Bus on Shoulder: Local Assessment of Shoulder Transit Lane
for Regional Buses in San Luis Obispo County

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Abstract

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The study looks at the applicability of integrating a Bus Only Shoulder (BOS) into the intermittently congested segment of US 101 in southern San Luis Obispo County. Policy, infrastructure and implementing criteria derived from case studies in Minnesota, Florida and California (San Diego) and the 2007 California Decision Document on BOS are applied to conditions in the region. One measure of performance, time savings, is projected to 2025 to determine the value of integrating the program by that horizon year. Given the substantial potential for time savings in that future year, recommendations are made to create the appropriate policy and infrastructure environment for the program.

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Shoulder Transit Lane Evaluation, Executive Summary

Introduction

This report looks at the current applications of Bus on Shoulder (also called Bus Only Shoulder, Bus Bypass Lane, or Shoulder Transit Lane) around the United States and the applicability of a similar project in the San Luis Obispo Region.

Bus Rapid Transit, as a complete system can increase bus efficiency and ridership. Fully integrated Bus Rapid Transit systems function well in larger metropolitan areas and Central Business Districts that can support 8 to 10 minutes headways during peak hour. Currently, San Luis Obispo County population is 263,824; with 44,439 of residents living in the City of SLO (2007 DOF). 2006 Employment Development Department statistics estimate the County labor force at 134,000; with 27,000 in the City of SLO. This data indicates there is not a large enough population or employment base to support a fully integrated Bus Rapid Transit system. However, one of the benefits of Bus Rapid Transit is the ability to add components incrementally. A segregated running way is a component of BRT that can increase bus speed over general traffic speed; it can also raise the visibility of the bus as a transportation option. Bus on Shoulder could be applicable to the San Luis Obispo region particularly because of the long-haul nature of the regional transit system. The study segment analyzed for this report is a 12 mile section of Highway 101 where the bus doesn't leave the roadway.

Regional Traffic Model suggests Level of Service F between SLO and Five Cities well before 2025. Bus on Shoulder is one strategy that should be explored to increase

overall system efficiency, reduce greenhouse gas emissions, and keep mass transit moving through the segment.

Criteria Development

Case studies identify several criteria for determining whether a segment should operate a bus on the shoulder. These criteria include region-wide policies and roadway infrastructure. Implementing procedures are also established through case study research. The following chart shows implementing procedures, policies, and infrastructure criteria that were applied to the study segment.

Table ES-1: Bus On Shoulder Criteria for Application

Policy	Infrastructure	Implementing
<ul style="list-style-type: none"> • Regional Transportation Plan • Long Range Transit Plan • Express Bus Stop Study • Corridor and Major Improvement studies • Legislation 	<ul style="list-style-type: none"> • Shoulder Width • Total Roadway Width • Outside and Inside Shoulder Width • Shoulder Depth or Structural Section • Shoulder Grade (Cross Slope) • Drainage • Frequency of Entry/Exit Ramps 	<ul style="list-style-type: none"> • Average Daily Traffic • Level of Service • Bus Frequency and On-Time Performance • Person Time Savings • Daily Vehicle Hours of Delay • Ridership and Capacity • Potential Time Savings

Findings

Policy Criteria

1. All policy documents reviewed support intermodal and multi-modal use of facilities.

2. The 1997 Major Improvement Study for the segment recommends Transportation Demand Management techniques, as does the 2005 (and prior years) Regional Transportation Plan.
3. The 1998 Express Bus Stop Study, 2005 Long Range Transit Plan, and a 2006 SLOCOG staff report recommend moving toward a regional express bus system where local services pulse with a regional long-haul bus line, the type of service that is perfect for a segregated running way.
4. California Vehicle Code prohibits the use of shoulders as traversable lanes. Caltrans June, 2008 Decision Document recommends supporting legislation to modify code to allow buses upon approval by the Department of Transportation.

Infrastructure Criteria

1. Existing shoulder width is insufficient in most parts of the segment, 10-12 foot shoulders would be required. In the segment of interest, most inside shoulders are 2 feet, most outside shoulders are 8.
2. Shoulder structural section may be insufficient. An in-depth study (consisting of core sample tests) would need to be conducted to determine if existing shoulder could carry significant weight for short intervals. Cross slope and drainage would need to be evaluated at that time as well.
3. Frequency of on/off ramps in the segment is not more than the Florida Special Lane Use study recommends.

Implementing Criteria

1. Policy would follow San Diego policy which informed the policies outlined in the Caltrans Decision Document
2. For the study segment, Peak Hour Volume and Peak Month Volume are higher than Average Annual Daily Traffic by a larger margin than the rest of the region
3. Level of Service and Congestion are higher in this segment than other parts of the region and are projected to become more so in the next 20 years. FREQ analysis from 2005 shows congestion (with speeds below 35 mph) is between 4:45 and 5:15 pm, for approximately 2 miles. FREQ projections show 2025 time and place of congestion between 3:45 pm and 7:00 pm for the entire length of the segment and from 3-8 pm at the south end.
4. Potential time savings of operating a shoulder transit lane on the corridor will save approximately 84.7 hours per day during PM Peak bus runs.

Recommendations:

Policy recommendations:

1. SLOCOG could add transit shoulder lane (bus on shoulder) option to SLOCOG's 2009 Regional Transportation Plan for implementation over the plan's 20 year time horizon, and include a permanent bus lane as an unconstrained project (Caltrans Decision Document no. 1)
2. SLOCOG could Support legislation to allow shoulder use for bus on shoulder (Current) with possible use of study segment for Pilot Project.
3. SLOCOG could add transit shoulder lane (BOS) option to the Long Range Transit Plan (Date not specified)

Infrastructure recommendations:

1. SLOCOG could conduct a study in greater detail on the corridor and identify existing segments that would require widening, leveling of cross slope, structural section, etc. (Caltrans Decision Document nos. 7, 8, 9, 12, 14)
2. Caltrans could upgrade shoulder section to carry weight of a bus during regular State Highway Operation and Protection Program (SHOPP) projects (Caltrans Decision Document nos. 7, 8, 9, 12, 14)
3. SLOCOG could program State Transportation Improvement Program (STIP) funds on Caltrans SHOPP projects on a percentage basis to improve shoulder infrastructure (Caltrans Decision Document nos. 7, 8, 9, 12, 14)
4. SLOCOG could program STIP funds for emergency pull-outs, striping, and signage (CT decision document nos. 10, 11)

Implementing recommendations

1. RTA could install Automatic Vehicle Locators (AVL) on buses to track on time performance as it relates to congestion on the corridor. This would assist in determining the locations at which the most time savings could be acquired (CT decision document nos. 3, 4)
2. RTA could install technologies that would track all rider on/off's to determine most popular routes, which would also assist in determining the locations at which the most time savings could be acquired. (CT decision document nos. 3, 4)
3. RTA could include Express Bus Concept in Short Range Transit Plan (CT decision document no. 5)

Shoulder Transit Lanes in the San Luis Obispo Region

1.0 Bus Rapid Transit and Shoulder Lanes

This report examines the current applications of Bus on Shoulder (also called Bus Only Shoulder, Bus Bypass Lane, or Shoulder Transit Lane) around the United States and the applicability of a similar project in south San Luis Obispo County. The report includes operating procedures established from case studies and Caltrans documents, an evaluation of supporting policies, and the existing infrastructure conditions of a study segment in the region. Regional Traffic Model suggests LOS D-F along this segment of the corridor in 2025 (depending on build scenario). Shoulder Transit Lanes is one strategy that should be explored to keep mass transit moving.

Because of the relative newness of Bus on Shoulder programs, there are not yet nationally recognized or consistent criteria for determining the appropriate location for Bus on Shoulder nor are there consistent standards for application and use. The forthcoming Transit Cooperative Research Program (TCRP) Report, *A Guide for Implementing Bus on Shoulder Programs* will:

“(1) identify conditions under which shoulders can be used for bus travel, including design and operational criteria; (2) identify the advantages and disadvantages and the cost/benefit potential of BOS operations programs; and (3) identify procedures and strategies that may be used by various

stakeholders (such as state and local transportation and transit agencies) to successfully implement a BOS project.” (TCRP D-13, Active Research).

Running a bus on the shoulder of a highway or freeway is an example of a segregated running way. Segregated running ways are one method that is used to prioritize buses in general traffic. It is part of a subset of tools within the Bus Rapid Transit (BRT) toolbox. Discussion of transit shoulder lanes or Bus on Shoulder has to include discussion of Bus Rapid Transit, because the goal of both is to raise the visibility and attractiveness of public transit.

TCRP Report 90 defines Bus Rapid Transit as “...a flexible rubber-tired rapid-transit mode that combines stations, vehicles, services, running ways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image. BRT applications are designed to be appropriate to the market they serve and their physical surroundings, and can be incrementally implemented in a variety of environments” (Levinson, 2003). Features of Bus Rapid Transit mimic those of light rail in order to attract choice riders. The benefit of BRT over light rail is that features can be added incrementally to reduce large capital costs to transit agencies and jurisdictions. However, BRT is most successful when implemented as a “fully integrated system” (Levinson, 2003).

Bus Rapid Transit is most effective in urban areas with a high level of established transit ridership. According to TCRP Report 90, only 3 BRT systems in the United

States are located in urbanized areas with less than 1 million residents. Those urbanized areas are Honolulu, Hawaii with .9 million, Hartford, Connecticut with .8 million; and Eugene, Oregon with .2 million. Additionally, the report concludes that BRT is most successful when the urban population exceeds 750,000 and employment in the central business district (CBD) is between 50,000 and 75,000. Service frequencies should be at least 8 to 10 minutes during peak periods and 12 to 15 minutes during off-peak periods to facilitate random passenger arrivals. Currently, San Luis Obispo County population is 263,824; with 44,439 of residents living in the City of SLO (2007 DOF). 2006 Employment Development Department statistics estimate the County labor force at 134,000; with 27,000 in the City of SLO. This data indicates there is not a large enough population or employment base to support a fully integrated Bus Rapid Transit system. However, one of the benefits of Bus Rapid Transit is the ability to add components incrementally. A segregated running way is a component that can increase bus speed over general traffic speed; it can also raise the visibility of the bus as a transportation option. Bus on Shoulder is applicable to the San Luis Obispo region particularly because of the long-haul nature of the regional transit system. The study segment analyzed for this report is a 12 mile section of Highway 101 where the bus doesn't leave the roadway.

Features of BRT are intended to increase travel speed of buses as well as provide amenities. Because buses are subject to several types of delay, operating speeds are generally only 60 percent of that of other vehicles (FTA,

n.d.). Some BRT features listed below are intended to increase bus speed, mimic Light Rail features, or attract riders based on comfort and convenience. Many do some combination of all three. Table 1.1 shows a list of BRT elements, including how transit shoulder lanes fit into the BRT menu of options.

Table 1.1: Components of Bus Rapid Transit

Stations and Stops	<ul style="list-style-type: none"> • Weather resistant • Convenient • Easily accessible by all modes (car, bike, walking, etc) • Accessible by Low-Floor Buses • Consistent in design for brand identity • Fare Collection facilities
Vehicles	<ul style="list-style-type: none"> • Low Floor Buses for fast boarding • Multi-door boarding (in conjunction with Electronic Fare Media) • Clean and Quiet vehicle technology (CNG or Hybrid) • Vehicle branding with logo and color scheme for identity
Intelligent Transportation Services	<ul style="list-style-type: none"> • Automatic Vehicle Locators • Signal Preemption • Real-Time Passenger Information • Electronic Fare Media
Marketing	<ul style="list-style-type: none"> • Branding with recognizable logo and name • Way-finding signs at stops and stations • Differentiate from regular system
Running Ways	<ul style="list-style-type: none"> • Segregated running ways keep buses out of traffic • Markings on lane can be used to differentiate General Purpose Lanes from Bus-Only Lanes • Lateral Guidance can be used to direct buses where lanes are narrow • Bus on shoulder

2.0 Bus on Shoulder Case Studies

Bus on Shoulders (or shoulder transit lanes) are used in several parts of the country. TCRP Synthesis 64: Bus Use of Shoulders, identifies fourteen locations (nine in the United States) where buses are operating on the shoulder of highways. Because there isn't an established set of criteria or circumstances that would allow or require buses to use shoulders for bypassing congestion, the report provides case studies of the existing projects. For the San Luis Obispo Region report, three case studies were reviewed and criteria established for evaluating the local study segment. The case studies are Minneapolis-Twin Cities, Minnesota; Miami-Dade, Florida; and San Diego, California. Appendices A, B, and C show the criteria and case studies in a table format. These three case studies were chosen for particular characteristics: the Minnesota Bus only Shoulder is the longest operating project in the country; the Florida project began with a Special Use Lane study (which informed the parameters of this study); and the San Diego study will determine how to operate project in California (which will apply to a project in this region).

2.1 Minneapolis-Twin Cities, Minnesota

Minneapolis-Twin Cities, Minnesota has been operating Bus on Shoulders for 16 years. In 1991 a short segment was established and in 1992 it was expanded to include other areas. Since that time the program has grown to 230 miles of Bus on Shoulder lanes serving 400 buses on 14 routes. A team was formed to establish other locations that may benefit from Bus on Shoulder lanes. The team was made of representatives from Metro Transit, bus operators, MnDOT,

Minnesota State Patrol and Metro Council of Governments. Additionally MnDOT established a key contact person to advocate for Bus on Shoulder programs in the state. After the first 5 years, MNDOT has assumed financial responsibility for shoulder upgrades along with regularly scheduled upgrades of general purpose lanes. Minnesota State Patrol reports or cites transit vehicles that violate the shoulder lane policy, but have chosen not to be involved with the planning team because operations have been deemed safe.

Policy

Operating guidelines for BOS were established by Team Transit (see stakeholders, above) and were approved by the Federal Highway Administration. Policies and implementing procedures have been added to Minnesota State Law: 169.306 Use of Shoulders by Buses. Minnesota Road Design Manual states, “The decision to allow shoulder use by buses should be considered during the planning phase of construction or reconstruction projects on roadways that do not have bus shoulders” (June 2008).

Infrastructure

Shoulder upgrades are worked into the general lane rehabilitation/upgrade, MdDot pays for it as part of regular upgrade. The following is a list of design criteria for the project:

- Design speed: 35 mph
- Shoulder width: 10 minimum
- Bridge shoulder width: 11.5

- Grade: match existing roadway
- Inslopes: 1:6
- Structural Capacity: must be approved by MNDot District Materials Engineer prior to use.
- Horizontal and vertical alignment: must match existing roadway
- Stopping sight distance: 250 ft
- Cross slope: .02-.05

Implementing

- Bus drivers maintain speeds no higher than 35 mph.
- Driver training happens in classroom and are reviewed annually.
- Drivers can choose to or not to use shoulder lane when traffic drops below 35 mph.
- Trip reliability has been cited as a key benefit of the BOS service.
- MnDOT pays for removal of vehicles in shoulder lane.
- Approximately 20 accidents are reported per year (equivalent to less than one accident per mile per year average), primarily sideswipes and damaged mirrors.
- Signs are located at the beginning and end of BOS lanes and at on-ramps. There are also intermittent signs through the duration of the lane.
- Stakeholders include Mn/DOT, Metro Transit, drivers and supervisors, Minnesota State Patrol, Center for Transportation Studies

2.2 Miami-Dade, Florida

Miami-Dade Transit began operating a bus on the shoulder of the two expressways in the region in March of 2007. Prior to the implementation of the Bus on Shoulder, Miami-Dade MPO commissioned a study to look at where special use lanes could/should be considered on roadways in the region.

Policy

The Special Use Lane study includes proposed legislation for the state of Florida. At the time of the report, Florida vehicle code did not permit the use of shoulders for transit, however the project, when implemented, was considered a “demonstration project” which allowed it to function on the shoulder. If/when the demonstration proves successful, legislation will be proposed to the State.

Transport 2030, The Miami-Dade MPO Long Range Transportation Plan (equivalent to the Regional Transportation Plan in California) emphasizes improving the public transportation system and incorporating High Occupancy Vehicle (HOV) lanes and reversible flow lanes along major expressways.

Miami-Dade also has a voter approved Public Transportation Plan that contributes a ½ cent sales tax to transportation projects, this plan calls for the implementation of an additional 2.5 million miles of service, including express routes.

Infrastructure

According to TCRP Synthesis 64, the Miami, Florida infrastructure requirements for the use of the shoulder include:

- 10-12 foot shoulders depending on the amount of road traffic in the corridor
- 2%-6% cross slope
- Color markings to differentiate regular shoulders from bus use shoulders.
- Special Use Lane Study recommends 1,250-2,500 feet between entry/exit of shoulder, existing distance in study is between .4 miles and 2.7 miles between ingress/egress.

Implementing

The Special Use Lanes study, conducted by The Corradino Group in November 2005 was the second phase of a study that looked at improving express bus service in the Miami-Dade region. The Special Use Lane study identified several sections of roadway, and determined whether the shoulder could be used for congestion by-pass. The report also recommended the following:

- Buses use shoulder only when mainline speed drops below 25 mph and “while operating on the shoulders the buses cannot exceed 35 mph nor operate more than 15 mph above the speeds on the mainline of the freeway” (Corradino Group, 2005).
- The report also indicated the average daily vehicle travel in the study areas ranges between 42,100 and 183,636, although it did not give a recommended capacity.
- The Special Use Lane study does show 3 year accident history for each corridor under study, however it does not create or determine an accident history threshold that would prohibit the use of the shoulder for transit. It

does say a high rate of accidents on the ramps could be a potential problem for transit operations (Corradino Group, 2005).

- Signs for the demonstration areas are at the start and end of the Bus on Shoulder, they are also placed intermittently throughout the length of the Bus on Shoulder.
- Stakeholders include Miami-Dade MPO, Office of the County Manager, Miami-Dade Transit, Miami-Dade Expressway Authority, Florida Department of Transportation, Turnpike Express.

2.3 San Diego, California

The San Diego Bus on Shoulder has been in operation since November 2005. The program operates on State Route 52 and Interstate 805 for approximately 5 miles. Both sections of highway shoulders are at least 10 feet wide in the area using Bus on Shoulder. The program was intended to be a two year pilot program, though it is still operating as a pilot as of 2008.

Policy

San Diego Association of Governments has in their Regional Transportation Plan, the addition of Managed and HOV lanes throughout the region. The Bus on Shoulder program is seen as a temporary solution until these facilities are built. The California Vehicle Code does not allow the shoulders to be used as traversable lanes. Because of this, shoulders had to be posted as full time transit lanes and “would not be available for emergency, maintenance, or enforcement

activities during any part of the day” (SANDAG 2005). California Department of Transportation has proposed changing legislation (see below).

Infrastructure

- The areas for the San Diego Bus on Shoulder were chosen primarily for the pre-existing width of the shoulder. All Buses on Shoulder operate on 10-12 foot shoulders.
- Some restriping was done to meet this minimum, so in some areas, general purpose lane width is 11 feet instead of the standard 12.
- Cross Slope and shoulder depth are not identified for the roadway sections, but the shoulder surface is being monitored for degradation.
- In order to deal with drainage issues, the bus drivers are instructed not to use shoulders during rain.

Implementing

Several implementing procedures were identified for driving on the shoulder. These same criteria are in the June 2008 Caltrans Decision Document On-time performance of buses was not a criterion in determining which sections of highway to use for BOS. Nor were time and place of congestion. Both sections with BOS were identified as having heavy peak hour congestion. San Diego Association of Governments was more interested in establishing Bus on Shoulder in areas where capital costs would be minimal for implementation.

Safety: As of April 2008 there is no report on the successes/failures of the project in San Diego. For increasing safety, drivers are instructed not to drive more than

10 miles per hour faster than the mainline traffic and are not to use the shoulder unless mainline traffic speeds drop below 25 miles per hour. Bus drivers were also given training for using the shoulder. Signage is limited to “Transit Only” stencils painted on the shoulder to indicate the use. Stakeholder groups during the planning phase included San Diego Council of Governments, California Department of Transportation (Caltrans), Metropolitan Transportation Services (MTS), and California Highway Patrol (CHP).

2.4 Caltrans Decision Document

This document was issued on June 16, 2008 regarding shoulder use for buses and recommends supporting pursuit of legislation to modify Vehicle Code to allow use of shoulder for transit under specific conditions (criteria).

Caltrans (as owner/operator of the State Highway System) could include shoulder upgrades as part of the SHOPP (State Highway Operation and Protection Program). As owner/operator, Caltrans can impose criteria and request that the MPO (in this case SLOCOG) secure funding to assist with implementation. Having the State Department on board is crucial for implementation of Bus On Shoulder.

The following are criteria included in the document that would be required by the department to allow the use of buses on shoulders. This report addresses many of the criteria shown. SLOCOG notes are shown below each criterion.

1. Permanent lane to carry buses is planned and is a regional priority

- a. (SLOCOG can address this lane in the 2008 Regional Transportation Plan, including it as an alternative)
- 2. Permanent lane is funded
 - a. (this is unrealistic for our region)
- 3. Ridership need
 - a. (RTA is reporting significant ridership increases. It is unclear in the decision document what would constitute ridership need. Additional buses would be required when buses reach capacity on a particular run) (On time performance does affect ridership, on time performance is compromised when traffic congestion is high. Bypassing traffic would improve on time performance which will positively impact ridership)
- 4. Significant travel time savings
 - a. see section 3.3.4, pages 47
- 5. Multimodal connectivity
 - a. (RTA buses (particularly route 10 in the segment of interest) are moving toward regional “express bus” with longer segments between stops and transfer points to local routes at Park and Ride lots that contain both car and bike facilities)
- 6. Other alternatives are not feasible
 - a. (This would vary by part of the region. For the segment of interest it isn’t feasible to operate the bus on the frontage road because when congestion increases on the freeway, cars use the frontage road,

which increases congestion on local roads and would affect bus on-time performance)

7. Structural section is adequate for carrying buses

- a. (Structural section is unknown at this time. Further analysis of shoulder would be required before implementation) (future SHOPP projects could include building shoulders with adequate structural section)

8. Drainage is addressed

- a. (Drainage concerns are unknown at this time. Future SHOPP projects could include modification of drains to allow for bus use)

9. Shoulder pavement width is sufficient

- a. (Shoulder pavement is insufficient in most sections at this time. Future SHOPP projects could include building shoulders with adequate width)

10. Enforcement/maintenance/emergency pull outs are provided

- a. (Pull outs are not currently provided, future SHOPP projects could include pull outs)

11. Signing and striping are adequate

- a. (At the time of implementation, signing and striping could be adequate)

12. Grade breaks and super elevation issues are addressed

- a. (Grade breaks and super elevation could be addressed through SHOPP)

13. Lateral obstructions in the clear recovery zone are eliminated or shielded

- a. (As much as possible, lateral obstructions should be avoided, 12 foot shoulders in these sections are required)

14. Guardrail and dike modifications are addressed

- a. (modification to guardrails will happen prior to implementation. 12 foot shoulders are required where lateral obstructions occur)

Caltrans identified the following risks associated with operating a bus on the shoulder:

1. Increased potential for tort liability
2. Use of shoulder for disabled vehicle or other emergencies is eliminated
3. Conflict with emergency vehicles that may need to use shoulder
4. Buses may encroach into lane where there are adjacent obstacles
5. Differential speeds may cause an increase in collisions
6. Other vehicles may follow the buses on the shoulder
7. Added vehicle loading may reduce the life of the pavement on the shoulder
8. Cross slope on the existing shoulder is normally different than adjacent lane
9. Clear and unambiguous signing will need to be established

3.0 Local Application: San Luis Obispo Region

The San Luis Obispo region is located along the central coast of California approximately half way between the San Francisco Bay Area and Los Angeles. The county is largely rural. It occupies 2.1 million acres (SLOCOG 2004) and has about 263,824 residents (2007 DOF).

- 80% of the population lives within small urbanized areas (North County, Central Area, and the South County, which is part of the Santa Maria UZA in Northern Santa Barbara County)
- 20% live in rural areas (2000 Census).

As of Census 2000, the County has 2 urbanized areas: Atascadero-Paso Robles UA (population 54,762) and San Luis Obispo UA (population 53,498). It is expected that the 2010 Census will designate the South County region a Small Urbanized Area as well (South County Area Transit, Short Range Transit Plan 2004). The City of San Luis Obispo is the governmental and employment center for the region and most of the commute traffic is into San Luis Obispo in the mornings and away from San Luis Obispo in the afternoon/evenings.

3.0 General Description of the Study Area

Highway 101 in San Luis Obispo County is the primary thoroughfare between Monterey County to the north and Santa Barbara County to the south. Development in SLO County is primarily along this corridor in the cities and communities of Paso Robles, Templeton, Atascadero, San Luis Obispo, Shell Beach, Pismo Beach, Grover Beach, Arroyo Grande, and Nipomo. Highway 101 is a four lane commute corridor linking all the above communities with the county seat: the City of San Luis Obispo.

Level of service (2004) varies between LOS A and C, with the most congestion in the segment between San Luis Obispo and the coastal communities to the south (see Figure 3.1).

Figure 3.1 Level of Service on Highway 101 in San Luis Obispo County

The ten mile study segment along Hwy 101 connects the city of San Luis Obispo (pop: 44,679) with the communities of Shell Beach, Pismo Beach, Grover Beach, Oceano, and Arroyo Grande (also referred to as the Five Cities, pop: 65,000).

This segment was chosen not only for its higher congestion than other segments, but also because the bus functions as an “express” along this corridor, entering the highway at Los Osos Valley Road in San Luis Obispo and exiting at the 4th Street exit in Pismo Beach (see Figure 3.2). This segment has between 60,000 and 77,000 cars per day; peak hour volume is between 5,700 and 9,800; and peak month daily volume is between 63,000 and 89,000 cars.

Figure 3.2: Magnified View of Study Segment From Above Map

The following sections address the implementing, policy, and infrastructure criteria identified in the case studies and Caltrans Decision Document.

3.1 Policy Framework

The following regional and state policy documents lay the groundwork for an integrated transportation that supports all modes. Many of these documents also encourage land uses that reduce auto-dependence, especially single occupant vehicles.

3.1.1 1997 Major Improvement Study

A Route 101 Major Investment Study (MIS) was conducted by Kolve Engineering of San Jose, CA for SLOCOG in September 1997. This study looked at Highway 101 between the cities of San Luis Obispo and Arroyo Grande, which overlaps with the study segment. The MIS is “a way of addressing corridor improvements by focusing on the specific travel demands of the corridor, and through a comprehensive and interactive process, defining alternative solutions to improve mobility for the corridor.” (Kolve Engineering, 1997, ES-1). The MIS recommends: Expanding Transportation Demand Management (TDM), Creating a Development Corridor Plan that will inform the infrastructure improvements when LOS drops, Implementing a monitoring program to determine how well the TDM program is working. Over the long term, the MIS recommends adding auxiliary lanes, but states, “Widening to serve full, unconstrained demand is not recommended.”

3.1.2 1998 and subsequent Regional Transportation Plan (RTP)

The San Luis Obispo region supports an intermodal and multi-modal transportation approach promoting “better connection of our highway, transit,

bicycle/pedestrian, and road networks, to our homes, schools, work, shopping, and other activities” (SLOCOG, RTP, 2005). The RTP (currently being updated) promotes land uses that reduce private vehicle dependency and at the same time encourages system efficiency through Transportation Demand Management, Intelligent Transportation Systems and Systems Management. Each of these techniques is employed with shoulder transit lanes. For instance improving bus service and ridership is a form of TDM; ITS can determine when running ways should be used; and creating additional capacity (in the form of a transit shoulder lane is a form of Transportation Systems Management.

3.1.3 1998 Express Bus Stop Study

SLOCOG conducted an Express Bus Stop Study in August 1998. This study focused on express bus stop configuration at particular locations along Highway 101 (not limited to the study segment). A set of recommendations titled, “Future Efforts” identify actions that SLOCOG, RTA, Caltrans, and local transit providers can do to improve express bus service. The following are recommendations that could incorporate Bus Rapid Transit and/or shoulder transit lanes if an update to the Express Bus Stop Study were conducted (SLOCOG, Express Bus Stop Study, 1998):

1. SLOCOG, RTA, and Caltrans should work together to develop standards for express bus site design (sight distance, passenger loading, etc).
2. SLOCOG should continue to require that all applicable future interchange Project Study Reports (PSRs) and other applicable engineering studies in

- the Route 101 Corridor assess express bus stop configurations and recommend configuration improvements where suitable.
3. SLOCOG and RTA should recommend that local, regional, and Caltrans planning (short and long range) efforts consider potential express bus and Park and Ride connections.
 4. RTA should work with SLOCOG, local transit systems, and member jurisdictions to evaluate existing bus routing and suggest potential local and regional route changes to accommodate express bus service (along Highway 101).

3.1.4 2005 Long Range Transit Plan (LRTP)

One objective of the 2005 SLOCOG Long Range Transit Plan is to “work with Caltrans, the Regional Transit Authority (RTA) and local jurisdictions to plan and build freeway express stops and Park and Ride lots for commute and express services...” (SLOCOG, Long Range Transit Plan, 2005) The plan also encourages maximizing work trip service effectiveness by exploring “commute and express transit services and rideshare options to respond to the more predictable home-to-work trip patterns.” While neither of these statements applies specifically to using BRT or BOS, they both emphasize improving regional and work trip service, which benefit directly from using Bus Rapid Transit and Bus on Shoulder. Improving express bus service and feeder service is a first step toward Bus Rapid Transit. Using a transit shoulder lane can enhance the express bus service by improving reliability and visibility to motorists.

3.1.5 2006 SLOCOG Bus Rapid Transit Report

An April 2006 Staff Report titled Bus Rapid Transit Assessment recommends assessing Bus Rapid Transit again in ten years (2016) when San Luis Obispo population, population density and possibly bus ridership have increased. In addition to recommending updating the 1998 Express Bus Stop Study, the report also recommends the following:

“... incorporating express bus stops into future interchange Project Study Reports (PSRs) or other applicable engineering studies along the Route 101 Corridor...Widening Highway 101, while not a sought after alternative by many, may be unavoidable in the future. Designating the additional lane as High Occupancy Vehicle (HOV) only will better serve the express bus and carpooling commuting population. With the expansion of Highway 101, all interchanges should incorporate express bus stops and park and ride lots where necessitated to provide high visibility and accessibility for commuters.”

3.1.6 Community 2050: Regional Blueprint

The Community 2050 Regional Blueprint is a regional land use and transportation document that addresses growth in the region over the next 40 years. Objectives included in Community 2050 are to “improve mobility through a combination of strategies and investments to accommodate anticipated growth in transportation demand and reduction in current levels of congestion” and “reduce dependency on single-occupant vehicle trips, fostering neighborhood and project designs that enable more walking and bicycling for healthier communities.”

3.1.7 GO California, issued in January 2006, states the following:

The Governor's Strategic Growth Plan for transportation is designed to reduce congestion below today's levels while accommodating future transportation needs from growth in the population and the economy. This will be done by both deploying demand-management strategies, such as dedicated truck lanes and high occupancy toll lanes, and building new capacity to increase "throughput" in the system. It will enable more traffic to move through existing roadways, rehabilitate thousands of miles of roads, add new lanes, and increase public transportation ridership. *This effort will require innovation in transportation planning*, construction and management, sustained coordination among regional transportation agencies and the state, and dedicated funding.

Bus on Shoulder is an innovative way to "enable more traffic to move through existing roadways" and "increase public transportation ridership", with minimal capital improvement costs.

3.1.8 Transportation Concept Report (TCR) for Hwy 101 in Caltrans District 5 (2001) lists the following recommendations for the corridor:

- a) Implement ITS components from the Central Coast Deployment Plan
- b) Reduce demand by encouraging and improving alternative modes such as passenger rail, transit, vanpools and ridesharing.
- c) Facilitate goods movement with projects identified in the California Statewide Goods Movement Strategy
- d) Construct system-wide operational improvements.

- e) Ensure any improvements to the facility will accommodate a future 6-lane facility.
- f) Enhance intermodal facilities and services to improve interconnectivity.
- g) Convert expressway portion of Sub-segment 4A to freeway.
- h) Convert expressway portions of Sub-segment 6C to freeway.
- i) Widen Segments 4 and 5A to 6-lane freeway after above measures have been fully implemented and if level of service continues to deteriorate.

Bus on Shoulder addresses points (b) and (f) by improving and encouraging alternative modes and enhancing intermodal services for interconnectivity. The option also incorporates e and i, by establishing infrastructure for conversion to 6-lane freeway, when necessary.

3.1.9 Legislation

The California Vehicle Code (CVC) does not permit the use of highway shoulders to be used as traversable lanes; therefore the San Diego BOS is considered a pilot project. As previously mentioned Caltrans released a Decision Document in June 2006 that recommends supporting legislation that would allow the use of freeway shoulders for transit.

3.2 Infrastructure

Current infrastructure will determine what upgrades to the roadway will be needed to provide for a shoulder transit lane in the future. Types of infrastructure upgrades include re-striping or more complex shoulder engineering. Shoulder width, structural section, and frequency of entry/exit ramps will also inform whether the bus should run on the inside or outside shoulder. These issues are discussed in the following sections.

3.2.1 Shoulder Width

Based on the case studies and Caltrans Decision Document, the width of the shoulder should be a minimum of 10 feet, but preferably 12 feet. For the study segment Caltrans recommends a 12 foot shoulder. If it is not possible to get 12 foot shoulders, 10' will be allowed, unless there adjacent obstacles that makes the width feel too narrow for bus drivers. Figure 3.3 is an example of an adjacent natural obstruction that would suggest a 12 foot lane if possible.

Figure 3.3: HWY 101 South at Shell Beach

Figure 3.4 (below) shows adjacent concerns: the three-beam barrier and trees are both situations that may make bus drivers feel uncomfortable. Additional width (through widening or restriping) may be required.

Figure 3.4: HWY 101 South at Shell Beach

Figure 3.5 shows a location where widening would cause a cut into adjacent landscape, this would require further design consideration for wider shoulders by either retaining walls or shifting lanes for additional width.

Figure 3.5: Highway 101 South, North of San Luis Bay Drive

3.4.1.1 Total roadway width

The minimum width requirement for a Bus on Shoulder lane and two general purpose lanes is 36 feet. This width includes a 2-foot median, two 12-foot general purpose lanes, and a 10-foot Shoulder lane. For traversable lanes, Caltrans requires 12 feet and preferred BOS width is 12 feet, this will require a 38 foot roadway. Since the shoulder function will be lost if a bus is running on the shoulder, the Caltrans preferred situation will be to have 2 general purpose

lanes, 1 BOS and an 8 ft shoulder: this will be 42 feet or 44 feet (depending upon the width of the BOS) (see Table 3.1)

Table 3.1 Roadway Width Requirements	
36 feet	Two 12' General Purpose Lanes
	One 10' Bus on Shoulder
	One 2' Shoulder
38 feet	Two 12' General Purpose Lanes
	One 12' Bus on Shoulder
	One 2' Shoulder
42 feet	Two 12' General Purpose Lanes
	One 10' Bus on Shoulder
	One 8' Shoulder
44 feet	Two 12' General Purpose Lanes
	One 12' Bus on Shoulder
	One 8' Shoulder

Figure 3.6 below shows the overall width on the southbound roadway. As shown, the majority of the roadway width on the southbound directions would not meet the minimum width for two general purpose lanes, a two foot buffer, and one bus on the shoulder. In addition to width, other factors need to be addressed to determine whether a bus could operate on the shoulder, such as structural section and cross slope. The following sections look at inside and outside shoulder width to determine if either inside or outside shoulder width is enough to fit a bus.

Figure 3.6: Southbound Total Roadway Width

3.2.1.2 Outside shoulder

If the bus were to run on the outside shoulder it would need 10-12 feet lateral clearance. Figure 3.7 shows that the outside shoulder currently lacks the width necessary to run a bus. Most shoulders are 8 feet wide and a few sections have no shoulder.

Figure 3.7: Southbound Outside Shoulder Width

3.2.1.3 Inside shoulder

Overall currently striped widths are also too narrow to allow Bus on Shoulder (Figure 3.8). Southbound inside shoulder is generally 1-2 feet wide. Expanding the shoulder would be required to create enough room for a bus on the inside shoulder.

Figure 3.8: Southbound Inside Shoulder Width

3.2.2 Shoulder Depth or Structural Section

Shoulder depth takes into account axle-loading, subsurface conditions, pavement type, length of service of the structural section, and quality and strength of raw materials that go in to the pavement mix. For this segment of roadway, structural section is not consistently recorded. It is possible that structural section is inadequate to carry buses.

3.2.3 Shoulder grade (cross slope)

Shoulders slope may be up to 5% grade, and is generally 2% on new construction (HDM, 2004, p. 300-3). Information about shoulder grade on the location of interest is not currently available; it is assumed that the shoulder is 2% grade on inside shoulder and up to 5% on outside shoulder, per Highway Design Manual Guidelines.

3.2.4 Drainage

The removal of water from the roadbed is used to prevent hydroplaning. According to the Highway Design Manual, “situations that should be evaluated for hydroplaning potential include... Where re-striping projects will reduce shoulder widths where dike, curb or concrete barrier are present.” (HDM, 2004, p. 830-4). Field observations show this corridor using curb openings and grates for drainage, however, because re-striping would be required on all sections of shoulder in the corridor, potential for hydroplaning should be considered. Caltrans decision document prohibits drivers from using the shoulder during rain.

3.2.5 Frequency of Entry/Exit Ramps

While entry/exit ramp frequency isn't identified in all case studies, for the Case Study in Florida, The Special Use Lanes Study recommends 1,250-2,500 feet between entry/exit of shoulder. Figure 3.9 shows that the frequency of on and off ramps on the southbound freeway direction. This map shows all entrances and exits to the freeway. Map does not differentiate between freeway entrances and freeway exits, because the bus will have to cross traffic in either situation.

Figure 3.9: HWY 101 Entry/Exit Frequency

Figure 3.10 shows the Southern portion of the corridor more closely. None of the entry/exit ramps are closer than 1,250 (minimum recommended in Miami-Dade Special Use Lane Study).

Figure 3.10: Entry/Exit Frequency on Southern Segment

3.2.6 Upgrade Costs

Because both median and outside shoulders are insufficient to warrant operating a bus on the shoulder currently, upgrades would need to be made prior to operation of Bus on Shoulder. it is recommended that the median or outside shoulder be build to a width and structural section that can support the weight and width of a bus. The following is a breakdown of costs associated with upgrades, based on current structure (Minnesota DOT). As shown in the chart, the project is least expensive when installing only signage and striping. Costs

become higher with more extensive upgrades. If shoulder depth is sufficient (currently unknown for study segment), the cost to upgrade existing shoulder along with roadway overlay is \$12,000 per mile. Cost is considerably higher when not done in conjunction with roadway work.

Table 3.2: Shoulder Upgrade Cost Estimates

Condition	Costs plus signing and striping
Shoulder width and bituminous depth are adequate. Catch basins do not need adjustments.	\$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 based 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 new construction project	\$30,000 per mile for both freeway and expressway

The table 3.3 is a list of programmed projects along US 101 in the San Luis Obispo Region. These projects consist of additional lanes, which represent a higher cost per mile than the shoulder improvements shown above. These projects would include improvements to adjacent shoulder where necessary, but would be 2 ft or 8 ft as required by California State law.

Table 3.3: SLOCOG Programmed SHOPP Projects

Route	Project	Length ¹	Construction Cost	Fiscal Year	Cost per mile
US 101	Southbound Oak Park to Halycon Climbing Lane	.9 miles	\$16 M	Future Funds (2013)	\$17.7 M
US 101	Spyglass Dr to Shell Beach Rd Climbing Lane+ Avila Road Overcrossing reconfiguration	1.3 miles	\$8.2 M	FY 2007	\$6.3 M
US 101	Santa Maria River Bridge Widening	.5 miles	\$86 M ²	Future Funds (2014)	\$172 M
US 101	Grand to ___ and Pismo Beach Climbing lanes	1.5 miles	\$9.5 M	FY 2009	\$6.3 M

¹ length is approximate

² high cost due to bridge structure

3.3 Operating/Implementing Procedures of BOS

Several implementing functions that are used by other successful BOS programs will be incorporated into the local program if/when it is adopted. These operational features are identified by Caltrans in the June 2008 Decision Document. The following are implementing features that should be assumed.¹

1. Buses will travel in the transit-only lane created from the existing shoulder.
2. Buses are allowed to drive on the transit-only lanes when the mainline traffic speeds drop below 35 mph. If the shoulder is obstructed in any way, the bus driver will merge back into the main line to avoid the obstruction.
3. The speed differential cannot exceed 15 miles per hour between the buses and the mainline traffic.
4. The maximum speed of the buses will be 35 miles per hour.
5. The main hours of operation will be from 6:00 am to 9:00 am and from 3:00 pm to 6:00 pm. The transit-only lane, however, will be available for 24 hours per day, and bus drivers will be told they can use it anytime that speeds drop below 35 mph.
6. Bus drivers must yield to any vehicle that enters the transit-only lane as well as any vehicle merging or exiting an interchange.
7. Only bus drivers trained on the operational guidelines and requirements will be allowed to use the transit lane.
8. Buses will not be permitted to travel in the transit-only lane during periods of rain or when the potential for flooding is present.
9. Only transit buses will be permitted to use the transit-only lane.

¹ Additional or different implementing features may arise after the publication of TCRP D-13 Active Research.

10. An extensive public outreach program aimed to inform motorists and transit riders, prior to opening the transit-only lane, will be developed and implemented.

The above implementing procedures would be included if/when the program begins. The implementing criteria (discussed below) address the triggers and potential benefits of the Bus On Shoulder program. They are: Average Annual Daily Traffic (AADT), Level of Service and Congestion, On-Time Bus Performance, and Vehicle & Person Time Savings. Person time savings is derived from ridership on the route during congestion time and service elasticity due to time savings.

3.3.1 Average Annual Daily Vehicle Traffic

The local study segment has higher Average Annual Daily Traffic (AADT), as well as peak hour and peak month traffic than adjoining segments in the County of San Luis Obispo. The higher peak hour and peak month traffic may contribute to significant on-time bus performance issues and will lead to increase in time savings associated with operating a Bus on Shoulder. Figures 3.11-3.13 show higher traffic volumes by segment within the area of interest. The darker line segments are where a bus may be more likely to need the shoulder for congestion bypass purposes.

AADT is determined by dividing the total traffic volume for the year by 365 (days in the year).

Peak hour volume is the estimated number of cars per hour during the most congested time of a day. Peak hour volume is shown for both directions.

Peak Month ADT is average daily traffic for the heaviest month of flow. For the study segment this occurs during the summer.

Figure 3.11: Average Annual Daily Vehicle Traffic (2006)

Figure 3.12: Peak Hour Traffic (2006)

Figure 3.13: Peak Month Traffic (2006)

3.3.2 Level of Service and Congestion

This section of roadway has the lowest Level of Service (LOS) among corridors served by transit. Within the region, the segment of interest has a greater variation and lower LOS than other segments of Highway 101. In addition to peak

and non-peak variation, there is also a greater variation in average daily vehicle travel between peak month and non-peak month. The region-wide average difference is 6,873 vehicles per day. The difference along the segment of interest is 8,750. Congestion is worse during summer months and may cause delays during summer peak hours; seasonal delays such as this are not easily accommodated by bus schedules because the seasonal peak doesn't coincide with the schedule changes (schedule changes for RTA happen annually, not seasonally).

In 2005, Caltrans conducted a simulation of traffic flow along the Highway 101 southbound corridor between the Cities of San Luis Obispo and Santa Maria using FREQ. The study measured existing congestion in the corridor and mapped projected congestion for 2025. The “base case” for 2025 included the following improvements that were, at the time, expected to happen. The following is a list of upgrades assumed in the out year of the FREQ analysis and the status of the project.

Table 3.4: Projected Study Segment Improvements in FREQ Analysis

Project	Status	Funding
Prado Road Interchange	To be built with future developer funds	Not programmed
LOVR Interchange	0-5 year timeline	Programmed FY 12/13
Avila Climbing Lane	Complete	
Price Street Extension	Unknown timeline, political opposition	Not programmed
Oak Park to Halcyon Climbing Lane	5-10 year timeline	Not programmed
Halcyon to Grand Avenue Auxiliary Lane	Under construction	FY 09/10
El Campo Road Interchange	Unknown timeline	Not programmed
Willow Road Interchange	0-5 year timeline	Programmed FY 09/10

The existing congestion and forecasts are shown in Figures 3.14 and 3.15.

Figure 3.14 shows that traffic falls below 35 miles per hour between the hours of 4:45 pm and 5:15 pm and only between Spyglass Drive and the Highway 1 junction in Pismo Beach. At current levels, there is not enough congestion to warrant operating a bus on the shoulder.

Figure 3.15 shows congestion projections along the corridor for the year 2025, assuming that the above upgrades have been made to the corridor.

The figure shows congestion with traffic traveling an average of 35 miles per hour between the Los Osos Valley Road interchange in San Luis Obispo and Highway 1 junction in Pismo Beach solidly from 4:30 pm to 7:00 pm and the majority is below 35 mph from 3:30 to 7:45.

Figure 3.14: Congestion Along Hwy 101 Southbound, 2005

Figure 3.15: Congestion Along Hwy 101 Southbound, 2025

3.3.3 Bus Frequency and On-Time Performance

San Luis Obispo Regional Transit Authority (RTA) Route 10 runs southbound on this section of roadway 17 times on each weekday, including 4 times during morning peak (6-9 am) and 5 times during afternoon peak (3-6 pm²). The Northbound Route 10 runs 16 times per weekday with 4 runs during morning peak (6-9 am) and 4 runs during afternoon peak (4-6 pm). Table 3.5 shows the total bus runs and directions (See Appendix E for 2008 Route 10 timetable). The numbers in bold show the direction and travel time when congestion levels might warrant using the shoulder. These values represent the maximum runs per day that operate during the 4-6 pm peak. Figure 3.14 above shows that congestion isn't below 35 mph for much of the corridor currently, however as shown in Figure 3.15, congestion will increase and (based on ridership and bus frequency increase) it is likely that several more buses will be operating during peak hours in the future (see next section).

Table 3.5: Route 10 bus runs by direction			
	total	6-9 am	3-6 pm
Northbound	16	4	4
southbound	17	4	5

RTA fleet has no automated vehicle location system, thus only manual records collected by drivers and occasional field checks inform the time performance reports assembled by dispatch. RTA has recently streamlined recording mechanisms for on-time performance; this includes on-time performance by

² This is not representative of what would be considered "peak" in San Luis Obispo, it is derived from the Caltrans Operating procedures list.

month for all RTA routes and daily performance logs that include the route, direction, first late stop location, schedule time, minutes late, and reason. The monthly logs can be used to determine if increased congestion during peak months cause a decrease in on-time performance. The daily performance logs can determine which bus runs tend to be late. Once historical data has accrued, it will be possible to query the data to determine the extent of performance issues along the corridor.

3.3.4 Vehicle and Person Time Savings

The time savings for the bus, when operating on a shoulder during congestion, can be used to determine whether the program can improve overall person through-put in the corridor. Daily Vehicle Hours of Delay (recorded and produced by Caltrans for all districts in the state) indicate the region doesn't experience much delay overall, but that the study segment is the most congested in the region. The following factors are used to determine vehicle and person time savings:

1. Ridership projections
2. Percent of riders on peak hour runs
3. Distance of delay and travel time on corridor (based on FREQ shown in Figure 3.15)
4. Proportional time savings (based on maximum bus on shoulder speed over mainline speed)
5. Elasticity of demand based on proportional time savings
6. Increase in transit ridership based on proportional time savings

Ridership and Bus Capacity

RTA Route 10 (from San Luis Obispo to Santa Maria) has the fastest increasing ridership of all RTA routes. Total ridership on RTA routes increased on average 7% per year between Fiscal Year 1992/93 and Fiscal Year 08/09, whereas Route 10 ridership increased 16% per year during that time (factors include increased bus frequency and additional service on Saturdays and Sundays). This increase is nearly double that of the other RTA routes. Using SPSS Time Series Modeler, the upper limit forecast shows ridership projection on route 10.

Table 3.6: RTA Route 10 Ridership		
Year	projection (SPSS)	PM Peak Period riders
2009	14,034	2,807
2010	15,369	3,074
2011	16,590	3,318
2012	17,527	3,505
2013	18,319	3,664
2014	19,017	3,803
2015	19,649	3,930
2016	20,231	4,046
2017	20,772	4,154
2018	21,281	4,256
2019	21,763	4,353
2020	22,221	4,444
2021	22,659	4,532
2022	23,079	4,616
2023	23,484	4,697
2024	23,874	4,775
2025	24,251	4,850

RTA tracks bus ridership on all runs of the day. For Route 10, these runs include buses that leave the downtown transit center at 3:33, 4:33 pm, 5:15 pm

(express), 5:15 regular, 5:33 pm, and 6:33 pm. Based on data from RTA (table 3.7), 20% of all riders on route 10 are traveling southbound during the peak congestion time shown in figure 3.15 FREQ output for 2025.

Table 3.7: Ridership on the study segment during PM Peak Period			
Month-Year	total riders	southbound riders between 3:30 and 6:30 (PM Peak Period)	percent
August-07	9,635	1,938	20.1%
September-07	8,839	1,936	21.9%
October-07	11,430	2,496	21.8%
November-07	10,340	2,261	21.9%
December-07	8,073	1,642	20.3%
January-08	9,941	2,299	23.1%
February-08	10,774	2,122	19.7%
March-08	11,151	2,096	18.8%
April-08	12,682	2,474	19.5%
May-08	12,496	2,604	20.8%
June-08	13,738	2,906	21.2%
July-08	13,933	2,830	20.3%
August-08	15,639	3,455	22.1%
September-08	16,766	3,498	20.9%
October-09	18,985	3,853	20.3%
November-08	13,832	2,734	19.8%
December-08	12,458	2,244	18.0%
January-09	12,633	2,585	20.5%
February-09	12,751	2,552	20.0%
Overall	236,096	48,525	20.6%

Potential Time Savings

Potential Time Savings is addressed as both a vehicle unit and person unit.

Vehicle Time Savings

Based on the expected implementing procedures shown in section 3.3, the bus could be operating on the shoulder when mainline traffic drops below 35 miles per hour. Table 3.8 shows the speed differences that are possible within the operating constraints established by Caltrans. As mainline traffic speed slows, the time savings associated with riding the bus will increase.

Time savings shown in the table below refer to the maximum savings. For example, when mainline traffic slows to 25 miles per hour, the bus can travel between 26 and 35 miles per hour. The time savings would then vary between 1-10 miles per hour faster than mainline speeds. The table shows that as the mainline traffic slows, there is a greater time savings for the bus traveling on the shoulder. This is true even when the speed difference is capped at 15 miles per hour (per Caltrans: the bus will not be able to travel more than 15 mph faster than the mainline).

Table 3.8: Vehicle Time Savings as a Proportion of Overall travel time

Mainline Speed	Shoulder Transit Lane Speed	Maximum Speed Difference	Car Driving Time	Bus Driving Time	Time Savings	Proportional Time Savings
7.5 Mile Corridor			(length of corridor/speed) * 60 minutes		car driving time - bus driving time	(car driving time-bus driving time) / car driving time
> 35 mph	Not on shoulder	0				
35	35	0	12.9	12.9	No savings	0
30	35	5	15.0	12.9	2.1 minutes	0.14
25	35	10	18.0	12.9	5.1 minutes	0.29
20	35	15	22.5	12.9	9.6 minutes	0.43
15	30	15	30.0	15.0	15 minutes	0.50
10	25	15	45.0	18.0	27 minutes	0.60
5	20	15	90.0	22.5	67.5 minutes	0.75
0	15	15	n/a	30.0	(unrealistic)	n/a

Person Time Savings

Person time savings on each vehicle factors in bus ridership, car occupancy and the elasticity associated with the improved service.

Ridership Elasticity and the effect on person time savings

Table 3.8 shows total time savings of operating a bus on the shoulder based on the varying mainline speed. However it does not show any increase in ridership that may be associated with the provided time savings. “Service elasticities indicate how transit ridership is affected by transit service quality factors (e.g., availability, convenience, speed, and comfort).” (Litman, 2004) In the case of operating a bus on the shoulder, there are at least 3 types of service elasticities in play: availability, convenience and speed. In addition to service elasticity, there is evidence that improved marketing and schedule information may also increase ridership. There may be some ridership response based on the increase in fuel and parking costs (which would likely happen in the 20 year time horizon but are outside the scope of this study). Evidence also suggests a cross-elasticity associated with a riders switching from car to bus use. Litman suggests a range of elasticities in transit ridership with respect to transit service, the recommended elasticities are .5 to .7 in the short term and .7-1.1 in the long term. Nuworsoo (2008) uses this range of elasticities to project increase in ridership based on proportional change in headway. (Where the existing headway is reduced from 30 minutes to 15 minutes, a .5 proportional headway (50% decrease) is correlated to an increase in riders by the elasticities defined above (.5-1.1).

Presumably the increase in efficiency and speed of the bus over mainline speed would cause an increase in ridership, although Litman doesn't establish an elasticity for time savings, he does suggest an elasticity for headway. Because time savings is a service type and could be subject to the service elasticity, a ratio of .5 is used. Based on Nuworsoo's study, the elasticity is applied to the proportional time savings. For instance, where the bus is run on the shoulder, there is a time savings of between 2.1 minutes (when the bus is traveling 35 mph and mainline traffic is traveling 30 mph) and 67.5 minutes (when the bus is traveling 20 mph and the mainline traffic is traveling 5mph). The proportional time savings associated with the mainline speed is shown in table 3.9:

Table 3.9: Potential 2009 PM peak ridership with service elasticity

Time Savings	Proportional Savings (car driving time - bus driving time) / car driving time	Disaggregate Elasticity			2009 actual ridership data e	Projected 2009 with Bus on Shoulder			Actual projected ridership with BOS	Increase in riders with BOS
		Low	Typical	High		Low	Typical	High		
		s1	s2	s3	e	$o=(x*s1*e)+e$	$o=(x*s2*e)+e$	$o=(x*s3*e)+e$		
		0.5	0.7	1.1	14,034					
No savings	0	-0.5	-0.7	-1.1	2,807					
2.1 minutes	0.14	-0.5	-0.7	-1.1	2,807	3,007	3,087	3,248	3,087	281
5.1 minutes	0.29	-0.5	-0.7	-1.1	2,807	3,208	3,368	3,689	3,368	561
9.6 minutes	0.43	-0.5	-0.7	-1.1	2,807	3,408	3,649	4,130	3,649	842
15 minutes	0.5	-0.5	-0.7	-1.1	2,807	3,509	3,789	4,351	3,789	982
27 minutes	0.6	-0.5	-0.7	-1.1	2,807	3,649	3,986	4,659	3,986	1,179
67.5 minutes (unrealistic)	0.75	-0.5	-0.7	-1.1	2,807	3,859	4,280	5,122	4,280	1,474

Value $e=14,034$ 2009 ridership, 2,807 is 20% of ridership (which is the percent of passengers during peak hour as shown in table 3.7). See Appendix F for ridership projection data

The table above shows an increase in riders as soon as there is a time savings on the corridor (when mainline traffic drops below 35 mph). The typical change ranges from 281 additional passengers to 1,474 additional passengers based on difference in speed.

Using the FREQ output for 2025, each of the bus runs would experience variable delay on the corridor. The 2025 average speeds and projected ridership are

shown in Table 3.10. The first column corresponds to the time of the run shown to the left of the FREQ output in figure 3.15. This full time segment corresponds to the PM Peak Period (time of most congestion) and the ridership numbers represent the Monthly ridership during PM Peak Period, spread evenly across all 15 minute time segments.

Table 3.10: Potential 2025 PM Peak Hour Riders

Table 3.10: Potential 2025 PM Peak Ridership due to Bus On Shoulder																		
2025 actual average speed by time of day	Speed	allowable bus speed	difference	car driving time	Driving Time		proportional time savings	time savings in minutes	Disaggregate Elasticity			2025 Monthly Ridership	Projected 2025 rider increase to BOS			due to BOS	Total 2025 riders (based on typical increase) due to BOS	increase over in riders due to BOS
					bus driving time	time savings			Low	Typical	High		Low	Typical	High			
									s1	s2	s3	e	$o=(x^s1^t)*e$	$o=(x^s2^t)*e$	$o=(x^s3^t)*e$			
Monthly Riders during Peak Period = 4,850																		
3:35 PM	42.1		n/a						0.5	0.7	1.1	4,850						
3:49 PM	31.3	35	3.7	14.4	12.9	0.10	1.50	-0.5	-0.7	-1.1	323	340	347	361	347	361	24	
4:05 PM	24.1	35	10.9	18.7	12.9	0.31	5.81	-0.5	-0.7	-1.1	323	374	394	434	394	434	70	
4:23 PM	22.6	35	12.4	20.0	12.9	0.36	7.09	-0.5	-0.7	-1.1	323	381	404	450	404	450	80	
4:34 PM	20.4	35	14.6	22.0	12.9	0.42	9.15	-0.5	-0.7	-1.1	323	391	417	471	417	471	94	
4:49 PM	24.0	35	11.0	18.8	12.9	0.31	5.89	-0.5	-0.7	-1.1	323	374	394	435	394	435	71	
5:07 PM	21.4	35	13.6	21.0	12.9	0.39	8.13	-0.5	-0.7	-1.1	323	386	411	461	411	461	88	
5:17 PM	21.6	35	13.4	20.9	12.9	0.38	8.02	-0.5	-0.7	-1.1	323	385	410	460	410	460	87	
5:35 PM	25.1	35	9.9	17.9	12.9	0.28	5.06	-0.5	-0.7	-1.1	323	369	387	424	387	424	64	
5:50 PM	27.4	35	7.6	16.4	12.9	0.22	3.54	-0.5	-0.7	-1.1	323	358	372	400	372	400	49	
6:05 PM	26.6	35	8.4	16.9	12.9	0.24	4.09	-0.5	-0.7	-1.1	323	362	378	409	378	409	55	
6:20 PM	26.2	35	8.8	17.2	12.9	0.25	4.30	-0.5	-0.7	-1.1	323	364	380	413	380	413	57	
6:35 PM	25.7	35	9.3	17.5	12.9	0.27	4.68	-0.5	-0.7	-1.1	323	366	384	418	384	418	60	
6:50 PM	27.6	35	7.4	16.3	12.9	0.21	3.47	-0.5	-0.7	-1.1	323	358	371	399	371	399	48	
7:05 PM	25.9	35	9.1	17.4	12.9	0.26	4.52	-0.5	-0.7	-1.1	323	365	382	416	382	416	59	
7:20 PM	26.6	35	8.4	16.9	12.9	0.24	4.09	-0.5	-0.7	-1.1	323	362	378	409	378	409	55	
7:35 PM	37.3		n/a															
7:50 PM	56.7		n/a															
average change	28.5	35	9.9	18.15	12.86	0.28	5.29	sum of pm peak hour riders			4,850	5,536	5,811	6,360	5,811	6,360	961	

Table 3.10 shows that the buses running during the PM peak period would experience proportional time savings of between 0.10 and 0.42. Because of this time savings there would be a variable increase of 24 to 94 additional riders per 15-minute time interval over the peak period. Figure 3.16 shows the distribution of time savings and monthly riders within the time intervals during the evening peak period.

Figure 3.16: Monthly PM Peak Period Riders Due to Time Savings

Person Time Savings

The proportional time savings during the PM peak period (3:30 to 7:35 pm) would vary between 0.10 and 0.42 depending on how slow the mainline traffic is moving during each of the 15 minute time increments. This proportional time savings

would translate into a potential increase in PM peak period riders. The overall increase in riders during the PM peak period would be 961 new monthly riders between 3:30 PM and 7:35 PM for a total of 5,811 monthly riders during the PM peak period. This constitutes a 20 percent increase over the projected baseline of 4,850 monthly riders during the PM peak period without the Bus on Shoulder. The time savings of the Bus operating on the shoulder during congestion in 2025 would range from 1.5 minutes at 3:49 PM to 9.1 minutes at 4:34 PM. Each rider during each time increment would save a variable number of minutes depending on the level of congestion (see Figure 3.16). Multiplying the variable time savings by the number of riders produces a total time savings of approximately 520 hours per month for all PM peak period BOS riders.

4.0 Conclusion

This study addressed policies, infrastructure, and implementing procedures in place in Minnesota, Florida, and San Diego California and compared the criteria to San Luis Obispo and the study segment. Based on the case study criteria and the criteria established by the June 2008 Caltrans Decision Document, a shoulder transit lane maybe feasible and valuable in the future. The Caltrans Decision Document suggests that “significant travel time savings” would be required prior to implementing Bus On Shoulder. Given the substantial time savings that would come from providing a Bus on Shoulder program in 2025, steps should be taken now to create a program that will be in place at the time when congestion increase to the level shown in the FREQ analysis. In order to implement a Bus On Shoulder before 2025, several steps will need to be taken. These steps are shown below:

Policy recommendations:

4. SLOCOG could add transit shoulder lane (bus on shoulder) option to SLOCOG’s 2009 Regional Transportation Plan for implementation over the plan’s 20 year time horizon, and include a permanent bus lane as an unconstrained project (Caltrans Decision Document no. 1)
5. SLOCOG could Support legislation to allow shoulder use for bus on shoulder (Current) with possible use of study segment for Pilot Project.
6. SLOCOG could add transit shoulder lane (BOS) option to the Long Range Transit Plan (Date not specified)

Infrastructure recommendations:

5. SLOCOG could conduct a study in greater detail on the corridor and identify existing segments that would require widening, leveling of cross slope, structural section, etc. (Caltrans Decision Document nos. 7, 8, 9, 12, 14)
6. Caltrans could upgrade shoulder section to carry weight of a bus during regular State Highway Operation and Protection Program (SHOPP) projects (Caltrans Decision Document nos. 7, 8, 9, 12, 14)
7. SLOCOG could program State Transportation Improvement Program (STIP) funds on Caltrans SHOPP projects on a percentage basis to improve shoulder infrastructure (Caltrans Decision Document nos. 7, 8, 9, 12, 14)
8. SLOCOG could program STIP funds for emergency pull-outs, striping, and signage (CT decision document nos. 10, 11)

Implementing recommendations

4. RTA could install Automatic Vehicle Locators (AVL) on buses to track on time performance as it relates to congestion on the corridor. This would assist in determining the locations at which the most time savings could be acquired (CT decision document nos. 3, 4)
5. RTA could install technologies that would track all rider on/off to determine most popular routes, which would also assist in determining the locations at which the most time savings could be acquired. (CT decision document nos. 3, 4)

6. RTA could include Express Bus Concept in Short Range Transit Plan (CT decision document no. 5)

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Appendix A: Policy Criteria from Case Studies

Policy Criteria			
	Minneapolis, MN	Miami-Dade	San Diego, CA
			San Luis Obispo, CA
Regional Transportation Plan		Long Range Transportation Plan calls for many improvements including widening of roadways, toll plazas, express lanes, and premium transit	RTP calls for system of managed/HOV lanes along San Diego freeways to provide this priority. Bus on Shoulder is seen as short term priority measure for buses to use existing shoulder during peak traffic periods until managed/HOV lanes are constructed.
Other policy documents		Special Use Lane Study: Transit Use of Shoulder Bypass Lanes (November 2005). People's Transportation Plan calls for implementation of 2.5 million additional miles of service, some as express routes. BRT Opportunities Report (June 2005)	Express Bus Stop Study recommends SLOCOG work with Caltrans, SLORTA, and local transit services to improve express bus service
Legislation	Minnesota Statutes 2005 169.306 [Use of Shoulder by Buses] allows buses to use shoulder.	Miami Dade MPO authored proposed legislation to allow for a 3 year pilot project to allow the use of shoulders for transit during peak congestion	All rules for San Diego apply to SLOCOG, and changes to CVC will also affect San Luis Obispo Region

Source: Special Use Lanes Study: Miami-Dade MPO; Bus-Only Shoulders in the Twin Cities: Transit Lane Demonstration Pilot Decision Document, SANDAG, TCRP synthesis 64, various SLOCOG documents. This table is a condensation of information reported in Chapter 4. See Chapter 4 references for detailed list.

Appendix B: Infrastructure Criteria from Case Studies

Infrastructure Criteria				
	Minneapolis, MN	Miami-Dade	San Diego, CA	San Luis Obispo, CA
Shoulder width	10 foot requirement where there are no barriers or bridges, bridge shoulders are at least 11.5 feet, new shoulders are constructed at 12 feet	10 foot requirement	10-12 feet	10 foot minimum, 12 foot where adjacent abutments exist
Shoulder depth	Shoulders on new roadway segments are built to withstand greater use. 7 inch depth. Shoulder upgrade programs increase depth to 3- to 5-inches	shoulder will be monitored for visible damage, future studies conducted on impacts.	four buses per lane per direction per day use shoulder. Pavement damage is being monitored.	shoulder depth is not identified for location of interest, current usage would be 4 buses per day, future use may be 14. Shoulder upgrade may be required.
Shoulder grade	2% to 5% allowed	2% - 6% percent cross slope	Not Identified	cross slope is not identified at this time, use of shoulder should be based on comfort of driver and passengers
Shoulder drainage	Catch basin design standards were changed to accommodate buses: concrete pad and structure being level with surface had improved lifetime of catch basins but decreased effectiveness somewhat.	not identified	No drainage changes scheduled. Buses are not allowed to use shoulder during periods of rain or flooding.	no drainage changes should be recommended at this time, drivers should not use shoulder in rain or flooding
Frequency of on/off ramps	Not Identified	areas assessed in the report range from .4 miles to 2.7 miles between ingress/egress. Report recommends 1,250-2,500 feet between bus entry/exit of shoulder	Not Identified	on/off ramps are frequent in the location of interest. Median Shoulders should be considered over the use of outside shoulders.

Source: Special Use Lanes Study: Miami-Dade MPO; Bus-Only Shoulders in the Twin Cities: Transit Lane Demonstration Pilot Decision Document, SANDAG, TCRP synthesis 64, various SLOCOG documents. This table is a condensation of information reported in Chapter 4, See Chapter 4 references for detailed list.

Appendix C: Implementing Criteria from Case Studies

Operating/Functional Criteria			
	Minneapolis, MN	Miami-Dade	San Diego, CA
			San Luis Obispo, CA
Roadway Capacity, LOS and Congestion	There must be predictable congestion delays, meaning the running speed of roadway must be less than 35 mph during the peak period and/or approaches to intersections have continuous backups. Congestion delays must occur one or more days per week.	42,100-183,636 average daily vehicle travel or areas in the study. No specific recommendation for capacity. Traffic must be moving 35 mph or less.	Heavy peak period congestion levels identified, but not requisite for BOS in San Diego (see below). Current ADT is between 60,000-77,000 peak month is 63,000-89,000. The study segment has the highest AADT and LOS in the region.
On-time performance	a minimum of six transit buses per day must use the proposed shoulder.	Not Identified	RTA hired new Contractor to provide buses, drivers and dispatch in January 2008, prior to this time no on-time performance record keeping existed. New On-Time performance record keeping is being initiated.
Person Time Savings	The expected time savings of using the shoulder must be greater than eight minutes per mile per week.	Not Identified	Potential time savings is between 1.4 minutes and 2.8 minutes per person when mainline speeds are high. Between 44 and 90 minutes when mainline speeds are low.

Source: Special Use Lanes Study: Miami-Dade MPO; Bus-Only Shoulders in the Twin Cities: Transit Lane Demonstration Pilot Decision Document, SANDAG, TCRP synthesis 64, various SLOCOG documents. This table is a condensation of information reported in Chapter 4. See Chapter 4 references for detailed list.

Appendix D: ridership change based on speed difference (based on Total Ridership for year)

Mainline Speed	bus on shoulder speed	potential time savings													
			proportional time savings	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
		see formula above (table __)													
no change in speed															
no time savings			0%	14,034	15,369	16,590	17,527	18,319	19,017	19,649	20,231	20,772	21,281	21,763	22,221
30 mph	35 mph		14%	3,087	16,906	18,249	19,280	20,151	20,919	21,614	22,254	22,850	23,410	23,939	24,443
25 mph	35 mph		29%	3,368	18,443	19,908	21,033	21,983	22,821	23,579	24,277	24,927	25,538	26,116	26,666
20 mph	35 mph		43%	3,649	19,980	21,567	22,786	23,815	24,722	25,544	26,300	27,004	27,666	28,292	28,888
15 mph	30 mph		50%	3,789	20,748	22,397	23,662	24,731	25,673	26,526	27,312	28,043	28,730	29,380	29,999
10 mph	25 mph		60%	3,986	21,824	23,558	24,889	26,013	27,004	27,902	28,728	29,497	30,220	30,904	31,554
5 mph	20 mph		75%	4,280	23,438	25,300	26,729	27,936	29,001	29,965	30,852	31,678	32,454	33,189	33,887
				-10,947	1,537	1,659	1,753	1,832	1,902	1,965	2,023	2,077	2,128	2,176	2,222
				-9,754	8,069	8,710	9,202	9,617	9,984	10,316	10,621	10,906	11,173	11,426	11,666

Appendix E: FREQ Output 2025 (Courtesy of Sam Toh)

FREQ12__VER_3.01__DAY-1__SPEEDS_(MPH)_AVG=CELL_AVG
COLUMNS=_SUBSECTIONS_ ROWS=_TIME_SLICES_ 11/24/2009 13:41

				US 101 Mainline Begin to Madonna On Madonna On to Prado Off Prado Off to Prado On Prado On to LOVR Off LOVR Off to LOVR On LOVR On to S Higuera Off S Higuera Off to S.H. On S Higuera On to SLBD Off SLBD Off to SLBD On SLBD On to Avila Dr Off Avila Rd Off to Avila On Avila On to Spyglass Off Spyglass Off to Spygl On S Sh Bch On to So SB On N Pismo Off to N Pis Off Rte 1 Off to Rte 1 Off Rte 1 On to Hinds Off Hinds Off to S Price On S Price On to Five C Off Five C Off to Five C On Five C On to 4th St Off 4th St Off to 4th St On 4th St On to ECR Off ECR Off to ECR On ECR On to Halcyon Off Halcyon Off to Halcy On Halcyon On to Grand Off Grand Off to Grand On Grand On to F Oaks Off F Oaks Off to Traf Wy On Traf Wy On to El Cmpo El Cmpo Rd Off & On El Cmpo Rd to Los B Off Los Berros Off to LB On LB On to Willow Off Willow Off to Willow On																																							
TS/SS				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
15:35 42.1 15:35 15:49 31.3 15:49 16:05 24.1 16:05 16:23 22.6 16:23 16:34 20.4 16:34 16:49 24.0 16:49 17:07 21.4 17:07 17:17 21.6 17:17 17:35 25.1 17:35 17:50 27.4 18:05 26.6 18:20 26.2 18:35 25.7 18:50 27.6 19:05 25.9 19:20 26.6 19:35 37.3 19:50 56.7	1	69	69	69	69	69	69	67	68	65	68	67	69	69	67	50	53	55	65	64	63	69	69	69	69	61	69	65	69	68	69	67	69	68	65	67	67	68	68	68	6		
	2	68	68	69	69	69	69	60	63	57	62	60	69	40	26	41	53	55	65	64	63	69	69	69	69	64	69	67	69	69	69	69	69	69	69	66	68	68	69	68	69	6	
	3	68	68	69	69	69	68	55	30	53	60	58	49	14	21	39	53	55	64	63	62	69	69	69	69	60	67	62	69	66	69	63	69	64	55	60	60	65	62	65	6		
	4	68	68	69	69	69	61	41	31	50	38	32	14	12	24	40	53	55	65	63	62	69	69	69	69	62	67	66	69	69	69	68	69	68	63	66	66	68	67	68	6		
	5	66	66	69	69	48	25	30	23	30	22	23	13	12	23	41	53	55	64	63	62	69	69	65	57	63	59	69	64	69	59	57	33	53	59	59	64	60	63	5			
	6	67	67	34	12	9	10	21	19	30	22	24	13	12	22	40	53	56	66	65	64	69	69	63	54	63	61	69	66	69	63	60	37	53	59	59	64	60	64	6			
	7	60	14	7	5	7	8	17	15	24	19	20	12	12	23	42	53	55	65	64	63	69	69	64	57	65	61	69	65	69	62	69	42	53	59	59	64	60	63	5			
	8	41	12	8	6	8	11	24	21	32	22	23	13	14	25	42	53	55	65	64	63	69	69	61	54	65	64	69	67	69	65	69	41	56	61	61	66	62	66	6			
	9	23	9	6	5	7	10	20	17	26	20	21	12	12	23	42	53	55	64	63	62	69	69	66	59	65	62	69	65	51	39	41	29	53	59	59	64	61	64	6			
	10	14	8	6	5	6	8	19	17	27	21	22	12	13	23	40	53	57	66	64	63	69	69	65	62	69	68	69	69	49	36	30	21	61	65	65	68	67	68	6			
	11	13	11	7	8	7	10	23	20	38	26	27	14	13	24	41	53	56	66	65	64	69	69	69	63	69	67	69	69	69	69	69	69	69	69	66	68	68	69	68	69	6	
	12	15	14	8	10	9	15	29	24	43	27	28	15	14	25	42	53	57	67	66	65	69	69	69	64	69	68	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	13	19	17	9	13	11	19	33	27	35	25	26	14	13	24	42	53	56	65	65	64	69	69	69	67	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	14	20	17	9	12	10	17	31	27	33	26	27	15	13	24	40	53	56	66	66	65	69	69	69	65	69	67	69	69	69	69	69	68	69	68	66	68	68	69	68	69	6	
	15	24	18	9	14	9	18	29	24	30	25	26	14	13	26	44	53	56	66	65	64	69	69	69	65	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	16	37	22	10	17	11	20	34	29	35	27	28	15	13	25	42	53	58	67	67	66	69	69	69	66	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	17	58	21	10	13	10	18	28	24	30	26	26	14	13	27	45	53	57	66	66	65	69	69	66	57	67	64	69	67	69	66	69	67	65	67	67	68	68	69	69	6		
	18	69	69	43	31	17	27	33	27	30	26	27	15	13	26	42	53	56	66	65	65	69	69	69	67	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	19	69	69	69	69	69	69	68	57	46	34	32	16	13	26	44	53	56	66	66	65	69	69	69	67	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	20	69	69	69	69	69	69	69	69	69	69	69	69	69	69	68	23	29	45	53	56	65	65	64	69	69	69	66	69	68	69	69	69	69	69	69	69	69	69	69	69	6	
	21	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	22	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	23	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
	24	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6	
MIN				13	8	6	5	6	8	17	15	24	19	20	12	12	21	39	53	55	64	63	62	69	69	61	54	63	59	69	64	49	36	30	21	53	59	59	64	60	63	5	
AVG				51	44	39	38	36	37	42	38	44	39	39	31	26	34	47	56	58	66	65	65	69	69	68	63	68	66	69	68	67	65	60	64	66	66	68	67	68	69	6	
MAX				69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	6

Appendix F: Ridership Increases by Year with Elasticity

7.5 mile corridor											
Car Driving Time (length of corridor/speed) * 60 minutes	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	14,034	2,807	2,807	2,807	2,807
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	2,807	2,807	3,007	3,087	3,087
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	2,807	3,208	3,688	3,689	3,688
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	2,807	3,408	3,649	4,130	3,649
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	2,807	3,509	3,789	4,351	3,789
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	2,807	3,649	3,986	4,659	3,986
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	2,807	3,859	4,280	5,122	4,280
2010											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	15,369	15,369	15,369	15,369	15,369
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	15,369	16,467	16,906	17,784	16,906
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	15,369	17,565	18,443	20,199	18,443
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	15,369	18,663	19,980	22,615	19,980
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	15,369	19,211	20,748	23,822	20,748
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	15,369	19,980	21,824	25,513	21,824
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	15,369	21,133	23,438	28,049	23,438
2011											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	16,590	16,590	16,590	16,590	16,590
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	16,590	17,775	18,249	19,197	18,249
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	16,590	18,960	19,908	21,804	19,908
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	16,590	20,145	21,567	24,411	21,567
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	16,590	20,738	22,397	25,715	22,397
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	16,590	21,567	23,558	27,540	23,558
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	16,590	22,812	25,300	30,277	25,300
2012											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	17,527	17,527	17,527	17,527	17,527
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	17,527	18,779	19,280	20,282	19,280
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	17,527	20,031	23,036	22,036	21,033
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	17,527	21,283	22,786	25,790	22,786
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	17,527	21,909	23,662	27,167	23,662
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	17,527	22,786	24,889	29,095	24,889
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	17,527	24,100	26,729	31,988	26,729
2013											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	18,319	18,319	18,319	18,319	18,319
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	18,319	19,627	20,151	21,198	20,151
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	18,319	20,936	21,983	24,076	21,983
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	18,319	22,244	23,815	26,955	23,815
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	18,319	22,899	24,731	28,394	24,731
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	18,319	23,815	26,013	30,409	26,013
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	18,319	25,188	27,936	33,432	27,936
2014											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	19,017	19,017	19,017	19,017	19,017
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	19,017	20,376	20,919	22,006	20,919
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	19,017	21,734	22,821	24,994	22,821
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	19,017	23,092	24,722	27,982	24,722
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	19,017	23,771	25,673	29,477	25,673
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	19,017	24,722	27,004	31,569	27,004
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	19,017	26,149	29,001	34,706	29,001
2015											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	19,649	19,649	19,649	19,649	19,649
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	19,649	21,053	21,614	22,737	21,614
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	19,649	22,456	23,579	25,825	23,579
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	19,649	23,860	25,544	28,912	25,544
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	19,649	24,561	26,526	30,456	26,526
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	19,649	25,544	27,902	32,618	27,902
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	19,649	27,018	29,965	35,860	29,965
2016											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	20,231	20,231	20,231	20,231	20,231
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	20,231	21,676	22,254	23,410	22,254
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	20,231	23,121	24,277	26,589	24,277
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	20,231	24,566	26,300	29,768	26,300
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	20,231	25,288	27,312	31,358	27,312
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	20,231	26,300	28,728	33,583	28,728
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	20,231	27,817	30,852	36,921	30,852
2017											
Car Driving Time (length of corridor/speed) * 60 m car driving time	Bus Driving Time	Time Savings car driving time - bus driving time	Proportional Savings (car driving time-bus driving time / car driving time)	Disaggregate Elasticity			Projected			Change (typical)	
				Low	Typical	High	Existing	Low	Typical	High	
				s1	s2	s3	e	o=(x*s1*e)+o=(x*s2*e)+o=(x*s2*e)+e	p=(x*s2*e)+e	o=(x*s2*e)+e	
n/a	12.9	12.9 No savings	0	0.5	0.7	1.1	20,231	20,231	20,231	20,231	20,231
	15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-1.1	20,231	21,676	22,254	23,410	22,254
	18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-1.1	20,231	23,121	24,277	26,589	24,277
	22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-1.1	20,231	24,566	26,300	29,768	26,300
	30.0	15.0 15 minutes	0.5	-0.5	-0.7	-1.1	20,231	25,288	27,312	31,358	27,312
	45.0	18.0 27 minutes	0.6	-0.5	-0.7	-1.1	20,231	26,300	28,728	33,583	28,728
n/a	90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-1.1	20,231	27,817	30,852	36,921	30,852

2019											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	21,281	21,281	21,281	23,410	23,410
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	21,281	22,802	23,410	24,626	25,538
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	21,281	24,322	25,538	27,970	28,730
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	21,281	25,842	27,666	31,314	32,986
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	21,281	26,602	28,730	35,327	38,839
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	21,281	27,666	30,220	35,327	38,839
90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-0.7	-1.1	21,281	29,262	32,454	35,327	38,839
n/a	30.0 (unrealistic)										
2020											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	21,763	21,763	21,763	23,939	23,939
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	21,763	23,318	23,939	25,183	26,116
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	21,763	24,872	26,116	28,603	28,292
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	21,763	26,427	28,292	32,023	29,380
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	21,763	27,204	29,380	33,733	30,904
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	21,763	28,292	30,904	36,127	33,189
90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-0.7	-1.1	21,763	29,924	33,189	39,718	33,189
n/a	30.0 (unrealistic)										
2021											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	22,221	22,221	22,221	24,443	24,443
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	22,221	23,809	24,443	25,713	26,666
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	22,221	25,396	26,666	29,205	28,888
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	22,221	26,983	28,888	32,697	29,999
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	22,221	27,777	29,999	34,443	31,554
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	22,221	28,888	31,554	36,887	33,887
90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-0.7	-1.1	22,221	30,554	33,887	40,554	33,887
n/a	30.0 (unrealistic)										
2022											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	22,659	22,659	22,659	24,925	24,925
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	22,659	24,278	24,925	26,220	27,191
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	22,659	25,896	27,191	29,781	29,457
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	22,659	27,515	29,457	33,341	30,590
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	22,659	28,324	30,590	35,122	32,176
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	22,659	29,457	32,176	37,614	34,555
90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-0.7	-1.1	22,659	31,156	34,555	41,353	34,555
n/a	30.0 (unrealistic)										
2023											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	23,079	23,079	23,079	25,387	25,387
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	23,079	24,728	25,387	26,706	27,695
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	23,079	26,376	27,695	30,333	30,003
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	23,079	28,025	30,003	33,960	31,157
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	23,079	28,849	31,157	35,773	32,773
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	23,079	30,003	32,773	38,312	35,196
90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-0.7	-1.1	23,079	31,734	35,196	42,120	35,196
n/a	30.0 (unrealistic)										
2024											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	23,484	23,484	23,484	25,832	25,832
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	23,484	25,161	25,832	27,174	28,180
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	23,484	26,839	28,180	30,555	30,529
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	23,484	28,516	30,529	34,555	31,703
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	23,484	29,355	31,703	36,400	33,347
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	23,484	30,529	33,347	38,983	35,813
90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-0.7	-1.1	23,484	32,290	35,813	42,858	35,813
n/a	30.0 (unrealistic)										
2025											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	23,874	23,874	23,874	26,261	26,677
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	23,874	25,579	26,261	27,626	29,102
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	23,874	27,285	28,649	31,377	31,527
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	23,874	28,990	31,036	35,129	32,739
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	23,874	29,842	32,230	37,005	33,901
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	23,874	31,036	33,901	39,631	36,408
90.0	22.5 67.5 minutes	0.75	-0.5	-0.7	-0.7	-1.1	23,874	32,827	36,408	43,570	36,408
n/a	30.0 (unrealistic)										
2026											
Car Driving Time (length of corridor/speed)	Tim Bus Driving Time * 60 mi car driving time	Savings (length of corridor/speed)	Proportional Savings (car driving time)	Disaggregate Elasticity s1	Typical s2	High s3	Existing e	Projected		Change (typical)	
								Low o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e	High o=(x*s1*e)-o=(x*s2*e)+o=(x*s2*e)+e		
12.9	12.9 No savings	0	0.5	0.7	0.7	1.1	24,251	24,251	24,251	26,677	26,677
15.0	12.9 2.1 minutes	0.14	-0.5	-0.7	-0.7	-1.1	24,251	25,984	26,677	28,062	29,102
18.0	12.9 5.1 minutes	0.29	-0.5	-0.7	-0.7	-1.1	24,251	27,716	29,102	31,873	31,527
22.5	12.9 9.6 minutes	0.43	-0.5	-0.7	-0.7	-1.1	24,251	29,448	31,527	35,684	32,739
30.0	15.0 15 minutes	0.5	-0.5	-0.7	-0.7	-1.1	24,251	30,314	32,739	37,590	34,437
45.0	18.0 27 minutes	0.6	-0.5	-0.7	-0.7	-1.1	24,251	31,527	34,437	40,257	34,437

Appendix F: SPSS Projections (Courtesy of Cornelius Nuworsoo)

Multiple Linear Regression with Monthly Dummy Variables -- SPSS :

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Model	(Constant)	-471.254	535.849		-.879	.380
1	series	49.649	2.325	.837	21.358	.000
	djan	-384.812	669.585	-.030	-.575	.566
	dfeb	-394.873	669.549	-.031	-.590	.556
	dmar	30.713	669.521	.002	.046	.963
	dapr	-97.289	669.501	-.008	-.145	.885
	dmay	-68.351	669.489	-.005	-.102	.919
	djul	98.379	669.973	.008	.147	.883
	daug	356.847	669.888	.028	.533	.595
	dsep	211.551	669.811	.017	.316	.752
	doct	679.254	669.743	.054	1.014	.312
	dnov	-221.984	669.682	-.018	-.331	.741
	ddec	-738.633	669.630	-.058	-1.103	.271

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.841 ^a	.708	.689	1951.866

Appendix G: RTA Ridership Data example (Courtesy of Jason Gillespie)

RIDERSHIP FOR FISCAL YEAR 2001-02													
2001-2	7	7EXP	8	9	9 SAT						10A	10B	10 ABS
JULY 2001	5,319	103	1,155	5,717	374						3,007	1,510	437
AUGUST 2001	5,162	142	2,501	5,476	366						3,591	1,715	444
SEPTEMBER 2001	4,244	175	3,880	5,462	385						2,760	1,367	448
OCTOBER 2001	4,977	199	3,972	6,935	278						3,520	1,726	330
NOVEMBER 2001	4,174	164	2,739	5,757	253						2,779	1,285	274
DECEMBER 2001	3,360	172	1,893	4,693	395						2,222	1,030	364
JANUARY 2002	3,942	171	1,980	5,886	312						2,749	1,399	320
FEBUARY 2002	4,376	122	3,577	5,809	380						2,842	1,451	361
MARCH 2002	4,538	123	3,557	5,788	521						2,884	1,403	378
APRIL 2002	4,478	97	2,788	5,863	357						2,970	1,470	346
MAY 2002	4,785	266	2,457	5,855	397						3,036	1,525	330
JUNE 2002	4,226	178	634	4,866	455						2,598	1,189	406
TOTAL	53,581	1,912	31,133	68,107	4,473	0	0	0	0	0	34,958	17,070	4,438

11	12	12 SAT	14	TC
637	1,208	245		
612	1,170	271		
514	1,055	348		
800	1,298	326		
514	1,066	281		
414	927	275		
581	1,156	281		
536	1,022	268		
510	1,114	309		
546	1,086	343		
621	1,193	381		
417	1,095	409		
6,702	13,390	3,737	0	

RIDERSHIP FOR FISCAL YEAR 2002-03													
2002-03	7	7EXP	8	9	9 SAT						10 A&B	10 C	10 ABS
JULY 2002	5,260	189	983	5,345	381						2,975	1,235	381
AUGUST 2002	5,085	153	2,411	5,527	492						3,381	970	377
SEPTEMBER 2002	6,276		4,641	8,133	575						4,577	999	468
OCTOBER 2002	5,211		4,272	7,218	386						4,211	1,066	309
NOVEMBER 2002	4,210		3,000	5,774	444						3,421	828	335
DECEMBER 2002	3,764		2,145	4,936	285						2,891	712	257
JANUARY 2003	4,353		2,034	5,739	384						3,748	784	333
FEBUARY 2003	4,372		3,548	5,860	380						3,488	794	357
MARCH 2003	4,932		3,638	6,249	486						3,785	815	422
APRIL 2003	4,687		2,764	6,148	364						3,548	869	291
MAY 2003	3,954		2,360	5,931	522						3,696	700	332
JUNE 2003	3,823		676	5,020	357						4,044	685	311
TOTAL	55,927	342	32,472	71,880	5,056	0	0	0	0	0	43,765	10,457	4,173

11	12	12 SAT	14	TC
363	1,164	255		
410	1,068	365		
373	1,461	449		
496	1,222	318		
382	1,045	389		
268	909	246		
379	1,061	286		
376	1,056	270		
388	1,148	322		
440	1,369	316		
450	1,285	276		
337	1,169	276		
4,662	13,957	3,768	0	

RIDERSHIP FOR FISCAL YEAR 2003-04													
2003-04	7	7EXP	8	9	9 SAT						10 A&B	10 C	10 ABS
JULY 2003	4,569		993	4,806	315						4,764	790	367
AUGUST 2003				4,907	429						4,098	644	436
SEPTEMBER 2003				6,303	356						3,937	798	329
OCTOBER 2003				6,805	318						4,343	958	353
NOVEMBER 2003				5,322	292						3,488	768	379
DECEMBER 2003				4,971	181						3,719	737	290
JANUARY 2004				7,637	322						3,510	606	420
FEBUARY 2004				7,823	301						3,616	658	318
MARCH 2004				9,557	285						4,592	799	403
APRIL 2004				8,678	313						4,074	758	267
MAY 2004				8,357	402						3,900	695	441
JUNE 2004				8,111	355						4,070	740	336
TOTAL	4,569	0	993	83,277	3,869	0	0	0	0	0	48,111	8,951	4,339

103,528

57,062

11	12	12 SAT	14	San
343	1,249	254		
1,920	6,424	406		
2,027	8,920	328		
1,945	9,019	315		
1,537	6,698	387		
1,496	6,094	223		
1,579	6,556	363		
1,599	8,325	320		
2,016	9,756	345		
1,737	7,382	241		
1,531	6,080	464		
1,554	5,689	298		
19,284	82,192	3,944	0	

87,754

107,038

RIDERSHIP FOR FISCAL YEAR 2004-05													
2004-05	7	7EXP	8	9	9 SAT						10 A&B	10 C	10 ABS
JULY 2004				8,156	424						4,376	710	436
AUGUST 2004				8,928	396						4,478	657	371
SEPTEMBER 2004				13,250	526						6,024	891	728
OCTOBER 2004				10,045	569						6,163		407
NOVEMBER 2004				9,368	414						5,608		332
DECEMBER 2004				7,792	308						5,050		276
JANUARY 2005				9,426	418						5,268		292
FEBRUARY 2005				9,150	368						5,262		315
MARCH 2005				10,081	432						5,829		350
APRIL 2005				9,683	566						6,030		595
MAY 2005				9,581	408						6,447		532
JUNE 2005				8,280	350						6,861		368
TOTAL	0	0	0	113,740	5,179	0	0	0	0	0	67,396	2,258	5,002

11	12	12 SAT	14	San
1,846	5,334	417		
1,932	8,110	343		
2,348	11,914	554		
1,815	8,364	395		
1,677	7,949	258		
1,503	6,030	225		
1,579	7,376	252		
1,758	8,515	260		
1,924	8,890	246		
1,871	8,908	422		
1,624	7,295	349		
1,625	5,420	291		
21,502	94,105	4,012	0	