

Multivariable Analysis of Roundabout Versus Traffic Signals -
A Case Study In Alberta

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ABSTRACT

Alberta Transportation policy states that roundabouts shall be considered as an alternative option for intersection designs where, in the judgment of the department, a greater degree of traffic control than a two-way stop is required on a paved roadway. This paper presents a multivariate evaluation between two proposed alternative treatments, a roundabout and a traffic signal, for the future intersection of Lochend Road (Highway 766) & Highway 1A, in the County of Rocky View, Alberta. At the time of the study the intersection was two-way stop controlled.

A multivariate evaluation process was used to compare both alternatives. A total of 13 evaluation criteria in three categories were applied to compare both alternative configurations and to select a recommended plan. The categories identified were cost, safety and operations. At the end, each category reached a numerical weighted score evaluation for each option; higher score indicates a more favorable evaluation. Scores are relative rather than absolute.

In this study, the results showed that a signalized intersection is favored over the roundabout option; and hence was the recommended option. The study offered a systematic and credible method of evaluation for consideration in the final decision making process.

INTRODUCTION

Modern roundabouts have been successfully implemented in several countries and are becoming more popular in North America. Recently, Alberta Transportation has produced the Roundabout Design Guidelines on Provincial Highways (Ref 1), which apply to the province of Alberta. The policy states that roundabouts shall be considered as the first option for intersection designs where, in the judgment of the department, a greater degree of traffic control than a two-way stop is required on a paved roadway, such as signalization or a four-way stop control. If a different control treatment is recommended for the location, the rationality behind the choice should be documented (Ref 1).

A traffic impact assessment was conducted to identify required improvements on the intersection of Lochend Road (Highway 766) & Highway 1A due to future development in the area (typically the 20 year horizon). The capacity analysis shows that the existing two-way stop control must be replaced for a higher degree of traffic control, in order to accommodate forecast future traffic at the intersection at an acceptable level of service for the approving authorities. A traffic signal warrant analysis was also conducted using the sixth edition of the Transportation Association of Canada (TAC) signal warrant matrix (Ref 2) and confirmed the need of signalization. However, a roundabout treatment must be considered as the first option according to the Province's policy. Therefore, both intersection treatments were selected as candidate solutions for the future upgrade of the intersection.

This paper presents a multivariate evaluation used to compare and identify the most suitable intersection treatment, between a roundabout and a traffic signal, for the future upgrade of the intersection of Lochend Road (Highway 766) & Highway 1A, in the County of Rocky View, Alberta. At the time of the study the intersection was two-way stop controlled. The evaluation aimed to identify the recommended intersection treatment and to document the analysis.

BACKGROUND INFORMATION

At the time of the study the intersection of Lochend Road (Highway 766) & Highway 1A was a four-leg intersection and controlled by a two way stop sign along Lochend Road. The intersection is located approximately six kilometers northwest of Calgary city limits (Figure 1). At this location, Highway 1A is a four-lane paved divided highway running east/west with the posted speed of 100 kilometers per hour (kph). Lochend Road (Highway 766) is a two-lane paved major collector roadway running north/south with a 9.0 meter surface and posted speed limit of 100 kph.

Figure 2 illustrates the total forecast traffic volumes for the weekday morning and afternoon peak hour by the year 2034. The total forecast traffic volumes include both the future background traffic and future developments' generated traffic.

Figure 1: Intersection Location (Source: Google Maps, 2012)

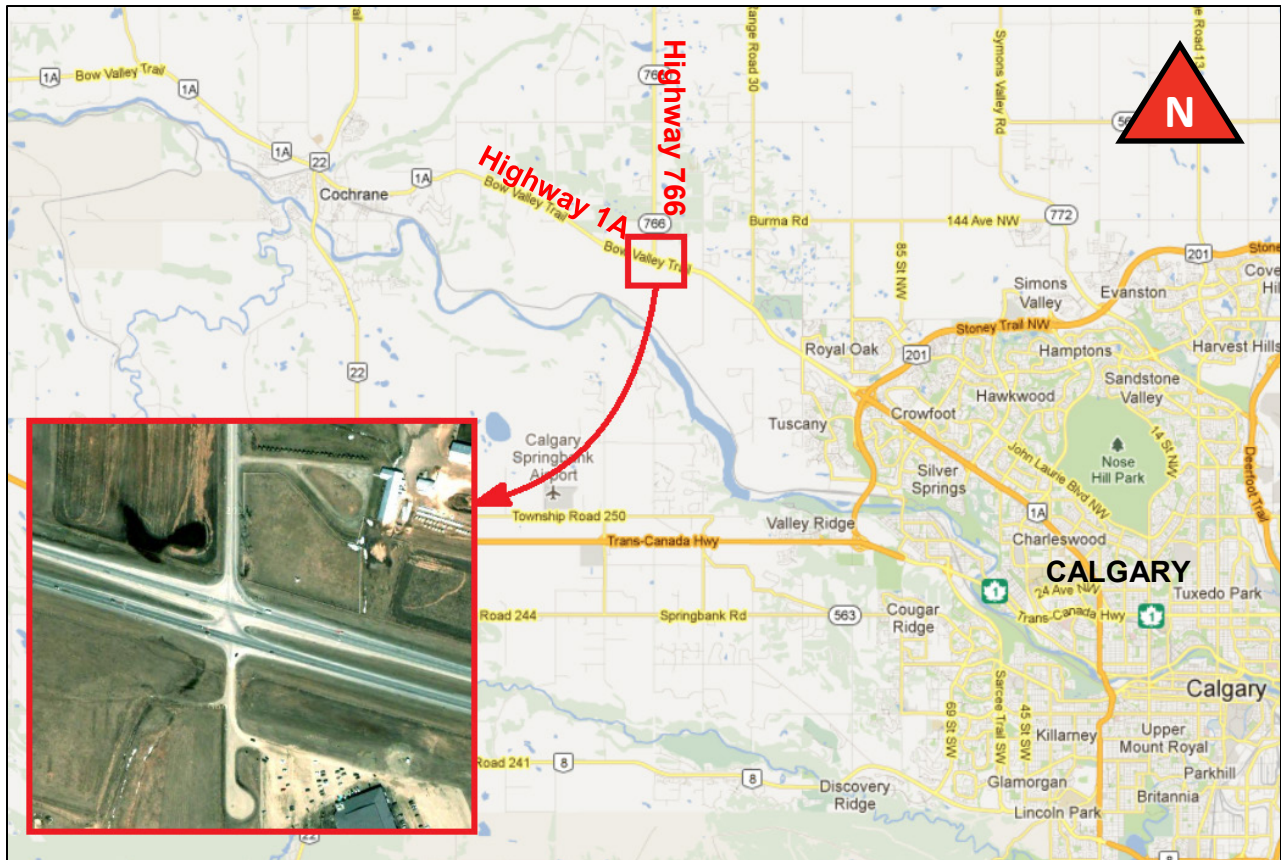
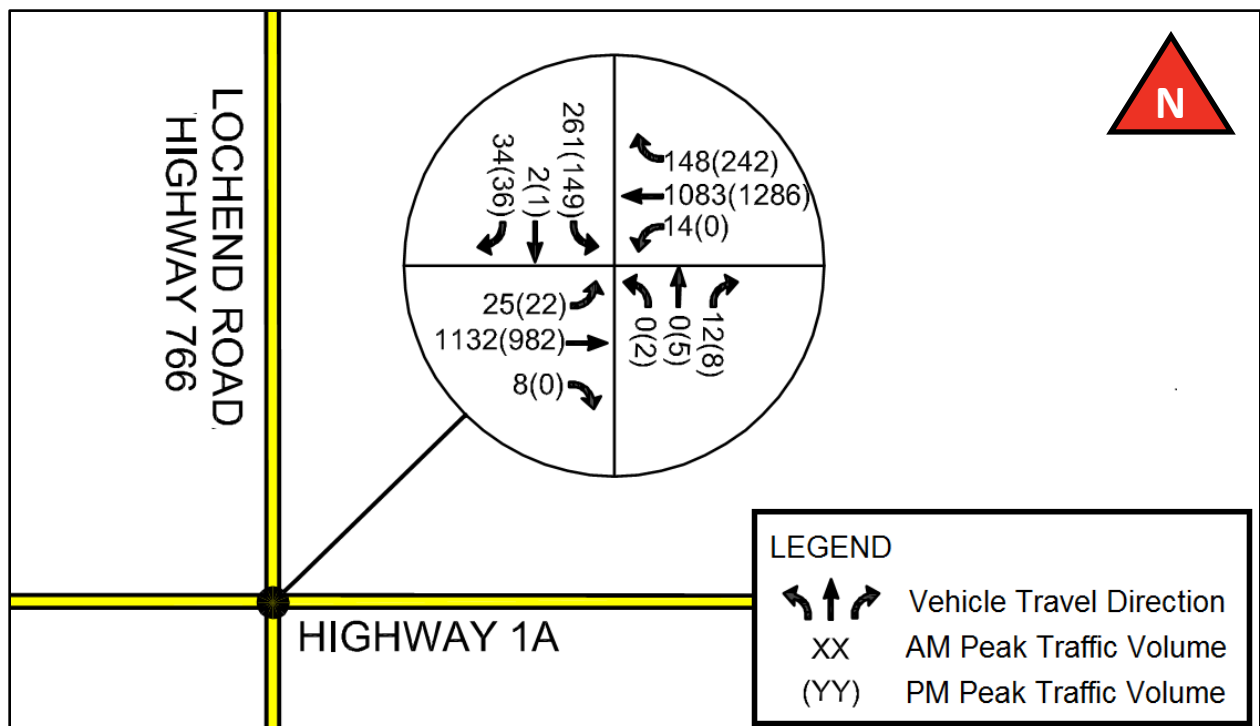


Figure 2: 2034 Total Forecast Traffic Volumes



DESCRIPTION OF ALTERNATIVES

Two intersection configuration alternatives for the Lochend Road (Highway 766) & Highway 1A were developed as follows:

Signalized Intersection

In order to accommodate the ultimate traffic volumes (2034) at acceptable level of services (LOS), the intersection of Lochend Road (Highway 766) & Highway 1A warrants a traffic signal control, and an auxiliary southbound left-turn lane with minimum 20m of storage length.

The proposed intersection configuration is: one left-turn (LT) auxiliary lane, two Thru lanes, and one right-turn (RT) auxiliary lane on both east and west approaches in Hwy 1A; one LT auxiliary lane, and one shared Thru/RT lane on the north approach; and one shared LT/Thru/RT lane on the south approach.

Roundabout

The proposed roundabout configuration is a double-lane approach on east and west legs (Hwy 1A); and one lane approach with auxiliary RT lane for north and south legs. The roundabout requires a two lane configuration.

A modern roundabout (referred in this paper just as roundabout) is a form of circular intersection that distinguishes from other types of circular intersections in its specific design and traffic control features. The main features are yield control for entering traffic, and appropriate geometric curvature and features to induce desirable vehicular speeds. Other features are a counter-clockwise traffic flow around a central island, and channelized approaches (Ref 3, 4, 5).

EVALUATION OF ALTERNATIVES

A multivariate evaluation process was used to compare both intersection treatments at the intersection of Lochend Road (Highway 766) & Highway 1A. Three categories were identified for the evaluation: cost, safety and operations. A total of 12 evaluation criteria –four per category– were applied to compare both intersection treatments and to select a recommended plan.

In the multivariable evaluation process an evaluation matrix is built for each category, cost, safety, and operations. Therefore three evaluation matrixes were completed in this study and are presented in Tables 5 to 7.

Table 1 shows the evaluation matrix template. Depending of the category –cost, safety, or operations– weight values are assigned to each evaluation criterion and their sum will equals 100. The weight assigned to each evaluation criterion reflects the opinion of how determinant the criterion is on the category to evaluate. Therefore the weight assigned to each evaluation criterion is not necessary the same for each matrix. As example, the evaluation criterion of *construction cost* –within the *cost category*– was

assigned a weight value of 25 in the *cost sensitivity matrix* compared to a weight value of 10 in the *operation sensitivity matrix*. This reflects the opinion that when evaluating the cost sensitivity, the construction cost criteria has strong influence on the result, while evaluating the operation sensitivity, the construction cost is relatively less determinant as compared to other evaluation criteria.

Table 1: Example of an Evaluation Matrix

Category	Evaluation Criteria	Weight	Signalized Intersection		Roundabout	
			Score	Weighted Score	Score	Weighted Score
COST	Construction Cost	xx				
	Roadway Modification Cost	xx				
	Footprint (Land Acquisition, Environmental, Historical, Utilities)	xx				
	Maintenance Cost	xx				
	SUB-TOTAL	XX		##		##
SAFETY	Intersection Conflicts	xx				
	Pedestrians and Cyclists	xx				
	Driver Expectation	xx				
	Crash Reduction Factors	xx				
	SUB-TOTAL	XX		##		##
OPERATIONS	Posted Speed	xx				
	Capacity	xx				
	Configuration Adaptability	xx				
	Design for Larger Vehicles	xx				
	SUB-TOTAL	XX		##		##
	TOTAL	100		Value1		Value2

Weighting must be completed at the very beginning of the process for each matrix. In this particular study weighting was based on previous experience in transportation projects for Alberta Transportation and municipalities.

Score points for each evaluation criterion are assigned to each treatment to compare (in this case, roundabout versus signalized intersections). The score points range from zero (very poor) to four (very good). The score points for each category remain the same in each evaluation matrix.

Finally, in each matrix, the weighted score for each evaluation criterion is calculated for both treatments. The weighted score of each evaluation criterion is the result of the product of the score points and the evaluation criteria's weight. A total weight score

(Value1 and Value2 in Table 1) is calculated for each treatment on each evaluation matrix.

The final result will be sum of all matrixes' total weighted score for each treatment. A higher score indicates a more favorable evaluation. Scores are relative rather than absolute.

Following, the 12 evaluation criteria selected in this study are defined and related information presented.

Cost

The category of Cost includes four evaluation criteria: construction cost, roadway modification cost, footprint, and maintenance cost.

Construction Cost: includes items such existing pavement removal, new paved roadway, and general earthworks. The signalization of the intersection will require adding a southbound left turn lane with minimum 20 m of storage length. Table 2 summarizes Level A cost estimates (high level cost estimates) for each intersection treatment. The construction costs difference between both alternatives is very high. The estimated costs do not include: signage, pavement marking, barrier, guardrail, removal of existing culverts, land costs, clearing, stripping, grading, topsoil, and armoring detail of storm water management facilities.

Table 2: Construction Cost Estimate

Lochend Road & Highway 1A Intersection Treatment	Cost
Traffic Signal + Southbound Left-turn Lane	\$ 740,000
Roundabout	\$ 3,500,000
The estimated cost does not include: signage, pavement marking, barrier, guardrail, removal of existing culverts, land costs, clearing, stripping, grading, topsoil, and armoring detail of storm water management facilities.	

Roadway Modification Cost: This refers to the cost of modifying the existing roadway as consequence of the intersection treatment. A modern roundabout requires approach modifications to achieve slow speeds.

Footprint: This is the cost associated to the footprint of each intersection treatment including required land acquisition, environmental impact costs, historical impact cost, and impact of utilities relocation. In general, a modern roundabout might require considerable more right-of-way than a signalized intersection. According to Federal

Highways Administration FHWA (Ref 5) a multilane roundabout typically requires an inscribed circle diameter of 46 to 91m (distance between curb to curb of the outer circulating lane); although no differentiation is provided for urban versus rural roundabouts. In a previous edition, the typical inscribed circle diameter was estimated 55 to 60m for a rural double lane roundabout (Ref 6). In general, urban roundabouts require smaller inscribed circle diameters due to geometrical constraints and smaller design vehicles (Ref 5). The conceptual design of Lochend Road (Highway 766) & Highway 1A assumed both treatments will require 0.4ha of land.

Maintenance Cost: The maintenance cost at signalized intersection includes traffic signal operation cost. A roundabout will require maintenance of landscaping features.

Safety

The category of Safety includes four evaluation criteria: intersection conflicts, pedestrian and cyclists, driver expectation, and crash reduction factors.

Intersection conflicts: Roundabouts have less conflict points compared to signalized intersections. In addition, they show less potential for hazardous conflicts such as high speed right-angle, left turn, and head-on collisions (Ref 3, 4, 5). However, two-lane roundabouts are less effective than one-lane roundabout as there are more conflict points between road users. These conflicts include drivers fail to maintain lane position, drivers enter next to an exiting vehicle, and drivers turn from the incorrect lane (Ref 5). In addition, in the case of roundabouts, crash frequency increases with the number of circulating lanes (Ref 3, 5). Traffic signals can move traffic in an orderly manner, reducing potential crash-producing conflicts and reducing the frequency of certain types of collisions (Ref 4).

Pedestrian and cyclists: Roundabouts are more challenging than a signalized intersection for pedestrians with visual and other physical impairments related to accessibility and usability of the facility (judging gaps between vehicles and deciding that a driver has yield to them). In addition, blind pedestrians rely solely on auditory information for crossing a street (Ref 3, 4). It was also identified that multilane roundabouts tend to have a higher percentage of vehicles that do not yield to pedestrians on either entry or exit, compared to single lane roundabouts. This might impact the effectiveness of the roundabout crosswalk for pedestrians (Ref 3).

One advantage of traffic signals is that they move traffic in an orderly fashion and can interrupt heavy traffic to permit other traffic to cross, such as vehicular or pedestrian traffic (Ref 4).

Driver expectation: The conformance of roadway geometry to driver expectancy is indicated by the presence of few or no geometric features that require the driver to make sudden adjustments in speed or unusual movements. The introduction of a roundabout on Hwy 1A might impact negatively driver expectation as compared to a signalized intersection. Both treatments, signalized intersection and roundabout, will require advance warning signs/signals.

Crash reduction factors: Table 3 presents the safety performance estimates for intersection conversion to roundabout (Ref 4). Roundabouts show statistically significant reduction of all type of collisions compared to other intersection treatments, except for all-way stop controlled intersections. When comparing the safety performance of roundabouts and all-way stop controlled intersection, it was found that they had the same statistics. When compared to signalized intersections, roundabouts show a collision reduction of 48% +/- 5 for all type of collisions, and 78% +/- 6 for fatal and injury collision type. The crash reduction factors are based on before-after treatment comparisons (Ref 3, 4).

Table 3: Safety Performance Estimates (Source: Reference 4)

Traffic Control Before Conversion to a Roundabout	Crash Severity	Crash Reduction Factor in Percentage (Standard Error)
All Sites (all environments, all number of lanes)	All	35 (3)
	Fatal/Injury	76 (3)
Signalized (all environments, all number of lanes)	All	48 (5)
	Fatal/Injury	78 (6)
All-Way Stop (all environments)	All	No statistically significant change
	Fatal/Injury	No statistically significant change

Federal Highway Administration (FHWA) also provides several crash modification factors (CMF) and crash reduction factors (CRF) throughout the Crash Modification Factors Clearinghouse (Ref 7). In the absence of collision data and prediction models, the application of CMF and CRF is recommended. Estimation of the safety benefit of a contemplated conversion of an existing intersection to a roundabout can be determined by applying the crash modification factors (CMF) to the expected collision frequency with the existing intersection treatment in place (Ref 3). However, this methodology assumes the conversion of one intersection control treatment (i.e. traffic signal) to a roundabout; and the comparison between traffic signals and roundabout may not be adjusted to the particular site characteristics as no collision data (by type and severity) is available for a future design.

Alberta Transportation policy states that roundabouts shall be considered as the first option for intersection designs where, in the judgment of the department, a greater degree of traffic control than a two-way stop is required on a paved roadway (Ref 1). However, FWHA recommends that the installation of a roundabout, as a safety improvement, should be based on a demonstrated safety problem that can be corrected by the roundabout. A review of collision reports and type of collisions is highly

recommended. Roundabouts are more appropriate for locations that include high frequencies of right-angle, head-on, and left turn collisions. However, roundabouts are less desirable at locations with a high frequency of rear-end collisions and fixed object collisions; where these type of collisions might actually increase with the introduction of the roundabout (Ref 4). Traffic signals are also effective reducing the frequency of certain types of collisions such as right-angle. In addition, the safety of a signalized intersection might be improved by the introduction of other countermeasures depending of the issue of concern.

Operations

The category of Operations includes four evaluation criteria: posted speed, capacity, configuration adaptability, and design for larger vehicles.

Posted Speed: The geometric design of the intersection as well as the traffic control selected will dictate the recommended vehicular posted speed. The signalized intersection will require posted speed of 80 kph and the introduction of advance flashing warnings. The roundabout operation is dependent on the posted speed. However, it is expected that operational speed inside the roundabout is at almost 50 kph.

Capacity: Capacity at roundabouts is generally higher than at signalized intersections. Because a roundabout operates on a yield-on-entry basis; however, unbalance volumes might result in operational problems (i.e. relative high volumes on one approach might impact the operation at other approaches) (Ref 8).

Configuration Adaptability: Long term sustainability is a measure of the intersection layout's ability to adapt to changing conditions over time (traffic volumes, vehicle type, regulations, technologies) while maintaining functionality.

Design for Larger Vehicles: In multi-lane roundabouts, it may be necessary to provide geometry that allows two larger vehicles to travel side-by-side through the roundabout. This may require larger roundabout radius and more land for construction.

Selection of the Preferred Treatment

Table 4 summarized the numerical weighted score evaluation used to compare the signalized intersection with the roundabout option. Tables 5 to 7 present the detailed evaluation matrixes showing the sensitivity analysis of the alternatives considering three categories as well as the score criteria.

The results favored the signalized intersection over the roundabout option. Therefore, based on the information available at this moment and the evaluation matrixes, the signalized intersection is recommended over the roundabout for this particular case (intersection of Lochend Road (Highway 766) & Highway 1A).

Table 4: Summary Evaluation Matrix

Category	Weighted Score	
	Signalized Intersection	Roundabout
Costs	88.75	60.00
Safety	94.00	78.75
Operations	88.75	65.00
TOTAL	271.50	203.75

Note: A higher score indicates a more favorable evaluation. Scores are relative rather than absolute.

CONCLUSIONS AND RECOMMENDATIONS

Based on the multivariate evaluation process, comparing a signalized intersection versus a roundabout treatment for the intersection of Lochend Road (Highway 766) & Highway 1A, the following conclusions are drawn:

- Both alternatives are viable options for traffic control at the intersection of Lochend Rd & Highway 1A.
- It is recommended the signalized intersection over the roundabout alternative based on the results from the numerical weighted score evaluation.

The study offered a systematic and credible method of evaluation for consideration in the final decision making process. The following recommendations are provided for future studies:

- Clearly define project methodology to compare the roundabout option versus other intersection treatments. The evaluation categories and evaluation criteria should be selected on a project basis and in conjunction with the approving authorities.
- Both weighting and score points presented in this paper related only to the particular case of analysis and are influenced by the information available for the site and engineering knowledge of the area. These values are not intended to be presented as guidelines for future projects.
- At the moment there are no warrant procedures for selecting the need of a roundabout while traffic signal warrants are a common practice. Nonetheless, engineering judgment is key in the process of identifying the candidates for traffic control and intersection treatment.

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Table 5: Cost Sensitivity Evaluation Matrix

Category	Evaluation Criteria	Weight	Signalized Intersection		Roundabout	
			Score	Weighted Score	Score	Weighted Score
COST	Construction Cost	25	4	25.00	1	6.25
	Roadway Modification Cost	5	4	5.00	1	1.25
	Footprint (Land Acquisition, Environmental, Historical, Utilities)	10	4	10.00	1	2.50
	Maintenance Cost	15	2	7.50	4	15.00
	SUB-TOTAL	55		47.50		25.00
SAFETY	Intersection Conflicts	5	3	3.75	4	5.00
	Pedestrians and Cyclists	5	4	5.00	2	2.50
	Driver Expectation	5	4	5.00	3	3.75
	Crash Reduction Factors	10	4	10.00	4	10.00
	SUB-TOTAL	25		23.75		21.25
OPERATIONS	Posted Speed	5	3	3.75	3	3.75
	Capacity	5	3	3.75	4	5.00
	Configuration Adaptability	5	4	5.00	2	2.50
	Design for Larger Vehicles	5	4	5.00	2	2.50
	SUB-TOTAL	20		17.50		13.75
	TOTAL	100		88.75		60.00

Table 6: Safety Sensitivity Evaluation Matrix

Category	Evaluation Criteria	Weight	Signalized Intersection		Roundabout	
			Score	Weighted Score	Score	Weighted Score
COST	Construction Cost	2	4	2.00	1	0.50
	Roadway Modification Cost	2	4	2.00	1	0.50
	Footprint (Land Acquisition, Environmental, Historical, Utilities)	5	4	5.00	1	1.25
	Maintenance Cost	2	2	1.00	4	2.00
	SUB-TOTAL	11		10.00		4.25
SAFETY	Intersection Conflicts	10	3	7.50	4	10.00
	Pedestrians and Cyclists	15	4	15.00	2	7.50
	Driver Expectation	15	4	15.00	3	11.25
	Crash Reduction Factors	35	4	35.00	4	35.00
	SUB-TOTAL	75		72.50		63.75
OPERATIONS	Posted Speed	5	3	3.75	3	3.75
	Capacity	5	3	3.75	4	5.00
	Configuration Adaptability	2	4	2.00	2	1.00
	Design for Larger Vehicles	2	4	2.00	2	1.00
	SUB-TOTAL	14		11.50		10.75
	TOTAL	100		94.00		78.75

Table 7: Operations Sensitivity Evaluation Matrix

Category	Evaluation Criteria	Weight	Signalized Intersection		Roundabout	
			Score	Weighted Score	Score	Weighted Score
COST	Construction Cost	10	4	10.00	1	2.50
	Roadway Modification Cost	5	4	5.00	1	1.25
	Footprint (Land Acquisition, Environmental, Historical, Utilities)	10	4	10.00	1	2.50
	Maintenance Cost	10	2	5.00	4	10.00
	SUB-TOTAL	35		30.00		16.25
SAFETY	Intersection Conflicts	5	3	3.75	4	5.00
	Pedestrians and Cyclists	5	4	5.00	2	2.50
	Driver Expectation	5	4	5.00	3	3.75
	Crash Reduction Factors	10	4	10.00	4	10.00
	SUB-TOTAL	25		23.75		21.25
OPERATIONS	Posted Speed	10	3	7.50	3	7.50
	Capacity	10	3	7.50	4	10.00
	Configuration Adaptability	10	4	10.00	2	5.00
	Design for Larger Vehicles	10	4	10.00	2	5.00
	SUB-TOTAL	40		35.00		27.50
	TOTAL	100		88.75		65.00