ADJUSTMENT OF DRIVER BEHAVIOR TO AN URBAN MULTI-LANE ROUNDABOUT

Final Report

SPR 041

ADJUSTMENT OF DRIVER BEHAVIOR TO AN URBAN MULTI-LANE ROUNDABOUT

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by

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for

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16. Abstract

In the summer of 2006, the city of Springfield, Oregon installed the first urban multi-lane roundabout in the state. It was hypothesized that after installation, speed variability on approaches to the intersection would decrease from the values with the previous signalized intersection. It was also hypothesized that the initially observed high incidence of driving errors associated with specific areas of the roundabout would decrease over time. Before and after speed recordings of approach roads to the intersection revealed a significant increase in mean speed, but no consistent change in speed variability. Some design features caused initial confusion amongst drivers negotiating the roundabout, but the number of observed incidences of confused behavior declined over the first six months of operation at a rate that fit a classic logarithmic learning curve.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

The author wishes to thank Brian F. Barnett, Traffic Engineer for the City of Springfield, Oregon for suggesting this study, and for his support in gathering study data. Additional thanks to Steve Rodolf, Assistant City Engineer for the City of Springfield, Oregon for his on-site assistance in familiarizing the author with the project.

DISCLAIMER

ADJUSTMENT OF DRIVER BEHAVIOR
TO AN URBAN MULTI-LANE ROUNDABOUT

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1.0 INTRODUCTION

1.1 OVERVIEW

In June of 2006, the City of Springfield, Oregon began a street construction project which included the replacement of an existing 'T' intersection controlled by a traffic light with a five-legged multi-lane roundabout. The new roundabout incorporated an access drive to a residential area and an extension of the 4-lane parkway which had formed the base of the 'T'. This was the first multi-lane urban roundabout in Oregon.

The safety and traffic capacity benefits of roundabouts are well documented.[1] The construction of the Springfield roundabout might appear to be an opportunity for a 'before and after" comparison of the traffic and safety impacts of this improvement to add to the already established record. For this project, however, the extension of the parkway that formerly formed the base of the 'T' changed the traffic dynamics too greatly for such a comparison. Fortunately there were other impacts of a new roundabout for which this project was well suited as a subject. This study selected two aspects of the change for examination that could give valid and potentially useful information.

The first aspect of the study examined approach speeds on two of the legs of the intersection before and after the change. The hypothesis was that, before the construction of the roundabout, motorists approaching the traffic signal would take a visual cue from the control light ahead and speed up or slow down in advance of the intersection to 'make the light' or coast up to the stop. After construction, motorists approaching the roundabout would have no variable incentive to change their speed. A comparison of the variability of approach speeds would serve to test the hypothesis that these speeds would show reduced variability following adaptation to the new roundabout intersection.

The second aspect of the study examined the 'learning curve' of drivers adapting to the multi-lane roundabout. Two specific locations at which a large number of driver errors was initially observed were monitored over a six-month period. The hypothesis was that the number of driver errors would decrease as drivers became familiar with the operation of the roundabout.

1.2 THE INTERSECTION AND THE PROJECT

As shown in Figure 1.1, the original intersection at Hayden Bridge Road and the divided Pioneer Parkway was unusual. Hayden Bridge Road approaching from the west was two lanes in each direction plus a center turn lane. To the east, Hayden Bridge Road was a single lane in each direction. The two lanes of Pioneer Parkway approaching the intersection from the south were controlled by the traffic signal at the intersection, but the two southbound lanes offset to the west diverged from Hayden Bridge Road about 80 feet before the signalized intersection control line.

[1] Jacquemart, Georges, "Modern Roundabout Practice in the United States", Synthesis of Highway Practice 264, Transportation Research Board , National Academy Press, Washington, D.C. 1998

Wayside Lane, a two-way access road for a residential area offset slightly to the east of the line of Pioneer Parkway, entered onto Hayden Bridge Road within the area of control of the traffic signal but was controlled by a stop sign.

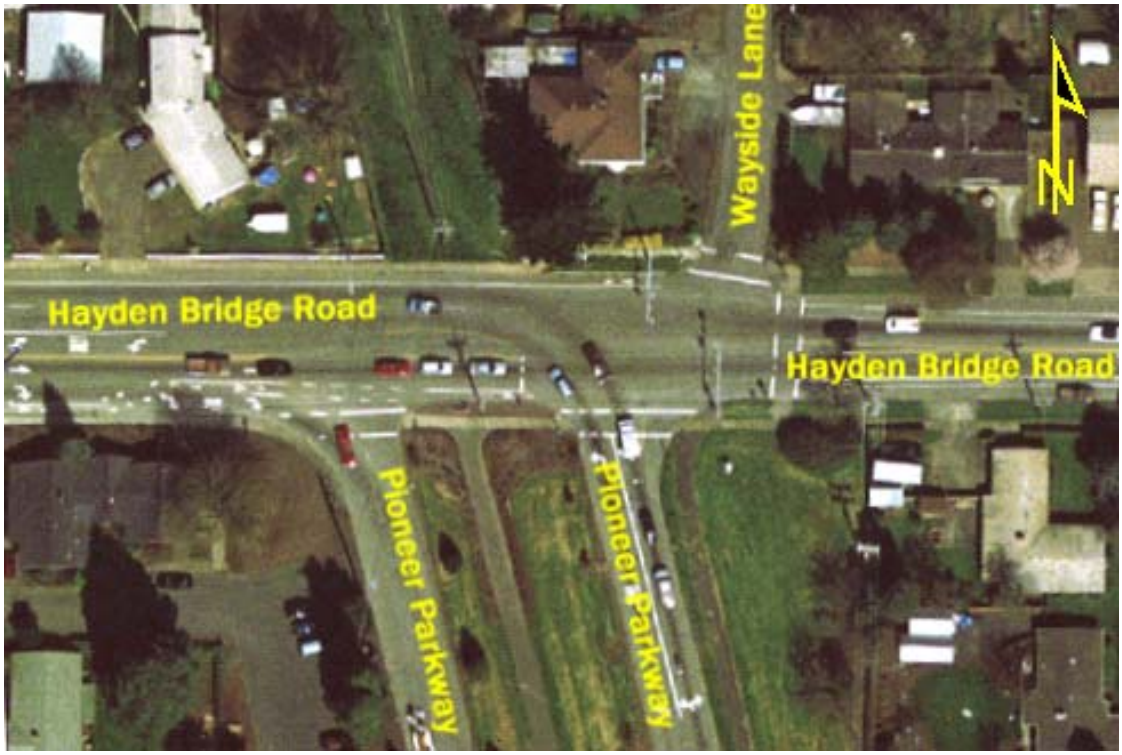


Figure 1.1: Arial view of intersection before project start

The primary traffic flow was traffic turning from northbound Pioneer Parkway onto westbound Hayden Bridge Road, and from eastbound Hayden Bridge Road onto southbound Pioneer Parkway.

The City of Springfield website described the project (see Figure 1.2) which would change the intersection:

> "The project consists of construction of four lanes Portland Cement Concrete (PCC) paving on Beltline Road from Hutton Street to Game Farm Road, then a new four lane PCC road (Martin Luther King, Jr. Pkwy) south to the intersection of Pioneer Parkway and Hayden Bridge Way."
>
> "At the intersection with Hayden Bridge Way, the project will construct a multi-lane modern roundabout. Because of the complicated geometry of this intersection, and to improve safety and efficient traffic flow, the project engineers selected a roundabout over a conventional, signal intersection. While the roundabout will provide a relatively low

maintenance, long lived and beautiful intersection form, there are some challenges to its construction."[2]

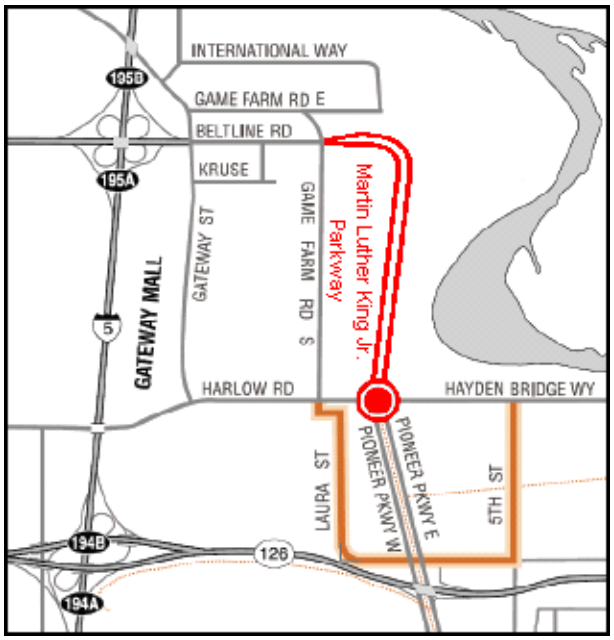


Figure 1.2: Location showing new construction

The roundabout itself has a number of unusual design elements, as shown in Figure 1.3:

1. Two 'right turn bypasses' from Martin Luther King Jr. Parkway southbound and from Hayden Bridge Road eastbound which allow turning traffic to completely avoid entering the roundabout.

2. A painted 'diverter wedge' which redirects the inside lane traffic on the south side of the roundabout into the outer lane at the eastbound exit.

3. A narrowing of the two-lane roundabout flow to a single lane around the north sector of the roundabout.

[2] http://www.ci.springfield.or.us/Pubworks/Martin_Luther_King_Webpage_files/mlk_project.html

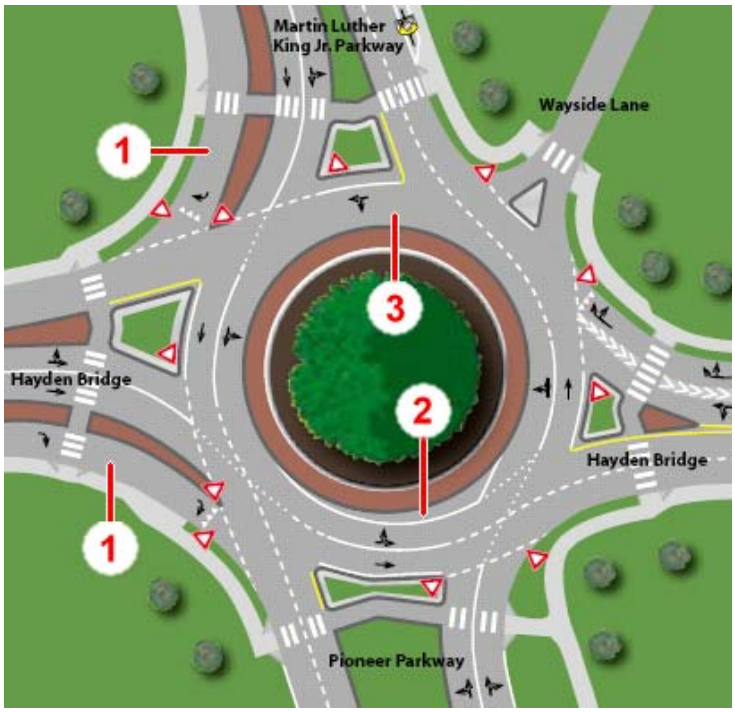


Figure 1.3: Diagram of the Springfield roundabout

2.0 THE STUDY

2.1 CHANGES IN THE VARIABILITY IN TRAFFIC SPEED APPROACHING THE ROUNDABOUT

2.1.1 Methodology

Drivers approaching an intersection controlled by a traffic light are typically able to look ahead and see the phase the signal is in. This visual cue is likely to influence the driver to either increase speed to 'make' the green light ahead, or to slow down in anticipation of coming to a stop at the red light. This may be quantified as variability in the measured speeds approaching the intersection. The hypothesis was that the conversion of the intersection – removing the signal and constructing the roundabout – would result in a decrease in the variability of vehicle speeds approaching the intersection.

Prior to the start of construction, standard road-tube speed measuring instrumentation was installed on the single westbound lane of Hayden Bridge road, 800 feet east of the intersection. A second instrumentation package was installed covering the two northbound lanes of Pioneer Parkway, 800 feet south of the intersection. The 800-foot distance was chosen to avoid the active braking zone for traffic approaching the intersection. This distance was based on observation of brake lights on vehicles approaching the intersection.

Both of these approaches to the intersection were free of traffic controls for a distance of well over one mile. The eastbound lanes of Hayden Bridge road west of the intersection were not instrumented, as there is a signaled intersection less than $1/8^{th}$ of a mile from the subject intersection that would induce a high degree of speed variability on its own.

Four months after the opening of the new roundabout, the speed measuring instrumentation was re-installed on the same routes at positions 800 feet back from the roundabout. Both sets of speed measurements were made for 24 hour periods mid-week.

2.1.2 Results

2.1.2.1 Westbound Hayden Bridge Road

Figure 2.1 shows the change in traffic speeds before and after the construction of the roundabout. The mean speed of traffic increased from 33.8 MPH before the installation of the roundabout to 35.3 MPH after the completion of the project. The posted speed of the road is 35 MPH. During the same period, the variance in speed decreased from 22.1 to 20.0. Both the change in the mean speed[3] and the change in the variance[4] are statistically significant.

[3] Two-sample t-test assuming unequal variances: t = -17.2, one-tail p = 7.1E-66
[4] Two-sample F-test for variance: one-tail p = 0.00014

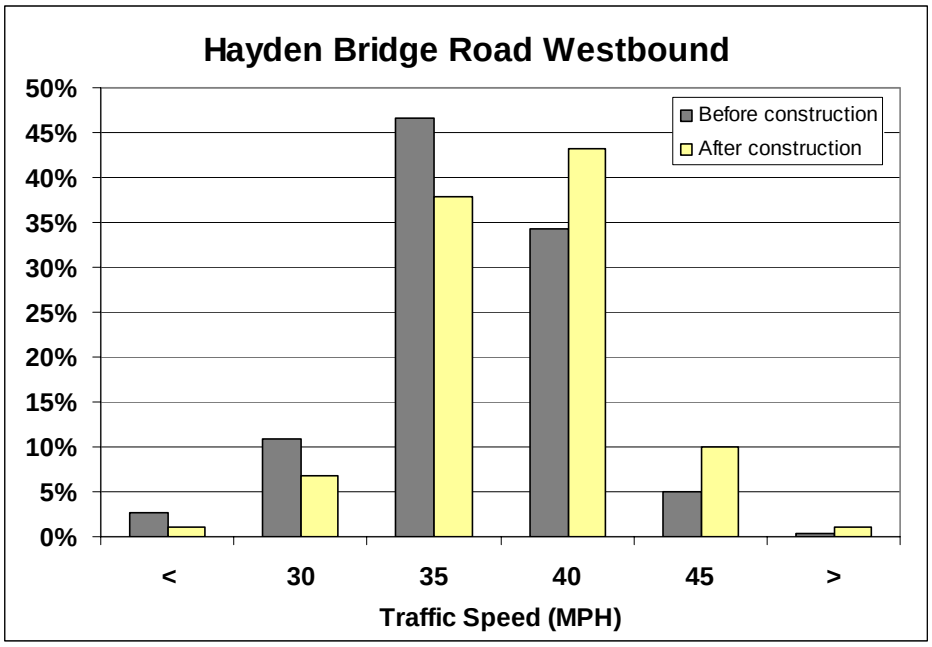


Figure 2.1: Change in traffic speeds on Hayden Bridge Road

2.1.2.2 Northbound Pioneer Parkway

Figures 2.2 and 2.3 show the changes in traffic speeds on Pioneer Parkway, in the right and left northbound lanes respectively. Both lanes showed an increase in mean speed following completion of the project: from 40.8 to 42.6 MPH for the right lane, and from 41.5 to 43.5 MPH for the left lane. The posted speed on the parkway is 45 MPH. Contrary to expectation, the speed variance increased for both lanes: from 24.3 to 29.2 for the right lane, and from 26.5 to 27.3 for the left lane. The mean speed increase is statistically significant for both lanes[5]. The unexpected variance increase for the right lane is statistically significant[6], but the variance increase for the left lane is not[7].

It may be that other variables played a greater role than anticipated, such as the predominance of left-turning traffic at the intersection and the need for drivers to plan for which lane they should be in.

[5] Two-sample t-tests assuming unequal variances: Right lane: t = -12.9, one-tail p = 1.27E-37; Left lane: t = -15.1, one-tail p = 3.25E-51

[6] Two-sample F-test for variance: one-tail p =6.82E-07

[7] Two-sample F-test for variance: one-tail p = 0.193

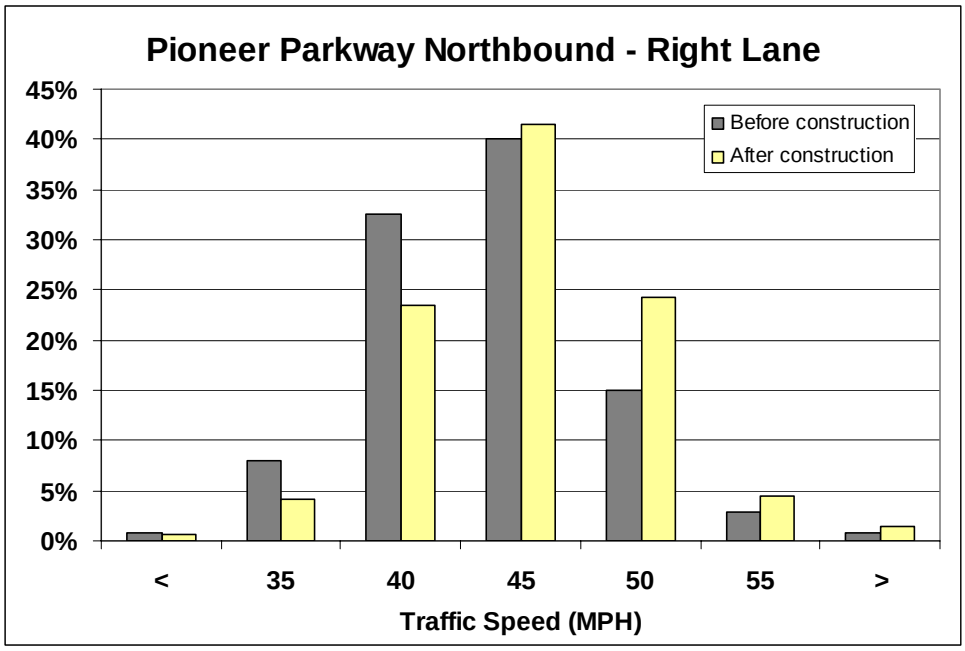


Figure 2.2: Change in traffic speeds on Pioneer Parkway, right lane

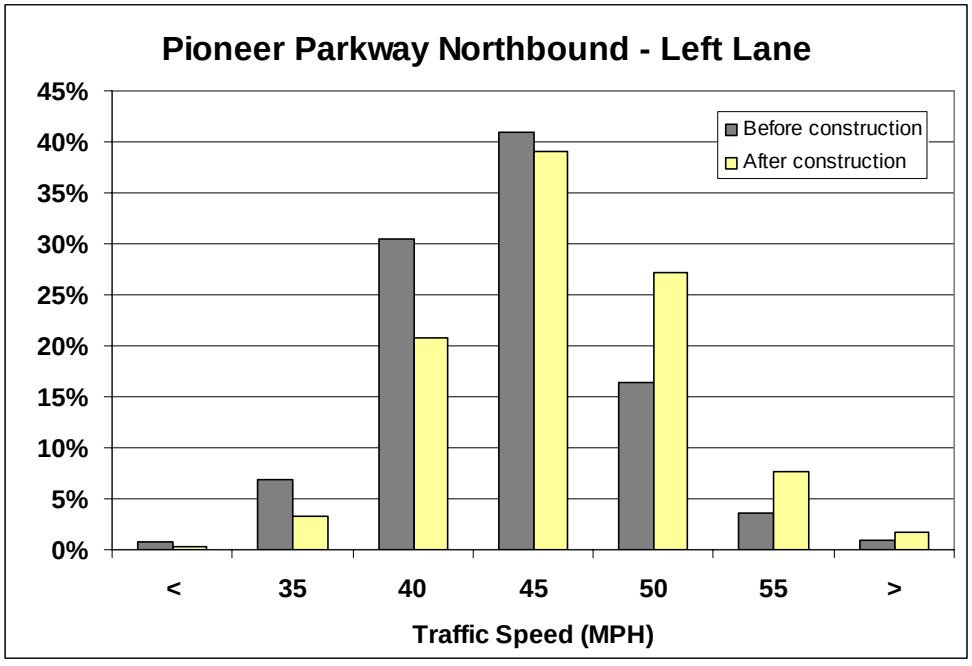


Figure 2.3: Change in traffic speeds on Pioneer Parkway, left lane

2.2 ADJUSTMENT OF DRIVERS TO THE NEW ROUNDABOUT

In advance of the opening of the new intersection, the City of Springfield initiated a broad program to educate area drivers about the new roundabout. A pamphlet of general information and driving tips was sent to every address within the city and to the nearby areas of neighboring Eugene, Oregon (see Appendix). Presentations to civic clubs and other public groups directly reached more than 900 people, with television and radio interviews and a newspaper insert reaching many more. Radio spots directed people to the city information website (www.gospringfieldoregon.info) for an instructional video, brochures, external links, and general information.

2.2.1 Methodology

Observations of the approaches and functioning of the roundabout during the first week of operation identified two easily quantifiable areas where drivers showed confusion or indecision in navigating the intersection. These areas were as follows:

- Westbound Hayden Bridge Road approaching the roundabout is a single traffic lane that diverges into two roundabout entry lanes. Vehicles entering via the right entry lane must exit onto Wayside Lane or Martin Luther King Jr. Parkway. Many of these vehicles were, however, observed making an abrupt lane change within the roundabout in order to continue circulating and avoid exiting onto Martin Luther King Jr. Parkway, as shown in Figure 2.4. The lane options were well marked, but the traffic change was apparently causing confusion at the new intersection.

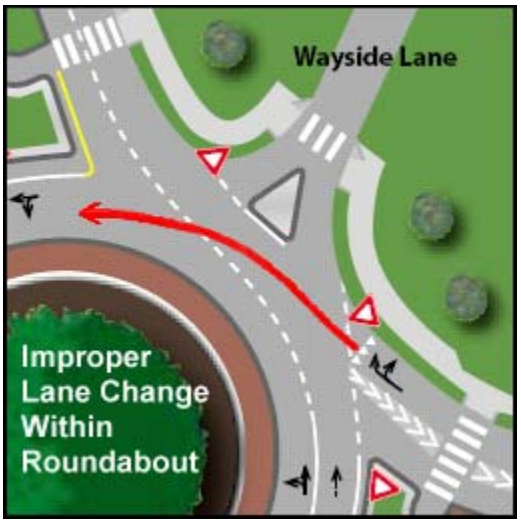


Figure 2.4: Lane change to avoid undesired exit of roundabout

- Vehicles approaching the roundabout in the left-hand lane of Hayden Bridge Road eastbound enter the roundabout in a lane which will allow them either to pass straight through the

roundabout, continuing on Hayden Bridge Road, or to continue around to exit onto either Wayside Lane or Martin Luther King Jr. Parkway. Many drivers were observed making a late merge from the left hand lane across a solid white line into the right hand lane as they approached the roundabout, as shown in Figure 2.5. The right hand entry lane, however, offers fewer exit options than does the left-hand lane. Again, the lane options were marked, but the new intersection was apparently confusing some drivers.

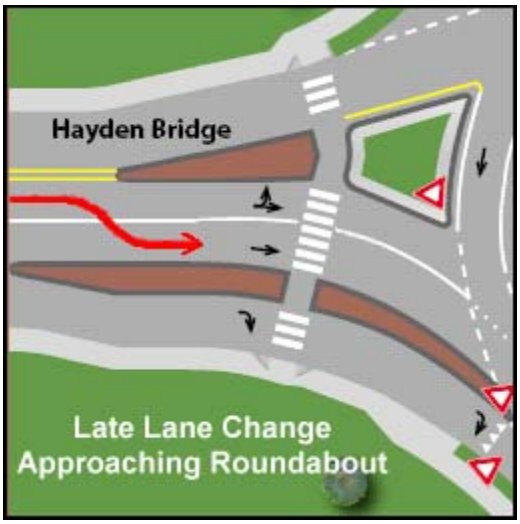


Figure 2.5: Late lane change on approach to the roundabout

Two camera positions shot 24 hours of video during the first week of operation to monitor unusual driver behavior. Seven weeks later, an additional pair of 24-hour videos was captured for comparison. On nine occasions during the first six months of roundabout operation, on-site observations were made by researchers to count and categorize errors made by drivers at specific approaches to the roundabout.

2.2.2 Results

2.2.2.1 Right entry lane from Hayden Bridge Road westbound

As noted earlier, the single westbound lane of Hayden Bridge Road westbound diverges into two lanes for entry into the roundabout. Vehicles entering via the left entry lane may exit onto Martin Luther King Jr. Parkway or may continue around to other exits. Vehicles entering via the right entry lane must exit onto either Wayside Lane or Martin Luther King Jr. Parkway.

A series of eight on-site observation sessions recorded the actions of vehicles entering the roundabout from the right entry lane. Initially, as many as 40% of all vehicles using this lane did not exit as required and performed an abrupt lane change within the roundabout in order to continue around to other exits. During construction, two-way traffic was

routed through the northern section of the partially completed roundabout with no option for turning onto Wayside Lane or the still-incomplete Martin Luther King parkway. Westbound traffic used what would become the right entry lane for the roundabout, and may have become accustomed to moving to the right to avoid oncoming traffic.

Observations over time showed an expected decrease in this behavior. Six months following the opening of the roundabout, the percentage of vehicles incorrectly using the right-hand entry lane had dropped to 3.3%. As shown in Figure 2.6, this change was well correlated to a logarithmic 'learning curve', with the correlation R^2 explaining 85.5% of the variation.

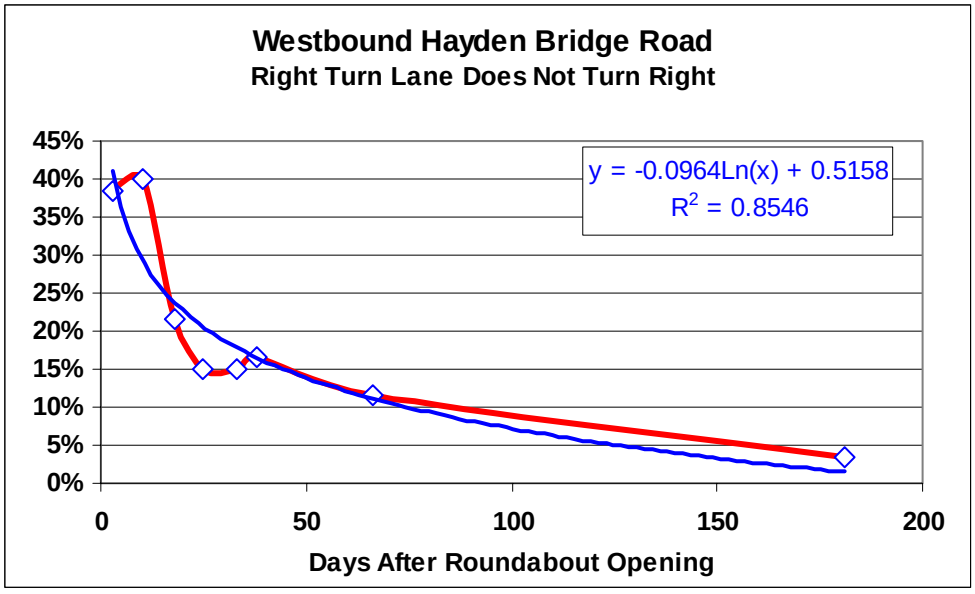


Figure 2.6: Change in improper use of right entry lane on westbound Hayden Bridge Road

2.2.2.2 Left lane Hayden Bridge Road eastbound approaching roundabout

The two eastbound lanes of Hayden Bridge Road approaching the roundabout diverge into three entry lanes.

- The left lane may continue through, staying on Hayden Bridge Road eastbound, or may circulate to exit on Wayside Lane or Martin Luther King Jr. Parkway northbound.

- The right lane becomes a center entrance lane which only allows vehicles to pass through the roundabout and continue on Hayden Bridge Road eastbound.

- A right-turn only bay splits off of the right lane of Hayden Bridge Road to permit turning onto Pioneer Parkway southbound.

Observations of the eastbound approach to the roundabout revealed a large percentage of vehicles performing a late merge from the left lane of Hayden Bridge Road, across a solid white lane line, into the center entrance lane. This action offers no additional options to the driver of the vehicle beyond what was available in the left lane.

The solid lane marking between the left and right lanes extends approximately 150 yards back from the roundabout entrance. For recording purposes, a vehicle was considered to have made a 'late merge' to the right lane if:

- The lane change was not complete by the time the vehicle was within 100 yards of the roundabout entrance, and;

- The vehicle continued in the right lane into the center entrance for the roundabout.

A series of seven on-site observation sessions recorded the actions of vehicles approaching the roundabout from the left lane of Hayden Bridge Road eastbound. Initially, 20% of all vehicles approaching in the left lane merged late into the right lane and continued on into the center entrance for the roundabout.

Observations over time showed an expected decrease in this behavior. Six months following the opening of the roundabout, the percentage of vehicles merging late into the right-hand lane had dropped to 5%. As shown in Figure 2.7, this change was well correlated to a logarithmic 'learning curve', with the correlation R^2 explaining 75.1% of the variation. The upward 'blip' in driving errors around the 35th day of operation for the roundabout may be attributed to an increase in drivers unfamiliar with the intersection due to the Christmas shopping season and the presence nearby of a large shopping mall.

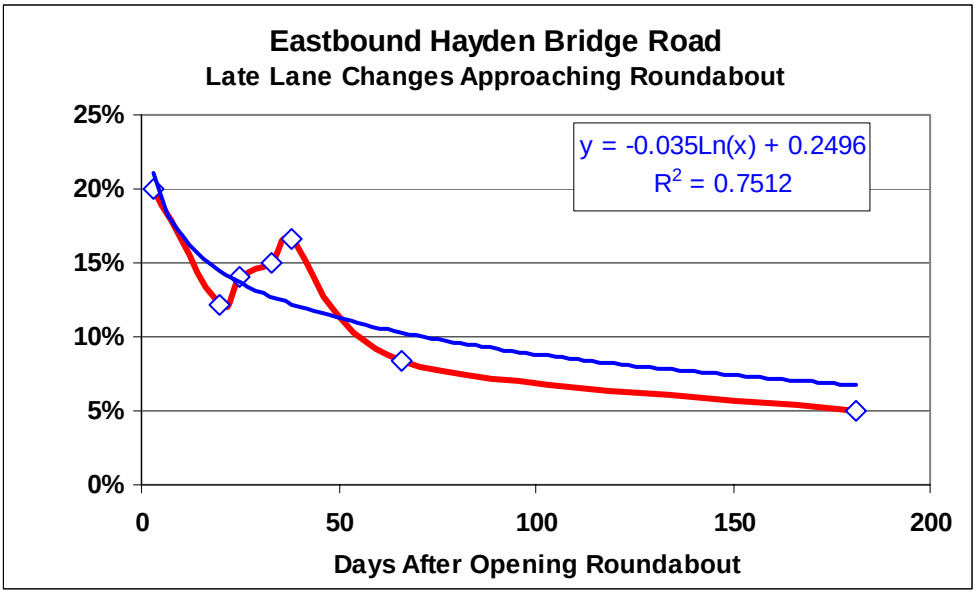


Figure 2.7: Change in late merge into right lane on eastbound Hayden Bridge Road

3.0 CONCLUSIONS

The impact of the new Springfield, Oregon roundabout intersection on the speed variability of approaching traffic was small and mixed. Of three approach lanes monitored, one decreased in variability, one increased in variability, and the third was inconclusive. The mean approach speed showed significant increases in all three lanes, averaging 4.5%. The hypothesized smoothing effect of the roundabout on the speed of approaching road traffic was not consistently supported by the study findings. Other variables related to traffic flow may have played a role.

The high incidence of driving errors observed in the opening weeks of the new intersection are assumed to stem from the lack of familiarity of local drivers with multi-lane roundabouts. Overall, the adjustment of drivers to the roundabout appeared smooth and followed an expected learning curve.

Roundabouts are known to be a valuable tool in effectively managing traffic flow in a safe and aesthetic manner. Although careful design is recognized as crucial to long-term efficient function, drivers can rapidly learn and adjust to situations that may initially cause confusion in navigating the roundabout.

APPENDIX: SPRINGFIELD ROUNDABOUT BROCHURE

City of Springfield
Transportation Division
Public Works Department
225 Fifth Street
Springfield, Oregon 97477

SPRINGFIELD

PIONEER PARKWAY
HAYDEN BRIDGE
MARTIN LUTHER KING, JR. PARKWAY

ROUNDABOUT

General Information and Driving Tips

City of Springfield

www.gospringfieldoregon.info

SPRINGFIELD

BENEFITS OF A ROUNDABOUT

Safety
Roundabouts are safer than other intersections because they eliminate head-on, right angle, and left-turning traffic crashes. Roundabouts encourage slower speeds and allow for easier decision making. When comparing a roundabout to a signal, studies show that roundabouts provide up to a 90% reduction in fatal crashes, 75% reduction in injury crashes, 30-40% reduction in pedestrian crashes, and 10% reduction in bicycle crashes. Roundabouts improve pedestrian safety by offering short crossings of one-way traffic moving at slow speeds.

Economy
Roundabouts save our citizens money. The City saves because operations and maintenance expenses of roundabouts are less than traffic signals. Drivers save through reduced waiting time and lower fuel consumption. More importantly, our community saves because collisions are less frequent and much less severe, reducing insurance cost, medical cost, and the human cost of injury and death. Roundabouts also reduce the need for roadway expansion to accommodate the lines of stopped vehicles generated by traffic signals.

Capacity
Roundabouts typically carry about 30-50% more vehicles than similarly sized signalized intersections during rush hour because traffic is always on the move. During light traffic conditions, roundabouts cause almost no delay, whereas traffic signals can cause delay to side streets and left-turning traffic from the major street. Increased capacity at roundabouts is due to the continuously flowing nature, versus waiting turns at a red light.

Environment
Fuel consumption and air pollution are reduced significantly due to fewer stops and lower travel delay.

Beauty
Roundabouts' central islands provide areas for landscaping, sculpture, or other aesthetic features. They also avoid the clutter of traffic signal controller boxes, poles and wires, and pavement cuts.

PEDESTRIANS
1. Always use the sidewalk.
2. Approach the crosswalk.
3. Look for approaching vehicles.
4. When safe, cross the street to the median island; it is there to provide pedestrians a refuge between lanes.
5. From the median island, look for approaching vehicles.
6. When safe, cross the remaining lane of traffic.

BICYCLES
1. Approach the roundabout in the bicycle lane.
2. Where the bicycle lane ends, either use the bicycle ramp up to the sidewalk, or merge with traffic. **BE ASSERTIVE WHEN MERGING WITH TRAFFIC.**
3. Bicycles using the street should follow the same rules as motorists, occupying the middle of the lane.
4. Bicycles using the sidewalk should follow the same rules as pedestrians.
5. Use the bike ramp to re-enter bike lane.

EMERGENCY VEHICLES
Do not enter the roundabout when emergency vehicles are approaching–pull to the right side. Allow vehicles in the roundabout to clear in front of the emergency vehicle. If you are in the roundabout, exit the roundabout and pull to the side. **NEVER STOP IN THE ROUNDABOUT.**

For additional information, contact:

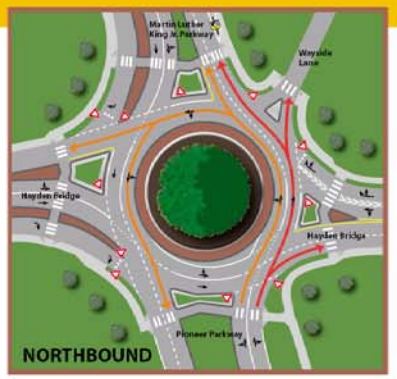
City of Springfield
Transportation Division
Public Works Department
225 Fifth Street, Springfield, Oregon 97477

Phone: 541-726-4584 · Fax: 541-726-3781
E-mail: publicworks@ci.springfield.or.us

www.gospringfieldoregon.info

3-2006

DRIVING THE ROUNDABOUT



TO EAST SPRINGFIELD OR WAYSIDE LANE

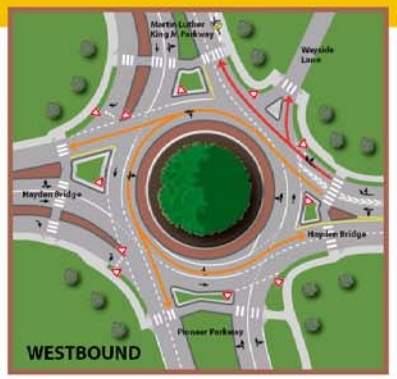
1. When approaching the roundabout, you must be in the RIGHT LANE.
2. Stop for pedestrians in the crosswalk or preparing to cross.
3. Yield to traffic in the roundabout.
4. Enter the roundabout when there is a safe gap in the traffic.
5. Stay in your lane.
6. Use your right turn signal and exit the roundabout.
7. Stop for pedestrians in the crosswalk or preparing to cross.

TO HOSPITAL OR I-5

- When approaching the roundabout, you can be in the LEFT LANE or RIGHT LANE.
- Follow instructions 2-7 as mentioned above.

TO GATEWAY AREA OR DOWNTOWN SPRINGFIELD

- When approaching the roundabout, you must be in the LEFT LANE.
- Follow instructions 2-7 as mentioned above.



TO WAYSIDE LANE, HOSPITAL OR I-5

1. When approaching the roundabout, you must be in the RIGHT LANE.
2. Stop for pedestrians in the crosswalk or preparing to cross.
3. Yield to traffic in the roundabout.
4. Enter the roundabout when there is a safe gap in the traffic.
5. Stay in your lane.
6. Use your right turn signal and exit the roundabout.
7. Stop for pedestrians in the crosswalk or preparing to cross.

TO GATEWAY AREA, DOWNTOWN OR EAST SPRINGFIELD

- When approaching the roundabout, you must be in the LEFT LANE.
- Follow instructions 2-7 as mentioned above.

TO GATEWAY AREA

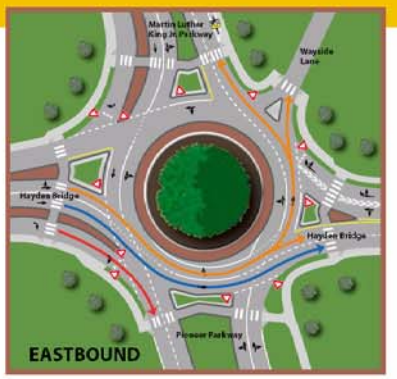
1. When approaching the roundabout, you must be in the RIGHT LANE.
2. Stop for pedestrians in the crosswalk or preparing to cross.
3. Yield to traffic exiting the roundabout.
4. Stop for pedestrians in the crosswalk or preparing to cross.

TO DOWNTOWN SPRINGFIELD

1. When approaching the roundabout, you can be in the CENTER LANE or LEFT LANE.
2. Stop for pedestrians in the crosswalk or preparing to cross.
3. Yield to traffic in the roundabout.
4. Enter the roundabout when there is a safe gap in the traffic.
5. Stay in your lane.
6. Use your right turn signal and exit the roundabout.
7. Stop for pedestrians in the crosswalk or preparing to cross.

TO EAST SPRINGFIELD, WAYSIDE LANE, HOSPITAL, OR I-5

- When approaching the roundabout, you must be in the LEFT LANE.
- Follow instructions 2-7 as mentioned above.



TO DOWNTOWN SPRINGFIELD

1. When approaching the roundabout, you must be in the RIGHT LANE.
2. Stop for pedestrians in the crosswalk or preparing to cross.
3. Yield to traffic exiting the roundabout.
4. Stop for pedestrians in the crosswalk or preparing to cross.

TO EAST SPRINGFIELD

1. When approaching the roundabout, you can be in the CENTER LANE or LEFT LANE.
2. Stop for pedestrians in the crosswalk or preparing to cross.
3. Yield to traffic in the roundabout.
4. Enter the roundabout when there is a safe gap in the traffic.
5. Stay in your lane.
6. Use your right turn signal and exit the roundabout.
7. Stop for pedestrians in the crosswalk or preparing to cross.

TO WAYSIDE LANE, HOSPITAL, I-5 OR GATEWAY AREA

- When approaching the roundabout, you must be in the LEFT LANE.
- Follow instructions 2-7 as mentioned above.