

Since 7 minutes was determined to be the minimum ideal time savings in the Austin based survey, it was intended to create brackets around a 7 minute threshold. This will allow for comparison between the Austin survey results and results that will be compiled later from the nationwide survey. Another change to the brackets of Question 10 was increasing the maximum time savings that could be desired to 14 minutes. An average estimate of time savings in typical conditions is 1 minute per mile; the Minnesota data analysis showed typical time savings ranged from 0.213 minutes per mile to 1.596 minutes per mile. The longest continuous section of BOS in Minnesota is 8.5 (Appendix A.1) and the data analysis in section 3.1 determined the most BOS miles a bus can travel during a morning commute is less than 11. The maximum bracket was based on these values. Furthermore, it was determined that a BOS bus having consistent time savings over 14 minutes (even 10 minutes) is not practical. If a time savings of 10 to 14 minutes consistently occurred during morning commutes, then the city should start looking at congestion management solutions and possibly HOV lanes.

6.2 ADDITIONS AND CHANGES TO CREATE A NATIONWIDE SURVEY

As previously stated, the goal of the nationwide survey is to get a national prospective of BOS and to determine regional trends, and further understand how BOS usage can be expanded nationally. To determine a person's location, Question 1 asks about which state a person lived in via a drop down menu. Question 2 allows for a person to type in their current city of residence. Respondents are asked to type in the city of their current mailing address. This information will be used to better understand a person's location, as well as gage the type and population of the city they live in, and whether they live in a suburban, urban or rural area, and the state of their current transit network.

Another change made from the Austin survey to the nationwide survey was to the multiple choice responses to the typical commute time question. An additional bracket was added that included commute times of 41 to 60 minutes. Commute times are often seen in this range all over the nation, and including this additional bracket was done to help improve the post survey analysis process. As previously mentioned, the nationwide survey asked about a person's current travel mode. The mode split varies vastly across the nation. The mode choice question serves two purposes. First, it acts as a check to see if the survey reached a sample that accurately depicts the national mindset. If the mode splits determined from the survey are similar to national and regional mode splits, that is a good sign to determine if the survey sample is good. Second, this question allows for filtering out people who do not drive SOVs. If a person did not answer option (a) Personal Vehicle, then they would be directed to the end of the survey. Therefore, the responses for question 5 through 11 will be by SOV drivers, the target population.

6.3 The Nationwide Survey

While the Austin-based survey was limited to less than 10 questions, there was no official limit for the nationwide survey. The aim was to keep the number of questions low. The survey contained a maximum of 11 questions. Respondents may only answer 4 questions if they are not SOV drivers. All 11 questions are summarized below in Table 20. The complete survey is included in Appendix B.3.

Table 20: State Preference Survey Questions

Nationwide Survey Questions
1. What state do you currently live in?
2. Please type in the space below the city you use as your mail address.
3. What is the time duration of your typical door to door one way work commute time (include parking, walking to and from your car, walking to and from your bus stop, etc)?
4. Which of the following travel mode do you typically use for your work commute?
5. Is any part of your commute trip spent using a freeway?
6. What percentage of your commute trip time do you spend in congestion?
7. Do you have flexibility in your work place arrival time?
8. How much earlier to do you leave home to ensure you are on time to work?
9. Knowing that taking a bus-on-shoulder option will guarantee you a consistent and dependable travel time in the morning; would you switch from driving to taking the bus?
10. How much of your total commute time would a bus using a freeway shoulder to bypass slow traffic need to save for you try the bus service?
11. Knowing that a bus service will use the shoulder of a freeway to not only improve travel time but also to increase reliability, would you be willing to try this bus service/

Questions 1, 2 and 3 are used to determine where the respondent lives and their travel characteristics. Question 4 asks which mode a person uses for their typical work commute. A respondent is only allowed to continue the survey if they state that they use a personal vehicle for their typical morning work commute; if they walk, use transit, or any other mode, they will be directed to the end of the survey.

Question 5 asks if a person uses the freeway. Question 6 asks about perceived congestion levels. Questions 7, 8, and 9 are asked to determine the importance of reliability and any time savings desired with respect to reliability. As previously mentioned, if a person answers "YES" to Question 7, he/she will skip Question 8 and go directly to Question 9. Question 10 asks about desired time savings while Question 11 asks if the respondent would be willing to try BOS.

6.4 Conclusion and Future

At the time of this report submission, the survey was online and awaiting responses. There are currently over 200 responses, but this number is intended to grow substantially. At the closing of the survey, a sample that gives a good national wide perspective of BOS will be obtained. The responses will be analyzed to determine the national perspective of BOS.

Chapter 7: Conclusions

While creating reliable, statistically significant, multi-variable or single-variable prediction models with the historical Twin Cities data was not possible, a lot was learned about the effects BOS has on transit ridership. In most cases, there is a clear indication of ridership increase after BOS implementation. The plot of route 464 in Figure 4 shows how BOS can instantly affect monthly ridership. The lack of statistically significant relationships shows that predicating human behavior is very difficult. While time savings, average speed and the time in which speeds are below 35 mph can be calculated based on empirical data, the average commuter likely responds only to *perceptions* of these values.

The data indicates, with 90% confidence, that ridership will increase by at least 4.5% and as much as 14.3%. There is a 71% chance of ridership increasing as a result of BOS implementation; and if there is a positive change in ridership it will be an average increase of 17%. Creating a forecasting model based on people's perceptions has been shown to be challenging. It appears that people will be willing to switch to BOS because of the *perceived* benefits, not the actual benefits.

The Miami analysis also stressed the impact that external factors, such as service cuts, have on ridership, and also showed the BOS can be a success by doing more than just increasing ridership. BOS is considered a success in Miami despite not having an increased ridership for all routes. Reliability and better service also constitute success for a system.

Ridership and revenue increase calculations were preformed in Chapter 4 for the Austin transit system. MoPac SB was the corridor that would benefit most from BOS implementation. After BOS implementation, ridership and revenue would increase most (in comparison to all four test corridors) on the MoPac SB test corridor. Despite the fact that shuttle ridership is free, MoPac SB buses still draw the most revenue and BOS implementation could generate revenue between $50,000 and $164,000. US-183 SB ranks second in revenue creation due to BOS. This is most likely because all routes on this corridor are express routes which charge $1.50 per ride. There is no doubt that the readership increase predicted in Chapter 3 can have very advantageous effects on fare box revenue.

The Austin community was characterized in the created stated preference survey. If a BOS service is to be successful in Austin, Capital Metro should target persons with commute times over 20 minutes and should ideally shoot for creating a 7 minute time savings. While people claim they want a time savings of 7 or more minutes, it is important to note that people cannot generally notice a time savings lower than a few minutes. Therefore, taking what was learned from the survey and practically applying the results shows that commuters want to be able to *perceive* a time savings if they are going to switch modes.

At the time of this report, the nationwide survey was online and awaiting responses. There are currently over 200 responses, but this number is intended to grow substantially. At the closing of the survey, a sample that gives a good national wide perspective of BOS will be obtained. The responses will be analyzed to determine the national perspective of BOS.

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Appendices

Appendix A.1: BOS Development Timeline

Roadway	From	To	Miles	Opened	Closed	Miles closed
T.H. 252	I-694	Hwy. 610	3.5	1992		
T.H. 252	Hwy. 610	I-694	3.3	1992		
T.H. 47	37th Ave. NE	85th Ave. NE	6.4	1992		
T.H. 47	85th Ave. NE	37th Ave. NE	6.6	1992		
T.H. 61	70th St.	21st St.	1.4	1992	2002	1.39
T.H. 61	21st St.	12th St.	0.9	1992	2002	0.89
I-94 4th St. exit	Plymouth Ave.	4th Ave. N.	1.0	1992		
I-94 3rd St ramp	7th Ave. N.	26th Ave. N.	1.3	1992		
CSAH 15	Henn. Co. drive	CSAH 51	0.3	1993		
T.H. 77	I-35E	Old Shakopee Rd.	4.9	1993		
T.H. 77	Old Shakopee Rd.	T.H. 13	2.1	1993		
T.H. 77	66th St.	T.H. 62	0.9	1994		
T.H. 100	Duluth St.	36th Ave. N.	1.4	1994	2002	1.4
Coon Rapids Blvd.	Avocet St.	Yucca St.	4.0	1994		
Coon Rapids Blvd.	Yucca St.	Avocet St.	4.0	1994		
T.H. 100	Excelsior Blvd.	T.H. 7	0.5	1994		
I-394	W of Xenia	E of T.H. 100	0.9	1994		
I-94	E of Snelling	W of Snelling	0.5	1994		
T.H. 61(segments)	I-494	Burns Ave.	1.2	1994	2003 (partial)	0.6
T.H. 61(segments)	Burns Ave.	I-494	1.2	1994	2003 (partial)	0.6
Cedar Ave	138th St.	140th St	0.3	1995		
Cedar Ave	140th St	138th St.	0.3	1995		
Cliff Road	I-35E	T.H. 77	0.7	1995		
I-694	Brooklyn Blvd.	Weaver Lake Rd.	6.9	1995	2005 (partial)	0.85
I-694	Hemlock Lane	Brooklyn Blvd.	4.2	1995		
I-35E	T.H. 110	T.H. 13	1.3	1995		
T.H. 5	Market Blvd.	Fuller	3.1	1995		
T.H. 5	Fuller	Market Blvd.	2.8	1995		
I-94	Hemlock bridge	Hemlock ramp	0.3	1996		
T.H. 36	I-35E	I-35W	4.1	1996		
T.H. 36	I-35W	I-35E	4.4	1996		
I-35W	26th St.	Lake St.	0.4	1996		
I-35W	35th St.	60th St.	3.3	1996		
I-35W	66th St.	76th St.	0.9	1996		
I-35W	57th St.	44th St.	1.4	1996		
I-35W	76th St.	66th St.	0.9	1996		
I-35E	TH 36	Cayuga Bridge	2.0	1997		
I-35E	Cayuga Bridge	TH 36	2.0	1997		
I-35W	CR C	I-694	3.2	1997		
I-35W	I-694	CR C	3.2	1997		
I-494	TH 169	Bush Lake Road	1.6	1997		
I-494	Bush Lake Road	TH 212	3.2	1997		
TH 77	73rd Street	66th Street	0.7	1997		
I-94	under Shingle Creek Pkwy.		0.4	1997		
TH 36	Edgerton	I-35E	0.6	1998		
I-35W	TH 280	8th St. SE	3.1	1998		
I-35W	8th St. SE	Stinson Blvd.	0.9	1998		
TH 169	TH 55	36th Ave. N.	2.6	1998		
TH 169	36th Ave. N.	TH 55	2.3	1998		
West River Road	Mill Pond	TH 169	0.2	1998		
I-35W	CR I	I-694	2.8	1999		
I-35W	I-694	CR I	3.1	1999		
I-94	Mounds Blvd.	6th St. on-ramp	0.6	1999		
I-94	TH 61	McKnight Road	2.1	1999		
I-94	McKnight Road	TH 61	2.8	1999		
TH 65	89th Ave. NE	85th Ave. NE	0.6	1999		
TH 61	south of Burns Ave.	Burns Ave.	0.5	1999		
I-94	Western Ave.	Cedar Ave.	5.8	2000		
I-94	Cedar Ave.	John Ireland Blvd.	7.2	2000		
TH 36	West of 35E	I-694	6.9	2000		
TH 36	I-694	West of I-35E	6.4	2000		
TH 100	Minnehaha Creek	Excelsior Blvd.	1.3	2000		

TH 100	Benton Blvd.	Minnehaha Creek	1.3	2001		
I-35E	TH 36	I-694	1.4	2001		
I-35E	Little Canada Rd.	TH 36	1.1	2001		
I-35E	West of Kellogg	Randolph	2.2	2001		
I-35E	South of Randolph	Grand	2.4	2001		
I-35W	Franklin Ave.	26th Street	0.5	2001		
TH 10	south of Foley Blvd.	Thurston Ave.	8.5	2001		
TH 10	Thurston Ave.	south of Foley Blvd.	8.4	2001		
TH 7	Shady Oak Road	west of TH 169	1.3	2001		
TH 7	west of TH 169	Shady Oak Road	1.3	2001		
I-394	Linden Ave.	HOV lane entrance	0.3	2002		
I-694	Main Street	Mississippi River	0.5	2002		
I-35W	Co. Road I	95th Ave.	2.5	2002		
I-35W	95th Ave.	Co. Road I	2.2	2002		
TH 169	I-494	TH 55	8.0	2002		
TH 169	36th Ave. N.	Between 63rd & I-694	3.5	2002		
TH 169	Between 63rd & I-694	36th Ave. N.	3.9	2002		
TH 169	TH 55	I-494	8.1	2002		
I-94	John Ireland Blvd.	Western Ave.	0.5	2002		
I-94	Co. Rd. 30	Weaver Lake Road	1.4	2003		
I-94	Weaver Lake Road	Co. Rd. 30	1.7	2003		
TH 51	Hoyt Ave.	Co. Rd. B	1.1	2003		
TH 51	Co. Rd. B	Hoyt Ave.	1.1	2003		
I-94	Dowling Ave.	I-694	3.4	2003		
TH 77	138th St.	I-35E	2.1	2003		
TH 77	Old Shakopee	73rd St.	1.9	2003		
TH 77	I-494	Old Shakopee	1.6	2003		
TH 77	TH 13	I-35E	2.4	2003		
I-35W/Hwy. 36	Stinson Blvd.	Cleveland Ave.	2.1	2004		
I-35E	I-694	Hwy. 96	1.8	2004		
I-35E	Hwy. 96	I-694	1.8	2004		
I-94	Hwy. 52	Mounds Blvd.	0.86	2004		
TH 10	Thurston Ave.	Armstrong	3.1	2005		
TH 10	Armstrong	Thurston Ave.	2.9	2005		
TH 51	Como	Pierce Butler	0.53	2005		
TH 51	Pierce Butler	Como	0.53	2005		
Hwy. 10	Thurston	Armstrong	3.1	2005		
Hwy. 10	Armstrong	Thurston	2.9	2005		
Hwy. 62	Hwy. 77	Portland	1.01	2005		
Hwy. 62	Portland	Hwy. 77	1.01	2005		
I-94	Shingle Creek Pkwy.	7th Street exit	6.0	2005		
Hwy. 62	Penn Hwy. 212	Hwy. 212	4.77	2005		
Hwy. 62	Hwy. 212	Penn	4.7	2005		
I-494	Hwy. 5	Hwy. 169	2	2005		
I-94	McKnight Road	Century Ave.	0.92	2005		
I-94	Century Ave.	McKnight Road	1.3	**2006**		

APPENDIX A.2: SUMMARY TABLE FOR MN ANALYSIS

Identification Information			*Y*			*X*					
Route	**Year**	**Sections**	**Before**	**After**	**Percent Difference**	**First?**	**Length**	**Years from Previous**	**Average Min/Day speed below 35mph**	**Average speed when below 35mph**	**Average Time Savings when speed below 35(min/mile)**
135	2001	MTA/MVD	66,157	79,837	20.68%	0	0.5	5	35.96	27.46	0.470
250	2004	MTE	368,014	474,355	28.90%	0	4.3	4	55.13	17.64	1.564
270	1998	MTC, MTD	157,029	253,455	61.41%	0	4	1	19.72	24.32	0.752
270	2004	MTE	261,993	270,719	3.33%	0	6.1	7	55.13	17.64	1.564
440	2003	MVL, MVQ	18,244	13,647	-25.20%	1	3.5	0	32.75	18.32	1.475
442	2003	MVL,MVQ,MVN	64,481	62,002	-3.84%	0	12.9	10	25.63	18.42	1.462
444	2003	MVL, MVQ	116,609	133,464	14.45%	0	3.5	10	32.75	18.32	1.475
445	2003	MVL, MVQ	68,320	70,203	2.76%	0	10.5	10	32.75	18.32	1.475
460	1996	MVE,MVF, MVG, MVH, MVI	206,748	240,911	16.52%	1	6.9	0	67.88	21.25	1.109
464	1996	MVE,MVF, MVG, MVH, MVI	30,439	30,844	1.33%	1	6.9	0	67.88	21.25	1.109
470	1994	MVS	101,881	121,353	19.11%	1	0.9	0	26.39	26.04	0.590
470	1996	MVE,MVF, MVI	121,353	129,329	6.57%	0	6	2	92.97	20.73	1.181
470	1997	MVR	119,752	150,274	25.49%	0	6.7	3	27.29	23.23	0.868
470	2001	MTA/MVD	162,148	142,522	-12.10%	0	7.2	7	35.96	27.46	0.470
470	2005	MVJ, MVK	151,912	146,618	-3.48%	0	9.22	11	56.74	23.39	0.851
472	1994	MVS	131,519	137,866	4.83%	0	0.9	1	26.39	26.04	0.590
472	1996	MVE, MVF, MVI	137,866	132,893	-3.61%	0	6	3	92.97	20.73	1.181
472	1997	MVR	140,715	129,490	-7.98%	0	6.7	4	27.29	23.23	0.868
472	2001	MTA/MVD	93,162	122,378	31.36%	0	7.2	8	35.96	27.46	0.470
472	2003	MVN, MVL	122,378	102,802	-16.00%	0	10.9	10	27.90	19.04	1.389
472	2005	MVJ, MVK	102,802	102,950	0.14%	0	12.92	12	56.74	23.39	0.851
476	2001	MTA/MVD	113,469	106,733	-5.94%	0	0.5	8	35.96	27.46	0.470
476	2003	MVL, MVN, MVQ	106,733	113,766	6.59%	0	6.4	10	25.63	18.42	1.462
476	2005	MVJ, MVK	113,766	141,573	24.44%	0	8.42	12	56.74	23.39	0.851
477	1993	MVM,MVP	139,661	187,528	34.27%	1	7	0	19.95	31.12	0.213
477	1994	MVS	161,729	202,823	25.41%	0	7.9	1	26.39	26.04	0.590
477	1996	MVE, MVF, MVI	202,823	236,910	16.81%	0	13	3	92.97	20.73	1.181
477	1997	MVR	219,086	244,476	11.59%	0	13.7	4	27.29	23.23	0.868
477	2003	MVL, MVO, MVQ,	309,804	342,015	10.40%	0	19.3	10	37.92	17.41	1.596
477	2005	MVJ,MVK	342,015	365,036	6.73%	0	21.32	12	56.74	23.39	0.851
480	2001	MVC, MVA	35,533	42,056	18.36%	0	5.9	6	36.43	19.77	1.310
484	2001	MVC, MVA	37,749	35,074	-7.09%	0	4.6	6	36.43	19.77	1.309

APPENDIX B.1: STATED PREFERENCE SURVEY FOR AUSTIN, TEXAS

Bus-on-ShoulderSurvey

This survey is targeted at persons who commute during the morning by personal vehicle.

Many Austinites use freeways during their morning commute. Most of these freeways are plagued with congestion during these times. Speeds during the morning are often below 10 miles per hour. Traffic on these corridors can add not only considerable time to a person's commute trip but also stress. Traffic on these corridors is variable with some days adding even more time to a person's commute.

The option of allowing buses to start using freeway shoulders like bus bypass lanes is being considered. A bus would be able to use the shoulder to bypass congestion on Austin's freeways. A bus using a shoulder will be able to move faster than personal vehicles and will allow for bus riders to save on their commute time. It will also add reliability to a commuter's trip since the bus's travel time will no longer be directly affected by any variability in traffic.

1. Do you currently drive alone and use Loop 1 (MoPac), IH-35 or US183 during the AM (7:00-9:00AM) traffic peak period?
    a. Yes
    b. No

2. How long is your typical door to door commute time (include parking, walking to and from your car, etc) ?
    a. Less than 10 minutes
    b. 10-20 minutes
    c. 21-30 minutes
    d. 31-40 minutes
    e. Greater than 41 minutes

3. What percentage of your trip is spent using Loop 1 (MoPac), IH-35 or US183?
    a. 0%-33%
    b. 33%-66%
    c. 66%-100%
    d. I don't use these corridors

4. What percentage of your trip do you spend in congestion?
    a. 0%-33%
    b. 33%-66%
    c. 66%-100%

5. Would you try a transit service knowing it will be able to use a shoulder to bypass congestion on the freeway?
   a. *Yes*
   b. *No*

For Questions 6-8

Congestion on Austin's Freeways is variable. The bus' ability to use the shoulder will allow for increased reliability in bus service. Using the bus for morning commute will allow for a consistent commute time.

6. Do you have any flexibility in what time you arrive at your place of employment?
   a. Yes, my employer allows for flexibility in my arrival time
   b. No, I have to be at work at a specific time

7. If your place of employment does not allow for flexibility in your arrival time, how much earlier do you leave home to ensure you are on time to work?
   a. 0-5 minutes
   b. 5-10 minutes
   c. 10-15 minutes
   d. 15-20 minutes
   e. More than 20 minutes
   f. My place of employment allows for flexibility in what time I arrive

8. Knowing that taking a bus-on-shoulder option will guarantee you a consistent travel time in the morning, would you switch from driving to taking the bus?
   a. Yes
   b. No

Most commuter bus routes in Austin travel from "Park and Rides" to Central Austin (University of Texas campus, The Capital, and Downtown). Switching to transit may require time to travel from home to the bus route and then from a bus stop to your destination. While there may be added time at the beginning and end of your trip, the time spent in congestion will be less.

9. How much time would a bus need to save on the freeway section of its route for you to use transit in the morning commute?
   a. 0 minutes
   b. 1-3 minutes
   c. 3-5 minutes
   d. 5-7 minutes
   e. 7-10 minutes
   f. Greater than 10 minutes

APPENDIX B.2: AUSTIN-BASED SURVEY RESULTS

1. Do you currently drive alone and use Loop 1 (MoPac), IH-35 or US183 during the AM (7:00-9:00AM) traffic peak period?		
Yes	186	63.05%
No	109	36.95%
Summation	295	100.00%

2. How long is your typical door to door commute time (include parking, walking to and from your car, etc) ?		
Less than 10 minutes	48	16.27%
10-20 minutes	79	26.78%
21-30 minutes	79	26.78%
31-40 minutes	48	16.27%
Greater than 41 minutes	41	13.90%
Summation	295	100.00%

3. What percentage of your trip is spent using Loop 1 (MoPac), IH-35 or US183?		
0% - 33%	83	28.14%
33% - 66%	59	20.00%
66%-100%	105	35.59%
I don't use these corridors	48	16.27%
Summation	295	100.00%

4. What percentage of your trip do you spend in congestion?		
0% - 33%	159	53.90%
33% - 66%	90	30.51%
66%-100%	46	15.59%
Summation	295	100.00%

5. Would you try a transit service knowing it will be able to use a shoulder to bypass congestion on the freeway?		
Yes	162	54.92%
No	133	45.08%
Summation	295	100.00%

6. Do you have any flexibility in what time you arrive at your place of employment?		
Yes, my employer allows for flexibly in my arrival time	188	63.73%
No, I have to be at work at a specific time	107	36.27%
Summation	295	100.00%

7. If your place of employment does not allow for flexibility in your arrival time, how much earlier do you leave home to ensure you are on time at work?		
0-5 minutes	25	8.47%
5-10 minutes	17	5.76%
10-15 minutes	33	11.19%
15-20 minutes	16	5.42%
More than 20 minutes	32	10.85%
My place of employment allows for flexibly in what time I arrive	172	58.31%
Summation	295	100.00%

8. Knowing that taking a bus-on-shoulder option will guarantee you a consistent travel time in the morning, would you switch from driving to taking the bus?		
Yes	129	43.73%
No	166	56.27%
Summation	295	100.00%

9. How much time would a bus need to save on the freeway section of its route for you to use transit in the morning commute?		
0 minutes	8	2.71%
1 -3 minutes	6	2.03%
3-5 minutes	3	1.02%
5-7 minutes	15	5.08%
7-10 minutes	37	12.54%
Greater than 10 minutes	101	34.24%
Time savings is not a factor in my decision	125	42.37%
Summation	295	100.00%

APPENDIX B.3: NATIONWIDE STATED PREFERENCE SURVEY

Bus-on-Shoulder Survey

Many U.S. freeways are plagued by congestion, most often during peak morning and evening rush hours. During heavy traffic times, speeds can drop below 10 miles per hour. Slow speeds and heavy congestion can add not only considerable time to a person's commute trip but also stress. For some freeways, the speed will always be very low, but on other freeways congestion can vary day to day. Variable congestion results in a lack of reliability during a driver's commute.

The option of allowing buses to operate on freeway shoulders as a bus bypass lane has started to occur in a few cities nationwide. Minneapolis started this system in 1992 with great success. Since then other cities such as San Diego, CA, Miami, FL, Cincinnati and Cleveland OH have also started using shoulders to allow buses to avoid congestion on freeways. A Bus-on-Shoulder (BOS) lane would allow for a bus to safely bypass slow traffic on congested freeways. A bus using a shoulder will be able to move faster than personal vehicles and will allow for bus riders to reduce their commute time. It will also add reliability to a bus rider's trip, since the bus's travel time will be less affected by slow traffic.

This survey will ask a maximum of 11 questions in reference to your morning commute to work. The goal of this survey is to gain an understanding of how BOS lanes will be received nationwide.

1) Which state do you currently live in?

   Drop down menu of 50 states and territories

2) Please type into the space below the city you use as your mailing address:

3) What is the time duration of your typical door to door one way work commute time (include parking, walking to and from your car, walking to and from your bus stop, etc)?
   a. Less than 10 minutes
   b. 10-20 minutes
   c. 21-30 minutes
   d. 31-40 minutes
   e. 41- 60 minutes
   f. Greater than 60 minutes

4) Which of the following travel mode do you typically use for your work commute?
   a. Personal vehicle (including car-pool and van-pool)
      [Proceed to Question 5]
   b. Walk or Bike (or other human powered modes)

[Proceed to End of Survey]

c. Bus Transit

[Proceed to End of Survey]

d. Rail Transit

[Proceed to End of Survey]

e. Other

[Proceed to End of Survey]

5) Is any part of your commute trip spent using a freeway?
   a. Yes
   b. No

6) What percentage of your commute trip time do you spend in congestion?
   a. 0%-33%
   b. 33%-66%
   c. 66%-100%

For Questions 7, 8 and 9

Congestion on freeways often varies from day to day. The bus' ability to use the shoulder will allow for increased reliability in bus service. Using the bus for the morning commute will allow for a consistent commute time every morning.

7) Do you have flexibility in your work place arrival time?
   a. Yes, my employer allows for flexibility in my arrival time

      [Proceed to Question 9]

   b. No, I have to be at work at a specific time

      [Proceed to Question 8]

8) How much earlier to do you leave home to ensure you are on time at work?
   a. 0-5 minutes
   b. 5-10 minutes
   c. 10-15 minutes
   d. 15-20 minutes
   e. More than 20 minutes

9) Knowing that taking a bus-on-shoulder option will guarantee you a consistent and dependable travel time in the morning; would you switch from driving to taking the bus?
   a. Yes
   b. No

Along with reliability, bus time savings is a key benefit that results from a bus using the freeway shoulder. However, using a bus service usually requires additional time to travel to and from the bus. This access time can include walking or biking to a nearby bus stop or driving to a "Park and Ride" facility.

Taking into account a bus's travel time including the access time, please answer Questions 10 and 11.

10) How much of your total commute time would a bus using a freeway shoulder to bypass slow traffic need to save for you try the bus service?
    a. 0 -4 minutes
    b. 4-7 minutes
    c. 7-10 minutes
    d. 10-14 minutes
    e. Greater than 14 minutes
    f. Times savings is not a factor in my decision

11) Knowing that a bus service will use the shoulder of a freeway to not only improve travel time, but also to increase reliability, would you be willing to try this bus service?
    a. Yes
    b. No