Integration of a Center-Running Guided Busway into an Arterial Street

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INTRODUCTION

Lane Transit District (LTD) is in the initial stages of developing a Bus Rapid Transit (BRT) system throughout the Eugene/Springfield metropolitan area in western Oregon. The BRT network will improve transit operations by providing frequent service on the major transportation corridors. This system would operate with several cross-town routes using the downtown Eugene Station as the network's major transfer point. Neighborhood bus routes are planned to connect with the BRT routes. The system will feature exclusive bus lanes, guided busways, and signal priority strategies (1).

Although the entire network will not be completed until at least 2015, revenue service on a pilot corridor is expected to commence within the next few years. This corridor was recently selected as one of ten Federal Transit Administration Bus Rapid Transit demonstration projects. With an overall length of 11 miles, the corridor has been broken into smaller sections for analysis and design. The first section to be designed is the Franklin Boulevard corridor, a major east-west arterial connecting Eugene and Springfield. This section runs from 11th Avenue to Glenwood Boulevard and is approximately 2 miles long. Franklin Boulevard presently has three lanes in each direction separated by a landscaped median of varying width. Figure 1 illustrates the corridor.

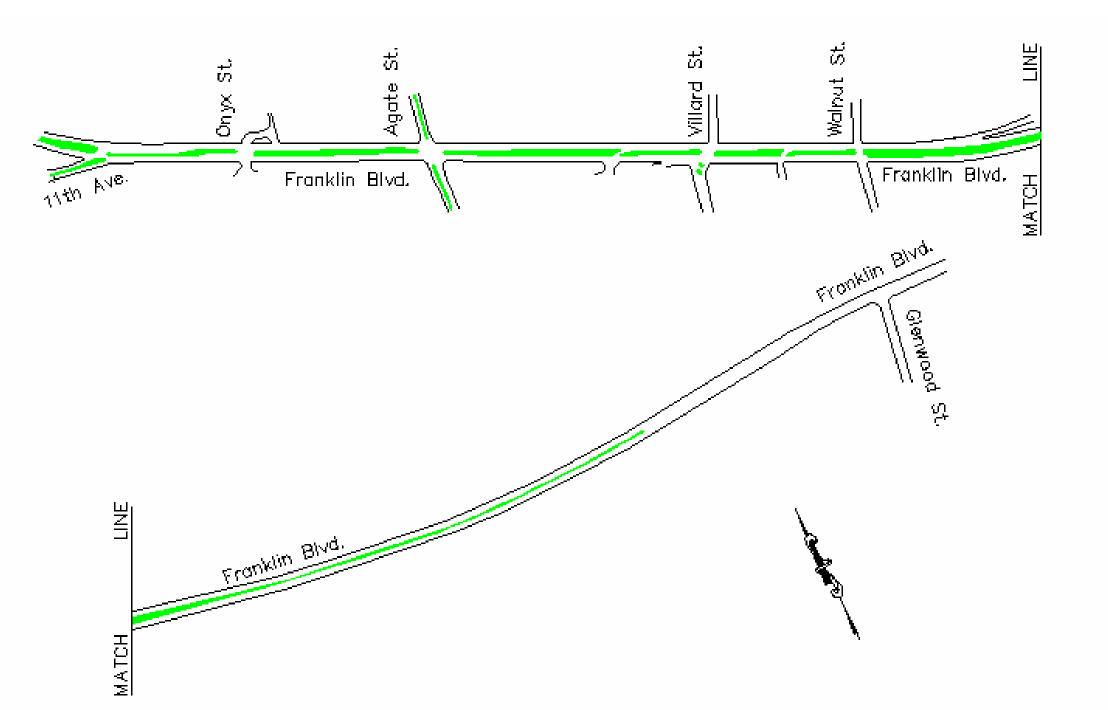

Figure 1

LTD has considered multiple alternatives for this corridor, including curbside bus lanes and several proposals involving guided busways. The guideways would run down the center of Franklin Boulevard removing portions of the median, and pass through six signalized intersections. Providing one guideway for each direction would be an ideal design. However, the right-of-way constraints and controversial issue of tree removal might require that one or more existing general-purpose lanes be removed. A single-guideway alternative would have the least impact on general-purpose traffic and is therefore the probable solution at this point in time. Since the single-lane guideway would carry bus traffic in both directions, the buses would be allowed to pass in designated intersections or turnouts, permitting more than one bus to occupy the guideway simultaneously. This paper discusses the development and analysis of operational strategies for a single-guideway alignment.

PROJECT OVERVIEW

Lane Transit District needed a method to analyze the impact of the guideway on the bus and general-purpose traffic operations. Simulation was chosen as the preferred tool for this task because it allows the user to model the interaction between traffic and transit vehicles. The system can be analyzed as a whole, rather than focusing on individual components. In addition, operating parameters such as geometry, signal control strategies, or traffic volumes could be easily modified.

The simulation model has two main purposes for LTD; these are to develop a visual tool showing the public how the guided busway would operate, and to evaluate the costs and benefits of the proposed alignment. Specific questions to be answered by the analysis include:

- What impact will the guideway have on bus travel times through the corridor?
- How will transit signal priority affect level of service?
- What are the limitations of the guideway in terms of scheduling and volume constraints?

Existing Conditions on Franklin Boulevard

There are six signalized intersections located along this corridor as shown on Figure 1. The intersections of Franklin Boulevard with 11th (west) and Glenwood (east) form the endpoints of the corridor and the guided busway. Glenwood is an isolated intersection and therefore has a free running traffic-actuated signal. The five closely-spaced intersections operate in coordination during the PM peak hour.

During the PM peak hour these intersections presently operate at level of service (LOS) "C" or better. The traffic volumes on the cross streets are relatively low. Franklin Boulevard carries roughly 1500 vph traveling east and 1200 vph traveling west. Traffic projections show that this volume is expected to increase to approximately 1700 vph eastbound and 1500 vph westbound in 2015.

Proposed Alternatives

In order for a bi-directional guideway to work, there must be passing locations built into the alignment. Two methods were considered for the project, allowing buses to pass either in designated intersections or at turnouts placed throughout the guideway. These two alternatives and the no build scenario are described below. Figures 2 and 3 illustrate the station passing and intersection passing scenarios.

No Build

- Buses run in general-purpose travel lanes
- No change in signal timing
- Bus stations at existing curbside locations

Single Guideway
Station Passing

- One shared guideway for buses operating in both directions
- Buses can pass at two stations or a mid-block turnout
- Transit signal priority at all intersections
- Bus stations relocated to the median

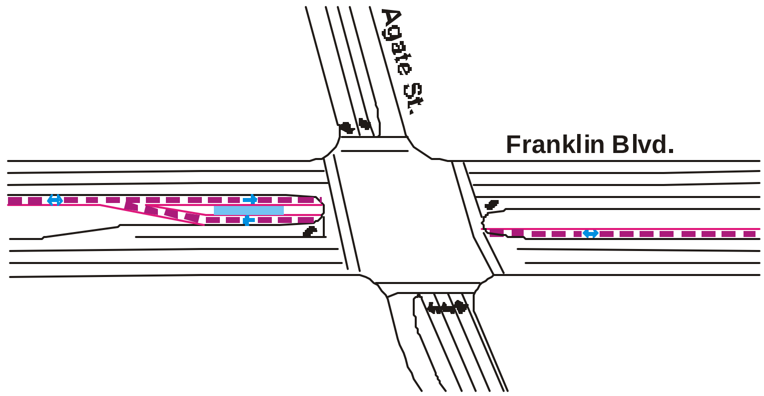

Figure 2

Single Guideway
Intersection Passing

- One shared guideway for buses operating in both directions
- Buses can pass in two designated intersections
- Transit signal priority at all intersections
- Bus stations relocated to the median

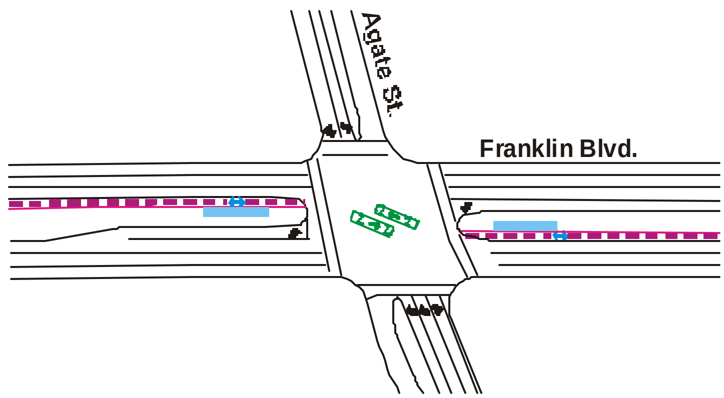

Figure 3

Development of Operational Strategy

The most important issue regarding the operating strategy is how to prevent a head-on collision of buses. Due to the distance between passing points, the bus drivers cannot rely on their vision alone to determine when it is safe to enter the guideway. This fact makes it necessary to ensure positive bus separation using some type of signalization. The first step in the development process was to create a set of guidelines for each alternative.

Station Passing Alternative

- EB buses have priority during the PM peak hour, WB during the AM peak hour
- Buses are held in the station until the section they wish to enter is empty of buses traveling in the opposing direction
- Buses can pass at the Agate Street station, Walnut Street station, or an in-between turnout
- Buses may follow closely in the same direction through the guideway
- Buses may have some level of priority over traffic

Intersection Passing Alternative

- EB buses have priority during the PM peak hour, WB during the AM peak hour
- Buses may pass at the intersections of Agate and Walnut, and the endpoints at 11^{th} and Glenwood
- Because of spatial limitations in the intersections (for passing), buses may follow each other through the guideway only if no buses have entered from the oncoming direction
- Buses are held at passing intersections until the oncoming bus reaches its stop line
- A bus waiting at the stop line for an oncoming bus does not place a signal priority call until both buses are at the stop line
- Buses traveling in the same direction are prevented from overtaking if a bus traveling in the oncoming direction has entered the busway
- Buses may have some level of priority over traffic

Bus-to-Wayside Controller

Using the guidelines outlined above, a Bus-to-Wayside Controller (BWC) was developed for each alternative, to monitor and control bus movements in the guideway. The BWC connects to bus detectors and signalheads located along the guideway. In the intersection passing alternative, it is integrated with the signal controllers. This ensures that neither bus will receive a green signal to enter the intersection unless the opposing bus is also ready for the passing maneuver. The BWC also ensures that there can never be a situation where two WB buses need to pass an EB bus, because there is not enough room in the intersection. The station passing alternative, however, does not have this limitation because the passing points at the station are long enough to hold multiple buses.

The corridor was broken into zones in-between the passing points. Detectors and signalheads in the model define the entry and exit points of the zones. Using detector information the BWC can perform the following tasks:

- Recognize when zones are occupied
- Count the number of buses in each zone
- Recognize the direction of travel for each bus in the zone
- Differentiate between buses and general traffic through detectors
- Allow buses to proceed through intersections during the east-west traffic phase

Signal Priority

Active signal priority has been added to the signal controllers in the guideway alternatives. This feature allows alterations to the phase lengths at the intersection, often through phase extension or early green (2). The phase extension method lengthens the green time for the movement with the transit vehicle. Early green will truncate the green time of the cross-street phase in order to return quicker to the transit vehicle's phase. This truncation is set up so that it never violates the pedestrian crossing time at the intersection. A queue jump was also implemented at the east end of the network. At this location the bus exits the guideway and must merge into the general-purpose lanes.

MODEL DEVELOPMENT AND SIMULATION

The simulation model is comprised of two components, the signal controllers (individual intersection controllers and BWC) and the VISSIM traffic and transit model. These two entities work together during the simulation to generate an animation file and output data. The signal controllers are designed to closely replicate the actual controllers in the field. Similarly, the traffic and transit model also requires detailed field data.

Data Inputs

In order to replicate field conditions accurately, the following information was used in the simulation model:

- Aerial photograph (to scale)
- Hourly traffic volumes per movement
- Pedestrian volumes
- Signal timing parameters including forceoffs, offsets, clearance intervals, and detector locations
- Posted speed limits
- Bus routes and schedules
- Transit stop locations with average dwell time and standard deviation

Validation

For this study, validation of the model was limited to travel time comparisons. LTD employees were asked to monitor their travel time when driving the corridor. A comparison of these travel times showed that they were within the range produced by the simulation model.

Impact Assessment Methodology

A 1997 and 2015 model was built for each alternative. Each had two bus lines operating with 10-minute headways. Measures of Effectiveness (MOEs) for this analysis were limited to travel time, level of service, and volume of buses through the guideway. It is generally accepted that a minimum of three simulation runs should be performed (3). For this project, ten one-hour simulation runs were performed for each model using the same ten random seeds. Data collection was not started until 300 seconds had passed to allow for sufficient vehicle buildup in the network.

Using the output of the ten simulation runs, comparisons of the intersection levels of service and the travel times were completed for all of the alternatives. A sensitivity analysis was also performed on the single-guideway alternatives.

Intersection Level of Service
Level of Service (LOS) was computed for all six signalized intersections using stopped delay averaged over the hour. LOS based on average stopped delay for every signalized intersection was compared between the scenarios.

Travel Time
Corridor travel times for buses and general purpose vehicles were measured from 11th Avenue west of Franklin Boulevard to the east side of the Glenwood Boulevard intersection.

Sensitivity Analysis
A two-component sensitivity analysis was performed for the single-guideway alternatives using the 1997 traffic volumes only. These analyses were expected to provide a better understanding of the operational characteristics of the single-lane guideway by testing the capacity and schedule limitations.

The first component of the sensitivity analysis monitored the effect of bus headway on travel time. Buses operated on a fixed schedule starting with a 15-minute headway in both directions. In every consecutive simulation, the headway was decreased in 1-minute intervals (for both directions) until a noticeable increase in travel time was observed. At this point, the headway was decreased in 30 and 15 second intervals to accumulate more detailed data. This analysis used the same random seed for each run.

The second component of the sensitivity analysis was used to determine the optimum directional offset in terms of travel time. The "offset" discussed here is the time separation between the arrival of the EB and WB buses at the east and west guideway entrances. The WB bus schedule was fixed on a 10-minute headway. The EB bus also ran on a 10-minute headway, however, the start time was changed for each run. The offset was increased in 30-second intervals and the average travel time recorded for each simulation run. The same random seed was used for each run.

Results

The data output from the simulation models contains detailed information on the travel time, delay, and vehicle volume. The following section presents the analysis and results of the impact assessment.

Intersection LOS
Table 1 displays the LOS for each signalized intersection. The no build alternative shows that all signalized intersections in this section of Franklin Boulevard are presently operating at an acceptable LOS and will likely continue to do so in 2015. In the guideway scenarios, the signal priority strategy increases delay to the side-street movements but benefits the east-west movements. Therefore the overall impact on intersection LOS is minimal.

TABLE 1 Level of Service at Signalized Intersections

Alternative	Year	Intersection					
		11th	Onyx	Agate	Villard	Walnut	Glenwood
No Build	1997	B	B	B	B	A	A
	2015	B	B	C	C	B	B
Single Guideway Station Passing	1997	B	B	C	C	A	B
	2015	B	B	C*	C	B	B
Single Guideway Intersection Passing	1997	B	B	C	B	A	B
	2015	B	B	C*	C	C	B

* An eastbound right-turn only lane has been added at the intersection

Travel Time

The results of the travel times analysis are shown in Table 2. The bus travel time also includes the dwell time at the bus stops. With the 1997 traffic volumes, bus travel times for the single-guideway scenarios are considerably longer than the no build alternative. The 2015 results, however, indicate some improvements in bus travel time over the no build alternative.

TABLE 2 Corridor Travel Time (seconds)

	No Build		Single Guideway Station Passing		Single Guideway Intersection Passing	
1997	EB	WB	EB	WB	EB	WB
Bus	385	384	411	480	369	432
General Purpose	284	285	284	287	284	285
2015	EB	WB	EB	WB	EB	WB
Bus	432	398	408	365*	366	415
General Purpose	316	299	330	315	335	332

* The network has been modified allowing the WB bus to enter the guideway at Walnut Street

The slower travel times displayed by the single-guideway alternatives are likely a result of the long section of guideway without passing opportunities between Glenwood Boulevard and Walnut Street. Westbound buses must wait until this section is empty before they can enter. Eastbound buses have more passing locations at the western end of the network, and as a result, they have more opportunities to enter the guideway. As outbound buses, they also have priority over the westbound buses. The intersection passing alternative displays slightly faster travel times than the station passing alternative for EB buses. This is due to the increased number of signals the buses must negotiate. With the intersection passing, the blocks and intersections are tied together, resulting in fewer potential stopping locations and allowing the bus to move with the EB green band, hitting fewer red signals.

Sensitivity Analysis

Travel times for the single-guideway alternatives are plotted against headway in Figures 4 and 5. Travel times remain relatively constant until headways drop below five minutes.   Buses operating on a short headway will almost always meet a bus traveling the opposite direction through the guideway and must wait for a passing opportunity. A comparison between Figures 4 and 5 shows that travel times fluctuate much more for the station passing alternative than for the intersection passing alternative. The travel times for the intersection passing alternative remain relatively unchanged with the increased headway. The information shown on Figure 5 can be misleading. Although the travel time is unchanged, the guideway does not have the capacity to accommodate all of the buses, and some are prevented from entering the guideway.

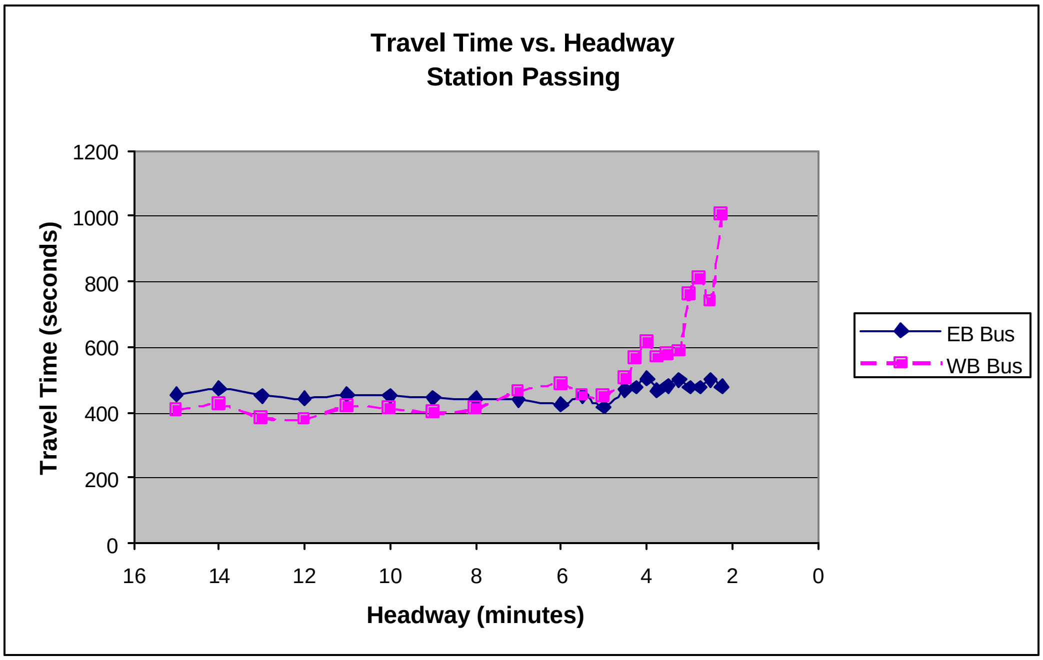

Figure 4

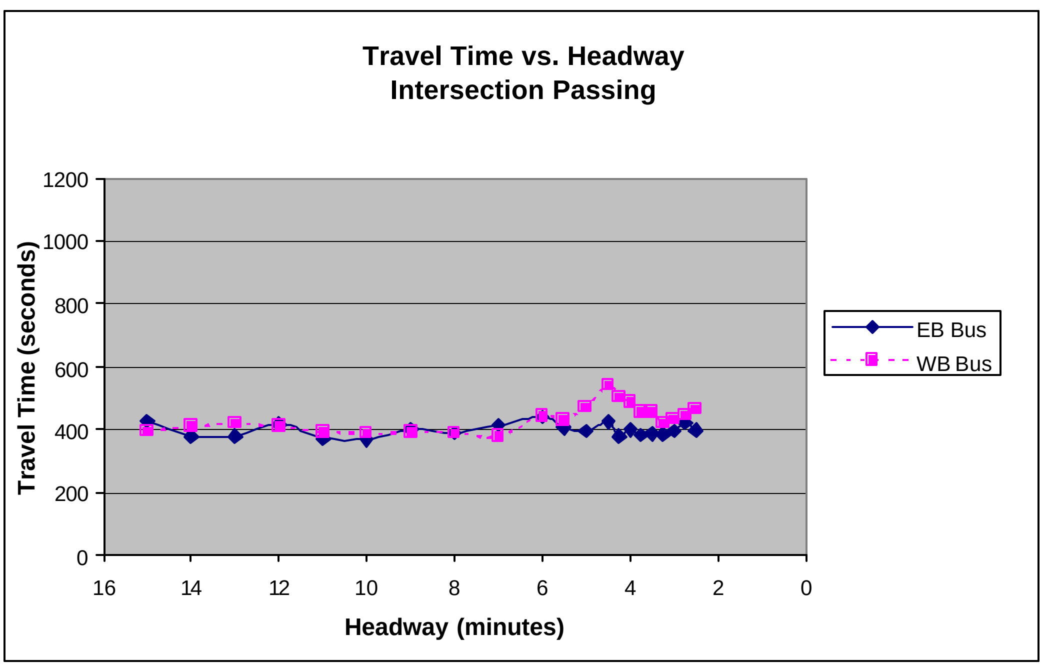

Figure 5

Based on these results, it is recommended that headways greater than five minutes be used in the field. LTD is planning to use a 10-minute headway between buses. Both of the single-lane guideway alternatives will be capable of handling that headway with minimal delay.

Figures 6 and 7 display the volume of buses traveling through the guideway. Similar to the travel times, the bus volumes also indicate a limiting value for headway. Figure 6 shows that headways shorter than five minutes will not allow all of the buses to pass through the guideway in the station passing alternative. The capacity of this alternative appears to be about 10 buses per hour in each direction. The intersection passing alternative has a much lower capacity. As the headway drops below eight minutes, the buses arrive at such short intervals that the eastbound route dominates the guideway. Since eastbound buses have priority over westbound, there is never a sufficient gap between the eastbound buses to allow the westbound buses access to the guideway. In this case the capacity appears to be 7-8 buses per hour in each direction. Again, the 10-minute headway proposed by LTD will be within the capacity constraints for either single-guideway alignment.

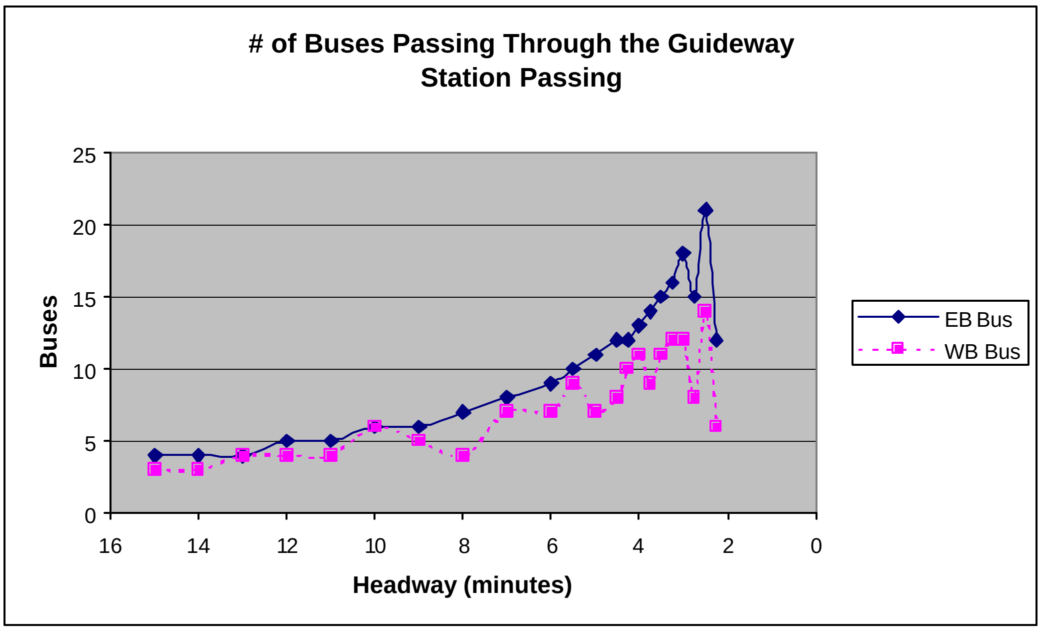

Figure 6

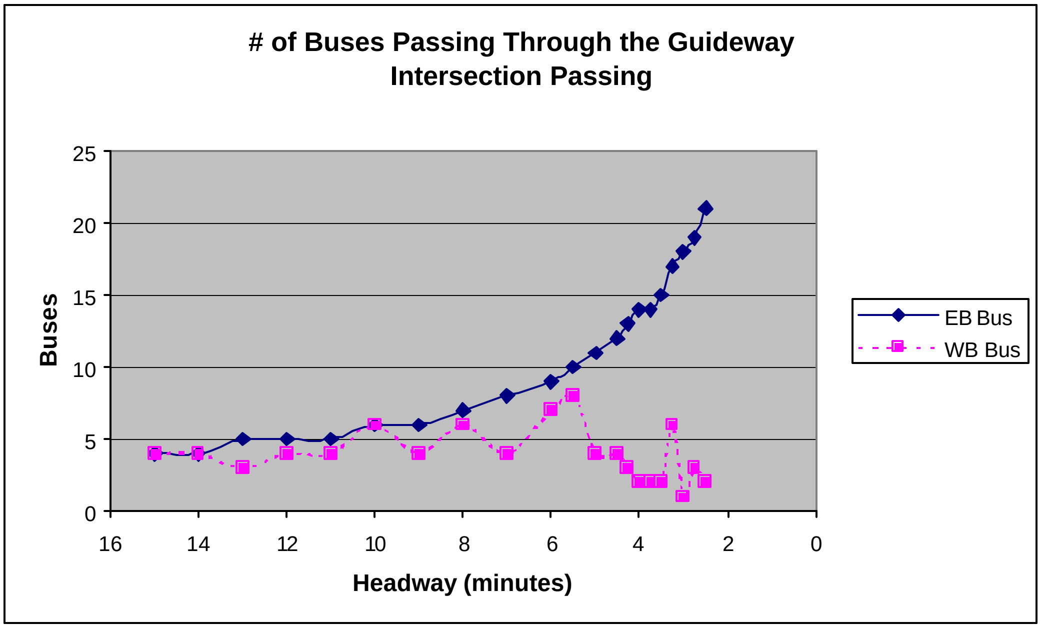

Figure 7

Figures 8 and 9 display the travel times corresponding to offset for the two alternatives. Both alternatives show a range of offset values resulting in shorter travel times for both directions, although it is more apparent on Figure 8. The offsets within this range are 480 to 600 seconds and 0 to 210 seconds for buses operating with a 10-minute headway. For example, the eastbound bus could enter the guideway 90 seconds later than the westbound bus. The westbound bus would immediately move through the longest section of guideway between Glenwood Boulevard and Walnut Street, and the two buses would pass somewhere between Walnut Street and 11th Avenue. This schedule minimizes travel time, as neither bus has to wait to enter the longest section of guideway.

The longer travel times corresponding to offsets from 210 to 480 seconds are a result of one bus being delayed at the entry to the long section between Walnut Street and Glenwood Boulevard. If the guideway had another passing point in the middle of that section, the capacity of the guideway would increase and strict adherence to schedule would not be a high priority.

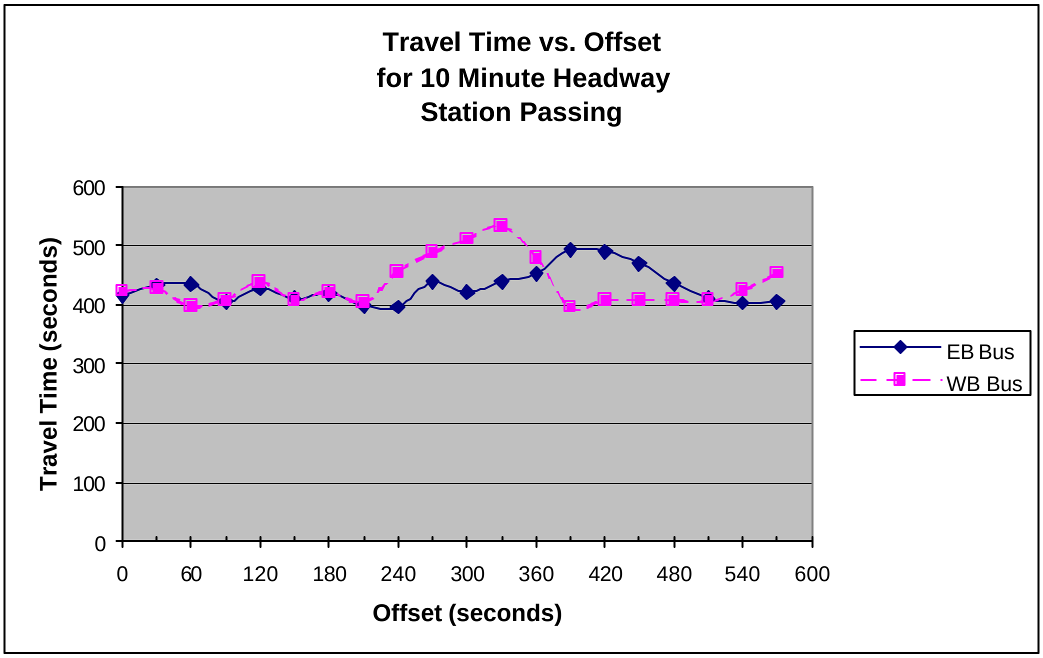

Figure 8

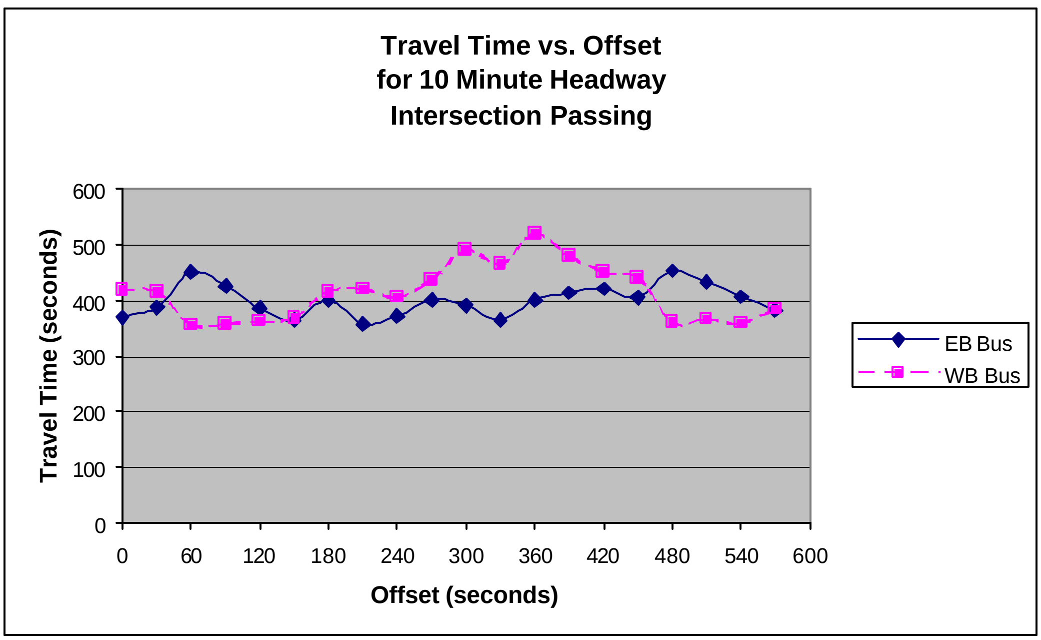

Figure 9

CONCLUSIONS

The results of this analysis can be used to recommend a preferred guideway configuration. Modeled with the 1997 traffic volumes, there is little improvement in bus travel time using the single-guideway alternatives. However the guideway with passing at the stations may prove to be a good choice as congestion on Franklin Boulevard increases. Travel time savings are noticeable with the 2015 traffic volumes, and could be improved with further analysis of the signal priority, the block signal strategy, and detector placement. The capacity of this guideway configuration exceeds the volume of buses that LTD is planning to operate. The bus separation logic for this alternative is also less complex than for the intersection passing alternative. The public may be more accepting of this alignment too, as the concept of passing in intersections has not been tested.

REFERENCES

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AUTHOR’S INFORMATION

Inga M. Note is employed with Innovative Transportation Concepts, Inc., in the firm’s Corvallis, Oregon office. The analysis for the first phase of this project was conducted as a master’s project in conjunction with Oregon State University. Since then, she has been involved in operational analysis for all segments of Lane Transit District’s Bus Rapid Transit pilot corridor project.